Diet of key predators responsible for livestock conflict in Namaqualand, South Africa

by
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Thesis presented in partial fulfilment of the requirements for the degree of Master of Science (Conservation Ecology) at the Stellenbosch University

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March 2016

Declaration

By submitting this thesis electronically, I declare that the entirety of the work contained therein is my own, original work, that I am the authorship owner thereof (unless to the extent explicitly otherwise stated) and that I have not previously in its entirety or in part submitted it for obtaining any qualification.

Date: March 2016

Abstract

Human-wildlife conflict (HWC) occurs in areas where humans and wildlife occupy the same area or compete for the same resources. Although some carnivores are responsible for incidental attacks on humans, predation on livestock is an increasingly common form of HWC. Understanding the ecology of these predators outside the confines of protected areas could provide insight into decreasing conflict and ensuring the persistence of these animals in non-protected areas. I analysed the diet of leopard (*Panthera pardus*), caracal (*Caracal caracal*) and black-backed jackal (*Canis mesomelas*) in Namaqualand, Northern Cape, South Africa, an area where HWC is commonly reported. Scats were collected for each predator in both protected areas (Namaqua National Park) and surrounding, non-protected farmlands (810 km^2). Eight caracals were also collared to analyse caracal diet from GPS-cluster data. The diet of the three predators was assessed across both land classifications (protected vs. non-protected). Prey availability was determined by means of camera and small mammal traps and compared between the two land classifications. The relative abundance index (RAI) was used to determine the abundance of prey species on the two contrasting land classifications and whether prey abundance and availability influenced the feeding ecology of leopard, caracal and jackal in Namaqualand. All three predators relied on the most abundant and easy to catch prey species, reflecting opportunistic feeding behaviour. In the protected national park, where livestock was absent, all three predators selected for natural prey items. These findings coincided with previous studies on leopard, caracal and black-backed jackal in South Africa. A shift in leopard diet was observed on farmlands, as livestock replaced small-to medium-sized ungulates in scats. For black-backed jackals, steenbok (*Raphicerus campestris*) contributed >20% to the total biomass consumed in protected areas while on farmlands sheep (*Ovis aries*) contributed > 20% and steenbok only < 5%. These findings in scat are mirrored in ungulate surveys; steenbok was the most abundant small-to medium-sized ungulate in the national park and sheep were the most abundant prey on farmlands. Caracal preferred hyrax (*Procavia capensis*) and lagomorpha as prey, while predation on livestock occurred in low frequencies (scat analysis, 6.9%), making caracal the predator which depended the least on livestock. Land-use also had very little effect on caracal diet. When analysing caracal diet by means of kill site analysis, sheep contributed the bulk to the total biomass consumed (59.5%). However, GPS cluster analysis is inherently biased towards the overestimation of larger bodied prey items and excludes smaller prey items (< 1 kg) which contributed > 25% to the total biomass consumed according to scat analysis. Predation of livestock by these three predators was not significant in relation to livestock availability on farmlands, especially for caracal. Due to the

opportunistic feeding behaviour of these predators it was more likely that livestock was an alternative prey source. A suitable natural prey base on farmlands would decrease livestock losses, especially where leopards depredate on stock. Leopards are the last remaining large predator in this area and the loss of these large felids could be detrimental to the healthy functioning of the ecosystem. If increased vigilance is practiced during the lambing period, lambs could survive to past their vulnerable size when they fall victim to jackals. Improved livestock husbandry methods, implementation of guarding animals and herders and various other holistic methods could decrease livestock losses in Namaqualand.

Opsomming

Konflik tussen mense en diere kom gewoonlik voor in areas waar wilde diere en mense dieselfde area beset en vir soortgelyke hulpbronne kompeteer. Deur die ekologie van roofdiere kwesbaar vir hierdie konflik buite beskermde gebiede te bestudeer, kan baie insigte verkry word oor hoe om konflik te vermy en te verminder. Verder kan dit verseker dat sulke predatore nie verlore gaan buite formeel beskermde areas nie. Hierdie studie het die dieet van luiperd, rooikat en rooijakkals in Namakwaland, Noord-Kaap, Suid-Afrika geanaliseer. Mismonsters van die drie predatore is versamel in die Namakwa Nasionale Park en omliggende veeplase (810 km^2). Agt rooikatte was ook voorsien met radio-nekbande om rooikat dieët verder te ontleed. Die dieet van die drie predatore is geanaliseer en vergelyk tussen beide die nasionale park en die omliggende plase. Die beskibaarheid van prooi op altwee grondgebruike is ook ontleed deur gebruik te maak van kameras in die veld en klein-soogdier lokvalle. ‘n Relatiewe volopheids-indeks (RVI) is gebruik om te bepaal of die beskibaarheid en getalle van prooi die dieet van luiperd, rooikat en rooijakkals beïnvloed in Namakwaland. Al drie van die predatore het opportunistiese voergedrag getoon. Die dieet was verder grootliks afhanklik van die volopheid van maklik-bekombare prooi. Vorige studies van luiperd-, rooikat- en rooijakkals-dieet stem ooreen met die resultate verkry van die mismonsters versamel in die nasionale park. ‘n Verskuiwing in luiperddieet is op kleinveeplase waargeneem waar vee essensieël die rol van kleiner bok-soorte vervang. ‘n Soortgelyke tendens is waargeneem in jakkalsdieet. Steenbok, wat > 20% bygedra het tot die algehele biomassa gevreet deur jakkals in die nasionale park, is effektief vervang deur skaap, wat > 20% bygedra het tot biomassa op aanliggende plase, waar steenbok slegs > 4%. Steenbok was ook die volopste van die kleiner bok-soorte in die nasionale park, met skaap die volopste prooi item op die plase. Rooikat het dassie en lagomorpha (hase en konyne) verkies in beide die nasionale park en die aanliggende plase. Rooikat het selde gevoed op vee; op 6.9% die laagste van al die predatore in die studie. Rooikat-dieet is ook ontleed van karkasse wat opgespoor is deur middel van GPS-kluster besoeke. Die data verkry bewys dat skaap ‘n beduidende deel van die algehele biomasssa gevreet deur rooikat bydra. Hierdie metode het egter alle prooi kleiner as 1 kg, wat meer as 25% bygedra het tot die algehele biomassa gevreet deur rooikat, uitgesluit. Luiperd was die hoofpredatoor van boerbokke in die droeë seisoen. Volgens die beskikbaarheid van vee was die predasie deur hierdie drie predatore op vee nie beduidend nie. Omdat hierdie predatore so ‘n aanpasbare patroon volg, in terme van hul dieet, is dit meer waarskynlik dat luiperd, jakkals en meer so rooikat vee gevang het as alternatiewe prooi. As daar op

plase ‘n voldoende, natuurlike prooi-basis beskikbaar is sal vee verlieste moontlik verminder, veral verlieste as gevolg van luiperd predasie. Luiperds is die laaste oorblywende groot karnivore in hierdie area en die moontlike verlies van hierdie diere sal groot nagevolge hê vir die algehele funksionering van Namakwaland as ‘n gesonde, interaktiewe ekosisteem. As daar meer waaksaamheid uitgeoefen word in tye wanneer ooie lam, kan lammers grootliks ongehinderd groei tot op ‘n punt waar jakkalse hulle nie meer sal teiken nie. Uiteindelik kan dit lei tot ‘n wen-wen situasie vir beide die ekosisteem se gesonde funksionering en produksie. ‘n Toename in vee-bestuur metodes, soos die gebruik van herders in die veld, vee waghonde en ander holistiese metodes kan vee verlieste in Namakwaland effektief verminder.

Acknowledgements

Working on this project has been a privilege. In these past two years I was fortunate enough to contribute to a cause which I believe in. I would like to express my gratitude to everyone involved in making this project a reality:

- To my supervisor, Dr Alison Leslie, for all the guidance and support throughout my research.
- My co-supervisor, Dr Quinton Martins who without this project would never have happened. His passion for cape leopard conservation was the driver behind the PEACE project.
- Dr Bogdan Cristescu and Kristine Teichman, the 'parents'. They provided me with constant advice and support throughout my time in the field. Without their guidance and suggestions I would have been lost. I can't thank you enough.
- The Cape Leopard Trust for providing logistical support, financial support and most importantly, a platform to do what we love.
- Woolworths for the biggest funding the project had and willingness to help protect our biodiversity and support local farmers.
- Bryan Havemann and Helen Turnbull from CLT for their constant logistical support and dealing with endless requests.
- Bernard and Elanza van Lente and the SANParks team who not only provided us with housing, but also constantly came to our aid when windpumps needed to be fixed and bakkies to be nudged off boulders.
- Conservation South Africa for being part of the solution.
- The private landowners – Nathan Aggenbag, Japie van Wyk, Gert van Wyk, Marius van Wyk, Flippie Kennedy, Corrie van der Westhuizen en Phillip, Pieter, Ivan van Niekerk, Robbie en JJ Archer, die Strydoms en almal anders . Ek weet dit is nie altyd maklik om saam met die 'groenes' te werk nie, maar ons waardeer al die tyd, hoop en geduld wat julle in hierdie projek ingesit het. Ons hoop dit wys positiewe resultate.

- All of our volunteers; the Americans – Chris Vlautin (sorry, Dr Vlautin), Ryan Wilbur, Alex Potash, Bradley (Bo) Larson, Jessica Gomez, Sam Childs, Kenneth Loonam, Jared Franklin and Natasha Bowman; the English ladies – Charlotte Beaton and Carrie Dunford; the Belgian – Sam Puls and our one South African, Elbé Visser. You guys have been amazing! I couldn't have done this without you (thanks for keeping me sane).
- All our volunteer vets (who doubled as research technicians), especially Victor Lizana Martin and Luca Mendes.
- Anita Meyer and Jeannie Hayward from CLT. Anita helped with all things scat and without her help I would not have known what to do.
- Die locals van Kamieskroon en Springbok wat vir ons en al die uitlandse vrywillegers gewys het wat gasvryheid is.
- Agrimark Springbok for always helping me when I pitch up with a weird list of things to buy; Supaquick Springbok and Autorama Springbok for all the tyres fixed.
- The Nematology department and Dr Malan and her team for allowing me to work on the microscope.
- Dr Dan Parker and Rhodes University for providing images to build a reference collection
- Sasha-Lee Maggs for spending her free time in the lab, washing and sorting scat. You helped me so much to get ahead of time.
- Rudi Swart for always being there when I needed him and for dealing with all the mood swings that came with thesis writing.
- And finally my amazing family, especially my dad. Sonder julle sou dit glad nie moontlik gewees het om hierdie projek te doen nie. Julle ondersteuning finansieel en emosioneel is iets wat ek nooit sal vergeet of prys gee nie. Pappa, jammer oor die bakkie – maar die Triton het weereens homself bewys!

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1.1. Human-wildlife conflict (HWC): a worldwide problem

Human wildlife conflict (HWC) can be loosely defined as an interaction where humans and wildlife occupy the same area and/or compete for the same resources (Inskip and Zimmerman 2009; Li, Buzzard, Chen and Jiang 2013). In recent times it is not uncommon for humans and wildlife to come into conflict with one another (Treves and Karanth 2003; Li *et al.* 2013; Campbell *et al.* 2014). The human population is growing at an exponential rate which results in an increase in agricultural activities, urbanisation, increased disease transmission between wild- and domestic animals and a further decrease in food resources for wildlife and diminishing natural habitat (Pettigrew *et al.* 2012). Wildlife is either forced out of their historical ranges or continue to live in close proximity to humans (Treves and Karanth 2003; Pettigrew *et al.* 2012; Kiffner *et al.* 2014). There is a general misconception that this conflict is restricted to poverty-stricken areas, however HWC is a worldwide problem (Madden and McQuinn 2014). HWC often results in negative impacts towards either humans, wildlife or both parties (Dickman, Macdonald and Macdonald 2011; Pettigrew *et al.* 2012).

While human-wildlife conflict has become synonymous with carnivores (Dickman *et al.* 2011), there are various other examples of HWC worldwide ranging across various animal species. For example, elephants in Africa are notorious “problem animals” due to the damaging of crops, destruction of artificial water sources such as water tanks and the raiding of food stores (Hoare 1999; Parker and Osborn 2006; Taruvinga and Mushunje 2014). Human-elephant conflict has resulted in retaliatory killings of elephants, however great conservations efforts have been made to mitigate human-elephant conflict in both Africa and India (Parker and Osborn 2006; Jadhav and Barua 2012; Mariki, Svarstad and Benjaminsen 2015). Baboons (*Papio ursinus*) in the Cape Peninsula, South Africa, are also responsible for property damage and the harassment of people in order to obtain alternate food sources (Hoffman and O’Riain 2012). In North America, grizzly bears (*Ursus arctos*) and black bears (*Ursus americanus*) have adapted to the increasing human population and have learnt to gain from anthropogenic food items that are easily accessible (Wilson *et al.* 2005; Don Carlos, Bright, Teel and Vaske 2009). In Africa, many species are responsible for fatal attacks on humans (Lamarque *et al.* 2009). Crocodiles (*Crocodylus niloticus*) and hippopotamuses (*Hippopotamus amphibius*) are the large animals responsible for the most fatal attacks on humans in Africa. This is a much less common form of HWC in Africa than crop damage by mammals, but it is still of great concern to many local people living in close proximity to these animals (Lamarque *et al.* 2009). Internationally snakes are perceived to be dangerous which leads to either accidental or intentional snake mortality (Bonnet, Naulleau and Shine 1999; Brown, Bishop and Brooks 2009). Free-roaming wildlife is also responsible for a large number of vehicle collisions in which wildlife and sometimes humans perish (Mouron; Morelle, Lehaire and Lejeune 2013; 2014). Disease transmission from wild to domestic animals is also of great concern and another factor responsible for HWC (Bengis, Kock and Fisher 2002; Wilkinson, Smith, Delahay and Cheeseman 2004). In the United Kingdom, culls were implemented to control badger (*Meles meles*) populations as these animals contribute to the spread of bovine tuberculosis (Donnelly *et al.* 2006; Byrne *et al.* 2014). A seemingly unlikely animal species that has also been involved in HWC is the beaver (*Castor fiber*), mostly due to the misconception that these animals have a negative effect on the environment (Czech and Lisle 2003).

1.1.1. Human-carnivore conflict (HCC)

Human-carnivore conflict (HCC) has become one of the most urgent conservation problems and is reportedly increasing in frequency (Jackson and Wangchuk 2004; Inskip and Zimmerman 2009; Pettigrew *et al.* 2012; Johansson *et al.* 2015). Carnivores play an important role in ecosystem functioning and exert top-down effects influencing other aspects of an ecosystem (Estes *et al.* 2011). However, the rapid growth and development of the human population is threating the persistence of these free-ranging species across the world (Dar, Minhas, Zaman and Linkie 2009; Inskip and Zimmerman 2009). In many areas carnivores are living in close proximity to human populations (Inskip and Zimmerman 2009). In general, a negative attitude in humans towards carnivores still exists, however the aesthetic value and possible economic benefit of carnivores is being increasingly recognised by communities (Campbell *et al.* 2014).

HCC is mutually detrimental to both humans and carnivore communities. In various regions throughout the world carnivores can threaten human lives through aggressive behaviour and sometimes fatal attacks (Loveridge, Wang, Frank and Seidensticker 2010). In the 1890’s, two lions from the Tsavo region, Kenya received infamy for the killing of between 28 and 135 people and became known as the man-eaters of Tsavo (Patterson 1907; Yeakel *et al.* 2009). In other parts of the world tigers (*Panthera tigris*) have been labelled as the felid responsible for the most human deaths (Siddiqi and Choudhury 1987; Karanth and Gopal 2005). In the 1920’s, 7000 deaths were recorded over a five-year period as a result of fatal tiger attacks in India (Peterhans and Gnoske 2001). In more recent times tiger attacks on humans have become less frequent; however livestock depredation is still a common occurrence (Johnson, Vongkhamheng, Hedemark and Saithongdam 2006). The livelihood of local people can also be threatened by carnivores as these animals tend to predate on livestock when living in close proximity to humans and agricultural land (Balme, Slowtow and Hunter 2009; Thorn, Green, Scott and Marnewick 2013). Wang (2008) reported that tigers and leopards (*Panthera pardus*) in Bhutan were responsible for losses of 17% of the annual income of households living around Jigme Sinyq Wangchuck National Park. Lions (*Panthera leo*) living close to Tsavo National Park in Kenya were responsible for the loss of 433 heads of livestock over a four-year period (Patterson, Kasiki, Selempo and Kays 2004; Lamarque *et al.* 2009). The depredation of livestock by carnivores leads to lethal persecution of many wild carnivores. The retaliatory killing of carnivores has become a common occurrence in areas where people live close to or sometimes within protected areas (Woodroffe, Thirgood and Rabinowitz 2005). Snow leopards (*Panthera uncia*) in the Tost Mountains of Mongolia were also found to predate on livestock, but this only made up 27% of the total diet (Johansson *et al.* 2015). Snow leopards occur in areas with rugged terrain and a low abundance of wild prey populations. With the increase in human activities in these rugged areas, livestock populations are becoming more abundant providing an alternate food source for snow leopards (Mishra *et al.* 2003; Jackson, Mishra and McCarthy 2010). The lethal persecution of these animals has become problematic due to their endangered status, prompting various conservation efforts to decrease livestock depredation and stabilise human-wildlife conflict in these areas (Jackson *et al.* 2010). Carnivores have been persecuted for predating not only on livestock, but also game species where game ranching is a source of income (Inskip and Zimmerman 2009; Loveridge *et al.* 2010).

Bears are known to be the cause of fatal human attacks, as well as contributing to livestock depredation. In India, the Asiatic black (*Ursus thibetanus*) and brown bears (*Ursus arctos*) were responsible for 3 human casualties and the killing of 355 head of livestock in the Great Himalayan National Park Conservation Area from 1989 to 1998 (Chauhan 2003). Sloth bears (*Melursus ursinu*s), occurring in the forests of India, are known to attack humans. These bears rarely feed on humans, but are mostly responsible for attacking and mauling people when coming into contact with people (Rajpurohit and Krausman 2000). Bears also prey on livestock in North America, along with wolves (*Canis lupus*) and coyotes (*Canis latrans*) [Wagner, Schmidt and Conover 1997]. There have been incidences where wolves also attack people, either due to being infected with the rabies virus, as a defensive mechanism or sometimes even predatory. In the latter case it is mostly older, single wolves or sometimes certain packs that exploit humans as a food source (Linnell *et al.* 2002).

Leopards are also known for fatal attacks on humans in both Africa and Asia (Loveridge *et al.* 2010). In India from 1905 – 1907 the Panar leopard killed 400 people – an example of just one of the infamous leopards in the world responsible for human deaths (Peterhans and Gnoske 2001). Attacks on humans by leopards have decreased however in some areas it still occurs. Leopards, being the smallest of the large felids (> 50 kg), tend to attack woman and children, mostly avoiding men (Peterhans and Gnoske 2001). Leopards also contribute to livestock losses, mostly preying on small stock such as sheep and goats or the young of larger livestock such as cattle. In a two-year period (2000-2002) in the Kweneng district of Botswana, 857 leopard attacks on livestock were recorded (Schiess-Meier, Ramsauer, Gabanapelo and Köning 2007). In Kenya from 1989 – 1995 leopards killed on average 4.3 cattle and 10.5 sheep per year (Mizutani 1999). Jaguars (*Panthera onca*) rarely, if ever, attack people, but they do contribute to livestock depredation in South America (Rabinowitz 2005; Constant 2014). Attacks on people by mesocarnivores are rare, but these animals are infamous for predating on smaller stock and causing large-scale damages (Loveridge *et al.* 2010). In France, the Eurasian lynx (*Lynx lynx*) killed 1 782 livestock from 1984 – 1998 (Stahl, Vandel, Herrenschmidt and Migot 2001). The Eurasian lynx and caracal (*Caracal caracal*) are the only smaller felids (10 – 40 kg) that have been credited with regular livestock kills, with most responsible felids weighing > 50 kg (Inskip and Zimmerman 2009; Loveridge *et al.* 2010). Dholes (*Cuon alpinus*), dingoes (*Canis lupus dingo*), coyotes (*Canis latrans*) and even African wild dogs (*Lycaon pictus*) are responsible for livestock depredation in certain areas of the world (Wang and Macdonald 2006; Gusset *et al.* 2009). Some canid species have even been credited with accelerating the decline of certain threatened species, such as the Arctic fox (*Vulpes lagopus*) preying on nesting seabirds (Sillero-Zubiri and Switzer 2004).

1.1.2. Livestock predation: The problem

When examining HCC and proposing possible solutions it is vital to understand all aspects involved (Woodroffe *et al.* 2005). Carnivores have high dietary requirements and thus often display an opportunistic feeding behaviour (Inskip and Zimmerman 2009). Human populations are encroaching upon wildlife areas which have led to an increase in agricultural activities in these areas (Li *et al.* 2013; Constant 2014). People are living closer to protected areas and the buffer zones between human settlement and formally protected areas are becoming smaller (Gusset *et al.* 2009). In some instances people live in protected areas and even practice livestock farming inside the boundaries of the protected area (Pettigrew *et al.* 2012; Li *et al.* 2013). This could lead to the ungulate biomass in these protected areas consisting primarily of livestock (Bagchi and Mischra 2006). The term “problem animal” has been used to describe wildlife that has a negative effect on human lives (Linnell *et al.* 1999; Marker and Dickman 2005). Linnell *et al.* (1999) defined two different types of problem animals. The first being an animal which might just be in the wrong place at the wrong time, moving between ranges, dispersing from a protected area or where people wandered into their territories. The second type of problem animal is one that has a preference for livestock (or humans), usually more than other individuals of the same species. Male individuals have also been identified as the main culprits, primarily due to their larger home ranges, larger dispersal rates and possible larger body size (Linnell *et al.* 2001; Bunnefeld *et al.* 2006; Loveridge *et al.* 2010). In certain areas where conflict occurs the people in the region can also be at fault if, for example, no management practises are in place and animals are not protected from carnivores in any way (Inskip and Zimmerman 2009).

Many people affected by human-carnivore conflict tend to turn to lethal persecution of carnivores, however, many of the species which are labelled as "problem animals" are also threatened species and protected legally from any lethal action (Treves, Wallace and White 2009; Thorn *et al.* 2013). Local people become more frustrated by such policies and in many cases still turn to illegal persecution of carnivores (Thorn *et al.* 2013; Constant 2014). Retaliatory killings by the affected human populations can result in a large-scale negative impact on the environment (Linnell, Swenson and Andersen 2001). There are areas where carnivores have been exterminated because it was thought that these animals were continuously feeding on livestock (Treves *et al.* 2004; Li *et al.* 2013). An example of this was the killing of wolves in the United States in response to the killing of livestock by these animals (Treves *et al.* 2004). In Bhutan, dholes were also nearly extirpated due to depredation on livestock (Wang and Macdonald 2006). In certain parts of Europe most of the larger carnivores have been exterminated or populations reduced in size due to conflict with people (Breitenmoser *et al.* 2010). The Eurasian lynx is one of the carnivores that were affected by human encroachment into natural areas in Europe (Stahl *et al.* 2001). In Scandinavia and Eastern Europe only a small number of individuals remained by 1900 and by 1940 in Western Europe, Eurasian lynx populations were declared extinct (Breitenmoser, Breitenmoser-Würsten and Capt 1998). Lynx have been reintroduced to Western Europe since 1970, however, conflict still remains and these animals are still being killed illegally by game hunters (Breitenmoser *et al.* 1998; Stahl *et al.* 2001). In the past, many countries, including South Africa, have had bounty systems in place to help control "problem animals" with the help of lethal methods (Beinart 2003; Musiani *et al.* 2005). In some cases the lethal control of a specific damage-causing animal can be justified (Anderson 1981; Loveridge *et al.* 2010). However, it can be challenging to identify the responsible problem animal and often the traps used are indiscriminate and many non-target individuals of a variety of species are also killed (Linnell *et al.* 1999). There are lethal methods that are more selective to the true "problem animals". These include: 1) poison collars placed on livestock (usually a vulnerable individual), or 2) traps baited with recent kills by the problem individual (Burns, Zemilcka and Savarie. 1996). There are also many alternate, non-lethal approaches to manage carnivores preying on livestock (Treves *et al.* 2009). One of the more effective methods is the increase in traditional animal husbandry methods which includes guarding of livestock (Graham, Beckerman and Thirgood 2005).

There is a difference in methods and approaches when implementing conservation strategies in developed versus non-developed countries (Loveridge *et al.* 2010). In some developed countries compensation schemes have been put in place to financially assist farmers that lose livestock to carnivores (Maclennan, Groom, Macdonald and Frank 2009; Treves *et al.* 2009). This requires an understanding of the conservation importance of carnivores and a strong commitment from both the private and governmental sectors (Constant 2014). However, draw-backs with compensation schemes also exist and Boitani, Ciucci and Raganella-Pelliccioni (2010) found that wolf-damage compensation programs in Italy were an unsustainable strategy to mitigate human-wolf conflict. In many developing countries governments do not have the resources to compensate for livestock losses and thus rarely support farmers (Dickman *et al.* 2011; Thorn *et al.* 2013). The lack of monetary support adds to the frustration experienced by local people regarding their livelihoods versus carnivores and leads to retaliatory killings of carnivores and often even non-target animals (Treves *et al.* 2006; Loveridge *et al.* 2010; Dickman *et al.* 2011). A trade-off also exists between promoting the economic growth of poorer countries by increasing agricultural activities with international opinions endorsing the conservation of threatened species (Treves *et al.* 2006).

The attitudes of people towards the carnivores they come into conflict with can be damaging and increase the challenges of aiding mitigation of human-carnivore conflict (Dickman 2005; Schumann, Walls and Harley 2012). However, in certain instances the cultural or aesthetic importance of carnivores to local people might aid mitigation (Loveridge *et al.* 2010). Economic factors can also help predict the levels of conflict which can result from human-carnivore interactions (Bagchi and Mishra 2006). Historically wolves were intensely persecuted due to depredation on livestock; however conservation of wolves in North America has recently been intensified with scientific literature and non-scientific arguments claiming the importance of wolves in ecosystems (Mech 2011; Redpath, Gutiérrez, Wood and Young 2015). In many areas livestock farming provide the main income and many people depend on the sale of livestock for their and their families livelihoods. This is especially true for low-income regions where people practice subsistence farming (Thorn *et al.* 2013). When these farmers loose only one individual from their stock it has a higher negative impact on their livelihood than large-scale farmers that have more stock (Loveridge *et al.* 2010). In Australia, dingoes are responsible for the great decline in Australia's sheep flock (Letnic, Ritchie and Dickman 2012). It has also been suggested that livestock depredation by dingoes, along with feral dog hybrids, could be responsible for the collapse of the Australian sheep industry within the next 30 – 40 years (Allen and West 2013). However, Forsyth *et al.* (2014) argue that these numbers are exaggerated. They do however agree that dingoes reduce the profitability of sheep farming, but mostly in rural communities where people do not have the resources to prevent dingo predation on their livestock. In Brazil, large ranches lost fewer cattle to carnivore attacks than smaller ranches (Michalski, Boulhosa, Faria and Peres 2006). Larger scale farming activities usually produce more money allowing the farmers to implement methods to decrease depredation (Loveridge *et al.* 2010; Thorn *et al.* 2013).

The damage caused by some carnivores has been estimated, in monetary terms, to aid the understanding of how this negatively affects people living in some of these conflict areas (Ogada, Woodroffe, Oguge and Frank 2003; Patterson *et al.* 2004; Van Niekerk, Taljaard and De Waal 2013). In Kenya and Zimbabwe, where most farmers are subsistence farmers, 11% to 12% of annual income is lost to predation on livestock, primarily by lions and leopards (Ogada *et al.* 2003). A study conducted by Madhusudan (2003) found that households living in or in close proximity to Bhadra Tiger Reserve in India lost an estimated 12% of their livestock to tigers. In some cases stock owners lose more individuals to disease, theft or even starvation (Constant 2014). In the Kweneng district, Botswana, only 0.34% of livestock losses were attributed to carnivores. Losses to other factors such as disease, theft, accidents or malnutrition were much higher, accounting for 2.8 - 12.6% of total stock loss (Schiess-Meier *et al.* 2007). However, there are some areas such as Bhadra Tiger reserve where livestock losses were 4 times more than losses from other causes such as disease (Madhusudan 2003; Constant 2014). It is true that carnivores do have an adverse effect on livestock numbers in certain areas of the world; however it is always important to note that other factors can also contribute to the decline in stock numbers (Dar *et al.* 2009; Constant 2014; Forsyth *et al.* 2014).

Though conservation organisations do try and resolve conflict where possible, some local people take offense to this action and feel robbed of their responsibility to look after their own stock (Treves, Wallace, Naughton-Treves and Morales 2006). When their safety is being jeopardised and economic losses are high there will be little co-operation with conservation strategies, as it is not seen as a priority (Goodrich 2010; Pettigrew *et al.* 2012). Conservation strategies are thus of great importance and human-carnivore conflict situations should be approached with caution and sensitivity (Loveridge *et al.* 2010; Suryawanshi, Bhatnagar, Redpath and Mishra 2013). Many times conservation strategies to mitigate human-wildlife conflict fail as a result of continued hostility towards wildlife from people or from other conservation conflicts which emerge during planning or implementing of plans (Treves *et al.* 2006; Dickman 2010). Conservation conflicts pose a challenge whenever a sustainable mitigation plan has to be implemented. Such conflicts include: 1) conflict of interest where stakeholders argue over the use of an area or resource, 2) conflicting beliefs and values, 3) conflicts over processes applied and the implementation of such solutions, 4) scientific studies are conducted, sometimes with little cooperation and input from locals, 5) conflicts regarding legislation and equality of different stakeholders and 6) personal conflicts between stakeholders (Redpath *et al.* 2015).

In developing countries where the majority of carnivore persecution occurs, there have been various conservation efforts to help decrease livestock losses and mitigate conflict (*Treves et al.* 2006), which includes the provision of solutions to decrease predation. In some cases translocation of problem animals has been used, however, it has been found that translocation does not always work for felids (Athreya, Odden, Linnell and Karanth 2010). Leopards have been recorded returning to their previous range (Stander 1997; Athreya 2006), along with other felids such as jaguars (Rabinowitz 1986) and cougars (Ruth *et al.* 1998). The use of livestock guarding dogs over the years has proved to be a successful solution (Gehring, Vercauteren and Landry 2010; Marker, Dickman and Schumann 2005). When using livestock guarding dogs to control depredation by coyotes in North America, an 11% decrease in livestock predation was observed (Smith, Linnell, Odden and Swenson 2000). Livestock guarding dogs are effective, but commitment is needed for this method to work as effectively as possible (Smith *et al.* 2000; Marker *et al.* 2005). Additionally, in some cases, llamas, donkeys and even domesticated buffalo have been found to be effective livestock guards (Crawshaw 2004). Herders (or shepherds) have also been found to be an effective livestock guarding practice (Frank, Woodroffe and Ogada 2005; Loveridge *et al.* 2010). In developing countries these roles are often filled by younger family members, preventing them from attending school, thereby driving the "poverty circle" even more (Dickman *et al.* 2011). In some cases herders are employed, providing a work opportunity, however these individuals might be at risk of diseases, be sleep deprived or even fall prey to carnivores themselves (Barua, Bhagwat and Jadev 2013). In some developed countries many traditional animal husbandry methods have been abandoned due to a more recent lack of predators occurring in these regions (Stahl *et al.* 2001). However, with the reintroduction and in a few cases the reoccurrence of these carnivores in certain areas, many people have found themselves losing livestock having lost their knowledge of animal husbandry methods, such as shepherds and guarding dogs (Stahl *et al.* 2001). Kraaling (enclosures, bomas) has been abandoned in some areas as these structures lead to overgrazing and land degradation, making the area more susceptible to erosion (Beinart 2003). The use of kraals have also been criticised as one of the reasons why some felids practice surplus killings (Nowell and Jackson 1996). However, Schiess-Meier *et al.* (2007) state that only a small percentage of livestock killings in Botswana occurred in an enclosure where animals were guarded at night. In conclusion, the best method that has been developed over the years includes a combination of securely built enclosures, guard dogs and herders/shepherds (Ogada *et al.* 2003).

1.2. Human-carnivore conflict in South Africa: with a focus on livestock losses

Historically, livestock farming has been a part of human lives in South Africa potentially before the 17th century (Beinart 2003). Before colonisation farming practices are thought to have been mostly nomadic, with high-intensity livestock guarding practices due to the large number of free-ranging predators. With the arrival of Jan van Riebeeck in 1652 and European settlers developing land for habitation, human-carnivore conflict intensified in the Cape (Stadler 2006). Dutch settlers started to farm on a large-scale with stock (sheep mostly obtained from the Khoisan people) and were dissatisfied with large predators causing damage to their stock (Beinart 2003). In the Cape Province, by the mid-nineteenth century, larger predators such as lions and hyenas (*Crocuta crocuta*) were extirpated from the area (Van Sittert 1998). Game species, such as the famous quagga (*Equus quagga quagga*) and bluebuck (*Hippotragus leucophaeus*), were also hunted to extinction for food and the decrease in natural prey for predators is cited as one of the main reasons why predators shifted to livestock predation (MacKenzie 1988; Brassine 2011). Predators such as leopards and caracals which also inhabit mountainous terrain used these areas to seek refuge in addition to restricting peak activity to night time (Beinart 2003; Skead 2011). Both these animals remained a problem for farmers, along with other canid species such as the black-backed jackal (*Canis mesomelas*), which increasingly started to inhabit areas where large predators were no longer present (Beinart 2003; Stadler 2006). The ability of black-backed jackals to adapt to changing circumstances and altering their ecology to compensate for disturbances have made these animals one of the most problematic animals in livestock farming in South Africa (Bekoff *et al.* 1984; Beinart 2003). Historical reports have shown that wild dogs were a considerable problem for Dutch settler farmers all the way back to the seventeenth and eighteenth century (Stadler 2006; Skead 2011). R. G Cumming (1856) claimed that wild dogs were known for not only killing stock which could be fed on, but killing any stock that crossed their path (Beinart 2003). Presently these animals are endangered with only a couple of small populations still remaining in South Africa (Gusset *et al.* 2009). Today, leopards and to some extent caracals are known for surplus killing where a large amount of animals are killed in one night, but only few are fed on (Bothma and Walker 1999; Marker and Dickman 2005).

Predators such as black-backed jackals and caracal were later classified by the government as “vermin” or “ongedierte” (in Dutch/Afrikaans) [Beinart 2003; Stadler 2006]. Bounties were put in place to control jackal and other problem animal numbers, and so called poison clubs and dog hunting clubs were established (Van Sittert 1998). The South African government subsidised predator control strategies prior to 1990, due to the large number of losses experienced by farmers (Bergman *et al.* 2013). In 1887 when the poison clubs were started, this practice was subsidised by the Department of Agriculture (Du Plessis 2013). Farms were not fenced, so many farmers implemented the kraaling system to protect livestock from predators, however this system was cause for land degradation and many people blamed these farmers for the desertification of some areas of South Africa (Beinart 2003; Van Niekerk *et al.* 2013). Kraaling of animals was also cause for increased disease transmission between animals (Van Sittert 1998). By the 1910’s, carnivores were responsible for a stock losses of between 5- 12% annually (Beinart 2003). This was the same percentage of stock that at that time was sent to abattoirs to be slaughtered for human consumption (Beinart 2003). In 1912 the government passed the Fencing Act (1912) and provided monetary support for farmers to fence their property, as well as providing mechanisms to facilitate the cooperation of neighbours when constructing fences (Van Sittert 1998; Beinart 2003; Bergman *et al.* 2013). In 1965, all smaller predator hunting concessions were abolished and merged into one hunting organisation, namely Oranjejag (Ferreira 1988). Oranjejag was run by government subsidies and all livestock farmers were expected to be members (Du Plessis 2013). Since the 1990s the South African government has ceased any subsidies to farmers for predator control and each farmer is now responsible for predator management on their specific farms (Du Plessis 2013).

While government was supporting predator management strategies, a large number of predators were killed. From 1914 – 1923 a total of 25 000 caracals were reportedly killed and later, from 1931 - 1952, about 2 200 caracals were killed annually only in the Karoo region (Marker and Dickman 2005; Bergman *et al.* 2013). Black-backed jackal were controlled even more intensely with over 350 000 animals reportedly killed in the Cape Province from 1889 - 1908 (Van Sittert 1998). With such large historical losses it is surprising that these predators still persist in large parts of South Africa and additionally are still considered “problem animals” (Brassine 2011; Nattrass and Conradie 2013). Problem animals or damage-causing animals are defined under the National Environmental Management Biodiversity Act, Act 10 of 2004 (NEMBA) (SA) as a wild vertebrate animal which causes damage to stock or other wild specimens, damages crops, natural flora or private property, threatens human life and occurs in such high numbers that agricultural grazing is being depleted [Department of Environmental Affairs 2010; Brassine 2011]. Very little research has been conducted in South Africa in order to fully understand predation on livestock by predators (Du Plessis, Avenant and De Waal 2015). Van Niekerk (2010) estimated that R1.39 billion is lost per annum due to predation of livestock. In South Africa many farmers have also shifted from livestock farming to game farming in an attempt at better financial security. However, many predators also predate on wild ungulates, especially fawns, so the conflict between predators and famers continues (Marker *et al.* 2005; Thorn, Green, Dalerum and Bateman 2012; Thorn *et al.* 2013). Currently predators are controlled on farms, both legally and illegally, using various lethal measures such as shooting, poisoning and the use of traps (Van Niekerk 2010; Forbes 2011; Du Plessis 2013). These strategies have thus far not been as successful as hoped. Conradie and Piesse (2013) found that leopard and caracal culling lead to increased livestock losses the following year. Many predators also travel vast distances to occupy empty territories, resulting in constant recruiting (Norton and Lawson 1985; Balme *et al.* 2009; Hayward and Kerley 2009). Black-backed jackals are also known to adapt their reproductive strategy, in reaction to increased persecution, by increasing litter sizes and by breeding at a younger age (Bingham and Purchase 2002; Beinart 2003; Nattrass and Conradie 2013). The killing of a dominant black-backed jackal results in sub-adults moving into the vacant territory which can result in smaller home ranges and a larger density of jackals (Bothma 2002; Ray, Hunter and Zigouris 2005; Brassine 2011). The lack of knowledge on the ecology of predators on farmlands in South Africa is surprising, as these problems have been part of farming for generations (Du Plessis 2013; Van Niekerk *et al.* 2013; Du Plessis *et al.* 2015).

1.3. Importance of diet in carnivore studies and mitigating HCC

Carnivores play an important role in any ecosystem and are considered important drivers of ecosystem structure and function (Beschta and Ripple 2009). Large carnivores exhibit a top-down regulatory role, not only on other smaller carnivores, but also on herbivore biomass (Prowse *et al.* 2014; Newsome *et al.* 2015). Medium-sized to smaller carnivores play important roles in ecosystem functioning and the loss of such carnivores can be detrimental to an ecosystem (Estes *et al.* 2011; Bagniewska and Kamler 2013). By preying on smaller prey, such as invertebrate species, birds and rodents, these carnivores also play a vital role in pest control on agricultural landscapes (Blaum, Tietjen and Rossminth 2009). Despite the importance of carnivores in natural systems their numbers are still decreasing worldwide, due to anthropogenic factors (Kissui 2008; Inskip and Zimmerman 2009). The availability of prey is one of the most important factors affecting the diet of a carnivore and this in turn influences the morphological, behavioural and physiological adaptations of that carnivore (Swanepoel *et al.* 2012; Kok and Nel 2004). Mammalian carnivores are vulnerable to extirpation due to their usually low densities and their large spatial requirements (Cardillo *et al.* 2005). Even though protected areas are critical to ensure the long-term persistence of carnivores in ecosystems (Balme, Slowtow and Hunter 2010) it is also important to have effective conservation management strategies for non-protected areas as a large amount of predator habitat constitutes areas outside of reserves (Martins 2010; Swanepoel *et al.* 2012).

Most studies on carnivore diet have focussed in protected areas. However, such dietary studies do not confront the pressing issue of HCC in a changing world (Balme, Lindsey, Swanepoel and Hunter 2013). Many carnivores are known to change their ecology to adapt to changing surroundings (Woodroffe 2000; Van de Ven, Tambling and Kerley 2013). These adaptable species might not be as vulnerable as some specialist carnivores, but their adaptive behaviour has resulted in HCC in many areas (Kamler *et al.* 2012b; Van Niekerk *et al* 2013). Food availability is one of the drivers determining the persistence of free-roaming carnivores, a factor which has often led to these animals depredating on livestock (Balme, Hunter and Slowtow 2007; Loveridge *et al.* 2010). It is thus crucial to understand what the feeding ecology of carnivores is outside of reserves where they continue to live in close proximity to humans and to what extent carnivore feeding ecology may have changed (Balme *et al.* 2009; Suryawanshi *et al.* 2013; Thorn *et al.* 2013). One of the main reasons for livestock depredation is the decrease in wildlife prey species and an increase in available domestic prey species (Pettigrew *et al.* 2012). Focussing on both the relevant carnivores and prey availability is crucial to understanding the drivers behind the feeding behaviour of these animals (Thorn *et al.* 2013). Such strategies can provide a better understanding of the ecology of these animals and lead to important solutions to mitigate HCC.

Worldwide many conflict mitigation studies have focused on dietary studies for baseline information to guide further research (Meriggi and Lovari 1996; Cunningham, Gustavson and Ballard 1999; Bacon, Becic, Epp and Boyce 2011). Morehouse and Boyce (2011) studied wolf diet in North America using a combination of GPS (Global Positioning System) cluster visitations and scat analysis and found cattle to be a prominent prey item. This was contradictory to previous studies which found primarily wild ungulates to occur in wolf diet. The aforementioned study also emphasised the importance that seasonality and land-use inclusion can have on a carnivore's diet, especially when the species is thought to play a role in livestock depredation (Morehouse and Boyce 2011; Du Plessis *et al.* 2015). Azevedo (2008) studied puma and jaguar diet in the Iguaçu National Park Area, South Brazil. Jaguars are said to be responsible for frequent livestock losses in this area due to a high abundance of livestock just outside of the park boundary and as a result of heavy persecution the Park now contains the last remaining population of jaguars in Southern Brazil (Conforti and Azevedo 2003). Azevedo (2008) assessed the diet of two carnivores in the area and found that jaguars predated on livestock to a higher extent that pumas. This study also concluded that livestock was only an alternative prey source for jaguars. In the instances where farms border protected areas, conflict between predator and farmer seems to be higher (Dar *et al.* 2009; Thorn *et al.* 2013). Many predators move into surrounding farmlands and often come across livestock, which is an abundant food source in these areas (Gurung and Seeland 2008; Balme *et al.* 2009). Similar to Azevedo (2008), Rowe-Rowe (1983) also found livestock remains in analysed black-backed jackal scats collected in a protected area in Kwazulu-Natal, South Africa. There is a high possibility that jackal use protected areas as refuge sites to escape persecution (Kaunda 2001; Kaunda and Skinner 2003; Loveridge and Macdonald 2004). The above mentioned studies were able to provide baseline strategies and management recommendations to prevent livestock losses, as well as providing information to local farmers regarding the extent to which these animals rely and predate on livestock (Inskip and Zimmerman 2009; Thorn *et al.* 2013).

Historically South Africa had widespread populations of free-ranging large carnivores (Skead 2011). Leopards are the last remaining apex predators in many small-stock regions, similar to Namaqualand, Northern Cape (Martins 2010; Skead 2011). However, studies on the role of these apex predators, which include livestock farms in the study area, are limited. In 1981, Stuart analysed the diet of various carnivores in the Cape Province. Leopard diet was analysed from 36 stomachs collected at 30 different localities across the Cape. However, stomachs were collected during control operations and the high occurrence of livestock recorded in the diet was seen as an overestimation due to sampling bias (Stuart 1981). Norton, Lawson, Henry and Avery (1986) were one of the first studies on leopard diet in the Western Cape and included a large scope of land-uses. Martins *et al.* (2011) studied leopard diet in the Cederberg Conservancy, Mann (2014) studied leopard diet in the Little Karoo, also in the Western Cape and Braczkowski, Watson, Coulson and Randall (2012a) in the Southern Cape. All three of the latter studies assessed leopard diet in a matrix of different land-uses and found stock to only contribute a small percentage to the total diet of leopards.

In South Africa livestock losses from carnivores such as black-backed jackal and caracal are thought to be high (Bergman *et al.* 2013; Du Plessis *et al.* 2015). However, most dietary studies on these two mesocarnivores have been done in the confines of protected areas, providing very little information as to the real impact of these animals on livestock farms (Du Plessis *et al.* 2015). The caracal, a smaller felid, is thought to be responsible for more livestock losses than leopard on small stock farms (Thorn *et al.* 2013). Past studies on caracal and black-backed jackal diet, mostly focussing on stomach contents, included small stock farms in their study area. However, recent studies are limited and studies in the Succulent Karoo biome are lacking (Du Plessis *et al.* 2015). Moolman (1984) studied caracal diet in the Mountain Zebra National Park (MZNP) and surrounding farmlands in the Cradock region, Eastern Cape. Caracal scats collected on the farmlands contained a high percentage of stock remains. Stuart (1981) found domestic stock to occur most frequently in caracal diet from 194 stomachs analysed from 135 localities in the Cape Province. Domestic stock was the second most frequently consumed prey item in black-backed jackal diet as analysed from 143 stomachs from 65 localities. Once again, the majority of the stomachs analysed were obtained from control operations, thus providing inadequate results (Stuart 1981). A more recent study on caracal diet which includes a variety of land-uses was done by Braczkowski *et al.* (2012b) which found a very low occurrence of livestock in caracal diet in the Southern Cape study area. However, farms included were mostly cattle farms providing very little novel insight to caracal predation on small-stock farms. A recent black-backed jackal study by Kamler *et al.* (2012a) found a seasonal variation in jackal diet, coinciding with the lambing periods. However, this study was carried out on only one small stock farm and jackal diet is known to vary spatially and temporally (Pyke, Pulliam and Charnov 1977; Brassine 2011). Du Plessis *et al.* (2015) assessed past research on both caracal and black-backed jackal ecology and the relevance of studies to human predator conflict management. The authors expressed concern for the lack of available relevant scientific knowledge. Research required on black-backed jackals and caracal included, 1) increased knowledge of these two mesocarnivores' territoriality, densities and ranging behaviour on livestock farms, 2) prey selection and timing of predation since it is clear that black-backed jackals and caracals exhibit an opportunistic feeding behaviour, but unclear whether some individuals may have developed a specialisation towards livestock predation, 3) timing of reproduction and whether it can coincide with lambing periods and 4) the controversial issue of "compensatory breeding" where it is believed that reproduction rates, litter sizes and age of sexually matured individuals might be adapted to compensate for an increased persecution of the species (Du Plessis *et al.* 2015).

1.4. Focal Species

1.4.1. The leopard (*Panthera pardus*) – an apex predator

The leopard (*Panthera pardus*) is the most widely distributed large felid in the world – particularly in Africa, where the highest numbers of leopards are currently found (Nowell and Jackson 1996; Skinner and Chimimba 2005). The success of leopards throughout such a wide range (occurring throughout sub-Saharan Africa, in the Middle East and parts of Asia) can mostly be attributed to their secretive nature and opportunistic feeding behaviour (Balme *et al.* 2007; Estes 2012; Chattha *et al.* 2015). Leopards occupy a wide variety of habitats ranging from semi-deserts to forested areas. In the tropical forests of Africa leopards are the only large predator still persisting (Estes 2012).

Leopards have been found to be more successful than other larger carnivores, such as hyena and lions, when living in close proximity to humans (Kissui 2008). The recorded preferred habitat for leopards is rocky outcrops (or koppies), hills, mountain ranges and forests; habitat types which allow for cover and refuge (Skinner and Chimimba 2005). Leopards have distinct markings in the form of rosettes and no two individuals will be found with the same physical features (Estes 2012). Weighing between 20 and 90 kg, leopards have a variable body mass further supporting an opportunistic feeding behaviour across a wide range of habitats (Hayward *et al.* 2006). A clear difference in size exists between males and females, with males generally being larger than females (Skinner and Chimimba 2005; Balme, Hunter and Braczkowski 2012a). Leopards are solitary felids, only associating with another individual long enough to mate (Estes 2012). Balme *et al.* (2012b) found that 40% of cub deaths were attributed to infanticide. Leopards are also territorial predators with males generally holding larger territories than females (Skinner and Chimimba 2005; Martins 2010).

Leopards are nocturnal, thus mostly hunting and moving around at night (Estes 2012). Some areas where cover is in excess, such as forested habitats, leopards may exhibit crepuscular and even diurnal behaviour (Martins and Harris 2013). Utilising stalking behaviour and being ambush hunters, leopards mostly rely on cover to conceal their movements (Balme *et al.* 2007; Estes 2012). The distances stalked by leopards vary depending on habitats (Stander *et al.* 1997). This reliance on cover as part of their hunting strategy can limit leopards to mostly remain in areas with adequate cover (Hayward *et al.* 2006). As mentioned these animals are extremely opportunistic in their feeding behaviour and in sub-Saharan Africa alone, 92 prey species have been recorded for leopards (Balme *et al.* 2007). Due to their body mass leopards require 1.6 to 4.9 kg of meat per day (Bothma and le Riche 1986; Stander *et al.* 1997; Hayward *et al.* 2006). Leopard diet mostly includes prey items weighing between 20-80 kg (Hayward *et al.* 2006) and can prey on anything ranging from invertebrates to an adult eland (*Taurotragus oryx*) [Bailey 1993; Hayward *et al.* 2006; Martins *et al.* 2011].

In 2008 the conservation status of leopards was reassessed by the International Union for Conservation of Nature (IUCN) and a decision was made to change their conservation status from "Least Concern" to "Near Threatened" (Henschel *et al.* 2008; Chattha *et al.* 2015). This reassessment was made due to the fact that despite leopards being common in certain areas their numbers are still decreasing over the extent of their range (Ray *et al.* 2005). A dramatic reduction of leopard numbers has been observed in Africa, where leopard range has been reduced by 37% (Ray *et al.* 2005; Balme *et al.* 2010). Some leopard species such as the Sri Lankan leopard (*Panthera pardus kotiya),* and the Persian leopard (*Panthera pardus saxicolor*)*,* are already classified as "Endangered" with the Amur leopard (*Panthera pardus orientalis*) and the Arabian leopard (*Panthera pardus nimr),* classified as "Critical" (Henschel *et al.* 2008). In 1986 it was estimated that only a mere 13% of potential leopard range was within the boundaries of protected areas (MacKinnon & MacKinnon 1986; Balme *et al.* 2010). See Figure 1.1 for a map illustrating remaining suitable leopard habitat in South Africa.

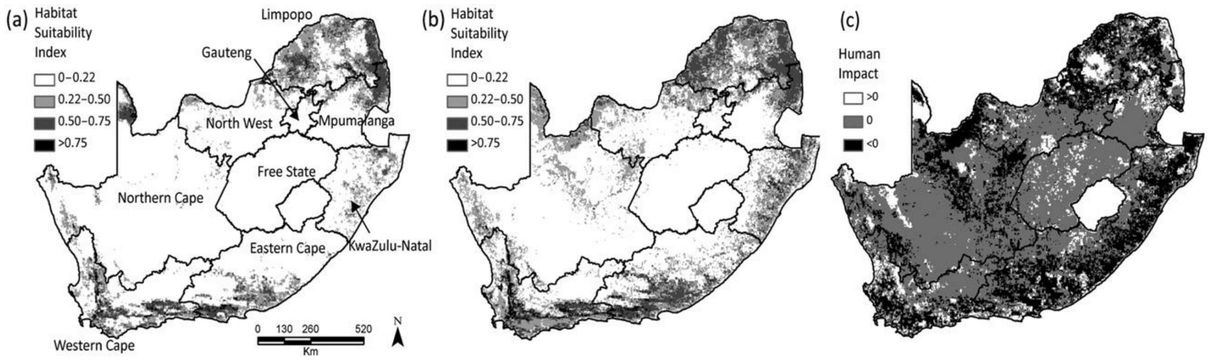


Figure 1.1. Suitable leopard habitat still available in South Africa according to Swanepoel *et al.* (2012) developed from a model with various environmental variables, a) excluding human variables, b) estimated human impact and c) where habitat suitability index represents logistic probabilities of occurrences. Negative values indicate areas where human impact has a negative effect on leopard habitat, positive values where human impact had a positive effect and zero values where leopard habitat suitability was not influence by human impacts.

1.4.2 The mesocarnivores

1.4.2.1 The caracal (*Caracal caracal*)

The caracal (*Caracal caracal*) is one of the most widespread felids on the African continent (Avenant and Nel 2002; Skinner and Chimimba 2005), occurring in the entire Southern African region extending to the margins of the Sahara Desert in the North, Morocco, Egypt, Sudan, Ethiopia, Somalia, Mauritania and northern Niger (Stuart 1982, Smith 2012). Caracal are also found in the Middle East, Eastern Turkey, the Arabian Peninsula, Turkmenistan, Pakistan, India, Kazakstan, Afganistan, Tajikistan and Uzbekistan (Stuart 1982; Nowell and Jackson 1996). They occupy a wide range of habitats including arid areas, open savannas, open grasslands and also the Afromontane and evergreen forests in South Africa and the tropical forests of the Democratic Republic of Congo (Stuart and Wilson 1988; Skinner and Chimimba 2005; Estes 2012; Smith 2012). Sometimes referred to incorrectly as a "lynx", these animals were first classified under the genus *Felis* (Skinner and

Chimimba 2005; Smith 2012). However, it was re-classified in the genus *Caracal* with one other felid, *Caracal aurata,* the African golden cat (Wozencraft 1993; Morales *et al.* 2003). Caracal received their name from the Turkish word "garah-gulak" or "caracal" when translated to english, which means "black-eared" (Skinner and Chimimba 2005; Ghoddousi, Ghadirian and Fahimi 2009). Caracal used to be captured and trained to hunt for people in India and Iran (Divyabhanusinh 1995; Ghoddousi *et al.* 2009).

Caracal are solitary cats, mostly active at night, but diurnal activity has been recorded (Avenant and Nel 1998; Iliman and Gürkan 2010; Estes 2012). These medium-sized cats, the largest of the smaller felids, can weigh up to 12 kg (females) and 15 kg (males) [Skinner and Chimimba 2005]. Males also hold larger territories than females, with more than one individual's home range overlapping with another (Stuart 1982). Studies in the Western Cape, South Africa, also discovered that caracals can travel vast distances before settling in a specific area (Norton and Lawson 1985; Bothma and Le Riche 1994). Norton and Lawson (1985) tracked a young male caracal which moved around in an area of 483 km^2 before settling in an area of 65 km^2 for 11 months. One of the fastest felids, caracal catch their prey by means of a fast-paced dash and are known to propel themselves into the air to catch airborne prey (Estes 2012; Smith 2012). These felids are predominantly hunters, but have been observed to scavenge when resources are limited (Stuart and Hickman 1991; Skinner and Chimimba 2005). Caracals have persisted in areas with high fragmentation and human development. This could mostly be ascribed to their secretive nature and high use of areas with cover (Stuart 1982; Skinner and Chimimba 2005). Caracals also tend to feed on prey items that are available in high numbers. These felids are opportunistic hunters with a generalist diet, comprising mostly of mammals, but may also include birds, reptiles and arthropods (Palmer and Fairall 1988; Estes 2012). Previous studies have recorded a prey range extending from 1 g to 31 kg in mass (Grobler 1981; Moolman 1984; Palmer And Fairall 1988; Avenant and Nel 2002; Braczkowski *et al.* 2012b).

Although widespread and relatively common, very little information is published on caracal feeding ecology (Stuart 1981; Avenant and Nel 1998, Braczkowski *et al.* 2012b). Caracals are reported to be one of the main carnivores responsible for small stock losses in South Africa, along with the black-backed jackals (*Canis mesomelas*) (Bergman *et al.* 2013; Du Plessis 2013). Between 1931 and 1952 an average of 2219 caracals were killed every year in the Karoo region of South Africa to help control predator numbers (Stuart 1981). The caracal has been categorised by the International Union for Conservation of Nature (IUCN) as "Least Concern" (Breitenmoser-Wursten, Henschel and Sogbohossou 2008). Caracal population numbers seem to be stable across their distribution in Africa due to being widespread and common, however in parts of Asia there are concerns that populations are declining due to habitat destruction (Ray *et al.* 2005).

1.4.2.2 The black-backed jackal (*Canis mesomelas*)

The black-backed jackal (*Canis mesomelas*) can clearly be distinguished by the dark saddle on the upper parts of the body. This feature aids in distinguishing black-backed jackal from the side-striped jackal (*Canis adustus*), along with having a lighter mass than the side-striped jackal (Loveridge and Nel 2004; Skinner and Chimimba 2005; Estes 2012). Black-backed jackal are common in arid areas. They are distributed throughout most of Southern Africa, including Namibia, south-west Angola, Botswana, south-west to east Zimbabwe, and the most southern parts of Mozambique. The species is found throughout South Africa, except for highly urbanised areas and the forested regions of Knysna. Black-backed jackals also occur in the more northern parts of Africa, from the Gulf of Aden southwards into southern Tanzania, 900 km from the edge of its southern distribution (Skinner and Chimimba 2005). Black-backed jackal are specially adapted for survival in drier regions having kidneys with a thick medulla which allows black-backed jackals to concentrate their urine in times of drought (Loveridge and Nel 2004; Brassine 2011). These canids show a preference for open habitats, but have been recorded in a wide range of habitat types including Nama-Karoo, Succulent Karoo, open and arid savannah, fynbos, arid coastal deserts and grasslands (Loveridge and Nel 2004; Skinner and Chimimba 2005; Estes 2012). Black-backed jackals also occur on farmlands, being drawn to an abundance of potential prey.

Black-backed jackals display both diurnal and nocturnal activity patterns (Estes 2012). In many protected areas where jackals are not persecuted or in areas of low human habitation they are often seen during the day, however in areas of high human activity and high persecution they are mostly active a night (Loveridge and Nel 2004; Skinner and Chimimba 2005). Black-backed jackals are infamous for their adaptable behaviour as a response to human activity (Skinner and Chimimba 2005). Most of the species' main prey items, such as certain rodent species are diurnal, another reason for their high activity during day (Ferguson, Galpin and De Wet 1988). Black-backed jackal are mostly seen travelling at a trot and generally only walk slowly when hunting for rodents and invertebrates with their ears pricked, listening for any prey activity (Skinner and Chimimba 2005). Like most canid species black-backed jackals are not solitary and have been observed to either forage singly, in pairs or at times in groups of three or more (Rowe-Rowe 1983). Little sexual dimorphism exists, however males are larger than females (Skinner and Chimimba 2005). In the drier western regions males exhibit a deep reddish brown coat in the winter months (Loveridge and Nel

2004). They are monogamous and a dominant pair will mark and defend their territory against intruders (Moehlman 1986; Ferguson, Nel and De Wet 1983; Skinner and Chimimba 2005). A dominate pairs territory will usually exclude other dominant pairs, however in other cases black-backed jackal territories may overlap (Walton and Joly 2003; Skinner and Chimimba 2005; Estes 2012).

Black-backed jackal hunting and scavenging activities have been observed in various ecosystems, especially in the savanna and open grassland areas (Owens and Owens 1978; McKenzie 1990). Although small in size, these canids are very proficient hunters (Lamprecht 1978; Estes 2012). Various studies have observed black-backed jackal forming groups to more effectively hunt larger antelope species (Estes 2012). Kamler, Foght and Collins (2009) observed a single adult black-backed jackal successfully killing an adult impala. Black-backed jackals are clear omnivores and exhibit a generalist diet (Loveridge and Nel 2004; Skinner and Chimimba 2005). Studies have found that mammals, insects, carrion and vegetable matter, such as seeds and fruits, constitute the largest portion of jackal diet (Rowe-Rowe 1976; Lamprecht 1978; Kok 1996; Nel, Loutit and Bothma 1997; Loveridge and Macdonald 2003; Do Linh San *et al.* 2009; Kamler, Klare and Macdonald 2012[a]). Past studies have reported high ungulate occurrence in black-backed jackal diet (Lamprecht 1978; Kok 1996; Do Linh San *et al.* 2009; Klare, Kamler, Stenkewitz and Macdonald 2010), however, most studies in diverse areas found rodents to be the dominant prey item (Rowe-Rowe 1983; Stuart 1987; Van der Merwe *et al.* 2009). Many authors have emphasised the complications with separating carrion and hunted prey remains from scat and stomach content analyses (Smithers 1983; Kok 1996). Smithers (1983) recorded > 50% of black-backed jackal diet being made up of insect remains from 96 stomachs analysed. Black-backed jackal are opportunistic hunters and scavengers and will mostly choose prey according to its high abundance, as well as selecting for prey that are easily captured (Skinner and Chimimba 2005).

Black-backed jackals have a long history of conflict with farmers in South Africa (Beinart 2003). Human presence is one of the main reasons for a decrease in natural prey across Southern Africa. Being opportunistic foragers, jackals have benefitted from the increased prey biomass available in the form of livestock (Brassine 2011; Kamler *et al.* 2012a). The persecution by humans could have altered many aspects of jackal biology (Skinner and Chimimba 2005). Black-backed jackal populations are capable of recovering from stresses placed on them, such as persecution, by exhibiting compensatory breeding (Beinart 2003; Nattrass and Conradie 2013). Ferguson *et al.* (1983) reported polygamy being exhibited by an alpha male in response to increased lethal persecution. Often farmers use lethal persecution to try and control black-backed jackal numbers, not realising that removing a dominant jackal allows sub-adults to move into the newly vacated territory (Bothma 2002; Ray *et al.* 2005). Sub-adults may be less efficient hunters and may select easier prey to catch such as livestock (Linnell *et al.* 1999). Black-backed jackal are not only being persecuted as a result of depredation on livestock, but more recently also due to them having a negative effect on the wildlife and game industry. In 2010, SANParks (South African National Parks) culled 132 black-backed jackal in the Karoo National Park and 212 in the Addo Elephant National Park due to the suspicion that jackals were responsible for springbok and other antelope decline (Nattrass and Conradie 2013). Despite the heavy persecution by farmers, both in the past and currently, predation on livestock by black-backed jackal has not decreased and black-backed jackal are still abundant in South Africa (Loveridge and Nel 2004; Blaum *et al.* 2009). The black-backed jackal is listed in the category "least concern" by the International Union for Conservation of Nature (IUCN) and has the lowest threat and vulnerability score of Africa's predators (Ray *et al.* 2005; Hoffmann 2014).

1.5 Study Area

1.5.1 Location and History

Namaqualand is situated in the western region of South Africa and also extends into Namibia from the Orange River in the south-west to Lüderitz (Cowling, Esler and Rundel 1999). In South Africa Namaqualand covers approximately 45 000 km² and extends from the Olifants River and Bokkeveld Mountains in the Western Cape, northwards towards Loeriesfontein in the Northern Cape, to just east of Vioolsdrif on the Orange River and to the west at Alexander Bay (Cowling *et al.* 1999; Desmet 2007) [See Figure 1.2]. Namaqualand can be divided into seven bioregions based on climate, physical environment and flora (Hilton-Taylor 1996; Desmet 2007). The study area lies on the western border of the Kamiesberg bioregion and the eastern border of the Hardeveld in the Northern Cape, South Africa. The study area includes the eastern section of Namaqua National Park (S 30. 16627 E017. 79619) and surrounding farmlands to the north, east and south of the national park. The Namaqualand National Park is situated approximately 495 km from Cape Town. It was proclaimed as a national park in 1988 and was established as an extension of the original 930 ha Skilpad Wildflower Reserve (Van Rooyen 2002; van Deventer and Nel 2006). Only the eastern, mountainous area of the national park was included in the study area in order to decrease variation in the physical environment. The study area provided an ideal location to investigate the diet of three predators in a protected area and its surrounding small stock farmlands. The entire Namaqualand region includes 420 private farms, covering about 52% of the region (Benjaminsen *et al.* 2006).

The San people were the first humans to utilise parts of Namaqualand, however they never stayed in the area permanently. The first people that settled in Namaqualand were the Khoi-Khoi, sometimes referred to as the Nama people, almost 200 years ago (Kostka 2005; Benjaminsen *et al.* 2006). In 1806 the British commando arrived in Namaqualand, enslaving many of the people who lived there (Kostka 2005). Many Namas were also used as labourers for the Afrikaans “trekboere” (travelling farmers) [Benjaminsen *et al.* 2006]. In 1878 the British rule allowed farmers, the former “trekboere”, to buy the land they were using under tenure from the Dutch East India Company (Kostka 2005). Most towns in Namaqualand started as mission stations and became refuge for the Nama-khoi people in the area (Boonzaaier 1996). Presently many descendants of the Nama-khoi live and farm in communal areas, which make up 30% of Namaqualand (Benjaminsen *et al.* 2006).

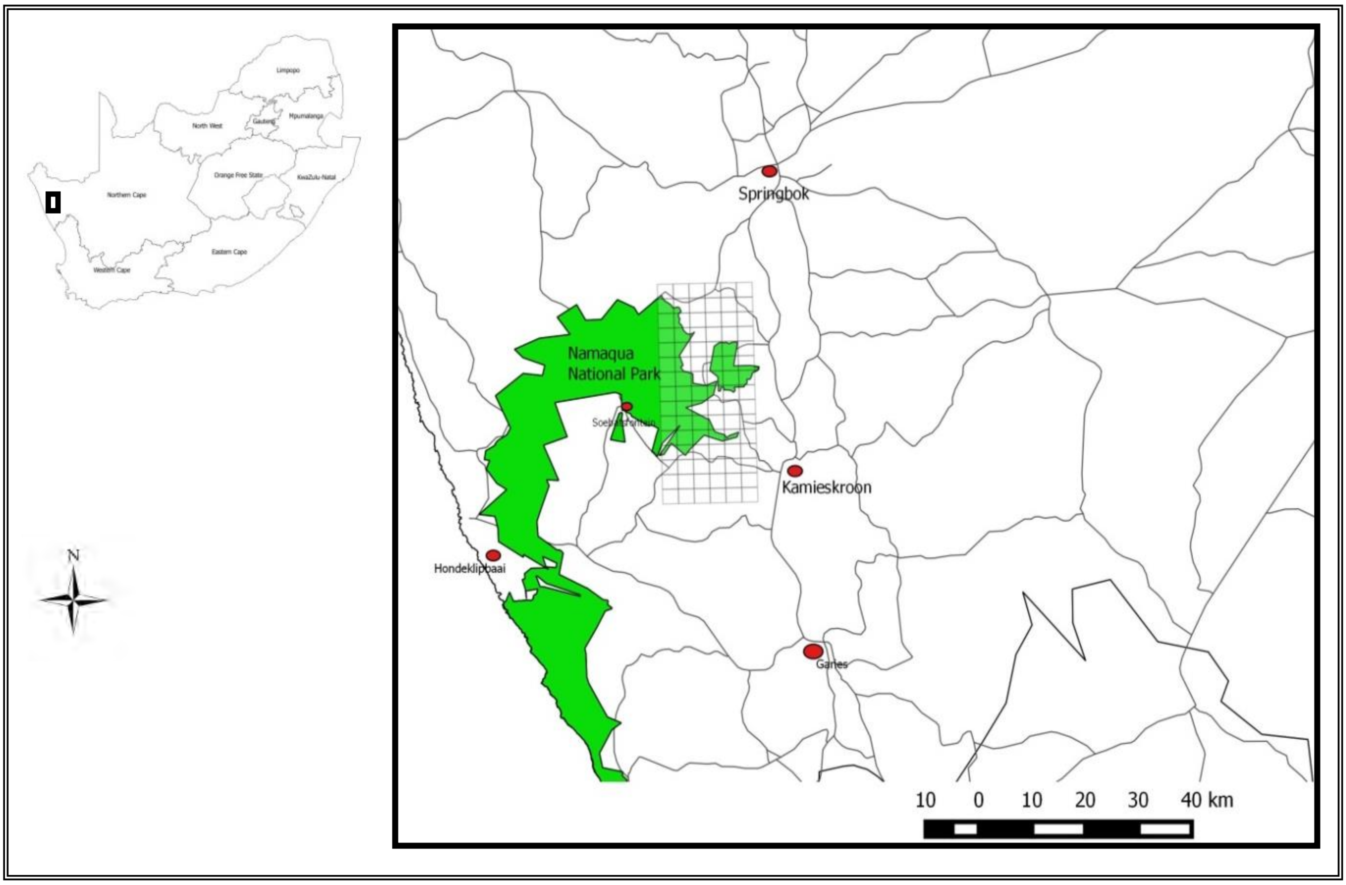


Figure 1.2. A map of South Africa (insert) showing the location of the study area (marked as the grid).

1.5.2 Climate

Namaqualand is classified as a semi-arid, winter rainfall region (Cowling *et al.* 1999). For the greater part of Namaqualand rainfall is reliable, especially when compared to other arid regions (Desmet

2007). However, rainfall can vary throughout the region and ranges from 50 mm annually in the north-west to up to 400 mm in the Kamiesberg region (Cowling *et al.* 1999). More specifically the study area of this study, primarily made up of Namaqualand Klipkoppe Shrubland, receives a mean annual precipitation (MAP) of 160 mm, with some years receiving < 100mm annually. These drought periods either last one or two years (Mucina and Rutherford 2006). Rainfall is the highest in June (Figure 1.3), but mostly occurs from May to September (Desmet 2007). The average rainfall recorded at Skilpad (S 30. 1663 E017. 7976) at an altitude of 683 m above sea level over 15 years was 340 mm (Namaqua National Park 2012).

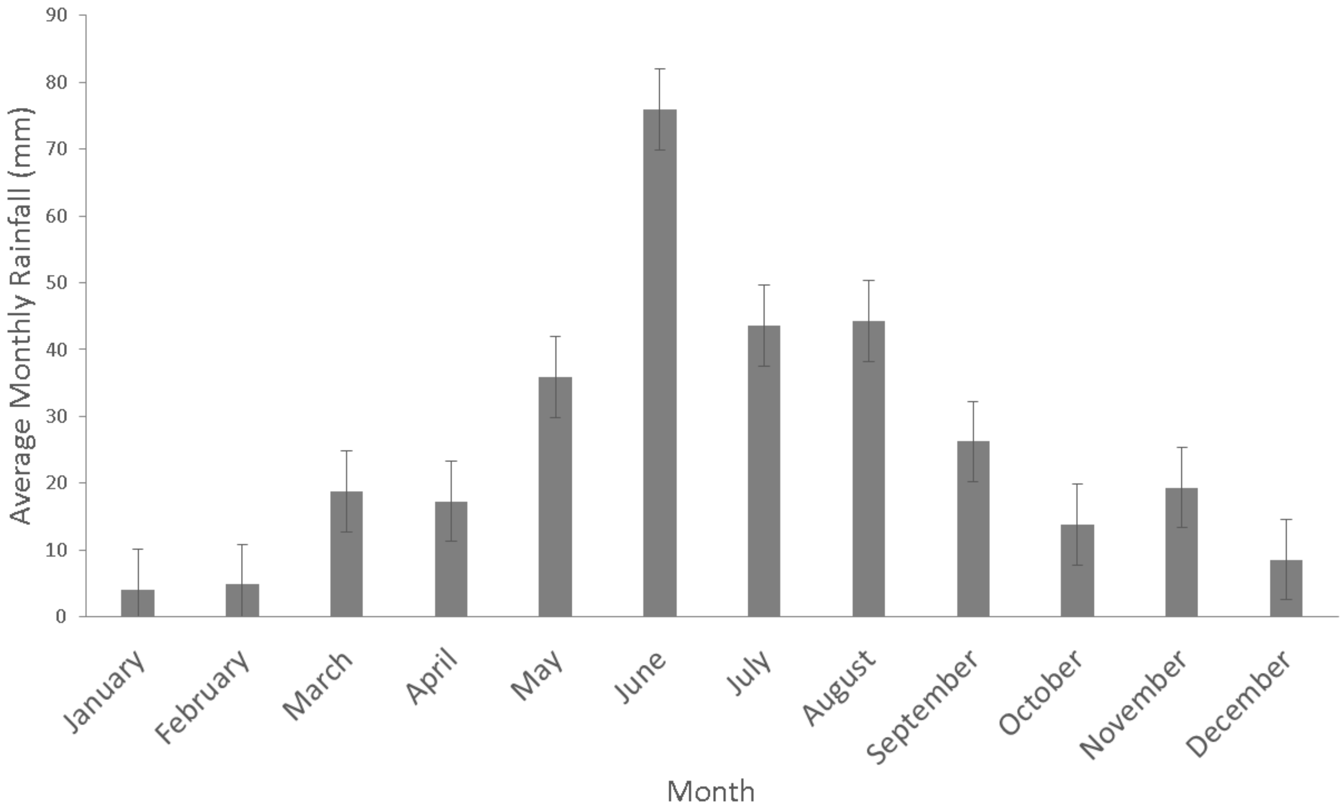


Figure 1.3. Average monthly rainfall for the study area over a 7 year period from 2008 -2014 (data from Skilpad in Namaqua National Park).

Summers are hot and can reach mean maximum temperatures of 30˚C, while temperatures can drop to 5˚C in the winter months, specifically in June and July (Mucina and Rutherford 2006) [Figure 1.4]. The highest recorded temperature for 2014 was 38.8˚C (26 February 2014) and the lowest was 2˚C (7 July 2014). Frost can occur for 8 days a year, but varies from year to year (Mucina and Rutherford 2006). Some years snow has fallen on the highest peaks of the Kamiesberg, but this area was not included in this study (Namaqua National Park 2012). Mist is common in the autumn and winter months and is said to be one of the factors important in seed germination in this area (Cowling and Pierce 1999).

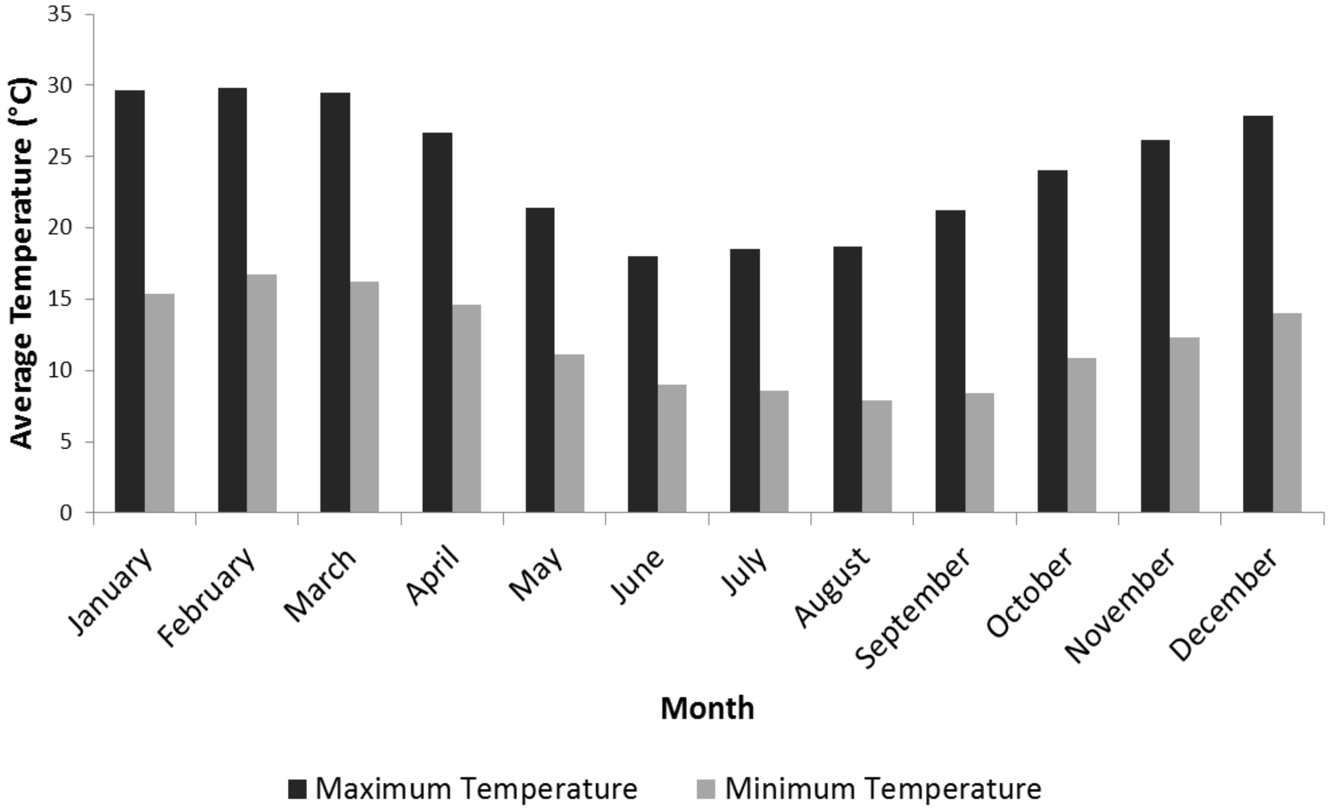


Figure 1.4. Average monthly maximum and minimum temperature for the study area over a 7 year period from 2008 -2014 (data from Skilpad in Namaqua National Park).

1.5.3 Geology and Soils

The landscape of Namaqualand is characterised by granite gneiss (Kamieskroon gneiss). This creates a scene of dome-shaped hills with flatter valleys in between (van Deventer and Nel 2006; Desmet 2007). Rock size varies from medium to large (Figure 1.5) to prominent rock domes (Figure 1.6) [Mucina and Rutherford 2006]. Elevation ranges from 180 m in the far west (not included in the study area) to 300 m at Melkboom (in Namaqua National Park) and finally to 750 m at Skilpad. The eastern section of the study area, including Skilpad, lies at the foothills of the Kamiesberg.

In the broader area of Namaqualand, three different soil types have been identified (Watkeys 1998). Soils in the study area ranged from sand to loam (Mucina and Rutherford 2006; Desmet 2007) and varied from lime-rich and shallow, from red to yellow in colour in the eastern sections to red, granite-derived colluvial soils more towards the west (Van Deventer and Nel 2006; Desmet 2007). In the western edge of the study area heuweltjies (circular termitaria) were observed (Desmet 2007). These heuweltjies create large, visible patches (± 10 m) in the soil consisting of a higher nutrient content than the surrounding area (Moore and Picker 1991).

Figure 1.5. The landscape of Namaqualand, consisting of medium to large granite gneiss and flatter valleys. © Corlé Jansen

Figure 1.6. The large rock domes of granite gneiss which can be seen in the study area. © Corlé Jansen

1.5.4 Vegetation

The study area forms part of the Succulent Karoo biome, one of only two semi-arid biodiversity hotspots in the world. Namaqualand makes up approximately a quarter of the Succulent Karoo and boasts 3500 flora species in 135 families and 724 genera, of which 25% is endemic to Namaqualand (Driver, Desmet, Rouget and Cowling 2003; Desmet 2007). The broader vegetation type, which is included in the majority of the study area, is Namaqualand Klipkoppe shrubland, which according to Mucina and Rutherford (2006) falls under Namaqualand Hardeveld. The area consists of open shrubland of up to 1m in height, comprising of dwarf to medium-sized shrubs. *Aloe dichotoma* var. *dichotoma*, or better known as the kokerboom (quiver tree), can be found on the north-facing slopes (Mucina and Rutherford 2006). Along the dry riverbeds *Acacia Karoo* is found. Another tree species commonly encountered in the study area was the rock-splitting fig (*Ficus ilicina)*, which is found on rocks or boulders (Trail 2015).

Important succulent shrubs found in the study area included *Euphorbia decussate* (melktou) and *Euphorbia mauritanica* (melkbos). Both these shrubs produce a toxic milky substance once a stem is broken, to protect it from herbivores (Esler, Milton and Dean 2006). *Didelta spinosa* and *Leipoldtia schultzei* both display flowers after good rains. Other important succulent shrubs occurring in the study area included *Cotyledon cuneata, C. orbiculata* var. *orbiculata, Crassula atropurpurea* var.

watermeyeri, Othonna cylindrical, Pelargonium crithmifolium, Ruschia goodiae, Sarcocaulon crassicaule, Tetragonia fruticose and *Zygophyllum foetidum* (Mucina and Rutherford 2006). Tall shrubs such as *Dodonaea viscosa* var. *angustifolia* (sand olive) which grows in sandy soils, *Putterlickia pyracantha* and the commonly encountered *Rhus undulata* also occur in the study area (Mucina and Rutherford 2006).

Small shrubs occur in the area with *Galenia africana* (kraalbos), a shrub found in overgrazed areas or abandoned ploughed fields (Esler *et al.* 2006). Other small shrubs included the distinct *Eriocephalus microphyllus var. pubescens* or commonly known as kapokbos, *Berkheya fruticose, Hermannia disermifolia, Lebeckia sericea*, the spiny *Acanthopsis spathularis, Asparagus capensis* var. *capensis, , Eriocephalus brevifolius, Galenia fruticose, Selago divaricate* and *S. glutinosa* (Mucina and Rutherford 2006). In winter and spring Namaqualand is transformed by mass floral displays, a popular tourist attraction (van Rooyen 2002; Botha, Cariick and Allsopp 2008). The occurrence of annual wildflower displays are often a result of human interferences such as old fields and potential overgrazing sites (van Rooyen 2002) [see Figure 1.7 and Figure 1.8 for a comparison of the same fields and area at Skilpad in two different seasons]

It is in spring season when herbaceous plants and geophytes such as *Tripteris amplectens, T. hyoseroides, Arctotis revoluta, Gazania leiopoda, Ursinia cakilefolia, Felicia bergeriana, Heliophila variabilis, Leysera gnaphalodes, Conicosia elongata and Oxalis obtuse* and *Senecio arenarius* appear (Mucina and Rutherford 2006; van Rooyen, Henstock, van Rooyen and van der Merwe 2010).

Figure 1.7. The fields in front of Skilpad, Namaqua National Park in the dry months (December- May). © Corlé Janse

Figure 1.8. The fields in front of Skilpad, Namaqua National Park in the wet months (June- November). © Corlé Jans

1.6 Objectives of this study

The main objectives of this study were to:

1. Determine the general diet of leopard, caracal and black-backed jackal across two land-uses, in addition to comparing diet between the two land-uses namely the Namaqua National Park and surrounding small stock farms.
2. Determine the relative abundance index (RAI) of available prey from data obtained from both camera traps and small mammal trapping and compare the RAI between the Namaqua National Park and surrounding farmlands.
3. Determine prey preference of the three species using diet data and abundance data from camera traps.
4. Test if caracal diet outcomes differ when using two different methodologies, namely scat analysis and GPS cluster visitations or kill sites.

1.7 References

Allen, B. L., and West, P. 2013. Influence of dingoes on sheep distribution in Australia. *Australian Veterinary Journal* **91**: 261–267.

Anderson, J. L. 1981. The re-establishment and management of a lion *Panthera leo* population in Zululand, South Africa. *Biological Conservation* **19**: 107–17.

Athreya, V. 2006. Is relocation a viable management option for unwanted animals? The case of the leopard in India. *Conservation and Society* **4**: 419–23.

Athreya, V., Odden, M., Linnell, J. D., And Karanth, K. U. 2010. Translocation as a Tool for Mitigating Conflict with Leopards in Human-Dominated Landscapes of India. *Conservation Biology* **25**: 133–141.

Avenant, N. L., and Nel, J. A. J. 1998. Home-range use, activity, and density of caracal in relation to prey density. *African Journal of Ecology* **36**: 347-359.

Avenant, N. L., and Nel, J. A. J. 2002. Among habitat variation in prey availability and use by caracal *Felis caracal*. *Mammal Biology* **67**: 18–33.

Bacon, M. M., Becic, G. M., Epp, M. T., and Boyce, M. S. 2011. Do GPS Clusters Really Work? Carnivore Diet from Scat Analysis and GPS Telemetry Methods. *Wildlife Society Bulletin* **35**: 409-415.

Bagchi, S., and Mishra, C. 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). *Journal of Zoology* **268**: 217-224.

Bagniewska, J. M., and Kamler, J. F. 2013. Do black-backed jackals affect numbers of smaller carnivores and prey? *African Journal of Ecology* **52**: 564-567.

Bailey, T. N. 1993. *The African leopard: ecology and behavior of a solitary felid*. New York: Columbia University Press.

Balme, G. A., Batchelor, A., Woronin Britz, N., Seymour, G., Grover, M., Hes, L., Macdonald, D. W., and Hunter, L. T. 2012b. Reproductive success of female leopards Panthera pardus: the importance of top-down processes. *Mammal Review* **43**: 221-237.

Balme, G. A., Hunter, L. T. B., and Braczkowski, A. 2012a. Applicability of Age-Based Hunting Regulations for African Leopards. *PLoS ONE* **7**: e35209.

Balme, G. A., Slotow, R., & Hunter, L. T. 2009. Impact of conservation interventions on the dynamics and persistence of a persecuted leopard (*Panthera pardus*) population. *Biological Conservation* **142**: 2681-2690.

Balme, G. A., Slotow, R., and Hunter, L. T. B. 2010. Edge effects and the impact of non-protected areas in carnivore conservation: leopards in the Phinda-Mkhuze Complex, South Africa. *Animal Conservation* **13**: 315–323.

Balme, G., Hunter, L., and Slotow, R. 2007. Feeding habitat selection by hunting *leopards Panthera pardus* in a woodland savanna: prey catchability versus abundance. *Animal Behaviour* **74:** 589 – 598.

Balme, G., Lindsey, P. A., Swanepoel, L. H., and Hunter, L. T. B. 2013. Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study. *Conservation Letters* **00**: 1 – 9.

Barua, M., Bhagwat, S. A., and Jadhav, S. 2013. The hidden dimensions of human–wildlife conflict: Health impacts, opportunity and transaction costs. *Biological Conservation* **157**: 309-316.

Beinart, W. 2003. *The rise of conservation in South Africa: settlers, livestock and the environment.* Oxford: Oxford University Press.

Bekoff, M., Daniels, T. J., and Gittleman, J. L. 1984. Life history patterns and the comparative social ecology of carnivores. *Annual review of ecology and systematics* **15**: 191-232.

Bengis, R. G., Kock, R. A., and Fischer, J. 2002. Infectious animal diseases: the wildlife/livestock interface. *Revue Scientifique et Technique-Office international des épizooties* **21**: 53-66.

Benjaminsen, T. A., Rohde, R., Sjaastad, E., Wisborg, P., and Lebert, T. 2006. Land reform, range ecology, and carrying capacities in Namaqualand, South Africa. *Annals of the Association of American Geographers* **96**: 524-540.

Bergman, D. L., De Waal, H. O., Avenant, N. L., Bodenchuk, M. J., Marlow, M. C., and Nolte, D. L. 2013. The Need to Address Black-backed Jackal and Caracal Predation in South Africa. In: J. B. Armstrong and G. R. Gallagher, eds. 2013. *Proceedings of the 15th Wildlife Damage Management Conference* South Carolina.

Beschta, R. L., and Ripple, W. J. 2009. Large predators and trophic cascades in terrestrial ecosystems of the western United States. *Biological Conservation* **142**: 2401-2414.

Bingham, J., and Purchase, G. K. 2002. Reproduction in the jackals *Canis adustus* Sundevall, 1846, and *Canis mesomelas* Schreber, 1778 (Carnivora: Canidae), in Zimbabwe. *African Zoology* **37**: 21-26.

Blaum, N., Tietjen, B., and Rossminth, E. Impact of Livestock Husbandly on Small- and Medium-Sized Carnivores in Kalahari Savannah Rangelands*. The Journal of Wildlife Management* **73**: 60-67.

Boitani, L., Ciucci, P., and Raganella-Pelliccioni, E. 2011. Ex-post compensation payments for wolf predation on livestock in Italy: a tool for conservation? *Wildlife Research* **37**: 722-730.

Bonnet, X., Naulleau, G., and Shine, R. 1999. The dangers of leaving home: dispersal and mortality in snakes. *Biological conservation* **89**: 39-50.

Boonzaier, E. 1996. *The Cape herders: a history of the Khoikhoi of southern Africa*. South Africa: New Africa Books.

Botha, M. S., Carrick, P. J., and Allsopp, N. 2008. Capturing lessons from land-users to aid the development of ecological restoration guidelines for lowland Namaqualand. *Biological Conservation* **141**: 885 – 895.

Bothma, J. D. P. 2002. *Game ranch management.* South Africa: Van Schaik Publishers.

Bothma, J. du P., and Le Riche, E. A. N. 1986. Prey preference and hunting efficiency of the Kalahari Desert leopard. In: S. D. Miller and D. D. Everett, eds. *Cats of the world: Biology, conservation and management* Washington, D. C: National Wildlife Federation.

Bothma, J. du P., and Le Riche, E. A. N. 1994. Scat analysis and aspects of defaecation in Northern Cape leopards. *South African Journal of Wildlife Research* **24**: 21 – 25.

Bothma, J. Du P., and Walker, C. 1999. *Larger Carnivores of the African Savanna*. New York: Springer-Verlag.

Braczkowski, A., Watson, L., Coulson, D., Lucas, J., Peiser, B., and Rossi, M. 2012b. The diet of caracal, *Caracal caracal*, in two areas of the southern Cape, South Africa as determined by scat analysis. *South African Journal of Wildlife Research* **42**: 111–116.

Braczkowski, A., Watson, L., Coulson, D., and Randall, R. 2012a. Diet of leopards in the southern Cape, South Africa. *African Journal of Ecology* **50**: 377 – 380.

Brassine, M. C. 2011. *The diet and ecological role of black-backed Jackals,* Canis mesomelas*, in two conservation areas in the Eastern Cape Province, South Africa*. Master's thesis, University of Rhodes, South Africa.

Breitenmoser, U., Breitenmoser-Würsten, C., and Capt, S. 1998. Re-introduction and present status of the lynx in Switzerland. *Hystrix* **10**: 17–30.

Breitenmoser, U., Ryser, A., Molinari-Jobin, A., Zimmermann, F., Haller, H., Molinari, P., and Breitenmoser-Würsten, C. 2010. In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

Breitenmoser-Würsten, C., Henschel, P. and Sogbohossou, E. 2008. Caracal caracal. In: The IUCN Red List of Threatened Species 2008. [online] Available from: http://www.iucnredlist.org/details/3847/0 (Accessed 19 January 2016).

Brown, J. R., Bishop, C. A., and Brooks, R. J. 2009. Effectiveness of Short-Distance Translocation and its effects on Western Rattlesnakes. *Journal of Wildlife Management* **73**: 419–425.

Bunnefeld, N., Linnell, J. D., Odden, J., Van Duijn, M. A. J., and Andersen, R. 2006. Risk taking by Eurasian lynx (*Lynx lynx*) in a human-dominated landscape: effects of sex and reproductive status. *Journal of Zoology* **270**: 31-39.

Burns, R. J., Zemilcka, D. E., and Savarie, P. J. 1996. Effectiveness of large livestock protection collars against depredating coyotes. *Wildlife Society Bulletin* **24**: 123–7.

Byrne, A. W., White, P. W., McGrath, G., O'Keeffe, J., and Martin, S. W. 2014. Risk of tuberculosis cattle herd breakdowns in Ireland: effects of badger culling effort, density and historic large-scale interventions. *Veterinary research* **45**: 109.

Campbell, H. A., Dwyer, R. G., Wilson, H., Irwin, T. R., and Franklin, C. E. 2014. Predicting the probability of large carnivore occurrence: a strategy to promote crocodile and human coexistence. *Animal Conservation* **18**: 387-395.

Cardillo, M., Mace, G. M., Jones, K. E., Bielby, J., Bininda-Emonds, O. R. P., Sechrest, W., Orme, C. D. L., and Purvis, A. 2005. Multiple Causes of High Extinction Risk in Large Mammal Species. *Science* **309**: 1239 – 1241.

Chattha, S. A., Hussain, S. M., Javid, A., Abbas, M. N., Mahmood, S., Barq, M. G., and Hussain, M. 2015. Seasonal Diet Composition of Leopard (*Panthera pardus*) in Machiara National Park, Azad Jammu and Kashmir, Pakistan. *Pakistan Journal of Zoology* **47**: 201 – 207.

Chauhan, N. P. S. 2003. Human casualties and livestock depredation by black and brown bears in the Indian Himalaya, 1989-98. U*rsus* **14**: 84-87.

Conforti, V. A., and de Azevedo, F. C. C. 2003. Local perceptions of jaguars (*Panthera onca*) and pumas (*Puma concolor*) in the Iguacu National Park area, south Brazil. *Biological Conservation* **111**: 215-221.

Conradie, B., and Piesse, J. 2013. *The Effect of Predator Culling on Livestock Losses: Ceres, South Africa, 1979 – 1987*. Centre for Social Science Research: University of Cape Town.

Constant, N. 2014. *A socio-ecological approach towards understanding conflict between leopards (*Panthera pardus*) and humans in South Africa: Implications for leopard conservation and farming livelihoods*. Doctoral dissertation, Durham University, United Kingdom.

Cowling, R. M., Esler, K. J., and Rundel, P. W. 1999. Namaqualand, South Africa – an overview of a unique winter-rainfall desert ecosystem. *Plant Ecology* **142**: 3-21.

Cowling, R., and Pierce, S. 1999*. Namaqualand: a succulent desert. South Africa*: Fernwood Press.

Crawshaw, P. G. 2004. Depredation of domestic animals by large cats in Brazil. *Human Dimensions of Wildlife* **9**: 329–30.

Cumming, R. G. 1856. *Five Years' Adventures in the Far Interior of South Africa: With Notices of the Native Tribes and Savage Animals*. London: John Murray.

Cunningham, S. C., Gustavson, C. R., and Ballard, W. B. 1999. Diet Selection of Mountain Lions in Southeastern Arizona. *Journal of Range Management* **3**: 202-207.

Czech, A., and Lisle, S. 2003. Understanding and Solving the Beaver (*Castor fiber L*.)-Human-Conflict: An Opportunity to Improve the Environment and Economy of Poland. *Kataloge der Oberösterreichischen Landesmuseen* **2**: 91-98.

Dar, N. I., Minhas, R. A., Zaman, Q., and Linkie, M. 2009. Predicting the patterns, perceptions and causes of human–carnivore conflict in and around Machiara National Park, Pakistan. *Biological Conservation* **142**: 2076-2082.

De Azevedo, F. C. C. 2008. Food habits and livestock depredation of sympatric jaguars and pumas in the Iguacu National Park area, south Brazil. *Biotropica* **40**: 494-500.

Department of Environmental Affairs 2010. National environmental management: Biodiversity Act, 2004 (Act No. 10 of 2004). Draft norms and standards for the management of damage-causing animals in South Africa. *Government Gazette* **33806**.

Desmet, P. G. 2007. Namaqualand—A brief overview of the physical and floristic environment. *Journal of Arid Environments* **70**: 570–587.

Dickman, A. J. 2005. An *assessment of pastoralist attitudes and wildlife conflict Rungwa in the Rungwa-Ruaha region, Tanzania, with particular reference to large carnivores.* Masters thesis, University of Oxford, United Kingdom.

Dickman, A. J., Macdonald, E. W., and Macdonald, D. W. 2011. A review of financial instruments to pay for predator conservation and encourage human–carnivore coexistence. *PNAS* **108**: 13937–13944.

Divyabhanusinh 1995. *The end of a trail – the cheetah in India*. New Delhi: Banyan Books.

Do Linh San, E., Malongwe, N. B., Fike, B., Somer, M. J., and Walters, M. 2009. A diverse autumn diet without dominant prey for opportunistic black-backed jackals *Canis mesomelas*. *Wildlife Biology in Practice* **5**: 96–103.

Don Carlos, A. W., Bright, A. D., Teel, T. L., and Vaske, J. J. 2009. Human–black bear conflict in urban areas: an integrated approach to management response. *Human Dimensions of Wildlife* **14**: 174-184.

Donnelly, C. A., Woodroffe, R., Cox, D. R., Bourne, F. J., Cheeseman, C. L., Clifton-Hadley, R. S., ... and Morrison, W. I. 2006. Positive and negative effects of widespread badger culling on tuberculosis in cattle. *Nature* **439**: 843-846.

Driver, A., Desmet, P. G., Rouget, M., Cowling, R. M., and Maze, K. E. 2003. *Succulent Karoo Ecosystem Plan Biodiversity Component Technical Report*. Cape Town: Cape Conservation Unit, Botanical Society of South Africa

Du Plessis, J. J. 2013. *Towards the development of a sustainable management strategy for* Canis mesomelas *and* Caracal caracal *on rangeland*. Dissertation, University of the Free State, South Africa.

Du Plessis, J. J., Avenant, N. L., and De Waal, H. O. 2015. Quality and quantity of the scientific information available on black-backed jackals and caracals: contributing to human–predator conflict management? *African Journal of Wildlife Research* **45**: 138–157.

Esler, K. J., Milton, S. J., and Dean, W. R. J. 2006. Karooveld: Ecology and Management. South Africa: Briza.

Estes, J. A., Terborgh, J., Brashares, J. S., Power, M. E., Berger, J., Bond, W. J., ... and Wardle, D. A. 2011. Trophic downgrading of planet Earth. *Science* **333**: 301-306.

Estes, R. D. 2012. *The behaviour guide to African mammals*. Berkely: The University of California Press.

Ferguson, J. W. H., Galpin, J. S., and De Wet, M. J. 1988. Factors affecting the activity patterns of black-backed jackals *Canis mesomelas*. *Journal of Zoology* **214**: 55-69.

Ferguson, J. W. H., Nel, J. A. J., and De Wet, M. J. 1983. Social organization and movement patterns of black-backed jackals *Canis mesomelas* in South Africa. *Journal of Zoology* **199**: 487- 502.

Ferreira, N. A. 1988. *Sekere aspekte van die ekologie en die beheer van die rooikat (*Felis caracal*) in die Oranje-Vrystaat*. Unpublished report, Orange Free State Provincial Adminstration, Directorate Environmental and Nature Conservation, Bloemfontein.

Forbes, R. W. 2011. *The diet of black-backed jackal (*Canis Mesomelas*) on two contrasting land-use types in the Eastern Cape Province, South Africa and the validation of a new analytical method of mammalian hair identification*. Maters thesis, Rhodes University, South Africa.

Forsyth, D. M., Woolnough, A. P., Nimmo, D. G., Ritchie, E. G., Kennedy, M., Pople, A., and Watson, I. 2014. A comment on the influence of dingoes on the Australian sheep flock. *Australian Veterinary Journal* **92**: 461-462.

Frank, L. G., Woodroffe R, Ogada, M. O. 2005. People and predators in the Laikipia District, Kenya. In: R. Woodroffe, S. Thirgood and A. Rabinowitz, eds. 2005. *People and Wildlife: Conflict or Coexistence?* United Kingdom: Cambridge University Press.

Gehring, T. M., Vercauteren, K. C., and Landry, J-M. 2010. Livestock Protection Dogs in the 21st Century: Is an Ancient Tool Relevant to Modern Conservation Challenges? *BioScience* **60**: 299-308.

Ghoddousi, A., Ghadirian, T., and Fahimi, H. 2009. Status of caracal in Bahram'gur Protected Area, Iran. *CATnews* **50**: 10-13.

Goodrich, J. M. 2010. Human–tiger conflict: a review and call for comprehensive plans. Integrated Zoology **5**: 300–312.

Graham, K., Beckerman, A. P., and Thirgood, S. 2005. Human-predator-prey conflicts: ecological correlates, prey losses and patterns of management. *Biological Conservation* **122**: 159–71.

Grobler, J. H. 1981. Feeding behaviour of the caracal *Felis caracal* Schreber 1776 in the Mountain Zebra National Park. *South African Journal of Zoology* **16**: 259- 262.

Gurung, D. B., and Seeland, K. 2008. Ecotourism in Bhutan: Extending its benefits to rural communities. *Annals of Tourism research* **35**: 489-508.

Gusset, M., Swarner, M. J., Mponwane, L., Keletile, K., and McNutt, J. W. 2009. Human–wildlife conflict in northern Botswana: livestock predation by Endangered African wild dog *Lycaon pictus* and other carnivores. *Oryx* **43**: 67-72.

Hayward, M. W., and Kerley, G. I. 2009. Fencing for conservation: Restriction of evolutionary potential or a riposte to threatening processes? *Biological Conservation* **142**: 1-13.

Hayward, M. W., Henschel, P., O'Brien, J., Hofmeyr, M., Balme, G and Kerley, G. I. H. 2006. Prey preferences of the leopard (*Panthera pardus*). *Journal of Zoology* **270**: 298-313.

Henschel, P., Hunter, L., Breitenmoser, U., Purchase, N., Packer, C., Khorozyan, I., Bauer, H., Marker, L., Sogbohossou, E., and Breitenmoser-Wursten, C. 2008. *Panthera pardus*. In: IUCN 2010. *IUCN Red List of Threatened Species. Version 2010.4.* [online] available from: http://www.iucnredlist.org/details/15954/0 (accessed 21 April 2015).

Hilton-Taylor, C. 1996. Red data list of Southern African plants. South Africa: National Botanical Institute.

Hoare, R. E. 1999. Determinants of human-elephant conflict in a land-use mosaic*. Journal of Applied Ecology* **36**: 689-700.

Hoffman, M. 2014. *Canis mesomelas*. The IUCN Red List of Threatened Species 2014: e.T3755A46122476 [online] available from: http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T3755A46122476.en. (accessed 26 October 2015).

Hoffman, T. S., and O'Riain, M. J. 2012. Monkey management: using spatial ecology to understand the extent and severity of human-baboon conflict in the Cape Peninsula, South Africa. *Ecology and Society* **17**: 13.

Ilemin Y., and Gürkan B. 2010. Activity Patterns and Status Assessment of the Caracal in Datça and Bozburun Peninsulas, Southwestern Turkey. *Zoology in the Middle East* **50**: 3–10.

Inskip, C., and Zimmerman, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. *Oryx* **43**: 18-34.

Jackson, R. M., and Wangchuk, R. 2004. A community-based approach to mitigating livestock depredation by snow leopards. *Human dimensions of wildlife* **9**: 1-16.

Jackson, R. M., Mishra, C., and McCarthy, Ale, S.B. 2010. Snow leopards: conflicts and conservation. In: D. W. MacDonald and A. J. Loveridge, eds. 2010. *The Biology and Conservation of Wild Felids.* United Kingdom*:* Oxford University Press.

Jadhav, S., and Barua, M. 2012. The Elephant Vanishes: Impact of human–elephant conflict on people's wellbeing. *Health & place* **18**: 1356-1365.

Johansson, O., McCarthy, T., Samelius, G., Andren, H., Tumursukh, L., and Mishra, C. 2015. Snow leopard predation in a livestock dominated landscape in Mongolia. *Biological Conservation* **184**: 251-258.

Johnson, A., Vongkhamheng, C., Hedemark, M., and Saithongdam, T. 2006. Effects of human-carnivore conflict on tiger (*Panthera tigris*) and prey populations in Lao PDR. *Animal Conservation* **9**: 421–30.

Kamler, J. F., Foght, J. L., and Collins, K. 2009. Single black-backed jackal (*Canis mesomelas*) kills adult impala (*Aepyceros melampus*) *African Journal of Ecology* **48**: 847–848.

Kamler, J. F., Klare, U., and Macdonald, D. W. 2012[a]. Seasonal diet and prey selection of black-backed jackals on a small-livestock farm in South Africa. *African Journal of Ecology* **50**: 299 – 307.

Kamler, J. F., Stenkewitz, U., Klare, U., Jacobsen, N, F., and Macdonald, D. W. 2012[b]. Resource Partitioning Among Cape Foxes, Bat-Eared Foxes, and Black-Backed Jackals in South Africa. *The Journal of Wildlife Management* **76**: 1241–1253.

Karanth, K. U., and Gopal, R. 2005. An ecology-based policy framework for human-tiger co-existence in India. In R. Woodroffe, S. Thirgood, and A. Rabinowitz, eds. 2005. *People and Wildlife: Conflict or Coexistence?* United Kingdom: Cambridge University Press.

Kaunda, S. K. K. 2001. Spatial utilization by black-backed jackals in southeastern Botswana *African Zoology* **36**: 143-152.

Kaunda, S. K. K., and Skinner, J. D. 2003. Black-backed jackal diet at Mokolodi Nature Reserve, Botswana. *African Journal of Ecology* **41**: 39-46.

Kiffner, C., Wenner, C., La Violet, A., Yeh, K., and Kioko, J. 2014. From savannah to farmland: effects of land-use on mammal communities in the Tarangire–Manyara ecosystem, Tanzania. *African Journal of Zoology* **53**: 156-166.

Kissui, B. M. 2008. Livestock predation by lions, leopards, spotted hyenas, and their vulnerability to retaliatory killing in the Maasai steppe, Tanzania. *Animal Conservation* **11**: 422-432.

Klare, U., Kamler, J. F., Stenkewitz, U., and Macdonald, D. W. 2010. Diet, prey selection, and predation impact of black-backed jackals in South Africa. *Journal of Wildlife Management* **74**: 1030–1042.

Kok, O. B. 1996. Die dieetsamestelling van enkele karnivoorsoorte in die Vrystaat, Suid-Afrika. *South African Journal of Science* **92**: 393–398.

Kok, O. B., and Nel, J. A. J. 2004. Convergence and divergence in prey of sympatric canids and felids: opportunism or phylogenetic constraint? *Biological Journal of the Linnean Society* **83:** 527–538.

Kostka, B. 2005. Namaqualand - A Short History of Nearly Everything. *FSM (Four Striped Mouse) Times* **4**: 8-17.

Lamarque, F., Anderson, J., Fergusson, R., Lagrange, M., Osei-Owusu, Y., and Bakker, L. 2009. *Human-wildlife conflict in Africa: causes, consequences and management strategies (No. 157)*. Food and Agriculture Organization of the United Nations (FAO).

Lamprecht, J. 1978. On diet, foraging behaviour and interspecific food competition of jackals in the Serengeti National Park, East Africa. *Zeitschrift für Säugetierkunde* **43**: 210-223.

Letnic, M., Ritchie, E. G., and Dickman, C. R. 2012. Top predators as biodiversity regulators: the dingo *Canis lupus* dingo as a case study *Biological Reviews* **87**: 390–413.

Li, X., Buzzard, P., Chen, Y., and Jiang, X. 2013. Patterns of Livestock Predation by Carnivores: Human–Wildlife Conflict in Northwest Yunnan, China. *Environmental Management* **52**: 1334-1340.

Linnell, J. D. C., Andersen, R., Andersone, Z., Balciauskas, L., Blanco, J. C., Boitani, L., ... and Wabakken, P. 2002. *The fear of wolves: a review of wolf attacks on people*. Trondheim: NINA Oppdragsmelding 731.

Linnell, J. D. C., Odden, J., Smith, M. E., Aanes, R., and Swenson, J. E. 1999. Large carnivores that kill livestock: do 'problem individuals' really exist? *Wildlife Society Bulletin* **27**: 698–705.

Linnell, J. D. C., Swenson, J. E., and Andersen, R. 2001. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation* **4**: 345–349.

Loveridge, A. J., and Macdonald, D. W. 2003. Niche separation in sympatric jackals (*Canis mesomelas* and *Canis adustus*). *Journal of Zoology* **259**: 143-153.

Loveridge, A. J., and Nel, J. A. J. 2004. Black-backed jackal. In: C. Sillero-Zubiri, M. Hoffman and D. W. Mcdonald, eds. 2004. *Canids: foxes, wolves, jackals and dogs - 2004 status survey and conservation action plan.* Switzerland and United Kingdom: IUCN/SSC Canid Specialist Group. [online]. Available: http://www.canids.org/cap/index.htm (accessed 2 December 2014).

Loveridge, A. J., Wang, S. W., Frank, L. G., and Seidensticker, J. 2010. People and wild felids: conservation of cats and management of conflicts In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

MacKenzie, J. M. 1988. *Hunting and settlement in southern Africa*. In: The empire of nature. New York: Manchester University Press.

MacKinnon, J., and MacKinnon, K. 1986. *Review of the Protected Areas System in the Afrotropical Realm.* Switzerland and United Kingdom: IUCN.

Maclennan, S. D., Groom, R. J., Macdonald, D. W., and Frank, L. G. 2009. Evaluation of a compensation scheme to bring about pastoralist tolerance of lions. *Biological Conservation* **142**: 2419-2427.

Madden, F., and McQuinn, B. 2014. Conservation's blind spot: The case for conflict transformation in wildlife conservation. *Biological Conservation* **178**: 97-106.

Madhusudan, M. D. 2003. Living amidst large wildlife: livestock and crop depredation by large mammals in the interior villages of Bhadra Tiger Reserve, South India. *Environmental Management* **31**: 466–75.

Mann, G. 2014. *Aspects of the ecology of leopards (*Panthera pardus*) in the little Karoo, South Africa*. Dissertation, Rhodes University, South Africa.

Mariki, S. B., Svarstad, H., and Benjaminsen, T. A. 2015. Elephants over the cliff: Explaining wildlife killings in Tanzania. *Land Use Policy* **44**: 19-30.

Marker, L., and Dickman, A, J. 2005. Notes on the spatial ecology of caracals (*Felis caracal*), with particular reference to Namibian farmlands. *African Journal of Ecology* **43**: 73–76.

Marker, L., Dickman, A., and Schumann, M. 2005. Using Livestock Guarding Dogs as a Conflict Resolution Strategy on Namibian Farms. *Carnivore Damage Prevention News* **5**: 28-32.

Martins, Q. 2010. *The ecology of the leopard* Panthera pardus *in the Cederberg Mountains*. Dissertation, University of Bristol, United Kingdom.

Martins, Q., and Harris, S. 2013. Movement, activity and hunting behaviour of leopards in the Cederberg mountains, South Africa. *African Journal of Ecology* **51**: 571-579.

Martins, Q., Horsnell, W. G. C., Titus, W., Rautenbach, T., and Harris, S. 2011. Diet determination of the Cape Mountain leopards using global positioning system location clusters and scat analysis. *Journal of Zoology* **283**: 81-87.

McKenzie, A. A. 1990. *Co-operative hunting in the black-backed jackal* Canis mesomelas. Dissertation, University of Pretoria, South Africa.

Mech, D. L. 2011. Is science in danger of sanctifying the wolf? *Biological Conservation* **150**: 143-149.

Meriggi, A., and Lovari, S. 1996. A review of wolf predation in southern Europe: does the wolf prefer wild prey to livestock? *Journal of applied ecology* **33**: 1561-1571.

Michalski, F., Boulhosa, R., Faria, A., and Peres, C. 2006. Human–wildlife conflicts in a fragmented Amazonian forest landscape: determinants of large felid depredation on livestock. *Animal Conservation* **9**: 179-188.

Mishra, C., Allen, P., McCarthy, T., Madhusudan, M. D., Bayarjargal, A., and Prins, H. H. T. 2003. The role of incentive programs in conserving the snow leopard *Uncia uncia*. *Conservation Biology* **17**: 1512–1520.

Mizutani, F. 1999. Impact of leopards on a working ranch in Laikipia, Kenya. *African Journal of Ecology* **37**: 211–25.

Moehlman, P. D. 1986. Ecology of cooperation in canids. In: D. I. Rubenstein and R. W. Wrangham, eds. 1986. *Ecological Aspects of Social Evolution*. New Jersey: Princeton University Press.

Moolman, L. C. 1984. 'n Vergelyking van die voedingsgewoontes van die rooikat *Felis caracal* binne en buite die Bergkwagga Nasionale Park. *Koedoe* **27**: 121-129.

Moore, J. M., and Picker, M. D. 1991. Heuweltjies (Earth Mounds) in the Clanwilliam District, Cape-Province, South- Africa—4000-Year-Old Termite Nests. *Oecologia* **86**: 424–432.

Morales, J., Soria, D., Montoya, P., Pérez, B., and Salesa, M. J. 2003. Caracal depereti nov. sp. y *Felis aff. silvestris* (Felidae, Mammalia) del Plioceno inferior de Layna (Soria, España). *Estudios geológicos* **59**: 229-247.

Morehouse, A. T., and Boyce, M. S. 2011. From venison to beef: seasonal changes in wolf diet composition in a livestock grazing landscape. *Frontiers in Ecology and the Environment* **9**: 440–445.

Morelle, K., Lehaire, F., and Lejeune, P. 2013 Spatio-temporal patterns of wildlife-vehicle collisions in a region with a high-density road network. *Nature Conservation* **5**: 53–73.

Mouron, D., Désiré, G., Boisaubert, B., Lamarque, F. and Sanaa, M. 1998. Recensement des collisions véhicules grands mammifères sauvages – évolution entre les inventaires de 1984-1986 et 1993-1994. *Gibier Faune Sauvage* **15**: 855–865.

Mucina, L and Rutherford, M.C. eds., 2006. *The vegetation of South Africa, Lesotho and Swaziland.* Pretoria*:* South African National Biodiversity Institute.

Musiani, M. T., Muhly, T., Gates, C. C., Callaghan, C., Smith, M. E., and To.soni, E. 2005. Seasonality and reoccurrence of depredation and wolf control in western North America. *Wildlife Society Bulletin* **33**: 876-887.

Namaqua National Park. 2012. *Namaqua National Park: Park Management plan*. South Africa: SANParks.

Natrass, N., and Conradie, B. 2013. *Jackal Narratives and Predator Control in the Karoo, South Africa.* Centre for Social Science Research: University of Cape Town.

Nel, J. A. J., Loutit, R., and Bothma, J. Du P. 1997. Prey use by black-backed jackals along a desert coast. *South African Journal of Wildlife Research* **27**: 100-104.

Newsome, T. M., Dellinger, J. A., Pavey, C. R., Ripple, W. J., Shores, C. R., Wirsing, A. J., and Dickman, C. R. 2015. The ecological effects of providing resource subsidies to predators. *Global Ecology and Biogeography* **24**: 1-11.

Norton, P. M., and Lawson, A. B. 1985. Radio tracking of leopards and caracals in the Stellenbosch area, Cape Province. *South African Journal of Wildlife Research* **15**: 17-24.

Norton, P. M., Lawson, A. B., Henley, S. R., and Avery, G. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *South African Journal of Wildlife Research* **16:** 47–52.

Nowell, K., and Jackson, P. eds. 1996. *Wild cats: status survey and conservation action plan*. Gland: IUCN.

Ogada, M, O., Woodroffe, R., Oguge, N. O., and Frank, L. 2003. Limiting Depredation by African Carnivores: the Role of Livestock Husbandry. *Conservation Biology* **17**: 1-10.

Owens, M. J., and Owens, D. D. 1987. Feeding ecology and its influence on social organization in Brown hyenas (*Hyaena brunnea*, Thunberg) of the Central Kalahari Desert. *East African Wildlife Journal* **16**: 113-135.

Palmer, R., and Fairall, N. 1988. Caracal and African wild cat diet in the Karoo National Park and the implications thereof for hyrax. *South African Journal of Wildlife Research* **18**: 30-34.

Parker, G. E., and Osborn, F, V. 2006. Investigating the potential for chilli *Capsicum* spp. to reduce human-wildlife conflict in Zimbabwe. *Oryx* **40**: 343–346.

Patterson, B. D., Kasiki, S. M., Selempo, E., and Kays, R. W. 2004. Livestock predation by lions (*Panthera leo*) and other carnivores on ranches neighbouring Tsavo National Park, Kenya. *Biological Conservation* **119**: 507–16.

Patterson, J. H. 1907. *The man-eaters of Tsavo*. London: MacMillan and Company.

Peterhans, J. C. K., and Gnoske, T. P. 2001. The science of 'man-eating' among lions *Panthera leo* with a reconstruction of the natural history of the 'Man-eaters of Tsavo'. *Journal of East African Natural History* **90**: 1–40.

Pettigrew, M., Xie, Y., Kang, A., Rao, M., Goodrich, J., Liu, T., and Berger, J. 2012. Human–carnivore conflict in China: a review of current approaches with recommendations for improved management. *Integrative Zoology* **7**: 210–226.

Prowse, T. A. A., Johnson, C. N., Cassey, P., Bradshaw, C. J. A., and Brook, B. W. 2014. Ecological and economic benefits to cattle rangelands of restoring an apex predator. *Journal of Applied Ecology* **52**: 455-466.

Pyke, G. H., Pulliam, H. R., and Charnov, E. L. 1977. Optimal foraging: a selective review of theory and tests. *The Quarterly Review of Biology* **52**: 137-154.

Rabinowitz, A. 1986. Jaguar predation on domestic livestock in Belize. *Wildlife Society Bulletin* **14**: 170–4.

Rabinowitz, A. 2005. Jaguars and livestock: living with the world's third largest cat. In R. Woodroffe, S. Thirgood and A. Rabinowitz, eds. 2005. *People and Wildlife: Conflict or Coexistence?* United Kingdom: Cambridge University Press.

Rajpurohit, K. S., and Krausman, P. R. 2000. Human-sloth-bear conflicts in Madhya Pradesh, India. *Wildlife Society Bulletin* **28**: 393-399.

Ray, J. C., Hunter, L., and Zigouris, J. 2005. *Setting conservation and research priorities for larger African carnivores.* Wildlife Conservation Society, New York.

Redpath, S. M., Gutiérrez, R. J., Wood, K. A., and Young, J. C. 2015. *Conflicts in Conservation: Navigating towards solutions.* Cambridge: Cambridge University Press.

Rowe-Rowe, D. T. 1976. Food of the black-backed jackal in nature conservation and farming areas in Natal. *African Journal of Ecology* **11**: 345–348.

Rowe-Rowe, D. T. 1983. Black-backed jackal diet in relation to food availability in the Natal Drakensberg. *South African Journal of Wildlife Research* **13**: 17-23.

Ruth, T. K., Logan, K. A., Sweanor, L. L.,Hornocker, M.G., and Temple, L. J. 1998. Evaluating cougar translocation in New Mexico. *Journal of Wildlife Management* **62**: 1264–75.

Schiess-Meier, M., Ramsauer, S., Gabanapelo, T., and Köning, B. 2007. Livestock predation — insights from problem animal control registers in Botswana. *Journal of Wildlife Management* **71**: 1267–1274.

Schumann, W., Walls, J. L., and Harley, V. 2012. Attitudes towards carnivores: the views of emerging commercial farmers in Namibia. *Oryx* **46**: 604–613.

Siddiqui, N. A., and Choudhury, J. H. 1987. Maneating behaviour of tigers (*Panthera tigris* Linn) of the Sundarbans. Twenty-eight years' record analysis. *Tigerpaper*.

Sillero-Zubiri, C., and Switzer, D. 2004. Management of wild canids in human-dominated landscapes. In: *Canids: foxes, wolves, jackals and dogs. Status survey and conservation action plan*. United Kingdom: IUCN Canid Specialist Group, Switzerland and Cambridge.

Skead, C. J. 2011. *Historical incidence of the larger land mammals in the broader Western and Northern Cape*, (A. F. Boshoff, G. I. H. Kerley, and P. H. Lloyd, eds. Centre for African Conservation Ecology, Nelson Mandela Metropolitan University, Port Elizabeth.

Skinner, J. D., and Chimimba, C. T. 2005. *The mammals of the southern African subregion.* Cape Town: Cambridge University Press.

Smith, E, R. 2012. *An assessment of caracal population density and human-predator conflict in the Winterberg, Eastern Cape, South Africa.* Masters Thesis, Rhodes University, South Africa.

Smith, M. E., Linnell, J. D., Odden, J., and Swenson, J. E. 2000. Review of methods to reduce livestock depredation: I. Guardian animals. *Acta Agriculturae Scandinavica* **50**: 279-290.

Smithers, R. H. N. 1983. *The mammals of the southern African subregion*. South Africa: University of Pretoria.

Stadler H. 2006. Historical perspectives on the development of problem animal management in the Cape Province. In: B. Daly, W. Davies-Mostert, S. Evans, Y. Friedmann, N. King, T. Snow and H. Stadler, eds. 2006. *Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa*. Johannesburg: Endangered Wildlife Trust.

Stahl, P., Vandel, J. M., Herrenschmidt, V., and Migot, P. 2001. The effect of removing lynx in reducing attacks on sheep in the French Jura Mountains. *Biological Conservation* **101**:15–22.

Stander, P. E. 1997. The ecology of lions and conflict with people in north-eastern Namibia. In J. V. Heerden, ed. *Symposium on Lions and Leopards as Game Ranch Animals, Onderstepoort, South Africa*. Namibia: Ministry of Environment and Tourism, Windhoek.

Stander, P. E., Haden, P. J., Kaqece, A., and Ghau, A. 1997. The ecology of asociality in Namibian leopards. *Journal of Zoology* **242**: 343-364.

Stuart, C. and Wilson, V. 1988. *The Cats of Southern Africa*. Zimbabwe: Chipingali Wildlife Trust, Bulawayo.

Stuart, C. T. 1981. Notes on the mammalian carnivores of the Cape Province, South Africa. *Bontebok* **1**: 1-58.

Stuart, C. T. 1982. *Aspects of the biology of the caracal (*Felis caracal *Schreber 1776) in the Cape Province, South Africa*. Masters thesis, University of Rhodes, South Africa.

Stuart, C. T. 1987. A comparison of the food of the black-backed jackal and caracal. *The Naturalist* **31**: 41–42.

Stuart, C. T., and Hickman, G. C. 1991. Prey of caracal *Felis caracal* in two areas of Cape Province, South Africa. *Journal of African Ecology* **105**: 373- 381.

Suryawanshi, K. R., Bhatnagar, Y. V., Redpath, S., and Mishra, C. 2013. People, predators and perceptions: patterns of livestock depredation by snow leopards and wolves. *Journal of Applied Ecology*. **50**: 550-560.

Swanepoel, L. H., Lindsay, P., Somers, M. J., van Hoven, W., and Dalerum, F. 2012. Extent and fragmentation of suitable leopard habitat in South Africa. *Animal Conservation* **16:** 41 – 50.

Taruvinga, A., and A. Mushunje. 2014. Society's Perceptions of African Elephants and their Relative Influence towards the Conservation of Elephants. *APCBEE Procedia* **10**: 299-304.

Thorn, M., Green, M., Dalerum, F., Bateman, P. W., and Scott, D. M. 2012. What drives human–carnivore conflict in the North West Province of South Africa? *Biological Conservation* **150**: 23–32.

Thorn, M., Green, M., Scott, D., and Marnewick, K. 2013. Characteristics and determinants of human-carnivore conflict in South African farmland. *Biodiversity Conservation* **22**: 1715–1730.

Trail, J. V. 2015. *Quiver Trees, Phantom Orchids and Rock Splitters: The Remarkable Survival Strategies of Plants*. Canada: ECW Press.

Treves, A., and Karanth, K. U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide. *Conservation Biology* **17**: 1491–9.

Treves, A., Naughton-Treves, L. I. S. A., Harper, E. K., Mladenoff, D. J., Rose, R. A., Sickley, T. A., and Wydeven, A. P. 2004. Predicting human-carnivore conflict: A spatial model derived from 25 years of data on wolf predation on livestock. *Conservation Biology* **18**: 114-125.

Treves, A., Wallace, R. B., and White, S. 2009. Participatory planning of interventions to mitigate human–wildlife conflicts. *Conservation Biology* **23**: 1577-1587.

Treves, A., Wallace, R. B., Naughton-Treves, L., and Morales, A. 2006. Co-managing human–wildlife conflicts: a review. *Human Dimensions of Wildlife* **11**: 383-396.

Van de Ven, T. M. F. N., Tamblin, C, J., and Kerley, G. I. H. 2013. Seasonal diet of black-backed jackal in the Eastern Karoo, South Africa. *Journal of Arid Environments* **99**: 23-27.

Van der Merwe, I., Tambling, C. J., Thorn, M., Scott, D. M., Yarnell, R. W., Green, M., Cameron, E. Z., and Bateman, P. W. 2009. An assessment of diet overlap of two mesocarnivores in the North West Province, South Africa. *African Zoology* **44**: 288-291.

Van Deventer, M., and Nel, J. A. J. 2006. Habitat, food, and small mammal community structure in Namaqualand. *Koedoe* **49:** 99-109.

Van Niekerk, H. N. 2010. *The cost of predation on small livestock in South Africa by medium-sized predators*. Maters thesis, University of the Free State, Bloemfontein.

Van Niekerk, W., Taljaard, P. R., and De Waal, H. O. 2013. *Factors affecting small livestock predation in the Western Cape Province of South Africa*. In AAAE and AEASA Conference, Cape Town.

Van Rooyen, M. W. 2002. Management of the old field vegetation in the Namaqua National Park, South Africa: conflicting demands of conservation and tourism. *The Geographical Journal* **168**: 211 – 233.

Van Rooyen, M. W., Henstock, R., van Rooyen, N., and van der Merwe, H. 2010. Plant diversity and flowering displays on old fields in the arid Namaqua National Park, South Africa. *Koedoe* **52**: 1 -7.

Van Sittert, L. 1998. Keeping the enemy at bay: the extermination of wild carnivora in the Cape Colony, 1889-1910. *Environmental History* **3**: 333-356.

Wagner, K, K., Schmidt, R. H., and Conover, m. R. 1997. Compensation Programs for Wildlife Damage in North America. *Wildlife Society Bulletin* **25:** 312-319.

Walton, L. R., and Joly, D. O. 2003. *Canis mesomelas*. *Mammalian species* **715**: 1-9.

Wang, S. W. 2008. *Understanding ecological interactions among predators, ungulates and farmers in Bhutan's Jigme Singye Wangchuck National Park*. Dissertation, Cornell University, USA.

Wang, S. W., and Macdonald, D. W. 2006. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. *Biological Conservation* **129**: 558–65.

Watkeys, M. 1998. Soils of the arid south-western zone of Africa. In: W, Dean and S, Milton, eds. The Karoo. *Ecological Patterns and Processes*. United Kingdom: Cambridge University Press.

Wilkinson, D., Smith, G. C., Delahay, R. J., and Cheeseman, C. L. 2004. A model of bovine tuberculosis in the badger *Meles meles*: an evaluation of different vaccination strategies. *Journal of Applied Ecolog*y **41**: 492–501.

Wilson, S. M., Madel, M. J., Mattson, D. J., Graham, J. M., Burchfield, J. A., and Belsky, J. M. 2005. Natural landscape features, human-related attractants, and conflict hotspots: a spatial analysis of human-grizzly bear conflicts. *Ursus* **16**: 117-129.

Woodroffe, R. 2000. Predators and people: using human densities to interpret declines of large carnivores. *Animal Conservation* **3**: 165–173.

Woodroffe, R., Thirgood, S., and Rabinowitz, A. 2005. Pe*ople and Wildlife, Conflict or Coexistence?* Cambridge: Cambridge University Press.

Wozencraft, W. C. 1993. Order carnivora. In: D. E. Wilson and D. M. Reeder. *Mammal species of the world: a taxonomic and geographic reference*. Washington, DC, Smithsonian Institute Press.

Yeakel, J. D., Patterson, B. D., Fox-Dobbs, K., Okumura, M. M., Cerling, T. E., Moore, J. W., ... and Dominy, N. J. 2009. Cooperation and individuality among man-eating lions. *Proceedings of the National Academy of Sciences* **106**: 19040-19043.

Chapter 2: Methodology

2.1. Data Collection

2.1.1. Diet Estimation through Scat Collection and Analysis

Leopard, caracal and black-backed jackal scats were collected opportunistically and along road transects from March 2014 to April 2015 (Figure 2.1). In addition to these two sampling methods caracal scats were also collected at GPS (Global Positioning System) cluster sites from radiocollared caracal (n = 8) which were visited in the field. GPS clusters were aggregations of GPS points generated when caracal spent a large amount of time within a 50 m radius. To avoid pseudo-replication only 2 scats were collected at each cluster site (Bacon, Becic, Epp and Boyce 2011). Past studies have recommended a minimum sample size of 50 scats to infer reliable results, especially for opportunistic predators (Trites and Joy 2005; Williams, Goodenough and Stafford 2012). Dietary studies mostly rely on the sampling of scats along a predetermined route as the main method of scat collection (Corbett 1989; Atkinson, Macdonald and Kamizola 2002; Glen and Dickman 2006; Do Linh San *et al.*2009; van der Merwe *et al.* 2009; Klare, Kamler, Stenkewitz and Macdonald 2010). In our study area there was a small number of roads in the Eastern section of the national park included in the study area contrasted with high number of roads on commercial farms; with the latter making road selection for transect walks difficult. In addition, female large felids generally avoid roads thereby sampling along roads only would have biased diet estimation to males (Kure 2003; Martins 2010; Palomares *et al.* 2012). Further, roads in the park and on some of the farms are used extensively by tourists seasonally, whereas predators are persecuted on farms, with both these aspects potentially affecting wildlife movements. Behavioural avoidance of roads and areas near roads has been documented for many predator species (Colchero *et al.* 2011; Rogala *et al.* 2011; Northrup *et al.* 2012). Making use of road transects as the main scat collection method would have therefore introduced potential biases and likely resulted in insufficient samples collected. Transects walks were rather used to supplement opportunistic scat collection which occurred throughout the study area on and off roads. Transect locations were selected along randomly chosen park roads and in focal camps (farm sections) that were used in a broader baseline predator ecology study in the region.

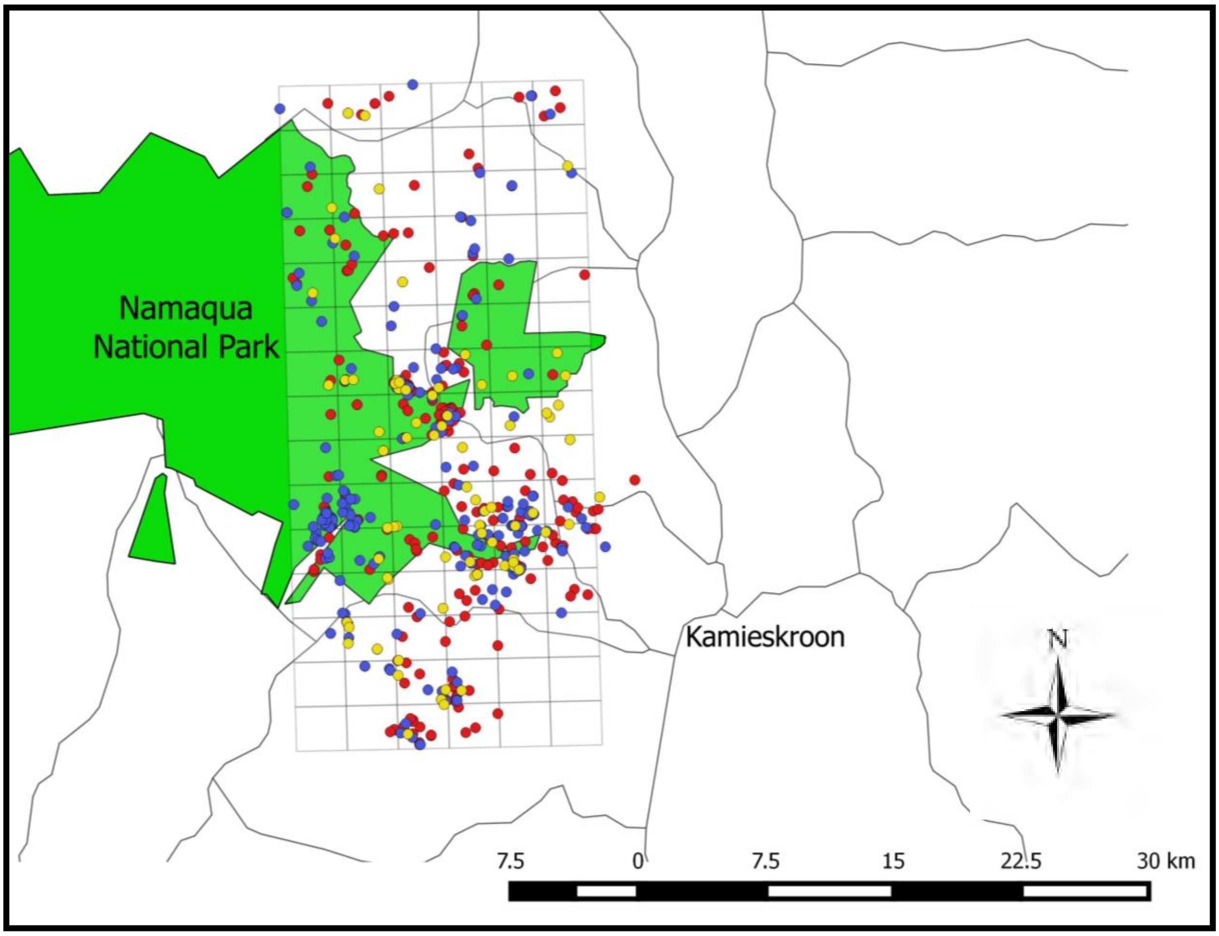


Figure 2.1. Map illustrating all locations in study area where leopard (yellow), caracal (red) and black-backed jackal (blue) scat was collected.

Predator scat samples were distinguished from each other by use of segmentation, size, shape and presence and size of bone shards visible (Walker 1996). Leopard scat can be identified by clear segmentation of the scats and the presence of large amounts of hair (Walker 1996). Leopard and caracal scat, like most scat deposited by felids, has clear segmentation (Walker 1996). Caracal scat is considerably smaller than leopard scat and a cut-off based on diameter was used to differentiate the two species (< 20 mm in diameter for caracal; >20 mm in diameter for leopard) [Walker 1996]. In addition, caracal scat has smaller bone shards than those often present in leopard scat. African wild cat (*Felis silvestris*), the other felid present in the study area, has much smaller scat which it typically buries [Walker 1996; Stuart and Stuart 2013]. Black-backed jackal scat can be identified by its size (15-20 mm in diameter) and shape (long with pointed ends) [Walker 1996; Kamler, Klare and Macdonald 2012]. Cape fox (*Vulpes chama*) and bat-eared fox (*Otocyon megalotis*) are two other canid species occurring in the study area. Care was taken to differentiate between black-backed jackal scat and fox scat. Fox scat is smaller in size and is mostly found in middens close to den sites, compared to black-backed jackal scat which is larger in size, contains more mammalian remains such as hair and bones and can mostly be found on conspicuous sites such as shrubs for marking purposes (Ferguson, Nel and De Wet 1983; Walker 1996). Black-backed jackals are social groomers and black-backed jackal hair can often be found in analysed scats (Kaunda and Skinner 2003; Klare *et al.* 2010). In the laboratory, felid scat was further positively identified due to the presence of hair from the focal predator as a result of grooming (Norton, Lawson, Henley and Avery 1986; Ott, Kerley and Boshoff 2007; Martins *et al.*2011; Braczkowski, Watson, Coulson and Randall 2012).

Because many felid species use scat as a means of territorial marking only half of each scat was collected (Martins *et al.* 2011). Canid species also use urine and at times the deposition of scat as a territorial marking tool (Estes 2012). Each scat collected was placed in a brown envelope with the following information: Species name, GPS location, categorical location (farm or national park), date, collection method (opportunistic, at a GPS cluster site or transect), substrate (shrub, sand, dirt) and position of scat in relation to access (middle of road, side of road, wildlife trail, no road/trail). Samples were stored with naphthalene (moth) balls and placed in a dry area until further analysis. Only a half of a scat was collected as leopards use scat deposition for territorial marking (Martins *et al.* 2011; Mann 2014).

2.1.2. Caracal capture and immobilisation

Eight caracal were captured, chemically immobilised and collared for this study (B. Cristescu and K. J Teichman unpublished GPS radiocollared caracal data). Research ethics approval was provided by Stellenbosch University (SU-ACUM14-00001), University of Cape Town (2013/V30/BC), South African National Parks (CRC-2013/029-2014) and the Northern Cape Department of Environment and Nature Conservation (FAUNA 1157/2013 and FAUNA 1158/2013). Suitable trap locations were determined by using camera trap data, predator sign, and local knowledge from farmers. Traps were set so that they were rapidly accessible and were fitted with VHF radio-transmitters, allowing researchers to remotely monitor traps every two hours throughout the day and night, adding to the physical trap checks.

Cage traps, foot snares and padded foothold traps were used for caracal capture. Cage traps have been successfully used to capture medium-sized felids, including bobcat (Knick 1990, Boitani and Powell 2012; Broman *et al.* 2014) and Canada lynx (Vashon *et al.* 2008). A combination of wire and rope-mesh single-door cage traps that were custom-built for caracal capture were used. Foot snares are considered one of the best techniques for humane felid capture and have been used for capturing various species (Mowat, Slough and Rivard 1994; Frank, Simpson and Woodroffe 2003; Balme *et al.*2007). Foothold traps have also been used extensively in wild felid research projects (Roelke *et al.* 2008, Svoboda *et al.*2013; Moen, Niemi, Burdett and Mech 2015). Visual, audio lures and/or bait were used to attract caracal to the traps.

Captured caracals were immobilized with Zoletil (Tiletamine-Zolazepam) at 3mg/kg using a DanInject air-powered pistol. Immobilized caracals were constantly monitored by a veterinarian with regard to temperature, heart and breath rates. Caracal sex, weight and age were recorded, with the latter based on tooth wear, colouration and body size (See Appendix 2A for datasheet). The animals were fitted with GPS radio-collars (Followit, Tellus Satellite Ultra Light, Lindesberg, Sweden). These collars were chosen due to light weight (± 200g), small size and Iridium satlink option which allowed for remote transmission of data from the collar to the researchers' e-mail via satellite link. This feature eliminated the need to approach the animals periodically for remote data downloads via UHF or VHF and enabled rapid field visitation of GPS clusters after the collared animal had left the site. The GPS collars utilised in this study also make use of a "drop-off" function which allows researchers to remotely detach collars from the predators. Collars were programmed to acquire a GPS location every three hours, 24 hours a day.

2.1.3. Diet Estimation through GPS Radio-collar Cluster Visitation

Collars transmitted data remotely via e-mail every 33 h, with delays (typically <24 h) in situations when the collar failed to connect to satellites for satlink data transmission. This technology allowed prompt identification of GPS location clusters from e-mailed location data compiled in 3-week monitoring sessions, based on a Python algorithm developed by Knopff, Knopff, Warren and Boyce (2009). Clusters were defined as ≥ 2 locations occurring in a 50-m radius within 6 days of each other. Clustered locations, where a collared animal remains for an extended period, might indicate a kill site (Knopff, Knopff, Warren and Boyce 2009; Cristescu, Stenhouse and Boyce 2015a). Because of logistical constraints including remoteness of the area, rugged terrain and number of field teams available, a subset of randomly selected clusters were visited.

The geometric centroids outputted by the Python algorithm were recorded in handheld GPS-s used by field teams to navigate to the cluster sites. Each cluster site was searched systematically, on a 50 m radius commencing at the cluster centroid. Total search time was standardized to two man-hours per site, with the exception of cluster sites where shrub cover was ≤ 50%. Such situations occurred when the entire site or > 50% was ploughed field or barren land, in which case total search time for the site was reduced to one man-hour. Teams typically comprised two people, in which case the standardized total cluster search period was divided by two, with each person searching half the 50 m radius disk. The search pattern followed a zigzag, starting at the centroid and walking out to the edge of the 50 m radius (see Appendix 2B). If time was still left once the outer edge of the disk was reached, the persons zigzagged back towards the centroid, revisiting certain areas within their allocated search zone to cover these in more detail.

Search teams looked for any prey remains including carcasses, bone fragments, hair, rumens, feathers and drag marks. If a prey item was located before the allotted search time was over, the location was marked in the GPS to enable revisitation and closer examination after the full cluster search was concluded. In the event that caracal scat was located during the search, a sample was collected once the search was completed. Scat samples were bagged in a brown paper envelope, labelled with the species name, GPS coordinates, categorical location (farm or national park), collection date, collection method (at a GPS cluster, including cluster ID), substrate (e.g., shrub, sand, dirt) and position of scat in relation to roads/wildlife trails (e.g., middle of trail, side of road). In the event where > 1 caracal scat was found, samples were collected from a maximum of two scats to minimize pseudo-replication (Bacon *et al.*2011). Scats that did not correspond to the age of the cluster (porous, old scats that easily crumbled upon applied pressure) were not collected. Photographs of prey remains were taken and the remains were used to determine the prey species (see Appendix 2C) [Skinner and Chimimba 2005, Stuart and Stuart 2007]. Hair was collected from any prey item that could not be reliably assigned to species level in the field and was later analysed under a compound microscope for species identification based on cuticle and medulla patterns (Keogh 1979; Keogh 1983; Martins *et al.*2011). When possible, prey sex and age were determined in the field, with age class (adult; sub-adult; YoY [Young-of-Year]) based on tooth wear (incisors and premolars) and gum recession line (Schroeder and Robb 2005). Mandible photographs were taken and later cross-referenced for age validation. When an ungulate femoral bone was located, prey body condition was assessed based on bone-marrow colour (white/yellow: good condition; pink: average condition; red: poor condition) [Yaetes, Edey and Hill 1975]. As young ungulates can have red bone-marrow due to vascularization characteristic of the bone growth process, body condition data were only collected for adult animals.

2.1.4. Prey Abundance Estimation through Camera Trapping

Camera trapping has been used in various studies to determine the relative abundance index (RAI) of a certain species or various species across a specific area (O'Brien, Kinnaird and Wibisono 2003; Jenks *et al.*2011; Braczkowski, Watson, Coulson and Randall 2012). Camera trapping is a non-invasive research technique that allows for continuous monitoring of animal occurrence (Karanth, Nichols and Kumar 2011). For this study prey was monitored using an 810 km^2 camera trap grid which delineated the study area extent. Grid cells were 3 km × 3 km squares (cell area = 9 km^2), with two camera trap stations used in rotation to monitor each cell. Because this study formed part of a larger project that included caracal as focal study species, cell size was selected to correspond to female caracal home range size (Avenant and Nel 1998; Martins 2010) to enable density estimation using marked (radio-collared) caracal. Each station had a single Cuddeback™ Ambush© Black Flash© camera attached to a metal post set at a standardized distance from the nearest edge of the jeep track (1 m) and at a specific lens height above the ground (0.4 m). The camera faced the jeep track perpendicularly. Initial station location was identified in a GIS (Geographic Information System) program through random generation of 2 points within each grid cell. For each point a perpendicular line to the nearest jeep track was traced in GIS, using a high resolution Google Earth image as base-layer. A point was generated at the location where the line intersected the jeep track and GPS coordinates for the point were extracted in GIS. Field teams navigated to the point and chose the final station placement by walking 100 m along the jeep track in both directions starting from the GIS-generated point, and selecting the location that maximized wildlife detection within 100 m from the initial point. Stations were preferentially placed at points where the jeep track was intersected by another jeep track, river bed, wildlife trail, or edge between distinct habitat types (e.g., shrubland and barren land/boulders, shrubland and ploughed field). All camera trap stations were set in the same broad vegetation type of Namaqualand Klipkoppe Scrubland, which is a component of the Succulent Karoo biome (Mucina and Rutherford 2006).

The camera trap survey ran for 12 months from May 2014 to April 2015. A total of 89 cameras (stations) where set out for the first rotation. At the end of the rotation only 82 stations had data which we were able to use (i.e., ≥ 2 months of the camera being active). For the second rotation 87 cameras were set out and only 77 had usable data. This resulted in a total of 176 stations set, of which 159 (90.3%) had usable data. Camera failure was generally as a result of either SD card failure, battery explosion or tampering of cameras by animals, particularly baboons and cattle.

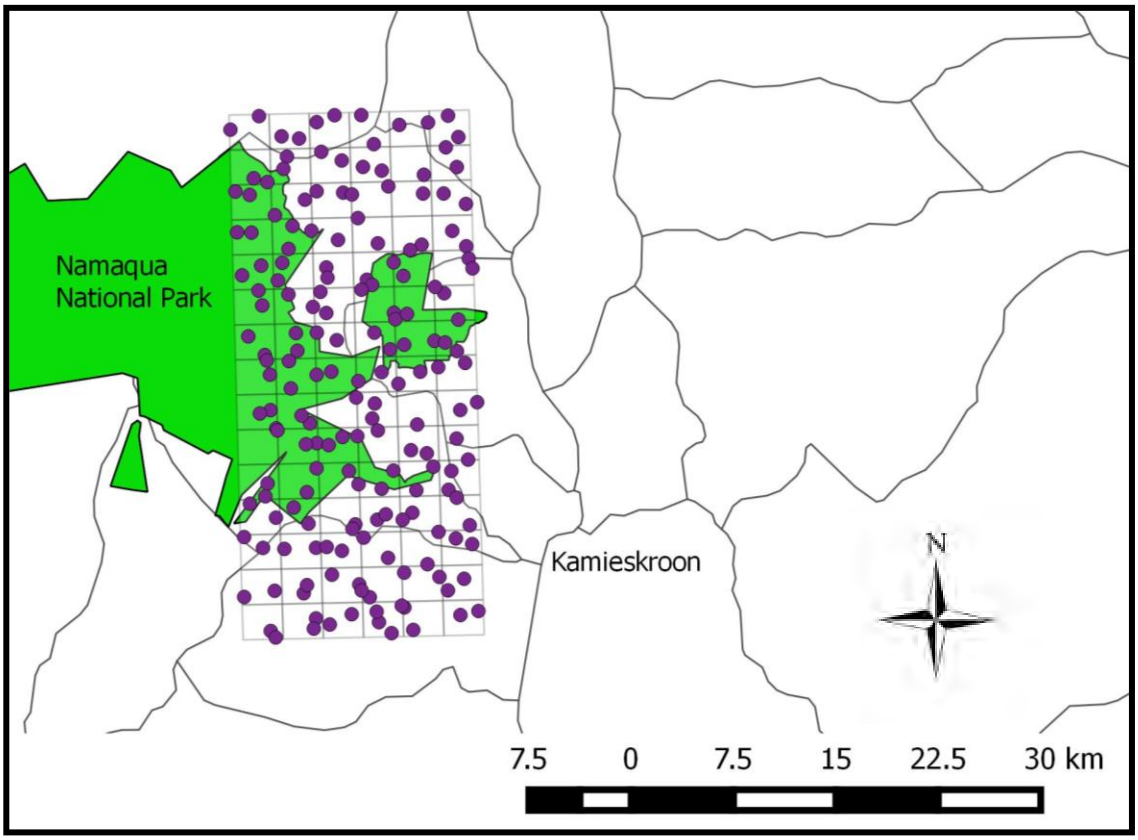


Figure 2.2. Map illustrating all locations in study area camera trapping occurred – each cell represents 9 km² with two camera stations for each grid cell.

2.1.5. Prey Abundance Estimation through Small Mammal Trapping

Live small mammal trapping was undertaken to determine prey species available on farms and in Namaqua National Park. This was necessary because small mammals such as rodents are not reliably detected with camera traps (O'Brien, Kinnaird and Wibisono 2011). Small mammal trapping occurred near camera trap stations for a period of three months from September to November 2014. Trapping only occurred in the spring as the region's semi-arid climate was the least extreme at this time of the year. Trapping was conducted at 94 of the camera trapping locations (59 farm and 35 national park) with 16 traps deployed at each location. Sherman aluminium traps (230 x 75 x 90 mm) were used and placed in a grid system with 4 rows of 4 traps each spaced 10 m from each other (see Appendix 2D).

Each Sherman trap contained a piece of apple and cucumber which were kept soaked in water until placed in traps to prevent captured animals from dehydrating, a peanut butter and oats bait ball wrapped in wax paper to limit desiccation of the bait, 2 pieces of dry cat food as bait for insectivores and a small bundle of sheep wool to prevent hypothermia. Each trap was wrapped in an aerothane sheet secured to the trap with elastic bands, which provided thermal insulation during colder nights and warmer mornings. When placed in the field traps were set under shrubs to shelter the captured animals from weather. Traps were set out for a total of three trap nights per site. Traps were opened just before sunset (17h00) and checked and closed just after sunrise (07h00). Once an animal was trapped, a Ziploc™ transparent bag was placed over half of the trap, the door facing inside the bag was opened gently and the animal was dropped into the bag for safe handling. Captured animals were scruffed through the bag and marked by a combination of hair clipping and marking a foot with non-toxic black nail varnish. Small mammals were identified to species level using Stuart and Stuart (2007) and De Graaff (1981) and photographs were taken. Animals were sexed by distinguishing the differences in genitalia (Hoffmann *et al.* 2010). Each individual was also weighed in the Ziploc™ bag and after the release of the animal the bag was weighed again and subtracted from the original weight recorded (Hoffmann *et al.* 2010).

2.2. Data Analysis

2.2.1. Diet Estimation through Scat Analysis

Scat samples were autoclaved at 120°C for 20 minutes to allow for complete sterilisation of samples. Autoclaved samples were individually placed in a sorting tray and sorted under a fumehood, removing macroscopic fragments (e.g., bones, insects) before washing the remains of the scat in a sieve (Cristescu, Stenhouse and Boyce 2015b). A mortar and pestle was used to help break up scats and grind faecal matter to ease the washing process. Once clean the hair was spread out on a petri dish and dried for 24 hours in the fumehood. Thereafter, hair samples were soaked in 70% ethanol for 24 hours to ensure no particles were still attached to the hairs before further analysis. Hairs were then rinsed with distilled water and dried for another 24 hours, or until dry, in the fumehood.

All mammal prey categories were identified to species level by means of cross-sections of hairs. Cross-sections were made by randomly selecting hairs with a pair of forceps and placing them longitudinally in a 3 mm plastic Pasteur pipette. Forbes (2011) concluded that a minimum of 15 hairs should be used to produce a viable cross-section for analysis. Cross-sections were made by using the methods proposed by Douglas (1989). Once hairs were placed in the pipette, molten wax (Paraplast Plus®, Leica Biosystems) was drawn up into the pipette after which it was immediately placed in a beaker of ice to ensure setting of the wax. Small cross-sections were then cut and mounted on glass slides using a small droplet of wax. A Leica DM 2000 light microscope was used to photograph and examine slides at 20x magnification (where possible 40x). LAS Core V4.0 software was used to measure cross-sections of the hairs for comparison with the reference collections (Rhodes University, Anita Meyer [The Cape Leopard Trust], Keogh (1979), Keogh (1983) and personal slides made from hair collected from carcasses encountered in the field). Using teeth collected from scat samples, rodents were identified to species level using de Graaff (1981) for further validation of species from cross-sections of hairs.

Macroscopic and microscopic presence and absence were recorded for each scat for the following prey categories: large mammals (> 40 kg), medium- to large-sized mammals (10 – 40 kg), medium-sized mammals (1 – 10 kg), small mammals (< 1 kg) [Mann 2014], livestock, birds, reptiles, invertebrates, fruit/seeds and vegetation. In some cases an item could be recorded as 'unknown ungulate' or 'unknown small mammal', however these were all grouped under 'unknown' category to simplify results. Invertebrates were identified to order level. Reptiles were divided into lizard, tortoise and snake. Fruits/seeds, vegetation and birds were only marked as present or absent and not identified to a lower level. All mammal prey categories were identified to species level by means of cross-sections of hairs as described above. All shrews were classified as Soricidae, all hares (*Lepus saxatilis*, *Lepus capensis*) and red rock rabbits (*Pronolagus rupestris*) as lagomorpha, *Otomys irroratus* and *Otomys unisulcatus* were grouped into *Otomys* spp. and *Elephantulus rupestris* and *Elephantulus edwardii* were grouped into *Elephantulus* spp.

The frequency of occurrence (per prey type) [FO], corrected frequency of occurrence (frequency of occurrence per scat) [CFO] and percentage biomass were calculated. FO was calculated as the number of times a prey item was recorded divided by the total number of prey items identified from all scats analysed, expressed as a percentage (Klare, Kamler and Macdonald 2011). Klare *et al.* (2011) recommend the use of frequency of occurrence per scat, further referred to as the CFO, where each scat has a total weighting of 1. If two prey items are present in one scat, each prey item would receive a weighting of 0.5 and less as the number of prey items per scat increases. Klare *et al.* (2011) concluded that the sole use of FO per prey item overestimates prey items such as invertebrates. Past studies recommend refraining from only using this method (FO) when representing diet results (Klare *et al.* 2011; Braczkowski *et al.* 2012). Various predator diet studies only present the frequency of occurrence (FO) and relative frequency of occurrence (CFO), ignoring the percentage biomass (Ott *et al.* 2007; Walker *et al.* 2007; Carrera *et al.* 2008; Van der Merwe *et al.* 2009; Braczkowski *et al.* 2012). Klare *et al.* (2011) concluded that a more in-depth representation of data is needed, especially when the diet study aims to present ecologically relevant results.*et al.*. Klare *et al.* (2011)

also concluded that the best method to use when applying biomass calculation models (BCM) is linear regression based on feeding trials. If possible, they advised to use feeding trial data for the same carnivore species or a closely-related species if no other past literature is available. Biomass establishes the importance of a food item in the diet of the target animal, whereas frequency of occurrence includes rare food items (Klare *et al.*2011). This approach helps understand a carnivore's feeding ecology – i.e.: whether it is a specialist or an opportunist. The main downfall of only using FO is that it cannot answer important ecological questions, such as the impact of predation on prey populations. However, when using BCM in human-wildlife conflict studies, it is advisable to note that these calculations could overestimate the biomass of livestock predated on (Klare *et al.*2011). For biomass calculations please refer to the individual focal species chapters.

2.2.2. Diet Estimation through GPS Radio-collar Cluster Visitation

Eight caracal were immobilised and collared from March 2014 to April 2015 (Appendix 2E). The same method used to identify hair found in scat was used to identify hair found at cluster sites (see section 2.2.1). To ensure consistency the same prey categories that were used for scat analysis were used to group prey items identified at GPS cluster sites (also section 2.2.1). The frequency of occurrence (per prey item) [FO] and corrected frequency of occurrence (frequency of occurrence per scat) [CFO] were calculated. For a more in-depth description of FO and CFO please refer to Chapter 2.2.1.

The frequency of occurrence (per prey item) [FO] which is calculated as the number of times a prey item is recorded divided by the total number of prey items and multiplied by a 100 to calculate a percentage. Biomass was calculated by assigning an estimated weight to each prey item identified at kill sites according to age (Morehouse and Boyce 2011; Pitman *et al.* 2013). Where the age was marked as unknown, an average of different age weight for the prey species was estimated and used. To correct the overestimation from kill site analysis a percentage estimation of consumption was made from photographs taken at kill sites. The percentage of a prey item which was consumed differed between age and prey species. Prey weighing < 4.5 kg, such as hyrax and lagomorpha, were consumed almost entirely (90%) with the exception of the rumen, viscera and fur (Estes 2012). The corrected biomass consumed was calculated by multiplying the biomass consumed with the percentage of prey consumed.

2.2.3. Prey Abundance and Preference Analysis

Prey relative abundance was obtained from camera traps placed in the field from May 2014 to April 2015. Camera trapping is increasingly used to estimate species abundances (O'Brien *et al.* 2003; Rautenbach 2010; Treves, Mwima, Plumptre and Isoke 2010; Jenks *et al.* 2011; Mann 2014). In instances where animals can be identified individually due to distinctive features or markings, mark-recapture models are used. However, not all animals can be individually identified and as a result different methods are used to estimate the abundance of these animals. Due to the rugged terrain of our study area and the shy nature and low densities of animals, camera traps were the most efficient method to determine abundance. Road counts and aerial counts were not used due to the mountainous terrain and lack of reliable road networks. The relative abundance index (RAI) of each species was calculated by multiplying the total useable captures of a specific species by 100 and then dividing by the total number of trap nights (Jenks *et al.* 2011). RAI can also present draw-backs to data analysis as variable detection probabilities between different species are not taken into account (Sollman, Mohamed, Samejima and Wilting 2013). To avoid overestimation of animals, a time interval of 0.5 hours was used to distinguish between independent captures of a species at the same camera station (Martins 2010; Rautenbach 2010; Jenks *et al.* 2011). This was problematic for group-living animals such as baboons and some ungulate species as it could underestimate the abundance (Mann 2014). Another draw-back of this method is the placement of cameras – to decrease bias a randomised system was used to determine camera placement sites. Certain species such as Klipspringer, Hyrax and Red Rock Rabbit reside in rocky areas and as cameras were placed on jeep tracks these species could be underestimated. Any photographs of farm workers, hikers, vehicles or domestic dogs were excluded from the analysis. Birds were also excluded as only larger species such as bustards were captured on the cameras.

Small mammal abundance was obtained from small mammal trapping with Sherman traps in the spring. Bush karoo rats (*Otomys unisulcatus*) are not easily trapped with Sherman traps (Cavallini and Nel 1990). Being the only method used for small mammal trapping an underestimation of Bush karoo rat abundance may have been recorded. A total of eight species of small mammals were trapped, but due to the low number of captures only data from captures of striped mouse (*Rhabdomys pumillio*) and Namaqua rock mouse (*Aethomys namaquensis*) were used and all *Elephantulus* spp. and round-eared sengi (*Macroscelides proboscideus*) were pooled as insectivores. Data were insufficient for a mark-recapture model therefore abundance was estimated as a relative abundance index (RAI), the same as for camera data. RAI was calculated as the total number of captures of a species divided by the total number of trap nights (Jenks *et al.* 2011). Calculations were performed separately for Namaqua National Park and the surrounding farmlands to ensure comparability between the two land-uses. Prey preference was also calculated separately for each land-use using Jacobs' index (Jacobs 1974). Prey abundance data were insufficient to enable comparison of prey preference among seasons. As small mammal trapping was only conducted in spring, no seasonality data were available for small mammal abundance.

2.3. Statistical Analysis

2.3.1. Diet Statistical Analysis

Predator diet was analysed from 82 leopard scats, 250 caracal scats and 196 black-backed jackal scats collected in Namaqua National Park and surrounding small-stock farms. Differences in prey species and prey categories between the two land-uses in Namaqualand were tested according to a Fishers exact test (STATSoft Statistica 2008).

2.3.2. Scat and GPS Radio-collar Cluster Visitation Statistical Analysis

Diet was analysed from 250 caracal scats and 91 kill sites. Differences in scat analysis and GPS cluster visitation methods were tested using a Fishers exact test (STATSoft Statistica 2008).

2.3.3. Prey abundance and Preference Statistical Analysis

Prey abundance was calculated as the RAI (relative abundance index) for each species/prey category (e.g., lagomorpha) on both land-uses. The data were not normally distributed, so a non-parametric test was performed. Mann-Whitney-U tests (STATSoft Statistica 2008) were applied to determine whether there was a significant difference between the RAI of a certain species/prey category between Namaqua National Park and surrounding farmlands. Mann-Whitney-U tests were applied for both camera trap analysis and small mammal trapping analysis. A species accumulation curve was generated using EstimateS ver. 9 (Collwell 2013) to estimate sampling effort required for prey species detection through camera trapping and small mammal trapping.

Prey preference was calculated using Jacobs' index, which compares the extent to which a prey species was preyed upon to its relative availability (Jacobs 1974). The CFO was used to determine which prey species were preferred by leopards. The following equation illustrates the Jacobs index:

$$D = (r_i - p_i)/(r_i + p_i - 2r_ip_i)$$

Where i is the relevant species, r is the proportion of scats and p is the RAI obtained from camera traps or small mammal traps. A certain prey species was preferred by the predator if $0 < D \leq 1$ and avoided when $-1 \leq D < 0$. A *D*-value close to 0 would indicate prey consumption in proportion to prey availability, meaning the prey items was neither preferred, nor avoided (Jacobs 1974).

2.4. References

Atkinson, R. P. D., Macdonald, D. W., and Kamizola, R. 2002. Dietary opportunism in side-striped jackals *Canis adustus* Sundevall. *Journal of Zoology* **257**: 129–139.

Avenant, N. L., and Nel, J. A. J. 1998. Home-range use, activity, and density of caracal in relation to prey density. *African Journal of Ecology* **36**: 347-359.

Bacon, M. M., Becic, G. M., Epp, M. T., and Boyce, M. S. 2011. Do GPS Clusters Really Work? Carnivore Diet from Scat Analysis and GPS Telemetry Methods. *Wildlife Society Bulletin* **35**: 409-415.

Balme, G., Hunter, L., and Slotow, R. 2007. Feeding habitat selection by hunting *leopards Panthera pardus* in a woodland savanna: prey catchability versus abundance. *Animal Behaviour* **74:** 589 – 598.

Boitani, L., and Powell, R. A. 2012. *Carnivore ecology and conservation: a handbook of techniques*. Oxford: Oxford University Press.

Braczkowski, A., Watson, L., Coulson, D., and Randall, R. 2012. Diet of leopards in the southern Cape, South Africa. *African Journal of Ecology* **50**: 377 – 380.

Braczkowski, A., Watson, L., Coulson, D., Lucas, J., Peiser, B., and Rossi, M. 2012. The diet of caracal, *Caracal caracal*, in two areas of the southern Cape, South Africa as determined by scat analysis. *South African Journal of Wildlife Research* **42**: 111–116.

Broman, D. J. A., Litvaitis, J. A., Ellingwood, M., Tate, P., and Reed, G. C. 2014. Modelling bobcat *Lynx rufus* habitat associations using telemetry locations and citizen-scientist observations: are the results comparable? *Wildlife Biology* **20**: 229-237.

Carrera, R., Ballard, W. B., Gipson, P., Kelly, B. T., Krausman, P. R., Wallace, M. C., and Villalobos, C. 2008. Comparison of Mexican wolf and coyote diets in Arizona and New Mexico. *The Journal of Wildlife Management* **72**: 376–381.

Cavallini, P., and Nel, J. A. J. 1990. The feeding ecology of the Cape grey mongoose, *Galerella pulverulenta* (Wagner 1839) in a coastal area. *African Journal of Ecology* **28:** 123-130.

Colchero, F., Conde, D. A., Manterola, C., Chávez, C., Rivera, A., and Ceballos, G. 2011. Jaguars on the move: modeling movement to mitigate fragmentation from road expansion in the Mayan Forest. *Animal Conservation* **14**: 1469-1795.

Collwell, R. K. 2013. *EstimateS*: Statistical estimation of species richness and shared species from samples. Version 9. Persistent URL <purl.oclc.org/estimates>.

Corbett, L. K. 1989. Assessing the diet of dingoes from feces: a comparison of 3 methods. *The Journal of Wildlife Management* **53**: 343-346.

Cristescu, B., Stenhouse, G. B., and Boyce, M. S. 2015a. Grizzly bear diet shifting on reclaimed mines. *Global Ecology and Conservation* **4**: 207–220.

Cristescu, B., Stenhouse, G. B., and Boyce, M. S. 2015b. Predicting multiple behaviors from GPS radiocollar cluster data. *Behavioral Ecology* **26**: 452–464.

De Graaff, G. 1981. *The rodents of southern Africa*. Pretoria: Buttersworth.

Do Linh San, E., Malongwe, N. B., Fike, B., Somer, M. J., and Walters, M. 2009. A diverse autumn diet without dominant prey for opportunistic black-backed jackals *Canis mesomelas*. *Wildlife Biology in Practice* **5**: 96–103.

Douglas, R. M. 1989. A new method of cross-sectioning hair of larger mammals. *South African Journal of Wildlife Research* **9**: 73-76.

Estes, R. D. 2012. *The behaviour guide to African mammals*. Berkely: The University of California Press.

Ferguson, J. W. H., Nel, J. A. J., and De Wet, M. J. 1983. Social organization and movement patterns of black-backed jackals *Canis mesomelas* in South Africa. *Journal of Zoology* **199**: 487- 502.

Forbes, R. W. 2011. The diet of black-backed jackal (*Canis mesomelas*) on two contrasting land-use types in the Eastern Cape Province, South Africa and the validation of a new analytical method of mammalian hair identification. Masters thesis, Rhodes University, South Africa.

Frank, L., Simpson, D., and Woodroffe, R. Foot Snares: An Effective Method for Capturing African Lions. *Wildlife Society Bulletin* **31**: 309-314.

Glen, A. S., and Dickman, C. R. 2006. Diet of the spotted-tailed quoll (*Dasyurus maculatus*) in eastern Australia: effects of season, sex and size. *Journal of Zoology* **269**: 241-248.

Hoffmann, A., Decher, J., Rovero, F., Schaer, J., Voight, C., and Wibbelt, G. 2010. Field Methods and Techniques for Monitoring Mammals In: J. Eymann, J. Degreef, Ch. Häuser, J.C. Monje, Y. Samyn and D. VandenSpiegel, eds. 2010. *Manual on field recording techniques and protocols for All Taxa Biodiversity Inventories and Monitoring*. Belgium: ABC Taxa.

Jacobs, J. 1974. Quantitative measurement of food selection: a modification of the forage ratio and Ivlev's electivity index. *Oecologia* **14**:413–417.

Jenks, K. E., Chanteap, P., Damrongchainarong, K., Cutter, P., Cutter, P., Redford, T., Lynam, A. J., Howard, J., Leimgruber, P. 2011. Using relative abundance indices from camera-trapping to test wildlife conservation hypotheses – an example from Khao Yai National Park, Thailand. *Tropical Conservation Science* **2**:113-131.

Kamler, J. F., Klare, U., and Macdonald, D. W. 2012. Seasonal diet and prey selection of black-backed jackals on a small-livestock farm in South Africa. *African Journal of Ecology* **50**: 299 – 307.

Karanth, K.U., Nichols, J. D., and Kumar, N. S. 2011. Estimating tiger abundance from camera trap data: field surveys and analytical issues. In: A. F. O'Connell, J. D. Nichols and K. U. Karanth, eds. 2011. *Camera Traps in Animal Ecology: Methods and Analyses.* Tokyo: Springer.

Kaunda, S. K. K., and Skinner, J. D. 2003. Black-backed jackal diet at Mokolodi Nature Reserve, Botswana. *African Journal of Ecology* **41**: 39-46.

Keogh, H. J. 1979. *An atlas of hair from southern African species with reference to its taxonomic and ecological significance*. Dissertation, University of Pretoria, South Africa.

Keogh, H. J. 1983. A photographic reference system of the microstructure of the hair of southern African bovids. *South African Journal of Wildlife Research* **13**: 89-131.

Klare, U., Kamler, J. F., and Macdonald, D. W. 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* **41**: 294–312.

Klare, U., Kamler, J. F., Stenkewitz, U., and Macdonald, D. W. 2010. Diet, prey selection, and predation impact of black-backed jackals in South Africa. *Journal of Wildlife Management* **74**: 1030–1042.

Knick, S. T. 1990. Ecology of Bobcats Relative to Exploitation and a Prey Decline in Southeastern Idaho. *Wildlife Monographs* **108**: 3-42.

Knopff, K. H., Knopff, A. A., Warren, M. B., and Boyce, M. S. 2009. Evaluating Global Positioning System Telemetry Techniques for Estimating Cougar Predation. *The Journal of Wildlife Management* **73**: 586-597.

Kure, N. 2003. *Living with leopards*. Cape Town: Sunbird.

Mann, G. 2014. Aspects of the ecology of leopards (*Panthera pardus*) in the little Karoo, South Africa. Dissertation, Rhodes University, South Africa.

Martins, Q. 2010. *The ecology of the leopard* Panthera pardus *in the Cederberg Mountains*. Dissertation, University of Bristol, United Kingdom.

Martins, Q., Horsnell, W. G. C., Titus, W., Rautenbach, T., and Harris, S. 2011. Diet determination of the Cape Mountain leopards using global positioning system location clusters and scat analysis. *Journal of Zoology* **283**: 81-87.

Moen, R., Niemi, G., Burdett, C. L., and Mech, L. D. 2015. *Canada Lynx in the Great Lakes Region*. Annual Report to USDA Forest Service and MN Cooperative Fish and Wildlife Research Unit. NRRI Technical Report No: NRRI/TR-2004-01.

Morehouse, A. T., and Boyce, M. S. 2011. From venison to beef: seasonal changes in wolf diet composition in a livestock grazing landscape. *Frontiers in Ecology and the Environment* **9**: 440–445.

Mowat, G., Slough, B. G., and Rivard, R. 1994. A Comparison of Three Live Capturing Devices for Lynx: Capture Efficiency and Injuries. *Wildlife Society Bulletin* **22**: 644-650.

Mucina, L and Rutherford, M.C. eds., 2006. *The vegetation of South Africa, Lesotho and Swaziland.* Pretoria*:* South African National Biodiversity Institute.

Northrup, J. M., Pitt, J., Muhly, T. B., Stenhouse, G. B., Musiani, M., and Boyce, M. S. 2012. Vehicle traffic shapes grizzly bear behaviour on a multiple-use landscape. *Journal of Applied Ecology* **49**: 1159–1167.

Norton, P. M., Lawson, A. B., Henley, S. R., and Avery, G. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *South African Journal of Wildlife Research* **16:** 47–52.

O'Brien, T. G., Kinnaird, M. F., and Wibisono, H. T. 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. *Animal Conservation* **6**: 131-139.

O'Brien, T. G., Kinniard, M. F., and Wibisono, H. T. 2011. Estimation of Species Richness of Large Vertebrates Using Camera Traps: An Example from an Indonesian Rainforest In: A. F. O'Connell, J. D. Nichols and K. U. Karanth, eds. 2011. *Camera Traps in Animal Ecology: Methods and Analyses.* Tokyo: Springer

Ott, T., Kerley, G. I. H., and Boshoff, A. F. 2007. Preliminary observations on the diet of leopards (*Panthera pardus*) from a conservation area and adjacent rangelands in the Baviaanskloof region, South Africa. *African Zoology* **42**: 31–37.

Palomares, F., Roques, S., Chavez, C., Silveira, L., Keller, C., Sollmann, R., ... and Jácomo, A. T. A. 2012. High proportion of male faeces in jaguar populations. *PloS one* **7**: 12.

Pitman, R. T., Mulvaney, J., Ramsay, P. M., Jooste, E., and Swanepoel, L. H. 2013. Global Positioning System-located kills and faecal samples: a comparison of leopard dietary estimates. *Journal of Zoology* **292**: 18–24.

Rautenbach, T. 2010. *Assessing the diet of the Cape leopard (*Panthera pardus*) in the Cederberg and Gamka mountains, South Africa*. Masters Thesis, Nelson Mandela Metropolitan University, South Africa.

Roelke, M. E., Johnson, W.E., Millan, J., Palomares, F., Revilla, E., Rodriguez, A., Calzada, J., Ferreras, P., Leon-Vizcaino, L., Delibes, M., and O'Brien, S. J. 2008 Exposure to disease agents in the endangered Iberian lynx (*Lynx pardinus*). *European Journal of Wildlife Research* **54**: 171–178.

Rogala, J. K., Hebblewhite, M., Whittington, J., White, C. A., Coleshill, J., and Musiani, M. 2011. Human activity differentially redistributes large mammals in the Canadian Rockies national parks. *Ecology and Society* **16**: 16. Online [URL] http://dx.doi.org/10.5751/ES-04251-160316.

Schroeder, M. A., and Robb, L. A. 2005. Criteria for gender and age. In: C, E Braun, eds. 2005. *Techniques for wildlife investigations and management*. USA: The Wildlife Society.

Skinner, J. D., and Chimimba, C. T. 2005. *The mammals of the southern African subregion.* Cape Town: Cambridge University Press.

Sollmann, R., Mohamed, A., Samejima, H., and Wilting, A. 2013. Risky business or simple solution–Relative abundance indices from camera-trapping. *Biological Conservation* **159**: 405-412.

Stuart, C., and Stuart, M. 2007. *Field Guide to the Mammals of Southern Africa: Revised Edition*. South Africa: Struik Publishers.

Stuart, C., and Stuart, M. 2013. *A Field Guide to the Tracks & Signs of Southern, Central and East*. Cape Town: Struik Nature.

Svoboda, N. J., Belant, J. L., Beyer, D. E., Duquette, J. F., and Martin, J. A. 2013. Identifying bobcat *Lynx rufus* kill sites using a global positioning system. *Wildlife Biology* **19**: 78-86.

Treves, A., Mwima, P., Plumptre, A. J., and Isoke, S. 2010. Camera-trapping forest–woodland wildlife of western Uganda reveals how gregariousness biases estimates of relative abundance and distribution. *Biological Conservation* **143:** 521-528.

Trites, A. W., and Joy, R. 2005. Dietary analysis from fecal samples: how many scats are enough? *Journal of Mammalogy* **86**: 704–712.

Van der Merwe, I., Tambling, C. J., Thorn, M., Scott, D. M., Yarnell, R. W., Green, M., Cameron, E. Z., and Bateman, P. W. 2009. An assessment of diet overlap of two mesocarnivores in the North West Province, South Africa. *African Zoology* **44**: 288-291.

Vashon, J. H., Meehan, A. L., Jakubas, W. J., Organ, J. F., Vashon, A. D., Mclaughlin, G. T., Matula, G. J. Jr., and Crowley, S. M. 2008. Spatial Ecology of a Canada Lynx Population in Northern Main. *Journal of Wildlife Management* **72**: 1479–1487.

Walker, C. 1996. *Signs of the wild: a field guide to the spoor & signs of the mammals of Southern Africa*. Cape Town: Struik Publishers.

Walker, R. S., Novaro, A. J., Perovic, P., Palacios, R., Donadio, E., Lucherini, M., Pia, M., López, M. S. 2007. Diets of three species of Andean carnivores in high-altitude deserts of Argentina. *Journal of Mammalogy* **88**: 519–525.

Williams, R. L., Goodenough, A. E., and Stafford, R. 2012. Statistical precision of diet diversity from scat and pellet analysis. *Ecological Informatics* **7**: 30-34.

Yeates, N. T. M., Edey, T. N., and Hill, M. K. 1975. *Animal Science: Reproduction, Climate, Meat, Wool*. Australia: Pergamon Press.

2.5. Appendices

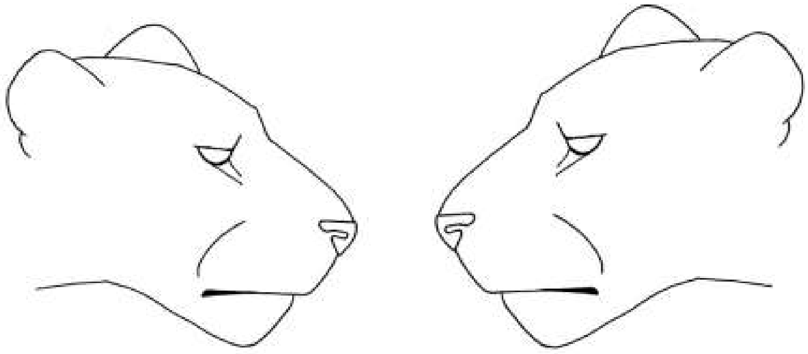
Appendix 2A– Datasheet filled out at each caracal capture, as provided by Dr Quinton Martins. Although the original sheet was set-up for leopard captures, the same rules apply to caracal capture.

Recorder: ____________________

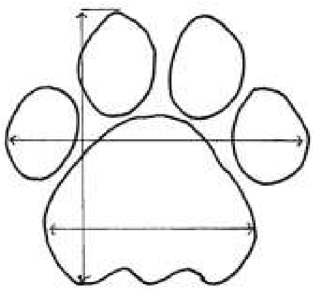
LEOPARD INDIVIDUAL RECORD.

Unique ID________________Trovan # (Location)______________________________

Name____________________Ranger ID________Date/location captured____________________



Sex ______Condition____________________
Weight ____________Stomach size:______/ 5
Head-tail ____________Curves:____________
Tail length ____________Curves:____________
Chest girth ____________Neck girth:__________
Head length ____________Head circ:__________
Shoulder height ____________Estimated age________
Radio-collar frequency ____________________



Paw: front right

IMMOBILISATION Drug/dose____________________
dart in, time__________animal down, time ______________
top-ups (time/dose/route) 1.____________________
2.______________3.______________
4______________5.______________
Recovery: head-up________first rise________first walk________
Recovery additional notes ____________________

SAMPLES: Tissue ☐ Hair ☐ Blood ☐ Faeces ☐ Tooth ☐ Ectoparasites☐desc__________

Haematology; time collected__________No Anticoagulant (red) ☐ Heparin (green) ☐ EDTA (purple) ☐

PHOTO CHECKLIST: Face r☐ l☐ Teeth r ☐ l☐ Body r☐ l☐ Tail r☐ l☐

PHYSIOLOGICAL DATA:

Time	Body Temp	Heart Rate	Resp. Rate	O2 Sat %	Blood Pressure Sys / Dia / Mean
					/ /
					/ /
					/ /
					/ /
					/ /

NOTES (females; include lactating, details of cubs, etc)____________________

Notes for completing Leopard Individual Record sheets.

Recorder: person writing down the data.

Unique ID: animal's sex followed by sequential number e.g. Houdini is M1, April is F2 etc. The number is always unique and never repeated so each animal can be identified by the number alone. If the animal dies, the number is never re-used on a new animal.

Trovan: list number followed by the chip's location in parenthesis. Fit two chips, one beneath right ear and one in right flank.

Name: housename, optional.

Ranger ID: how animal is referred to by rangers (usually first line of whisker spots).

Date/location captured: location can be general or GPS/Grid ref.

Head profile diagrams: draw in whisker spots and any notches in the ears as well as facial scars. (Can also include cheek/eye spots which are unique to individuals though this is complicated and would be better recorded as a digital still). When transferring the data to electronic form, the digital stills of the face could be inserted here.

Measurements: see Diagram 1 which follows.

Head-tail. From nose tip to tail tip, not along curves (A-D on Diag 1): measure with tape alongside leopard laid out with straight neck and tail. Curves is the same measurement taken along curves with a flexible tape measure.

Tail Length. Tail tip to sacrum (B-C on Diag 1). Curves is the same measurement taken along curves with a flexible tape measure.

Chest girth. Measured around chest immediately behind forelegs ('armpits').

Neck girth. Measured immediately behind skull.

Head length. From back of skull (from end of sagittal crest which can be felt) to nose tip along curves.

Head circumference. Around cheeks with tape held against front edge of ears.

Shoulder height. From top of right scapula to front right foot as though in walking position (best taken from lower surface of plantar pad as though flat on ground); see Diag 1.

Paw measurements; refer to diagram. Each is the greatest distance between the two indicated points. Paw should be relaxed and not twisted for measurements. Also draw any distinguishing characteristics such as healed wounds (don't bother if superficial- they'll disappear).

Stomach Size: estimate how full, where 0 is starving and 5 is fully distended.

Estimated age; based on tooth wear: see attached Diagram 2.

Samples; check the box only for those taken during handling. Haematology- take blood in order indicated

Photographs: take photos (digital preferred) of each side of the animal's face, the teeth (each side), both sides of the body and both sides of the tail bands. Check off each in boxes provided.

Notes; include anything of interest and go over the page if required. For females include any details of pregnancy, lactation, if she has cubs (number/age/sex if possible) etc. Also include mention of any distinguishing characteristics beyond those recorded on head profiles.

Diagram 1: Guide for body measurements.
Dotted lines indicate approximate locations for skull, neck and chest measurements.

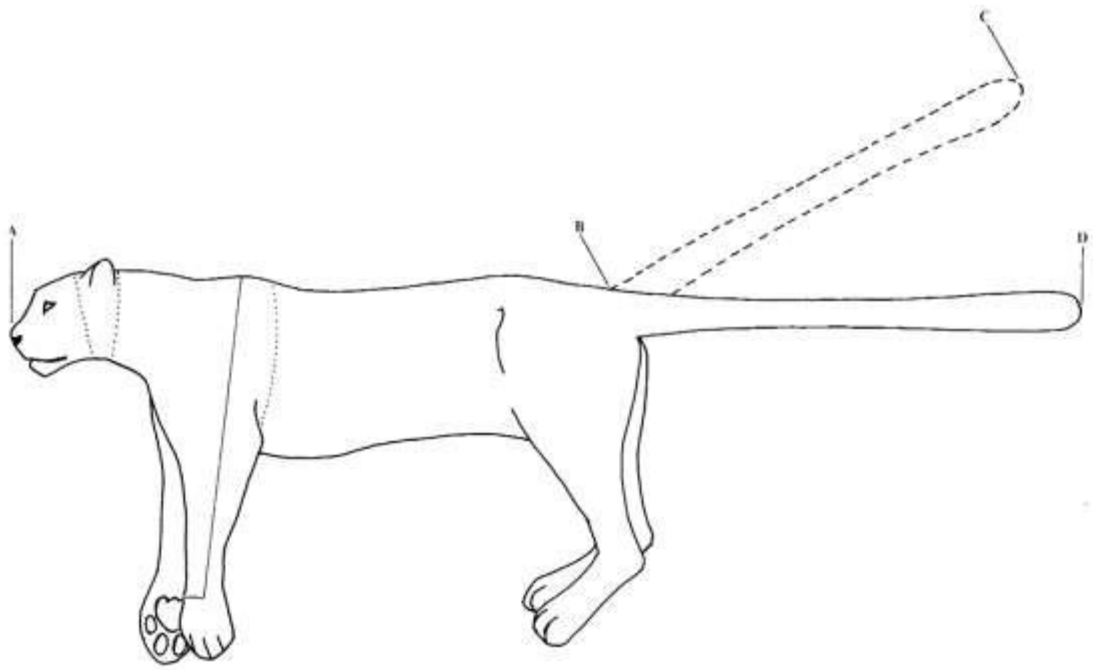
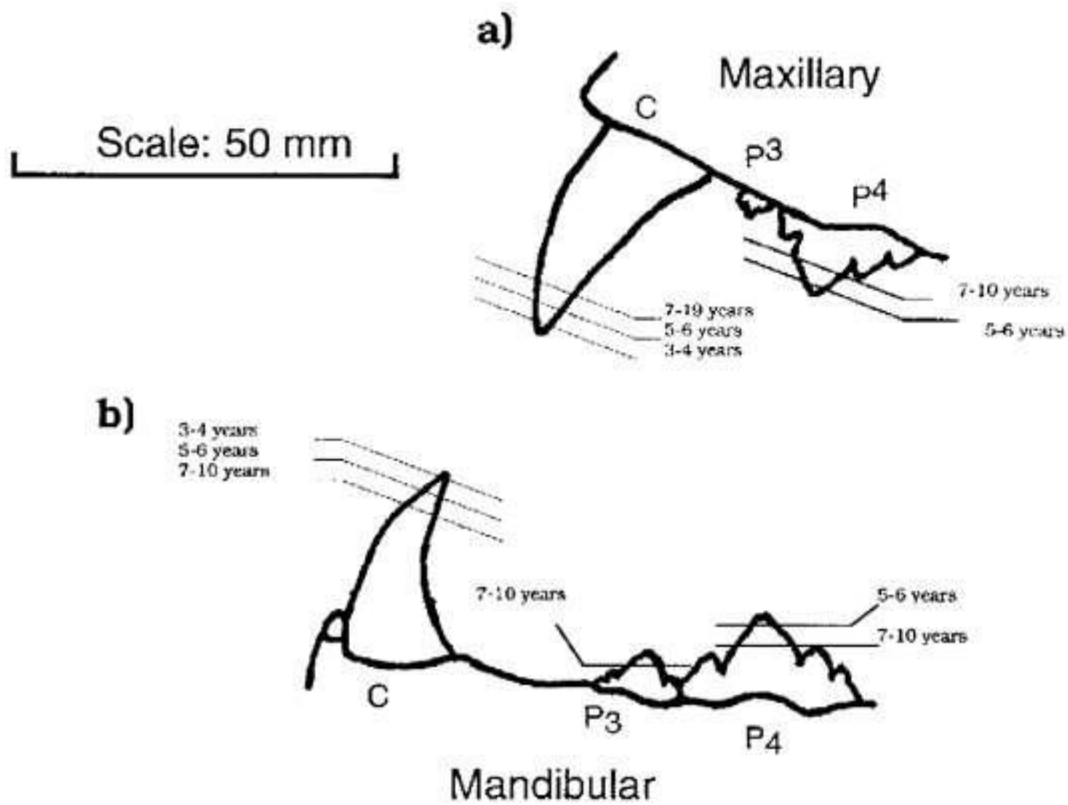
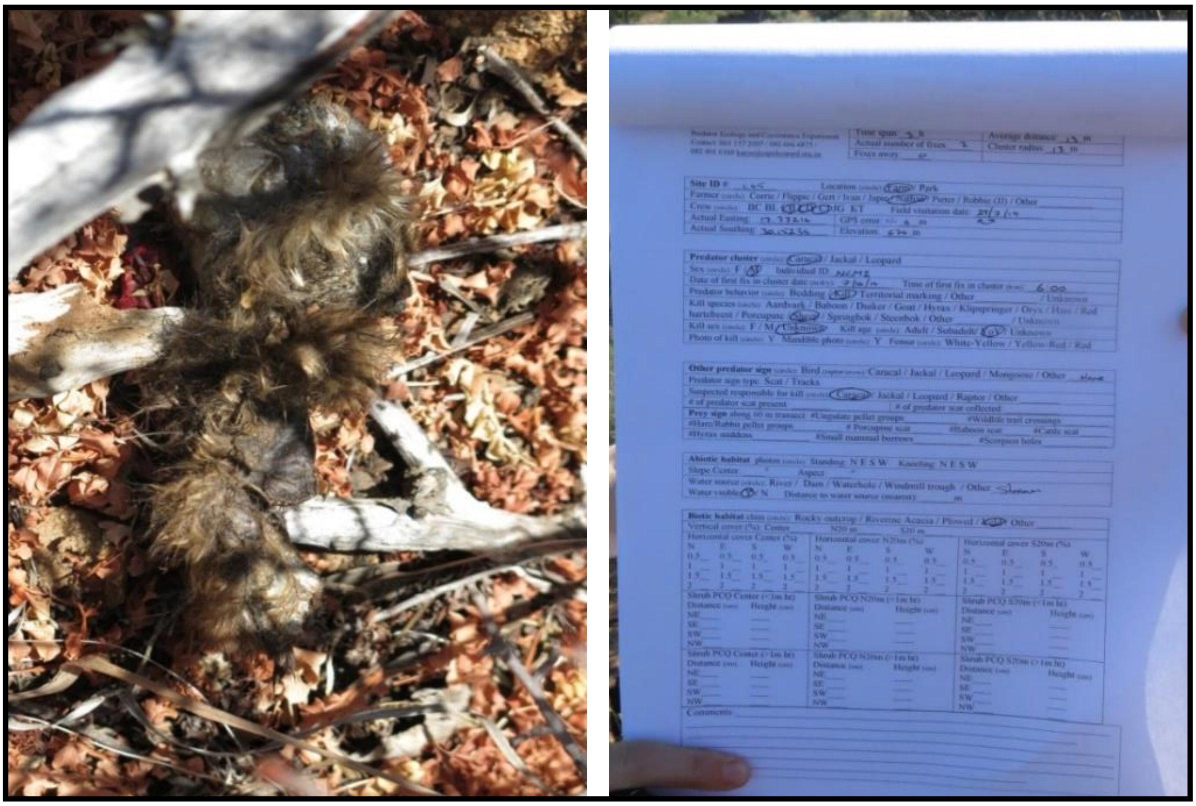


Diagram 2: Guide for aging leopards according to tooth wear (after Stander, 1997).

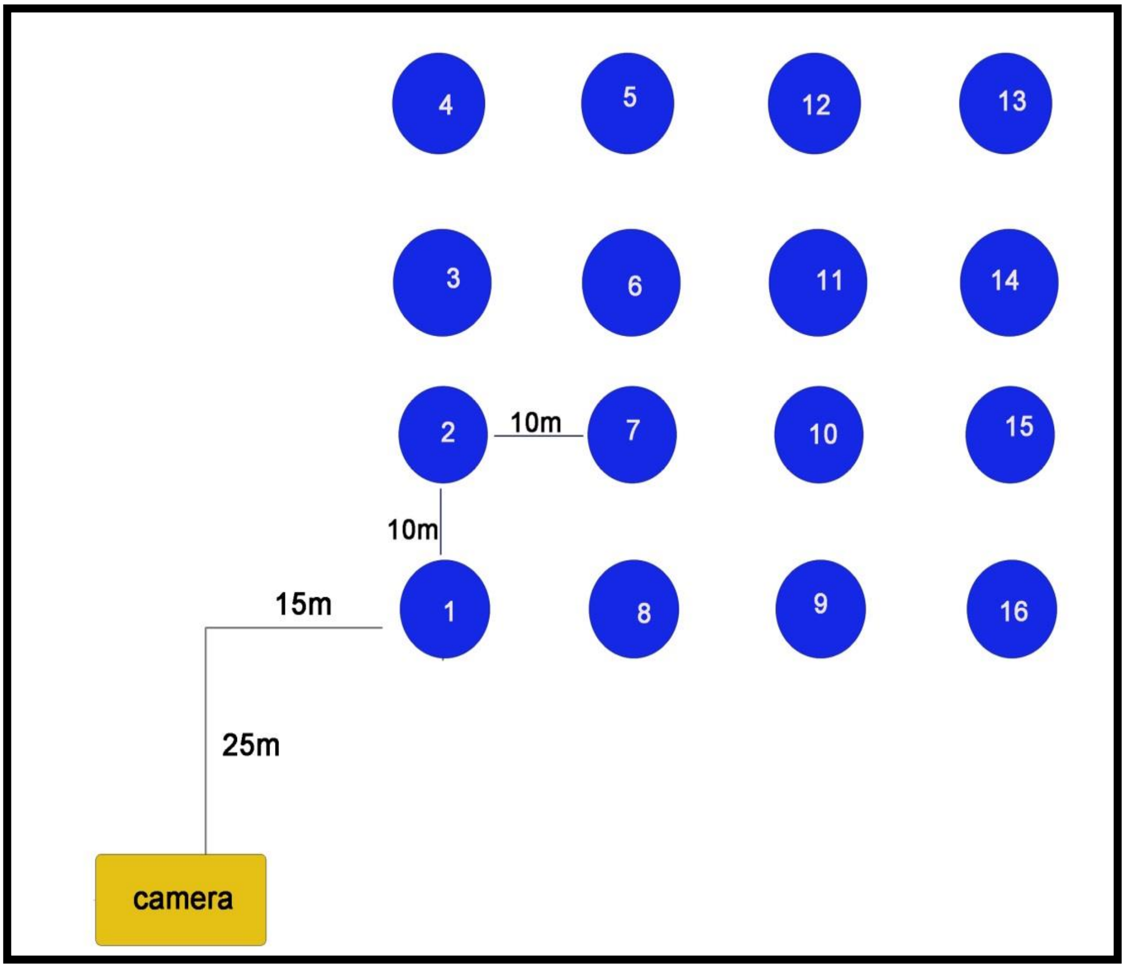


Appendix 2B– GPS cluster visitation searching method on a 50 m radius. A zigzag search pattern was used, with each person starting at the centroid and walking out to the edge of the 50 m radius.

Appendix 2C - Photographic example of hyrax (Procavia capensis) kill remains (left) and the data sheet filled out for each kill site visited (right).



Appendix 2D – Small mammal trap outline



Appendix 2E – Sex, weight and estimated age at time of capture for the 8 caracal radio-collared for this study.

Animal ID[a]	Sex	Weight(kg)	Estimated age[b]
NCM1	M	8.9	Subadult
NCM2	M	12.5	Adult
NCM3	M	12	Adult
NCM4	M	14.4	Adult
NCM5	M	10.4	Subadult
NCM6	M	8	Subadult
NCM7	M	15	Adult
NCM8	M	10.8	Adult

[a]N = Namaqua; C = Caracal; M = Male; # = number caught

[b] Subadult < 1.5 years and Adult > 1.5 years

Chapter 3: The diet of leopard (*Panthera pardus*) in Namaqualand, South Africa

3.1. Abstract

The leopard (*Panthera pardus*) is an apex predator and the last large carnivore still persisting in Namaqualand, Northern Cape, much of South Africa. Studies on the diet of the leopard on small-stock farms are lacking and even more so in the Northern Cape. Leopards are known to depredate on livestock and assessing the extent to which these animals predate on stock could provide important information to propose solutions to mitigate human-leopard conflict in Namaqualand. Leopards are elusive big cats, which poses challenges when studying the ecology of these animals in remote, mountainous terrains. This study used scat analysis to determine the general diet of leopards in Namaqualand, as well as compare the diet between two land-uses, namely the Namaqua National Park and surrounding small stock farmlands. Prey availability across the 810 km² study area was determined with the use of camera trapping. The data obtained from the camera traps allowed this study to compare diet with prey availability showing that leopard diet is dependent on abundant prey items. Leopards had a strong preference for hyrax (*Procavia capensis*) but overall obtained most biomass from livestock consumption, primarily goats and to a lower extent sheep. In Namaqua National Park hyrax and medium-sized ungulates [steenbok (*Raphicerus campestris*), duiker (*Sylvicapra grimmia*) and klipspringer (*Oreotragus oreotragus*)] were the main prey items in leopard diet, however on the farmlands medium-sized ungulates were replaced with livestockDue to a high level of depredation observed which could potentially lead to high persecution of leopards in Namaqualand it is crucial to implement conservation strategies to decrease livestock losses. Providing a suitable wild prey base on farmlands and increasing livestock guarding could decrease livestock losses.

3.2. Introduction

Human-carnivore conflict is an ever increasing problem and usually arises in areas where humans and carnivores compete for the same resources and/or occupy the same area (Pettigrew *et al.* 2012). With the increased expansion of human development and continued urbanisation of natural areas, carnivores have been pushed out of historical ranges or forced to continue to live in close proximity to humans (Treves and Karanth 2003; Kiffner *et al.* 2014). Human development is encroaching on natural habitat and in many areas buffer zones between protected areas and local communities are becoming smaller (Gusset *et al.* 2009). In some instances buffer zones do not exist or people live inside protected areas practicing animal husbandry (Bagchi and Mishra 2006). This often results in a higher livestock biomass when compared to the natural ungulate biomass (Bagchi and Mishra 2006; Li, Buzzard, Chen and Jiang 2013). Livestock predation by carnivores is one of the main causes for human-carnivore conflict, often leading to local people engaging in retaliatory killings of carnivores. These killings have resulted in various carnivores being exterminated from certain regions; dholes (*Cuon alpinus*) in Bhutan (Wang and Macdonald 2006), Eurasian lynx (*Lynx lynx*) in Europe (Stahl, Vandel, Herrenschmidt and Migot 2001) and lions (*Panthera leo*) and hyenas (*Crocuta crocuta*) in parts of South Africa (Beinart 2003).

Felids are involved in conflict with humans worldwide (Inskip & Zimmermann 2009). In particular larger felids, ranging in size from 12 kg to 235 kg, have been found to be responsible for the largest losses (Loveridge, Wang, Frank and Seidensticker, 2010). In areas where people rely on income from livestock husbandry, the loss of stock results in negative attitudes towards damage-causing animals. When subsistence farmers lose stock to carnivores the economic loss is much greater than what would be experiences by large-scale farmers (Loveridge *et al.* 2010). In Kenya and Zimbabwe, lions and leopards were responsible for 11 - 12% of annual income loss for subsistence stock farmers (Ogada, Woodroffe, Oguge and Frank 2003). Subsistence farmers lack the revenue to prevent livestock losses; in contrast various larger scale stock farmers can afford to manage predators and often lose a larger percentage of stock to causes other than carnivores, such as disease and natural disasters (Mizutani 1997; Schiess-Meier, Ramsauer, Gabanapelo and Köning 2007; Palmeira *et al.* 2008).

Mitigating human-carnivore conflict has become a priority in conservation (Linnell *et al.* 1999; Can *et al.* 2014). Predators form an important part of ecosystems and the loss of these predators can lead to ecological perturbations (Palomares and Caro 1999; Miller *et al.* 2001; Beschta and Ripple 2009). To sustain larger predators, sufficient viable habitat with a suitable prey base is required (Martins

2010). Protected areas that fall under these criteria are scarce and as a result many large predators compete with humans for suitable habitat often resulting in conflict and lethal persecution (both legal and illegal) [Hayward *et al.* 2006; Martins 2010). Mammalian carnivores generally occur at low densities and have large spatial requirements making them particularly vulnerable to extirpation due to fragmentation of suitable habitat (Balme, Slotow and Hunter 2010). It is thus crucial to have effective conservation management strategies outside protected areas such as on farmlands, which occupy the most extensive land-base in Southern Africa. Mitigating losses experienced by local communities is one of the main strategies required for predator conservation. This includes improving husbandry skills by promoting herding, kraaling and guardian dogs, changing the attitudes of local people and in some cases compensation for stock losses (Johansson *et al.* 2015).

The availability and abundance of prey, along with various other landscape attributes, play a key role in habitat selection of carnivores (Stephens and Krebs 1986; Balme, Hunter and Slotow 2007). Many mammalian carnivores are opportunistic in their feeding behaviour and will adapt to feed on the prey which is most abundant (prey abundance hypothesis) [Hopcraft, Sinclair and Packer 2005]. Alternatively, carnivores may also alter their feeding habits according to which prey items are easier to catch (landscape hypothesis) [Hopcraft *et al.* 2005]. A carnivore's diet can also be illustrative of the availability of prey, especially when the carnivore displays adaptable feeding behaviour (Karanth and Sunquist 1995). When analysing predator/prey relationships the latter can be used as an indicator of ecosystem functioning, along with determining the role a carnivore plays in a particular ecosystem (Klare, Kamler and Macdonald 2011; Mann 2014; Chattha *et al.* 2015). Dietary analyses is thus useful not only to test the extent of predation of livestock by carnivores, but also as a tool to determine which resources are required for the persistence of a certain carnivore species (Chattha *et al.* 2015).

Leopards (*Panthera pardus*) are the most widespread large felids in the world. Their success across such a wide variety of habitats can be attributed to their solitary, secretive nature, their adaptability to a variety of habitats and terrain and their opportunistic feeding behaviour (Martins *et al.* 2011; Estes 2012). These predominantly nocturnal felids are known to have a flexible diet and mostly select prey that are widely available (Ott, Kerley and Boshoff 2007; Rautenbach 2010). A total of 92 prey items have been recorded for leopards in sub-Saharan Africa (Bailey 1993; Hayward *et al.* 2006), ranging from invertebrates to adult eland (*Taurotragus oryx*) [Bailey 1993]. Leopards have high dietary needs and require between 1.6 kg to 4.9 kg of meat each day (Bothma and le Riche 1986; Stander, Haden, Kaqece and Ghau 1997; Hayward *et al.* 2006). High dietary requirements and adaptable foraging behaviour have earned the leopard a reputation as a livestock killer (Marker and

Dickman 2005; Balme, Slowtow and Hunter 2009). Leopards are the smallest of the large felids (*Panthera* genus) and mostly select for smaller stock such as sheep, goats and calves, compared to lions and tigers which have been recorded to prey on fully grown cattle (Loveridge *et al.* 2010). A dramatic reduction of leopard numbers has been observed in Africa, where leopard range has been reduced by 37% (Ray *et al.* 2005; Balme *et al.* 2010). In 1986 it was estimated that only 13% of potential leopard range was within the boundaries of protected areas (MacKinnon and MacKinnon 1986; Balme *et al.* 2010). This further emphasizes the need to study and understand leopard ecology outside the boundaries of protected areas, going beyond the traditional approach of leopard research inside protected areas only (Balme, Lindsey, Swanepoel and Hunter 2013).

Namaqualand is a semi-arid region of South Africa and many people living in the area are reliant on livestock farming as their only source of income (Allsopp, Laurent, Debeaudoin and Samuels 2007). Due to an increase in farming activities human-wildlife conflict is extensive in this region, with carnivores including leopard, caracal (*Caracal caracal*) and black-backed jackal (*Canis mesomelas*) being persecuted due to livestock losses (Stein, Fuller, Damery, Sievert and Marker 2010; Thorn, Green, Scott and Marnewick. 2013). Historically other large carnivores were present in this region, but due to eradication of these carnivores in earlier years the predator community has been altered and leopard is the only larger carnivore still persisting in this region (Skead 2011). The leopard is considered to be the apex predator in this area and as such is also a vital component of this study. Namaqualand could still provide an adequate range of habitat for large predator persistence (Loveridge and Nel 2004; Swanepoel *et al.*2012). Swanepoel *et al.* (2012) confirmed that Eastern parts of the Northern Cape, including parts of Namaqualand, are considered as suitable leopard habitat. Leopard habitat in Namaqualand is largely contiguous and conflict with farmers is the greatest threat to predator persistence in this region making conflict mitigation measures necessary. The most popular methods used by farmers to control for the loss of livestock include traps that are indiscriminate, killing non-target species such as bat-eared fox (*Otocyon megalotis*) and aardwolf (*Proteles cristata*) which do not depredate on livestock. It is estimated that up to 85% of animals caught in such traps are non-target species, or by-catch (The Cape Leopard Trust 2011). Practical and sustainable mitigation strategies could facilitate both the persistence of leopards, as well as food security for the people that live in this region. Understanding leopard diet is a first step towards the conservation of this species enabling suggestions for non-retaliatory livestock management practices in the event that leopards consume stock on Namaqualand farms.

3.2.1 Aims and Objectives

The main objective of this study was to provide a current account of leopard diet in Namaqualand to act as baseline data for understanding the role of leopards in this system. Diet was also compared between the Namaqua National Park and surrounding farmlands to further deepen understanding of leopard feeding ecology, especially the role of leopards in livestock predation in the area. This study hypothesises that land-use will influence prey composition in leopard diet, in addition to influencing prey categories occurring in leopard diet. This information will contribute to the compilation of a leopard management strategy for the region and assist with mitigation of conflict in the study area. Prey availability and prey preference were determined and compared between the two land-uses. Quantifying prey availability and preference will aid in understanding what effect prey availability has on diet choice of leopards in the region and whether livestock predation occurs as a response to decreased wild prey options.

3.3 Methods

3.3.1. Study Area

The study was conducted in Namaqua National Park (S30. 16627 E017. 79619) and the surrounding farmlands, encompassing a total area of 810 km^2. For a full description of the study area see Chapter 1, section 1.5.

3.3.2. Data Collection

For an in-depth description of scat collection see Chapter 2, section 2.1.1. For prey abundance estimation through camera trapping see Chapter 2, section 2.1.2.

3.3.3 Data Analysis

3.3.3.1. Scat Analysis

See Chapter 2, section 2.2.1 for scat washing methods and methodology regarding the preparing of cross-sections and identification of mammalian hair.

The frequency of occurrence (per prey item) [FO], corrected frequency of occurrence (frequency of occurrence per scat) [CFO] and percentage biomass were calculated. For a more in-depth description of FO and CFO refer to Chapter 2, section 2.2.1.

To estimate the biomass of prey consumed by leopards this study used Ackerman, Lindzey, and Hemker (1984)'s linear regression equation to calculate a correction factor for each prey item:

$$y = 1.98 + 0.035x$$

Where y is the weight of prey consumed per scat collected (kg/scat) and x is the average body weight of the prey item (kg) (Martins *et al.*2011; Mann 2014). According to Ackerman *et al.* (1984) prey items with an average weight of less than 2 kg cannot be corrected for digestibility as there is an assumption that such a small prey item does not comprise a whole scat; the BCM was thus only applicable for prey items weighing > 2 kg. Currently there are no feeding trial data available for leopards, however Ackerman's equation which corrects for cougar (*Puma concolor*) diet, with cougars being North American felids of similar size and diet range to the leopard were used (Bacon, Becic, Epp and Boyce.2011; Martins *et al.*2011). Prey items occurring in < 5% of a total scat was excluded from biomass calculations as these prey items usually occurred in trace amounts (Bacon *et al.* 2011; Mann 2014).

3.3.3.2. Prey Abundance and Preference Analysis

See Chapter 2, section 2.2.3 for more information. Please note that only camera trapping analysis is applicable to this chapter.

3.3.4. Statistical Analysis

For diet statistical analysis please refer to Chapter 2, section 2.3.1 and for prey abundance and preference statistical analysis from camera trap data refer to Chapter 2, section 2.3.3.

3.4. Results

3.4.1. Leopard diet

A total of 86 leopard scats were prepared for analysis, however only 82 scats were used for analysis; 28 from Namaqua National Park and 54 from surrounding farmlands. The 4 scats that were excluded lacked hair and/or discrete bone shards. A total of 24 prey species were recorded from the 82 scats used in the analysis, with mammals occurring in > 90% of the total diet. According to the CFO, hyrax (*Procavia capensis*) [22.4%] was the prey item occurring most frequently, which together with goat (*Capra hircus*) [16.3%] and Lagomorpha (10.8%) made up the top three most predominant prey items (Table 3.1). Medium-sized mammals (35%), livestock (27.8%) and medium- to large mammals (21.7%) occurred most frequently in leopard diet.

Table 3.1. Prey classes and prey species recorded in leopard scat (n=82) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Frequency of occurrence (FO) (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=100). Corrected frequency of occurrence (CFO) (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=82). For a table with all species identified see Appendix 3A.

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 100	FO (%)	Number of Occurrences (per scat) n = 82	CFO (%)
Large mammals (>40 kg)		**3**	**3**	**3**	**3.66**
Medium- to large mammals (10 – 40 kg)		**21**	**21**	**17.8**	**21.7**
Duiker (*Sylvicapra grimmia*)	16.1	8	8	7	8.5
Medium mammals (1 - 10 kg)		**35**	**35**	**28.7**	**35**
Hyrax (*Procavia capensis*)	3.03	22	22	18.3	22.4
Lagomorpha	2.35	11	11	8.8	10.8
Small mammals (<1 kg)		**8**	**8**	**4.8**	**5.9**
Livestock		**24**	**24**	**22.8**	**27.8**
Goat (*Capra hircus)*	50	14	13.7	13.3	16.3
Sheep (*Ovis aries*)	40	8	7.8	8	9.8
Birds	**1.57**	**2**	**2**	**1.5**	**1.8**
Invertebrates		**2**	**2**	**0.8**	**1**
Vegetation	**0.001**	**4**	**3.9**	**1.5**	**1.8**
Unknown	**-**	**1**	**1**	**1**	**1.2**

The total biomass ingested based on the 82 scats was 1980.7kg, with goat (35.3%) and sheep (*Ovis aries*) [16.2%] making up the largest amount of biomass consumed (Table 3.2). Red hartebeest (*Alcelaphus buselaphus*) [14.2%], cattle (*Bos taurus*) [12.4%] and duiker (*Sylvicapra grimmia*) [6.5%] were other prey items contributing to the bulk of biomass consumed. Rock hyrax was the most frequently consumed prey item, but only made up 3.4% of total biomass consumed. Small mammals (< 1 kg) did not make up a large percentage of biomass consumed (not one species contributed > 0.10%). When converting biomass consumed to the actual biomass consumed correction factors (CFs) were used. These CFs were calculated using Ackerman's (1984) linear regression equation to help convert naïve biomass to actual biomass consumed. The total biomass consumed was 257.9 kg, much lower than the naïve biomass calculated. Once the CF was applied to each prey item, goat (21.8%), hyrax (19.1%) and sheep (11.3%) were the top three prey items contributing to total biomass consumed. Lagomorpha (9.5%), duiker (8.5%) and klipspringer (*Oreotragus oreotragus*) [7%] rounded out the top prey items consumed in terms of actual biomass. The percentage biomass of small mammals consumed also increased from 0.2% to 1.4%.

Table 3.2. Biomass consumed calculated from leopard scat (n=82) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a table listing all species see Appendix 3B.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=93)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Goat (*Capra hircus*)	50	3.73	14	15.05	700	35.34	56.15	21.77
Hyrax (*Procavia capensis*)	3.03	2.09	22	23.66	66.66	3.37	49.35	19.13
Sheep (*Ovis aries*)	40	3.38	8	8.60	320	16.16	29.08	11.27
Lagomorpha	2.35	2.06	11	11.83	25.85	1.31	24.39	9.46
Duiker (*Sylivapra grimmia*)	16.1	2.54	8	8.60	128.80	6.50	21.88	8.48
Total	**469.3**	**45.9**	**93**	**100**	**1980.7**	**100**	**257.9**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Ackerman *et al.* (1984), $Y = 1.98 + 0.035x$; only for prey >2 kg

[c]Prey weight x Number of occurrences

[d]Correction factor x Prey item occurrence

3.4.2. Namaqua National Park versus surrounding farms

A total of 28 scats were analysed from Namaqua National Park and 54 from surrounding farmlands. Hyrax (29.8%), duiker (16.1%), klipspringer (10.7%) and steenbok (*Raphicerus campestris*) [10.2%] were found to be the most frequently consumed prey items in the national park (Table 2.3). On the surrounding farmlands, goat (22.8%), hyrax (18.5%) and sheep (14.8%) were the prey items occurring most frequently in the analysed scats (Table 3.3). No invertebrates (0%) were ingested on the farmlands and no birds in the national park (0%). A significant difference was found when comparing the occurrence of goat (X^2 = 6.72 df = 1, p = 0.028) and sheep (X^2 = 7.13 df = 1, p = 0.046) in leopard diet across the two land-uses.

In the national park medium- to large mammals (37.5%) and medium mammals (36.4%) were the prey classes found most frequently in leopard diet, however on the farms the most frequently consumed prey classes shifted to livestock (40.4%) and medium mammals (34.3%) [Figure 3.1]. Medium- to large mammals occurred significantly more in leopard diet in the national park than on the farmlands (X^2 = 7.80, df = 1, p =0.007). Contrastingly, livestock filled the role of medium- to large mammals on farmlands and a significant difference was observed in livestock occurrence in diet when compared between the two land-uses (X^2 = 16.44, df = 1, p = 0.000).

Table 3.3. Prey classes and prey species recorded in leopard scat collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. FO (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences. CFO (%) was calculated as the number of occurrences per scat divided by the total number of scats collected. For a table containing a full list of species identified see Appendix 3C (Namaqua National Park) and Appendix 3D (farmlands).

		Namaqua National Park				Farmlands			
Prey Item	**Prey Weight (kg)**	**Number of Occurrences (prey items) n = 39**	**FO (%)**	**Number of Occurrences (per scat) n = 28**	**CFO (%)**	**Number of Occurrences (prey items) n = 61**	**FO (%)**	**Number of Occurrences (per scat) n = 54**	**CFO (%)**
Large mammals (>40 kg)		**2**	**5.13**	**2**	**7.14**	**1**	**1.64**	**1**	**1.85**
Medium- to large mammals (10 – 40 kg)		**11**	**30.76**	**10.5**	**37.5**	**8**	**13.11**	**7.33**	**13.57**
Duiker (*Sylvicapra grimmia*)	16.1	5	12.82	4.5	16.07	3	4.92	2.5	4.63
Klipspringer (*Oreotragus oreotragus*)	11.9	4	10.26	3	10.71	3	4.92	2.33	4.31
Steenbok (*Raphicerus campestris*)	11.1	3	7.69	3	10.71	2	3.28	2	3.70

Medium mammals (1 - 10 kg)		**15**	**38.46**	**10.16**	**36.29**	**21**	**34.43**	**18.5**	**34.26**
Hyrax (*Procavia capensis*)	3.03	11	28.21	8.33	29.75	11	18.03	10	18.52
Lagomorpha	2.35	3	7.69	1.33	4.75	8	13.11	7.5	13.89
Small mammals (<1 kg)		**4**	**10.26**	**1.83**	**6.54**	**4**	**6.56**	**3**	**5.56**
Livestock		**1**	**2.56**	**1**	**3.57**	**23**	**37.70**	**21.83**	**40.43**
Goat (*Capra hircus)*	50	1	2.56	1	3.57	13	21.31	12.33	22.83
Sheep (*Ovis aries*)	40	0	0	0	0	8	13.11	8	14.81
Birds	**1.57**	**0**	**0**	**0**	**0**	**2**	**3.28**	**1.5**	**2.78**
Invertebrates		**2**	**5.13**	**0.83**	**2.96**	**0**	**0**	**0**	**0**
Vegetation	**0.001**	**2**	**5.13**	**0.66**	**2.36**	**2**	**3.28**	**0.83**	**1.54**
Unknown	**-**	**1**	**2.56**	**1**	**3.57**	**0**	**0**	**0**	**0**

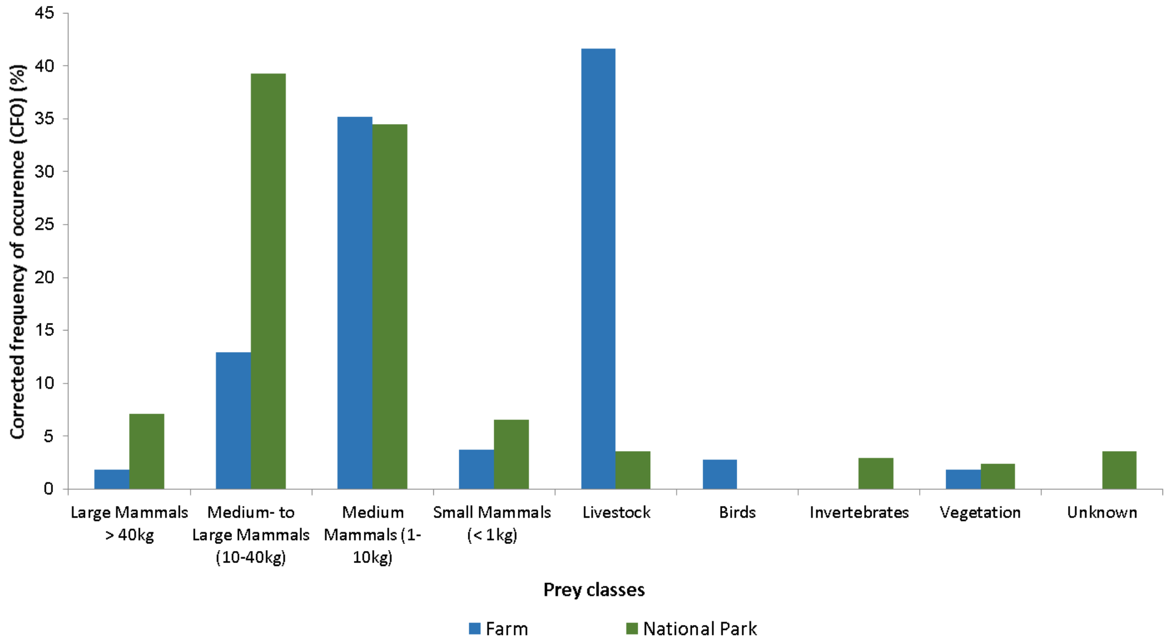


Figure 3.1. Prey classes recorded in leopard scat (n=82) collected in Namaqua National Park (n=28) and on surrounding farmlands (n=54), Northern Cape, South Africa. CFO (%) was calculated as the number of occurrences per scat divided by the total number of scats collected.

The total biomass of prey items analysed from leopard scats was 222.4 kg for the national park and 279.58 kg on the farms. Hyrax (30.3%), duiker (16.8%), klipspringer (12.7%) and steenbok (9.4%) made up the bulk (> 65%) of total biomass consumed in the national park (Table 3.4) while on the farmlands, goat (27.2%), sheep (20.2%), hyrax (14.2%) and lagomorpha (10.2%) made up > 70% of total biomass consumed (Table 3.5). Leopard diet on the farmlands comprised mostly livestock, particularly goat.

Table 3.4. Biomass consumed of the five main prey items calculated from leopard scat (n=28) collected in Namaqua National Park, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a table listing all species see Appendix 3E.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=34)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	2.1	11	32.4	33.3	7.3	67.5	30.2
Duiker (*Sylvicapra grimmia*)	16.1	2.5	5	14.7	80.5	17.6	37.4	16.7
Klipspringer (*Oreotragus oreotragus*)	11.9	2.4	4	11.8	47.6	10.4	28.2	12.6
Steenbok (*Raphicerus campestris*)	11.1	2.4	3	8.8	33.3	7.3	20.9	9.4
Red Hartebeest (*Alcelaphus buselaphus*)	140.26	6.9	1	2.9	140.3	30.7	20.3	9.1
Total	**480.3**	**45.9**	**34**	**100**	**456.9**	**100**	**223.4**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Ackerman *et al.* (1984), ; $Y = 1.98 + 0.035x$; only for prey >2 kg

[c]Prey weight x Number of occurrences

[d]Correction factor x Prey item occurrence

Table 3.5. Biomass consumed of the five main prey items calculated from leopard scat (n=54) collected on farmlands in Namaqualand, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a table listing all species see Appendix 3F.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=59)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Goat (*Capra hircus*)	50	3.7	13	22	650	42.4	82.2	29.6
Sheep (*Ovis aries*)	40	3.4	8	13.6	320	20.9	45.8	16.5
Hyrax (*Procavia capensis*)	3.03	2.1	11	18.6	33.3	2.2	38.9	14
Lagomorpha	2.35	2.1	8	13.6	18.8	1.2	28	10.1
Cattle (*Bos taurus*)	123	6.3	2	3.4	246	16	21.3	7.7
Total	**480.3**	**45.9**	**59**	**100**	**1534.8**	**100**	**277.8**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Ackerman *et al.* (1984), $Y = 1.98 + 0.035x$; only for prey >2 kg

[c]Prey weight x Number of occurrences

[d]Correction factor x Prey item occurrence

3.4.4. Prey abundance and preference

For national park prey abundance, data from 43 camera traps was used in the analysis. As farmlands made up a larger portion of the study area more cameras were deployed according to the grid system. Data on farmlands was collected from 120 cameras and analysed for prey abundance. Total trap nights for the study amounted to 19 320; 5687 in the national park and 13 633 on the surrounding farmlands. There was a significant difference in duiker ($U = 1213$, $df = 1$, $p < 0.05$), hyrax ($U = 2211.5$, $df = 1$, $p < 0.05$) and steenbok ($U = 1368$, $df = 1$, $p < 0.05$) abundances when compared between the national park and the surrounding farmlands. Steenbok and duiker had a higher abundance in the national park; whereas hyrax abundance was higher on the farmlands. These prey items were some of the most frequently preyed upon species in the national park where no livestock occurred. Klipspringer, another common prey item in leopard diet inside the national park, showed no significant difference in abundance between the two land-uses ($U = 2437$, $df = 1$, $p < 0.05$).

Lagomorpha, sheep, duiker, steenbok and porcupine (*Hystrix africaeaustralis*) were the main prey items in the study area across both land-uses with the highest RAI. Most of the prey items that had a RAI of < 1 were small-sized mammals such as yellow mongoose, small-spotted genet, striped polecat and meerkat. When assessing the prey preference for some of these animals a prey preference was apparent. This illustrates the potential bias that exists when calculating the *D*-value (Jacobs' index) for prey items that occur in the diet of the study animal for < 5%. Oryx (*Oryx gazella*) [10.8%], steenbok (7.1%), duiker (7%) and lagomorpha (6.1%) were the four most abundant prey items in Namaqua National Park (Figure 3.2). Lagomorpha (12.5%) and duiker (6.1%) were the two most abundant wildlife prey species/groups on the farmlands. As expected there was a significant difference in livestock abundance between the two land-uses, namely sheep ($U = 1827.5$, $df = 1$, $p < 0.05$), goat ($U = 2128.5$, $df = 1$, $p < 0.05$) and cattle ($U = 2012.5$, $df = 1$, $p < 0.05$). Sheep were most abundant on the farmlands (13.4%), followed by goat (4.4%) and cattle (3.7%).

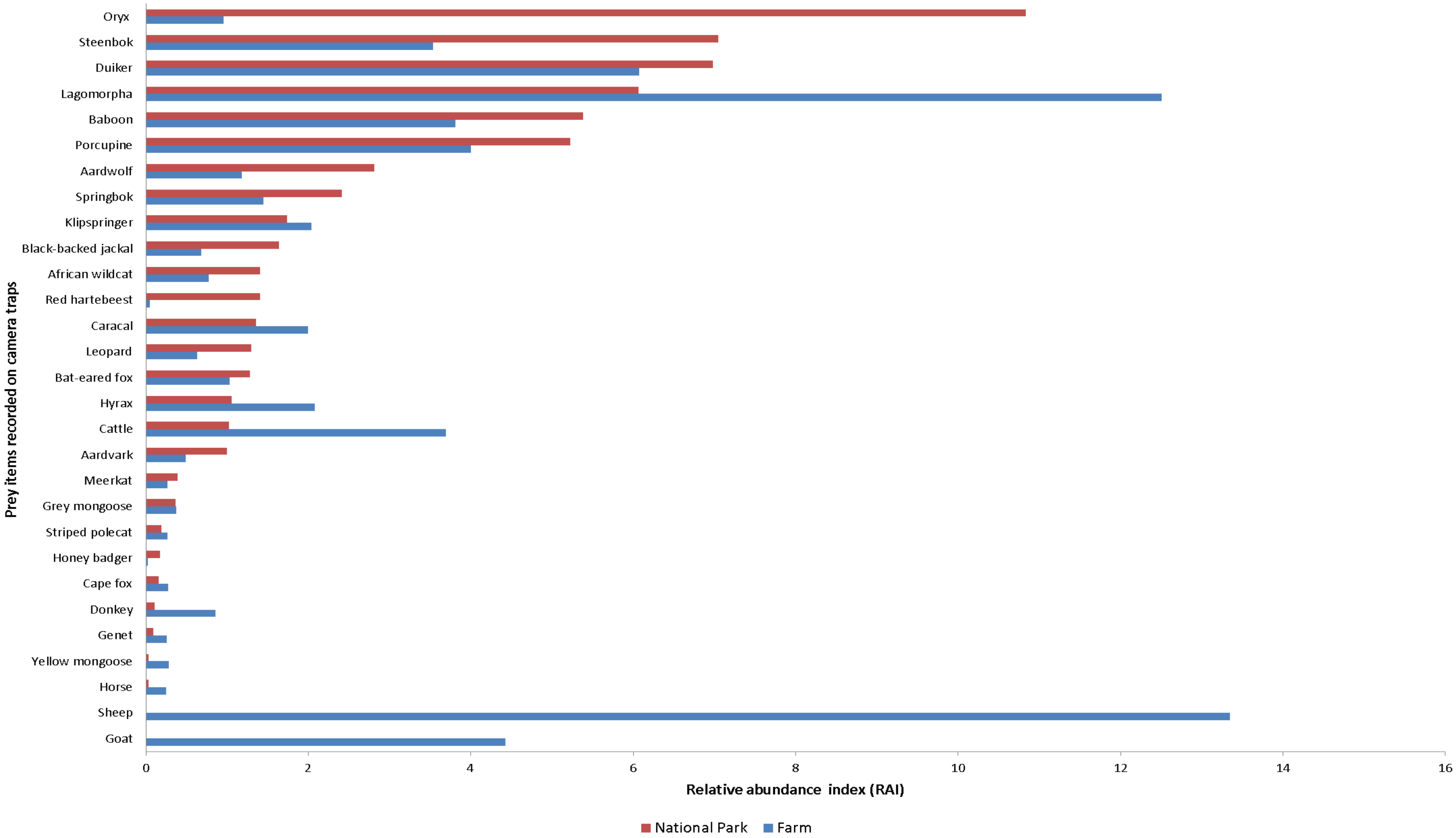


Figure 3.2. Prey relative abundance index (RAI) calculated from camera trap data collected from March 2014 – April 2015. RAI was calculated as the total detections of a certain mammalian species, multiplying by 100 (to calculate the number of photo captures per 100 trap nights), and dividing by the total number of trap nights.

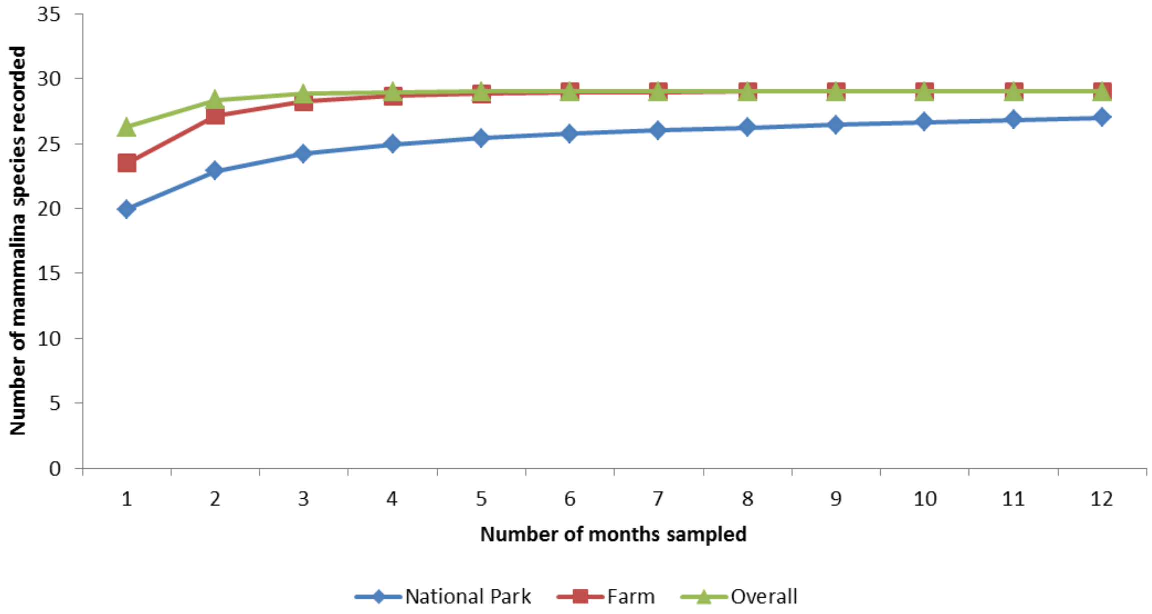


Figure 3.3. Species accumulation curve (100 randomised iterations) for the entire study area (ICE Mean = 29; ACE Mean = 29), in Namaqua National Park (ICE Mean = 27.8; ACE Mean = 27.4) and the surrounding farmlands (ICE Mean = 29; ICE Mean = 29) of the 29 wild mammal prey items ≥ 1 kg in weight and livestock in the study area.

From 19 320 camera trapping nights, 12 716 photographs of medium-to-large mammalian species were obtained which were identified to species level. Twenty nine mammals, 4 bird species and 1 reptile species (tortoise) were identified, however only mammals of medium-to-large body size were used in the analysis. A species accumulation curve, according to the number of months cameras were active, was calculated (Figure 3.3). The species accumulation curve reached an asymptote, indicating that most species were sampled (ICE mean 29).

Prey preference was analysed using camera data collected from the 159 camera traps that were placed in the field for a period of 12 months (rotated once within each grid cell). When analysing prey preference for leopard diet across both land-uses, most prey items were preferred. A Jacobs' index between 0.5 and 1 indicates a strong preference. Both the CFO and relative biomass consumed values were used to calculate the Jacobs' index for prey preference. Mammalian prey items for which leopards displayed a strong preference (> 0.60) were hyrax, yellow mongoose (*Cynictis penicillata*), goat, small spotted genet (*Genetta genetta*), red hartebeest, striped polecat (*Ictonyx striatus*)[only when analysing with CFO] and klipspringer (Figure 3.4). Caracal and porcupine were the only two prey species that had a *D*-value of < 0 for both CFO and biomass calculations.

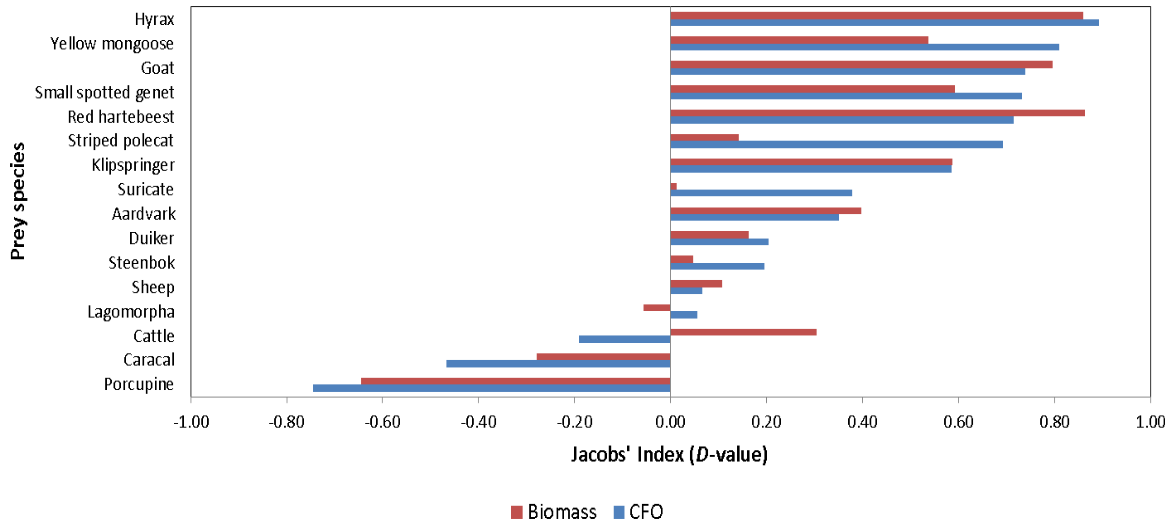


Figure 3.4. Jacobs' Index (*D*-value) showing preference (+ 1) and avoidance (- 1) for prey species. A *D*-value close to 0 indicate prey consumption in proportion to prey availability, (prey items was neither preferred, nor avoided).The biomass consumed and the corrected frequency of occurrence (%) used to calculate the *D*-value are illustrated.

Prey preference was also compared between the two land-uses (Table 3.6). In Namaqua National Park, goat was the prey item with the highest preference; however it was a prey item that had a RAI of 0 and an occurrence in diet of < 5%. It is suggested that prey items with similar numbers in terms of presence in the study area and in the diet, should be excluded from the analysis. However, including all prey items would allow for more accurate results for other species occurring in the diet at > 5% (Hayward *et al.* 2006; Mann 2014). Hyrax, klipspringer, duiker and red hartebeest were significant prey items in the leopard's diet and considered to be strongly preferred (> 0.50). Steenbok, having a very low, but positive *D*-value, is a prey item which was consumed in proportion to its availability and was neither preferred nor avoided. Lagomorpha's *D*-value only illustrated a very low avoidance (- 0.05) of the prey item, compared to caracal (-0.47) and porcupine (-0.74) which had a high avoidance value as a prey item. On the farmlands no prey item had a *D*-value of +1. Hyrax, goat and klipspringer were all preferred prey items with a *D*-value of > 0.50. The *D*-values for small spotted genet, striped polecat and yellow mongoose emphasize the bias that exists for prey items which occur in < 5% of the diet, wherein prey items that occur only once in scats may have a *D*-value of +1 or close to +1.

Table 3.6. Relative abundance index (RAI) of all mammalian species recorded on the camera traps in both Namaqua National Park and the surrounding farmlands in Namaqualand, Northern Cape. The corrected frequency of occurrence (CFO) used in Jacobs' Index calculations for each separate land-use is also summarised. See Appendix 3G (CFO) and Appendix 3H (biomass consumed) for comparative figure of *D*-values calculated for the national park and farmlands.

Prey species	RAI (%) in Namaqua National Park	CFO (%) in Namaqua National Park	Jacobs' Index (D)	RAI (%) on farmlands	CFO (%) on farmlands	Jacobs' index (D)
Goat	0.00	4.14	1	4.43	24.1	0.75
Hyrax	1.06	34.48	0.96	2.08	19.55	0.84
Klipspringer	1.74	12.42	0.78	2.04	4.55	0.39
Meerkat	0.39	2.07	0.69	0.26	0	-1
Aardvark	1.00	4.14	0.62	0.49	0	-1
Duiker	6.98	18.63	0.51	6.07	4.89	-0.11
Red hartebeest	1.41	4.14	0.50	0.05	1.95	0.95
Steenbok	7.05	12.42	0.30	3.54	3.91	0.05
Lagomorpha	6.07	5.50	-0.05	12.51	14.66	0.09
Porcupine	5.22	2.07	-0.45	4	0	-1
Caracal	1.35	0.00	-1	2	0.98	-0.35
Small spotted genet	0.09	0.00	-1	0.26	1.95	0.77
Yellow mongoose	0.04	0.00	-1	0.29	2.93	0.83
Striped polecat	0.19	0.00	-1	0.26	1.95	0.77
Cattle	1.02	0.00	-1	3.7	2.93	-0.12
Sheep	0.00	0.00	-1	13.35	15.64	0.09

Oryx	10.83	0	-1	0.96	0	-1
Baboon	5.38	0	-1	3.81	0	-1
Aardwolf	2.81	0	-1	1.18	0	-1
Springbok	2.41	0	-1	1.45	0	-1
Black-backed jackal	1.64	0	-1	0.68	0	-1
African wildcat	1.41	0	-1	0.77	0	-1
Leopard	1.30	0	-1	0.63	0	-1
Bat-eared fox	1.28	0	-1	1.03	0	-1
Grey mongoose	0.37	0	-1	0.37	0	-1
Honey badger	0.18	0	-1	0.02	0	-1
Cape fox	0.16	0	-1	0.27	0	-1
Donkey	0.11	0	-1	0.86	0	-1
Horse	0.04	0	-1	0.25	0	-1

3.5. Discussion

3.5.1. General diet of leopards in Namaqualand

In Namaqualand leopards are the apex predators and exhibit a clear opportunistic feeding behaviour. This is evident from the main prey items of leopards in Namaqualand. Hyrax (*Procavia capensis*), a medium-sized mammal (3.03kg) was the main prey item of leopard in Namaqualand. Hayward *et al.* (2006) found that worldwide leopards exhibit a preference for medium-sized ungulates (10- 40 kg). However, the studies reviewed by Hayward *et al.* (2006) mostly focus on leopard diet in protected areas, ignoring the importance of understanding diet across various land-uses (Balme *et al.* 2013). In other areas of South Africa leopards also prey on smaller prey items, such as hyrax, lagomorphs and even rodents (Norton *et al.* 1986; Rautenbach 2010; Martins *et al.* 2011). The selection of these smaller prey items as a food source for leopards is primarily due to these prey items being readily available (Balme *et al.* 2007; Rautenbach 2010). Various studies support the opportunistic feeding behaviour of leopards, where they shift their diet to select for smaller prey items when an adequate sized prey range is lacking (Bothma and Le Riche 1984; Henschel, Abernethy and White 2005; Balme *et al.* 2007; Braczkowski *et al.* 2012; Mann 2014). Hyrax, in areas where present, are a major prey source for leopards in the Western and Northern Cape (Bothma and La Riche 1994; Martins *et al.* 2011). The body size of leopards in my study area is unknown, but from camera data collected and one individual captured for collaring purposes it can be assumed that they might be larger than leopards in the Fynbos and Succulent Karoo biome in the Western Cape, but possibly smaller than savanna leopards in the KTP, Northern Cape (Skinner and Chimimba 2005; Martins *et al.* 2011; Balme, Hunter and Braczkowski 2012; Mann 2014). It is thus not surprising that in Namaqualand where hyrax is reasonably abundant it is the main wild prey item.

Only one other study on leopard diet in the Northern Cape region has been undertaken. Bothma and le Riche (1994) observed leopard diet in the Augrabies Falls National Park and Kgalagadi Transfrontier Park (KTP), Northern Cape. In the Augrabies Falls National Park hyrax were one of the main prey items consumed, corresponding with other leopard diet studies throughout South Africa (Norton *et al.* 1986; *Ott et al.* 2007; Rautenbach 2010; Martins *et al.* 2011). In the KTP little deviation was found in terms of leopard diet compared to previous studies, but excluded the presence of rock hyrax as this prey item is not present in that region. In the Western Cape, Martins *et al.* (2011) showed that rock hyrax and klipspringer were the main prey items in leopard diet in the Cederberg Mountains. This also corresponded with Norton *et al.*'s (1986) study of leopard diet using faecal analysis in the Clanwilliam region, Gamka Mountains, Jonkershoek region and Wemmershoek, all in the Western Cape. However, leopard presence in a region is not limited by the availability of a certain prey item, in this instance hyrax (Estes 2012). Where hyrax is not present, leopard will shift their diet to select for other available prey items, as in studies by Ott *et al.* (2007) and Braczkowski *et al.* (2012) where leopards mostly preyed on the most available medium-sized ungulate species and a larger rodent species. In Namaqualand klipspringer was the main wild prey item for preference in leopard diet, although occurring less frequently than hyrax and lagomorph in scats analysed. In the Cederberg Mountains klipspringer was also a preferred prey item for leopards (Martins *et al.* 2011). Leopards in Namaqualand were even found to prey on other smaller carnivores such as small-spotted genet, yellow mongoose, striped polecat and caracal. Aardvark (*Orycteropus afer*) was preyed on infrequently. In the present study, 24 prey items were identified in leopard diet. This compares well to studies in similar ecosystems, such as Rautenbach (2010) who identified 17 prey items, Martins *et al.* (2011) with 23 prey items in the Cederberg Mountains and Mann (2014) who identified 21 mammalian prey species

In the Western Cape, leopards have persisted by relying on mountainous areas and natural prey, despite increased human urbanisation and agricultural practices (Martins and Martins 2006; Swanepoel *et al.* 2012). Only three studies analysing leopard diet in the Western Cape have observed domestic stock as a prey item. Norton *et al.* (1986) and Martins *et al.* (2011) studied leopard diet in the Cederberg Mountains, a rugged and mountainous area, where small-stock farming is practised. Mann (2014) studied leopard diet in the Little Karoo. Various previous studies have suggested that livestock predation by leopards occurs mostly opportunistically (Ott *et al.* 2007; Loveridge *et al.* 2010; Chattha *et al.* 2015). A large part of Namaqualand is also mountainous and these areas were included in the present study. Leopards prefer, but are not restricted, to such areas in most parts of South Africa, in particular where human practises and presence have increased (Estes 2012; Swanepoel *et al.* 2012). Goats (Boergoat breed) are agile climbers venturing into rugged terrain where they are presumably exposed to high risk of predation by leopards. Goat was a preferred prey item in leopard diet in Namaqualand. Preying on sheep would require a leopard to travel further from the refuge of mountains, but catching a sheep may be easier than catching a goat (Rafiq, Afzal, Jasra, Ahmad, Khan and Farooq 2010).

The predominance of goat in leopard diet from scat could be attributed to a certain individual leopard specializing in goat predation, possibly as a result of overlap in leopard territory with large areas of farmlands where a high availability of goat may be present (Linnell *et al.* 1999; Linnell, Swenson and Anderson 2001; Loveridge *et al.* 2010). However, scat was collected across the entire study area with sampling covering the home ranges of several leopards of both sexes (B. Cristescu and K. J Teichman unpublished camera trap data). Therefore, leopards that prey on livestock might do so due to higher encounter rate with livestock than wild prey of similar size (and hence energetic reward) to livestock, ease of capturing and subduing domestic prey, or by developing a habit for catching livestock (Linnell *et al.* 1999; Balme *et al.* 2007). For future leopard studies and in particular when analysing diet to mitigate human-carnivore conflict, it would be preferable to use scat analysis in combination with GPS cluster visitation for accurate results (Martins *et al.* 2011; Pitman *et al.* 2013). GPS cluster visitation can provide more information on individual leopard diet and further the understanding of what drives leopard prey preference in Namaqualand.

3.5.2. Namaqua National Park versus surrounding farmlands

Analysing diet from Namaqua National Park was expected to be more comparable to a wide range of previous leopard studies, as most studies have been done in protected areas. In the national park leopard's diet consisted mainly of hyrax and medium-sized ungulates (duiker, klipspringer and steenbok). The prey species and prey weight range coincides with Hayward *et al.* (2006)'s main findings on leopard prey preference (10 – 40 kg), as well as other studies on leopard diet in South Africa (Bothma and Le Riche 1994; Ott *et al.* 2007; Martins *et al.* 2011; Braczkowski *et al.* 2012; Mann 2014).However, on farmlands, the percentage by which medium-sized ungulates contributed to the total biomass consumed by leopards decreased to just over 10%. Livestock however, replaced medium-sized ungulates in the diet, with small domestic stock contributing > 40% to the total biomass consumed. There are two determinants that influence the diet of an opportunistic predator. The first being which prey is the most abundant, or widely available, and the second, which prey item requires the lowest energy expenditure to prey upon (Balme *et al.* 2007). Livestock on farms in Namaqualand are abundant and presumably easier to capture than wild prey thereby representing an advantageous prey for leopards to tackle. With leopard diet shifting towards livestock and hyrax on farmlands, it can be suggested that these prey items are readily available on this land-use.

Camera data substantiated that livestock was an abundantly available prey source with livestock abundance being higher than that of wild ungulates on farmlands. Sheep had the highest abundance across the study area, 100% of that abundance being located on farmlands. Livestock on the farmlands represent a similar abundance to medium-sized ungulates in the national park and predictably less effort is required to catch livestock. Camera data also confirmed wild ungulate abundance to be lower on the surrounding farmlands, compared to the national park. It is possible that abundance data for klipspringer and hyrax were not accurate enough to infer RAI (Relative

Abundance Index) results confidently. Difference in detection probabilities of certain prey items could have resulted in bias when analysing the RAI (Sollman, Mohamed, Samejima and Wilting 2013). Both these animals live in rugged, rocky areas (Skinner and Chimimba 2005). With cameras being placed along jeep tracks and other linear features it is possible that camera placement would have minimized detection of some prey species, such as rock-dwelling prey. However, some cameras were placed at habitat edges between shrubland and rocky areas thereby sampling species using both habitats. Further, hyrax was observed grazing away from rocky habitat in Namaqualand; therefore cameras could have captured them outside the rocky areas which they use as safe refuge (Estes 2012).

Goat hair occurred in only one scat collected in the national park and, being absent from the park, was the prey item most preferred in the park on the basis of Jacobs' index. However, as leopards travel vast distances it is very probable that the goat was caught and consumed on farmlands, but the scat was deposited in the national park. Some studies have recommended excluding prey items from prey preference calculations if occurring in < 5% of the total scats, as biases can occur (Klare *et al.* 2010; Kamler, Klare and Macdonald, 2012). However, other studies have included all prey species in diet preference estimation (Hayward *et al.* 2006; Mann 2014). According to Jacobs' index, only two prey items, porcupine and lagomorpha, occurring in scats collected in the national park, were avoided as prey items by leopard. Red hartebeest occurred once in scats collected in the national park and once on farmlands. With red hartebeest abundance being higher in the national park, the Jacobs' was higher on farmlands than in the park. This further illustrated the draw-backs of the use of Jacobs' index for rare prey items. Hyrax and klipspringer were two of the prey items that leopards showed the strongest preference for in the national park. Martins *et al.* (2011) found similar results in the Cederberg Mountains using both scat analysis and GPS cluster visitations. The study by Martins *et al.* (2011) was carried out on various land-uses, including protected areas and small private reserves. Using scat analysis as the primary method for carnivore diet estimation is useful, but with radio-collared, large carnivores GPS clusters can be identified to guide field visitation of potential kill sites (Cristescu *et al.* 2015b). This is an expensive and invasive technique which requires adequate sample sizes to be scientifically significant (Blame *et al.* 2013). Using GPS cluster visitation in combination with scat analysis has been cited as the most appropriate method for diet determination studies (Bacon *et al.* 2011; Cristescu, Stenhouse and Boyce 2015a). In the current study scat analysis alone yielded comparable findings on leopard diet composition to those of studies employing both scat analysis and GPS cluster visitation (Martins *et al.* 2011; Pitman, Swanepoel and Ramsay 2012; Tambling *et al.* 2012; Mann 2014; Pitman *et al.* 2013).

Leopards are known for killing and sometimes feeding on smaller carnivores such as cheetah (*Actinonyx jubatus*), caracal, black-backed jackal (*Canis mesomelas*) and even genet (Stander *et al.* 1997; Hayward *et al.* 2006). The reason for killing of carnivores might be to decrease interspecific competition for resources (Loveridge *et al.* 2010). In Namaqualand, leopard only preyed on smaller carnivores such as small-spotted genet, striped polecat and yellow mongoose on the farmlands, with the exception of meerkat. The caracal remains analysed from one of the scats suggest that the prey was a kitten (identified by the size of claws present). The interspecific killing of other carnivores on the farmlands could suggest that competition is higher on this land-use type due to the increased available prey spectrum, resulting in an increase in carnivore numbers due to surplus prey availability. Another suggestion is that this is an opportunistic food source for leopards on farmlands in Namaqualand where natural wild prey items were lower than in the national park based on RAI results. Caracal were more abundant on the farmlands when compared to the national park, further substantiating why caracal remains were observed in leopard scat from farmlands. Leopard and caracal likely compete for food on farmland, in particular for rock hyrax which is a main prey item for both felids. Both these predators may also be drawn to farmlands due to an increased food source (livestock) and water sources (Treves *et al.* 2004).

On the farmlands, after hyrax, lagomorpha was the main wildlife prey item which contributed a large percentage to the total biomass consumed. Opportunistic predators select for prey items which are abundant and readily available (Loveridge *et al.* 2010). On the farmlands, lagomorpha was the natural prey item with the largest relative abundance, higher than in the national park. Shrub and Cape hares are mixed feeders and prefer to feed on short grass (Skinner and Chimimba 2005). Hares are often seen in areas where domestic stock and wildlife regularly graze and grasses are maintained short (Skinner and Chimimba 2005). The higher abundance of lagomorphs on the farmlands could suggest why lagomorpha as a prey item occurred more frequently in leopard diet on the farmlands, than in the national park where larger-bodied prey items such as klipspringer, duiker and steenbok were readily available. Few past studies have reported lagomorphs to be an important prey species for leopards (Mitchell, Shenton and Uys 1965; Norton *et al.* 1986; Martins *et al.* 2011). In protected areas other natural prey items are readily available and prey may also have higher overall abundances, potentially resulting in lagomorphs occurring in smaller percentages in leopard diet.

Mann (2014) conducted leopard research in the Gamkaberg district, Little Karoo, Western Cape. Rautenbach (2010) also ran a diet study in the Gamkaberg area and the Cederberg region. However, Mann (2014) observed more large ungulate presence in leopard diet in Gamkaberg than Rautenbach (2010). Mann (2014) argued that game farming in the area was a novel land-use and that leopard in this region required time to adapt to the new prey range and select for the larger ungulates as prey items. The Namaqua National park was proclaimed in 2001 and thereafter three game species were slowly introduced, namely springbok (*Antidorcas marsupialis*), red hartebeest and oryx. Springbok was the first new antelope species reintroduced in 2003, with red hartebeest and oryx following in 2005. In Namaqualand leopards preyed on red hartebeest, a species weighing more > 40 kg. Red hartebeest was the only introduced ungulate species occurring in leopard diet based on our samples. However, the use of scat analysis as a dietary analysis tool makes the difference between hunted and scavenged prey difficult to impossible to distinguish (Klare *et al.* 2010). On various accounts dead red hartebeest were found in the national park (pers. observation). Red hartebeest are water-dependant antelope, but where melons or roots are available they will utilise these resources for water (Estes 2012). Red hartebeest are also natural migrating grazers; however in Namaqualand they are restricted to the confines of the Namaqua National Park (Novellie 1990; Estes 2012). The red hartebeest remains detected in scat could have been from leopard scavenging on animal(s) that died from dehydration. The year of data collection was drought-stricken and could explain the cases of dead or sometimes dying hartebeest observed.

Camera trapping is a non-invasive method which allows researchers to monitor vast areas (O'Brien 2008; Swann, Kawanishi and Palmer 2010; Mann 2014). Most studies that aim to estimate abundance of carnivore prey use actual counts of prey by means of transects, spoor and scat/pellets. However, the Namaqualand study area has rugged terrain and a limited road network, making transect counts unfeasible. Camera traps were deemed the most appropriate tool to use in the study area. Using abundance data from camera traps in conjunction with scat analysis provides a non-invasive framework for determining carnivore diet and understanding the ecological role that carnivores and their prey play in the ecosystem. Previous studies suggest that the loss of an adequate prey range can cause carnivores, especially felids, to shift their diet to alternative prey (Crawshaw 2004; Loveridge *et al.* 2010). In South Brazil jaguars adapted their feeding behaviour to select for prey items which are more readily available (Azevedo 2008). Jaguars have been found to prefer natural prey to livestock, but when wild prey numbers were low these animals shifted their diet to more readily available prey items such as cattle (Rabinowitz and Nottingham 1986; Azvedo 2008). In areas where natural prey numbers were low, snow leopards alternatively preyed on domestic stock, resulting in 58% of snow leopard diet to be livestock (Bagchi and Mishra 2006). In Namaqualand the evidence suggests a similar pattern; leopards prefer natural prey, but in areas where an adequate natural prey range is limited and alternative prey numbers are high and unprotected leopards will shift to livestock as an abundant prey item. It is suggested that famers in the area manage their land as such to still allow natural prey for leopards to persist, in addition to making use of kraaling and guarding/herding methods to decrease stock losses (Johansson *et al.* 2015).

3.6. Conclusion

The results of this study confirm the opportunistic feeding behaviour exhibited by leopards. Leopards mainly preferred hyrax and medium-sized ungulates, however on the farmlands, where the availability of these prey items were in some cases lower, leopards selected for prey species which were more abundant, namely small livestock. It can thus also be concluded that the diet of leopard reflects the abundance of prey items, as well as the appropriate size range which is preferred by leopard as a prey item. Medium-sized ungulates were more abundant in the national park, where these animals were a preferred source of prey, than on the farmlands. Leopard opportunistically also fed on smaller carnivores on farmlands, potentially eliminating these animals as competitors, due to a lack of suitable prey base or due to increased encounters between carnivores on farmlands due to an influx of prey items. This study found livestock predation by leopards to be the higher than what was found in other studies on leopard diet in the Succulent Karoo biome. With leopard being the apex predator in the study area and the last remaining large carnivore in the region it is important to establish practical and long-term mitigation strategies in Namaqualand to ensure the persistence of leopard. The results from this study suggest that a suitable wild prey base can decrease depredation by leopard on farmlands. It is also important to promote cooperation from farmers and to increase farmer livelihoods by proposing solutions to decrease livestock losses.

3.7. References

Ackerman, B. B., Lindzey, F. G., and Hemker, T. P. 1984. Cougar food habits in southern Utah. *The Journal of Wildlife Management* **48**: 147–155.

Allsopp, N., Laurent, C., Debeaudoin, L. M. C., and Samuels, M. U. 2007. Environmental perceptions and practices of livestock keepers on the Namaqualand Commons challenge conventional rangeland management. *Journal of Arid Environments* **70**: 740-754.

Bacon, M. M., Becic, G. M., Epp, M. T., and Boyce, M. S. 2011. Do GPS Clusters Really Work? Carnivore Diet from Scat Analysis and GPS Telemetry Methods. *Wildlife Society Bulletin* **35**: 409-415.

Bagchi, S., and Mishra, C. 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). *Journal of Zoology* **268**: 217-224.

Bailey, T. N. 1993. *The African leopard: ecology and behavior of a solitary felid*. New York: Columbia University Press.

Balme, G. A., Hunter, L. T. B., and Braczkowski, A. 2012. Applicability of Age-Based Hunting Regulations for African Leopards. *PLoS ONE* **7**: e35209.

Balme, G. A., Slotow, R., and Hunter, L. T. 2009. Impact of conservation interventions on the dynamics and persistence of a persecuted leopard (*Panthera pardus*) population. *Biological Conservation* **142**: 2681-2690.

Balme, G. A., Slotow, R., and Hunter, L. T. B. 2010. Edge effects and the impact of non-protected areas in carnivore conservation: leopards in the Phinda-Mkhuze Complex, South Africa. *Animal Conservation* **13**: 315–323.

Balme, G., Hunter, L., and Slotow, R. 2007. Feeding habitat selection by hunting *leopards Panthera pardus* in a woodland savanna: prey catchability versus abundance. *Animal Behaviour* **74:** 589 – 598.

Balme, G., Lindsey, P. A., Swanepoel, L. H., and Hunter, L. T. B. 2013. Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study. *Conservation Letters* **00**: 1 – 9.

Beinart, W. 2003. *The rise of conservation in South Africa: settlers, livestock and the environment*. Oxford: Oxford University Press.

Beschta, R. L., and Ripple, W. J. 2009. Large predators and trophic cascades in terrestrial ecosystems of the western United States. *Biological Conservation* **142**: 2401-2414.

Bothma, J. du P., and Le Riche, E. A. N. 1984. Aspects of the ecology and behaviour of the leopard *Panthera pardus* in the Kalahari Desert. *Koedoe* **84**: 259 – 279.

Bothma, J. du P., and Le Riche, E. A. N. 1986. Prey preference and hunting efficiency of the Kalahari Desert leopard. In: S. D. Miller and D. D. Everett, eds. *Cats of the world: Biology, conservation and management* Washington, D. C: National Wildlife Federation.

Bothma, J. du P., and Le Riche, E. A. N. 1994. Scat analysis and aspects of defaecation in Northern Cape leopards. *South African Journal of Wildlife Research* **24**: 21 – 25.

Braczkowski, A., Watson, L., Coulson, D., and Randall, R. 2012. Diet of leopards in the southern Cape, South Africa. *African Journal of Ecology* **50**: 377 – 380.

Can, E. O., D'Cruze, D., Garschelis, D. L., Beecham, J., and Macdonald, D. W. 2014. Resolving Human-Bear Conflict: A Global Survey of Countries, Experts, and Key Factors. *Conservation Letters* **7**: 501-513.

Chattha, S. A., Hussain, S. M., Javid, A., Abbas, M. N., Mahmood, S., Barq, M. G., and Hussain, M. 2015. Seasonal Diet Composition of Leopard (*Panthera pardus*) in Machiara National Park, Azad Jammu and Kashmir, Pakistan. *Pakistan Journal of Zoology* **47**: 201 – 207.

Crawshaw, P. G. 2004. Depredation of domestic animals by large cats in Brazil. *Human Dimensions of Wildlife* **9**: 329–30.

Cristescu, B., Stenhouse, G. B., and Boyce, M. S. 2015a. Grizzly bear diet shifting on reclaimed mines. *Global Ecology and Conservation* **4**: 207–220.

Cristescu, B., Stenhouse, G. B., and Boyce, M. S. 2015b. Predicting multiple behaviors from GPS radiocollar cluster data. *Behavioral Ecology* **26**: 452–464.

De Azevedo, F. C. C. 2008. Food habits and livestock depredation of sympatric jaguars and pumas in the Iguacu National Park area, south Brazil. *Biotropica* **40**: 494-500.

Department of Agriculture Forestry and Fisheries. 2013. Abstract of Agricultural Statistics 2013. *Department of Agriculture Forestry and Fisheries* [online] Available: http://www.daff.gov.za/docs/statsinfo/Abstact2013.pdf (accessed 11 December 2014).

Estes, R. D. 2012. *The behaviour guide to African mammals*. Berkely: The University of California Press.

Graupner, E. D., and Graupner, O. F. 1971. Predator-prey interrelationships in a natural big game population. Final report TN.6.4.1/4F. Pretoria. In: T. N, Bailey. 1993. *The African leopard: ecology and behaviour of a solitary felid*. New York: Columbia University Press.

Grimbeek, A. M. 1992. The ecology of the leopard (*Panthera pardus*) in the Waterberg. Masters thesis, University of Pretoria, South Africa.

Gusset, M., Swarner, M. J., Mponwane, L., Keletile, K., and McNutt, J. W. 2009. Human–wildlife conflict in northern Botswana: livestock predation by Endangered African wild dog *Lycaon pictus* and other carnivores. *Oryx* **43**: 67-72.

Hayward, M. W., Henschel, P., O'Brien, J., Hofmeyr, M., Balme, G and Kerley, G. I. H. 2006. Prey preferences of the leopard (*Panthera pardus*). *Journal of Zoology* **270**: 298-313.

Henschel, P., Abernethy, K. A., and White, L. J. T. 2005. Leopard food habits in the Lopé National Park, Gabon, Central Africa. *African Journal of Ecology* **43**: 21 – 28.

Hopcraft, J. G. C., Sinclair, A. R. E., and Packer, C. 2005. Planning for success: Serengeti lions seek prey accessibility rather than abundance. *Journal of Animal Ecology* **74**: 559–66.

Inskip, C., and Zimmermann, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. *Oryx* **43**: 18–34.

Johansson, O., McCarthy, T., Samelius, G., Andren, H., Tumursukh, L., and Mishra, C. 2015. Snow leopard predation in a livestock dominated landscape in Mongolia. *Biological Conservation* **184**: 251-258.

Kamler, J. F., Klare, U., and Macdonald, D. W. 2012. Seasonal diet and prey selection of black-backed jackals on a small-livestock farm in South Africa. *African Journal of Ecology* **50**: 299 – 307.

Karanth, K. U and Sunquist, M. E. 1995. Prey selection by tiger, leopard and dhole in tropical forests. *Journal of Animal Ecology* **64**: 439–450.

Kiffner, C., Wenner, C., La Violet, A., Yeh, K., and Kioko, J. 2014. From savannah to farmland: effects of land-use on mammal communities in the Tarangire–Manyara ecosystem, Tanzania. *African Journal of Zoology* **53**: 156-166.

Klare, U., Kamler, J. F., and Macdonald, D. W. 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* **41**: 294–312.

Klare, U., Kamler, J. F., Stenkewitz, U., and Macdonald, D. W. 2010. Diet, prey selection, and predation impact of black-backed jackals in South Africa. *Journal of Wildlife Management* **74**: 1030–1042.

Kure, N. 2003. *Living with leopards*. Cape Town: Sunbird.

Le Roux, P. G., and Skinner, J.D. 1989. A note on the ecology of the leopard (*Panthera pardus Linnaeus*) in the Londolozi Game Reserve. *African Journal of Ecology* **27**: 167 - 171.

Li, X., Buzzard, P., Chen, Y., and Jiang, X. 2013. Patterns of Livestock Predation by Carnivores: Human–Wildlife Conflict in Northwest Yunnan, China. *Environmental Management* **52**: 1334-1340.

Linnell, D. C., Odden, J., Smith, M. E., Aanes, R., and Swenson, J. E. 1999. Large Carnivores That Kill Livestock: Do "Problem Individuals" Really Exist? *Wildlife Society Bulletin* **27**: 698 – 705.

Linnell, J. D. C., Swenson, J. E., and Andersen, R. 2001. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation* **4**:345–349.

Loveridge A. J., and Nel J. A. J. 2004. Black-backed jackal, Schreber, 1775, Least Concern (2004). In: *Canids: foxes, wolves, jackals and dogs – IUCN 2004 Status Survey and Conservation Action Plan 6.3*. New York: IUCN.

Loveridge, A. J., Wang, S. W., Frank, L. G., and Seidensticker, J. 2010. People and wild felids: conservation of cats and management of conflicts In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

MacKinnon, J., and MacKinnon, K. 1986. Review of the Protected Areas System in the Afrotropical Realm. Switzerland and United Kingdom: IUCN.

Mann, G. 2014. Aspects of the ecology of leopards (*Panthera pardus*) in the little Karoo, South Africa. Dissertation, Rhodes University, South Africa.

Marker, L., and Dickman, A, J. 2005. Factors affecting leopard (*Panthera pardus*) spatial ecology, with particular reference to Namibian farmlands. *South African Journal of Wildlife Research* **35**: 105–115.

Martins, Q and Martins, N. 2006. Leopards of the Cape: conservation and conservation concerns. *International Journal of Environmental studies* **63**: 579-585.

Martins, Q. 2010. *The ecology of the leopard* Panthera pardus *in the Cederberg Mountains*. Dissertation, University of Bristol, United Kingdom.

Martins, Q., Horsnell, W. G. C., Titus, W., Rautenbach, T., and Harris, S. 2011. Diet determination of the Cape Mountain leopards using global positioning system location clusters and scat analysis. *Journal of Zoology* **283**: 81-87.

Miller, B., Dugelby, B., Foreman, D., Martinez Del Rio, C., Noss, R., Phillips, M., Reading, R., Soulé, M. E., Terborgh J., and Willcox, L. 2001. The importance of large carnivores to healthy ecosystems. *Endangered Species Update* **18**: 202–210.

Mitchell, B. L., Shenton, J. B., and Uys, J. C. M. 1965. Predation on Large Mammals in the Kafue National Park, Zambia. *Zoologica Africana* **1**: 297-318.

Mizutani, F. 1999. Impact of leopards on a working ranch in Laikipia, Kenya. *African Journal of Ecology* **37**: 211–225.

Norton, P. M., Lawson, A. B., Henley, S. R., and Avery, G. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *South African Journal of Wildlife Research* **16:** 47–52.

Novellie, P. 1990. Habitat use by indigenous grazing ungulates in relation to sward structure and veld condition. *Journal of the Grassland Society of Southern Africa* **7**: 16-23.

O'Brien, T. G. 2008. On the use of automated cameras to estimate species richness for large- and medium-sized rainforest mammals. *Animal Conservation* **11**: 179 – 181.

Ogada, M, O., Woodroffe, R., Oguge, N. O., and Frank, L. 2003. Limiting Depredation by African Carnivores: the Role of Livestock Husbandry. *Conservation Biology* **17**: 1-10.

Ott, T., Kerley, G. I. H., and Boshoff, A. F. 2007. Preliminary observations on the diet of leopards (*Panthera pardus*) from a conservation area and adjacent rangelands in the Baviaanskloof region, South Africa. *African Zoology* **42**: 31–37.

Palmeira, F.B.L., Crawshaw Jr, P. G., Haddad, C. M., Ferraz, K.M.P.M.B., and Verdade, L. 2008. Cattle depredation by puma (*Puma concolor*) and jaguar (*Panthera onca*) in central-western Brazil. *Biological Conservation* **141**:118-125.

Palomares, F., and Caro, T. M. 1999. Interspecific killing among mammalian carnivores. *American Naturalist* **153**: 492-508.

Pettigrew, M., Xie, Y., Kang, A., Rao, M., Goodrich, J., Liu, T., and Berger, J. 2012. Human–carnivore conflict in China: a review of current approaches with recommendations for improved management. *Integrative Zoology* **7**: 210–226.

Pitman, R. T., Mulvaney, J., Ramsay, P. M., Jooste, E., and Swanepoel, L. H. 2013. Global Positioning System-located kills and faecal samples: a comparison of leopard dietary estimates. *Journal of Zoology* **292**: 18–24.

Pitman, R. T., Swanepoel, L. H., and Ramsay, P. M. 2012. Predictive modelling of leopard predation using contextual Global Positioning System cluster analysis. *Journal of Zoology* **288**: 222–230.

Rabinowitz, A., and Nottingham, B. G. 1986. Ecology and behaviour of the Jaguar (*Panthera onca*) in Belize, Central America. *Journal of Zoology* **210**: 149–59.

Rafiq, M, K., Afzal, J., Jasra, A. W., Ahmad, I., Khan, T. N., and Farooq, M. U. 2010. Foraging Preferences of Free-Ranging Sheep and Goats on the Native Vegetation of Rangelands of Pubbi Hills in Pakistan. *International Journal of Agriculture and Biology* **12**: 944–946.

Rautenbach, T. 2010. *Assessing the diet of the Cape leopard (*Panthera pardus*) in the Cederberg and Gamka mountains, South Africa*. Masters Thesis, Nelson Mandela Metropolitan University, South Africa.

Ray, J. C., Hunter, L., and Zigouris, J. 2005. *Setting conservation and research priorities for larger African carnivores.* New York: Wildlife Conservation Society.

Schiess-Meier, M., Ramsauer, S., Gabanapelo, T., and Köning, B. 2007. Livestock predation — insights from problem animal control registers in Botswana. *Journal of Wildlife Management* **71**: 1267–1274.

Skead, C. J. 2011. *Historical incidence of the larger land mammals in the broader Western and Northern Cape*. IN: A. F. Boshoff, G. I. H. Kerley, and P. H. Lloyd, eds. Port Elizabeth: Centre for African Conservation Ecology, Nelson Mandela Metropolitan University.

Skinner, J. D., and Chimimba, C. T. 2005. *The mammals of the southern African subregion.* Cape Town: Cambridge University Press.

Sollmann, R., Mohamed, A., Samejima, H., and Wilting, A. 2013. Risky business or simple solution–Relative abundance indices from camera-trapping. *Biological Conservation* **159**: 405-412.

Stahl, P., Vandel, J. M., Herrenschmidt, V., and Migot, P. 2001. The effect of removing lynx in reducing attacks on sheep in the French Jura Mountains. *Biological Conservation* **101**: 15–22.

Stander, P. E., Haden, P. J., Kaqece, A., and Ghau, A. 1997. The ecology of asociality in Namibian leopards. *Journal of Zoology* **242**: 343-364.

Stein, A. B., Fuller, T. K., Damery, D. T., Sievert, L., and Marker, L. L. 2010. Farm management and economic analyses of leopard conservation in north-central Namibia. *Animal Conservation* **13**: 419–427.

Stephens, D. W and Krebs, J. R. 1986. *Foraging Theory*. New Jersey: Princeton University Press.

Swanepoel, L. H., Lindsay, P., Somers, M. J., van Hoven, W., and Dalerum, F. 2012. Extent and fragmentation of suitable leopard habitat in South Africa. *Animal Conservation* **16:** 41 – 50.

Swann, D. E., Kawanishi, K., and Palmer, J. 2011. Evaluating Types and Features of Camera Traps in Ecological Studies: A Guide for Researchers. In: A. F. O'Connell, J. D. Nichols and K. U. Karanth, eds. 2011. *Camera Traps in Animal Ecology: Methods and Analyses.* Tokyo: Springer.

The Cape Leopard Trust (CLT). 2011. *The Cape leopard trust annual report 2011*. Cape Town: The Cape Leopard Trust.

Thorn, M., Green, M., Scott, D., and Marnewick, K. 2013. Characteristics and determinants of human-carnivore conflict in South African farmland. *Biodiversity Conservation* **22**: 1715–1730.

Treves, A., and Karanth, K. U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide*. Conservation Biology* **17**: 1491–9.

Treves, A., Naughton-Treves, L. I. S. A., Harper, E. K., Mladenoff, D. J., Rose, R. A., Sickley, T. A., and Wydeven, A. P. 2004. Predicting human-carnivore conflict: A spatial model derived from 25 years of data on wolf predation on livestock. *Conservation Biology* **18**: 114-125.

Wang, S. W., and Macdonald, D. W. 2006. Livestock predation by carnivores in Jigme Singye Wangchuck National Park, Bhutan. *Biological Conservation* **129**: 558–65.

3.8. Appendices

Appendix 3A - Prey items recorded in leopard scat (n=82) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Frequency of occurrence (FO) (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=100). Corrected frequency of occurrence (CFO) (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=82).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 100	FO (%)	Number of Occurrences (per scat) n = 82	CFO (%)
Large mammals (>40 kg)		**3**	**3**	**3**	**3.66**
Red Hartebeest (*Alcelaphus buselaphus*)	140.26	2	2	2.00	2.44
Aardvark (*Orycteropus afer*)	43.3	1	1	1.00	1.22
Medium- to large mammals (10 – 40 kg)		**21**	**21**	**17.83**	**21.74**
Duiker (*Sylvicapra grimmia*)	16.1	8	8	7.00	8.54
Caracal (*Caracal caracal*)	12.75	1	1	0.50	0.61
Klipspringer (*Oreotragus oreotragus*)	11.9	7	7	5.33	6.50
Steenbok (*Raphicerus campestris*)	11.1	5	5	5.00	6.10
Medium mammals (1 - 10 kg)		**35**	**35**	**28.66**	**34.95**
Porcupine (*Hystrix africaeaustralis*)	9.52	1	1	0.50	0.61
Hyrax (*Procavia capensis*)	3.03	22	22	18.33	22.35
Lagomorpha	2.35	11	11	8.83	10.77
Small spotted genet (*Genetta genetta*)	1.9	1	1	1.00	1.22
Small mammals (<1 kg)		**8**	**8**	**4.83**	**5.89**
Yellow Mongoose (*Cynictis penicillata*)	0.829	2	1.96	1.5	1.82
Striped polecat (*Ictonyx striatus*)	0.764	1	0.98	1	1.22
Meerkat (*Suricate suricate*)	0.728	1	0.98	0.5	0.61
Otomys spp.	0.131	2	1.96	1	1.22
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	1	0.98	0.5	0.61
Soricidae	0.011	1	0.98	0.33	0.4
Livestock		**24**	**24**	**22.83**	**27.84**
Cattle (*Bos taurus*)	123	2	1.96	1.50	1.83

Goat (*Capra hircus)*	50	14	13.73	13.33	16.26
Sheep (*Ovis aries*)	40	8	7.84	8.00	9.76
Birds	**1.57**	**2**	**1.96**	**1.50**	**1.83**
Invertebrates		**2**	**2**	**0.83**	**1.01**
Coleoptera	0.004	1	0.98	0.50	0.61
Scorpiones	0.004	1	0.98	0.33	0.4
Vegetation	**0.001**	**4**	**3.92**	**1.49**	**1.82**
Unknown	**-**	**1**	**1.00**	**0.98**	**1.20**

Appendix 3B - Biomass consumed calculated from leopard scat (n=82) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=93)	Prey items occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Goat (*Capra hircus*)	50	3.73	14	15.05	700	35.34	56.15	21.77
Hyrax (*Procavia capensis*)	3.03	2.09	22	23.66	66.66	3.37	49.35	19.13
Sheep (*Ovis aries*)	40	3.38	8	8.60	320	16.16	29.08	11.27
Lagomorpha	2.35	2.06	11	11.83	25.85	1.31	24.39	9.46
Duiker (*Sylivapra grimmia*)	16.1	2.54	8	8.60	128.80	6.50	21.88	8.48
Klipspringer (*Oreotragus oreotragus*)	11.9	2.40	7	7.53	83.30	4.21	18.04	6.99
Red Hartebeest (*Alcelaphus buselaphus*)	140.26	6.89	2	2.15	280.52	14.16	14.82	5.74
Cattle (*Bos taurus*)	123	6.29	2	2.15	246	12.42	13.52	5.24
Steenbok (*Raphicerus campestris*)	11.1	2.37	5	5.38	55.50	2.80	12.73	4.94
Birds	1.57	1.57	2	2.15	3.14	0.16	3.38	1.31
Aardvark (*Orycteropus afer*)	43.3	3.50	1	1.08	43.30	2.19	3.76	1.46
Caracal (*Caracal caracal*)	12.75	2.43	1	1.08	12.75	0.64	2.61	1.01
Porcupine (*Hystrix africaeaustralis*)	9.52	2.31	1	1.08	9.52	0.48	2.49	0.96

Small spotted genet (*Genetta genetta*)	1.9	1.90	1	1.08	1.90	0.10	2.04	0.79
Yellow Mongoose (*Cynictis penicillata*)	0.829	0.83	2	2.15	1.66	0.08	1.78	0.69
Striped Polecat (*Ictonyx striatus*)	0.764	0.76	1	1.08	0.76	0.04	0.82	0.32
Meerkat (*Suricate suricate*)	0.728	0.73	1	1.08	0.73	0.04	0.78	0.30
***Otomys* spp**	0.131	0.13	2	2.15	0.26	0.01	0.28	0.11
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	0.03	1	1.08	0.03	0	0.03	0.01
Soricidae	0.011	0.01	1	1.08	0.01	0	0.01	0
Total	**469.27**	**45.92**	**93**	**100**	**1980.69**	**100**	**257.93**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Ackerman *et al.* (1984), $Y = 1.98 + 0.035x$; only for prey >2 kg

[c]Prey weight x Number of occurrences

[d]Correction factor x Prey items occurrence

Appendix 3C - Prey items recorded in leopard scat collected in Namaqua National Park, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=39). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=28).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 39	FO (%)	Number of Occurrences (per scat) n = 28	CFO (%)
Large mammals (>40 kg)		**2**	**5.13**	**2**	**7.14**
Red Hartebeest (*Alcelaphus buselaphus*)	140.26	1	2.56	1	3.57
Aardvark (*Orycteropus afer*)	43.3	1	2.56	1	3.57
Medium- to large mammals (10 – 40 kg)		**11**	**30.76**	**10.5**	**37.5**
Duiker (*Sylvicapra grimmia*)	16.1	5	12.82	4.5	16.07
Caracal (*Caracal caracal*)	12.75	0	0	0	0
Klipspringer (*Oreotragus oreotragus*)	11.9	4	10.26	3	10.71
Steenbok (*Raphicerus campestris*)	11.1	3	7.69	3	10.71
Medium mammals (1 - 10 kg)		**15**	**38.46**	**10.16**	**36.29**
Porcupine (*Hystrix africaeaustralis*)	9.52	1	2.56	0.5	1.79
Hyrax (*Procavia capensis*)	3.03	11	28.21	8.33	29.75
Lagomorpha	2.35	3	7.69	1.33	4.75
Small spotted genet (*Genetta genetta*)	1.9	0	0	0	0
Small mammals (<1 kg)		**4**	**10.26**	**1.83**	**6.54**
Yellow Mongoose (*Cynictis penicillata*)	0.829	0	0	0	0
Striped polecat (*Ictonyx striatus*)	0.764	0	0	0	0
Meerkat (*Suricate suricate*)	0.728	1	2.56	0.5	1.79
Otomys spp.	0.131	2	5.13	1	3.57
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	0	0	0	0
Soricidae	0.011	1	2.56	0.33	1.18
Livestock		**1**	**2.56**	**1**	**3.57**
Cattle (*Bos taurus*)	123	0	0	0	0
Goat (*Capra hircus)*	50	1	2.56	1	3.57
Sheep (*Ovis aries*)	40	0	0	0	0
Birds	**1.57**	**0**	**0**	**0**	**0**
Invertebrates		**2**	**5.13**	**0.83**	**2.96**
Coleoptera	0.004	1	2.56	0.5	1.79
Scorpiones	0.004	1	2.56	0.33	1.18
Vegetation	**0.001**	**2**	**5.13**	**0.66**	**2.36**
Unknown	**-**	**1**	**2.56**	**1**	**3.57**

Appendix 3D - Prey items recorded in leopard scat collected on farmlands in Namaqualand, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=61). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=54).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 61	FO (%)	Number of Occurrences (per scat) n = 54	CFO (%)
Large mammals (>40 kg)		**1**	**1.64**	**1**	**1.85**
Red Hartebeest (*Alcelaphus buselaphus*)	140.26	1	1.64	1	1.85
Aardvark (*Orycteropus afer*)	43.3	0	0	0	0
Medium- to large mammals (10 – 40 kg)		**8**	**13.11**	**7.33**	**13.57**
Duiker (*Sylvicapra grimmia*)	16.1	3	4.92	2.5	4.63
Caracal (*Caracal caracal*)	12.75	1	1.64	0.5	0.93
Klipspringer (*Oreotragus oreotragus*)	11.9	3	4.92	2.33	4.31
Steenbok (*Raphicerus campestris*)	11.1	2	3.28	2	3.70
Medium mammals (1 - 10 kg)		**21**	**34.43**	**18.5**	**34.26**
Porcupine (*Hystrix africaeaustralis*)	9.52	0	0	0	0
Hyrax (*Procavia capensis*)	3.03	11	18.03	10	18.52
Lagomorpha	2.35	8	13.11	7.5	13.89
Small spotted genet (*Genetta genetta*)	1.9	1	1.64	1	1.85
Small mammals (<1 kg)		**4**	**6.56**	**3**	**5.56**
Yellow Mongoose (*Cynictis penicillata*)	0.829	2	3.28	1.5	2.78
Striped polecat (*Ictonyx striatus*)	0.764	1	1.64	1	1.85
Meerkat (*Suricate suricate*)	0.728	0	0	0	0
Otomys spp.	0.131	0	0	0	0
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	1	1.64	0.5	0.93
Soricidae	0.011	0	0	0	0
Livestock		**23**	**37.70**	**21.83**	**40.43**
Cattle (*Bos taurus*)	123	2	3.28	1.5	2.78
Goat (*Capra hircus*)	50	13	21.31	12.33	22.83
Sheep (*Ovis aries*)	40	8	13.11	8	14.81
Birds	**1.57**	**2**	**3.28**	**1.5**	**2.78**
Invertebrates		**0**	**0**	**0**	**0**
Coleoptera	0.004	0	0	0	0
Scorpiones	0.004	0	0	0	0
Vegetation	**0.001**	**2**	**3.28**	**0.83**	**1.54**
Unknown	**-**	**0**	**0**	**0**	**0**

Appendix 3E - Biomass consumed calculated from leopard scat (n=28) collected in Namaqua National Park, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=34)	Prey items occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	2.09	11	32.35	33.33	7.30	67.49	30.20
Duiker (*Sylvicapra grimmia*)	16.1	2.54	5	14.71	80.50	17.62	37.40	16.74
Klipspringer (*Oreotragus oreotragus*)	11.9	2.40	4	11.76	47.60	10.42	28.19	12.62
Steenbok (*Raphicerus campestris*)	11.1	2.37	3	8.82	33.30	7.29	20.90	9.35
Red Hartebeest (*Alcelaphus buselaphus*)	140.26	6.89	1	2.94	140.26	30.70	20.26	9.07
Lagomorpha	2.35	2.06	3	8.82	7.05	1.54	18.20	8.14
Goat (*Capra hircus*)	50	3.73	1	2.94	50	10.94	10.97	4.91
Aardvark (*Orycteropus afer*)	43.3	3.50	1	2.94	43.30	9.48	10.28	4.60
Porcupine (*Hystrix africaeaustralis*)	9.52	2.31	1	2.94	9.52	2.08	6.80	3.04
Suricate (*Suricate suricate*)	0.728	0.73	1	2.94	0.73	0.16	2.14	0.96
***Otomys* spp**	0.131	0.13	2	5.88	0.26	0.06	0.77	0.34
Soricidae	11	0.01	1	2.94	11	2.41	0.03	0.01
Yellow Mongoose (*Cynictis penicillata*)	0.829	0.83	0	0	0	0	0	0
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	0.03	0	0	0	0	0	0

Sheep (*Ovis aries*)	40	3.38	0	0	0	0	0	0
Cattle (*Bos taurus*)	123	6.29	0	0	0	0	0	0
Caracal (*Caracal caracal*)	12.75	2.43	0	0	0	0	0	0
Striped Polecat (*Ictonyx striatus*)	0.764	0.76	0	0	0	0	0	0
Small spotted genet (*Genetta genetta*)	1.9	1.90	0	0	0	0	0	0
Birds	1.57	1.57	0	0	0	0	0	0
Total	**480.26**	**45.93**	**34.00**	**100**	**456.85**	**100**	**223.44**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Ackerman *et al.* (1984), $Y = 1.98 + 0.035x$; only for prey >2 kg

[c]Prey weight x Number of occurrences

[d]Correction factor x Prey items occurrence

Appendix 3F - Biomass consumed calculated from leopard scat (n=54) collected on farmlands in Namaqualand, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=59)	Prey items occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Goat (*Capra hircus*)	50	3.73	13	22.03	650	42.35	82.19	29.58
Sheep (*Ovis aries*)	40	3.38	8	13.56	320	20.85	45.83	16.50
Hyrax (*Procavia capensis*)	3.03	2.09	11	18.64	33.33	2.17	38.89	14
Lagomorpha	2.35	2.06	8	13.56	18.80	1.22	27.96	10.07
Cattle (*Bos taurus*)	123	6.29	2	3.39	246	16.03	21.31	7.67
Duiker (*Sylvicapra grimmia*)	16.1	2.54	3	5.08	48.30	3.15	12.93	4.66
Klipspringer (*Oreotragus oreotragus*)	11.9	2.40	3	5.08	35.70	2.33	12.19	4.39
Red Hartebeest (*Alcelaphus buselaphus*)	140.26	6.89	1	1.69	140.26	9.14	11.68	4.20
Steenbok (*Raphicerus campestris*)	11.1	2.37	2	3.39	22.20	1.45	8.03	2.89
Birds	1.57	1.57	2	3.39	3.14	0.20	5.32	1.92
Caracal (*Caracal caracal*)	12.75	2.43	1	1.69	12.75	0.83	4.11	1.48
Small spotted genet (*Genetta genetta*)	1.9	1.90	1	1.69	1.90	0.12	3.22	1.16
Yellow Mongoose (*Cynictis penicillata*)	0.829	0.83	2	3.39	1.66	0.11	2.81	1.01
Striped Polecat (*Ictonyx striatus*)	0.764	0.76	1	1.69	0.76	0.05	1.29	0.47
Hairy-footed gerbil	0.025	0.03	1	1.69	0.03	0	0.04	0.02

(*Gerbillurus paeba*)								
Aardvark (*Orycteropus afer*)	43.3	3.50	0	0	0	0	0	0
Suricate (*Suricate suricate*)	0.728	0.73	0	0	0	0	0	0
Porcupine (*Hystrix africaeaustralis*)	9.52	2.31	0	0	0	0	0	0
Soricidae	11	0.01	0	0	0	0	0	0
***Otomys* spp**	0.131	0.13	0	0	0	0	0	0
Total	**480.26**	**45.93**	**59**	**100**	**1534.83**	**100**	**277.80**	**100**

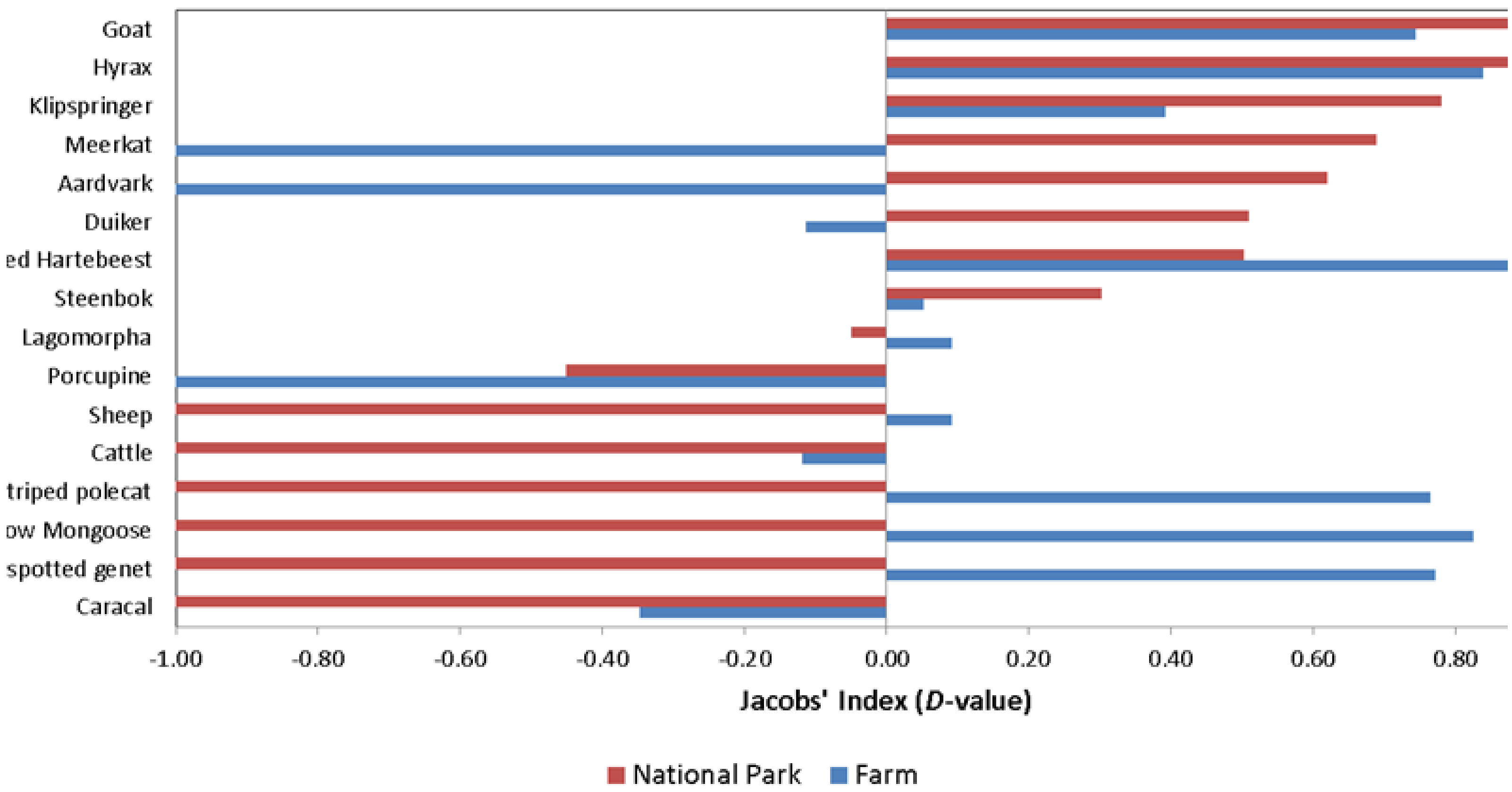
[a]From Skinner and Chimimba (2005)

[b] From Ackerman *et al.* (1984), $Y = 1.98 + 0.035x$; only for prey >2 kg

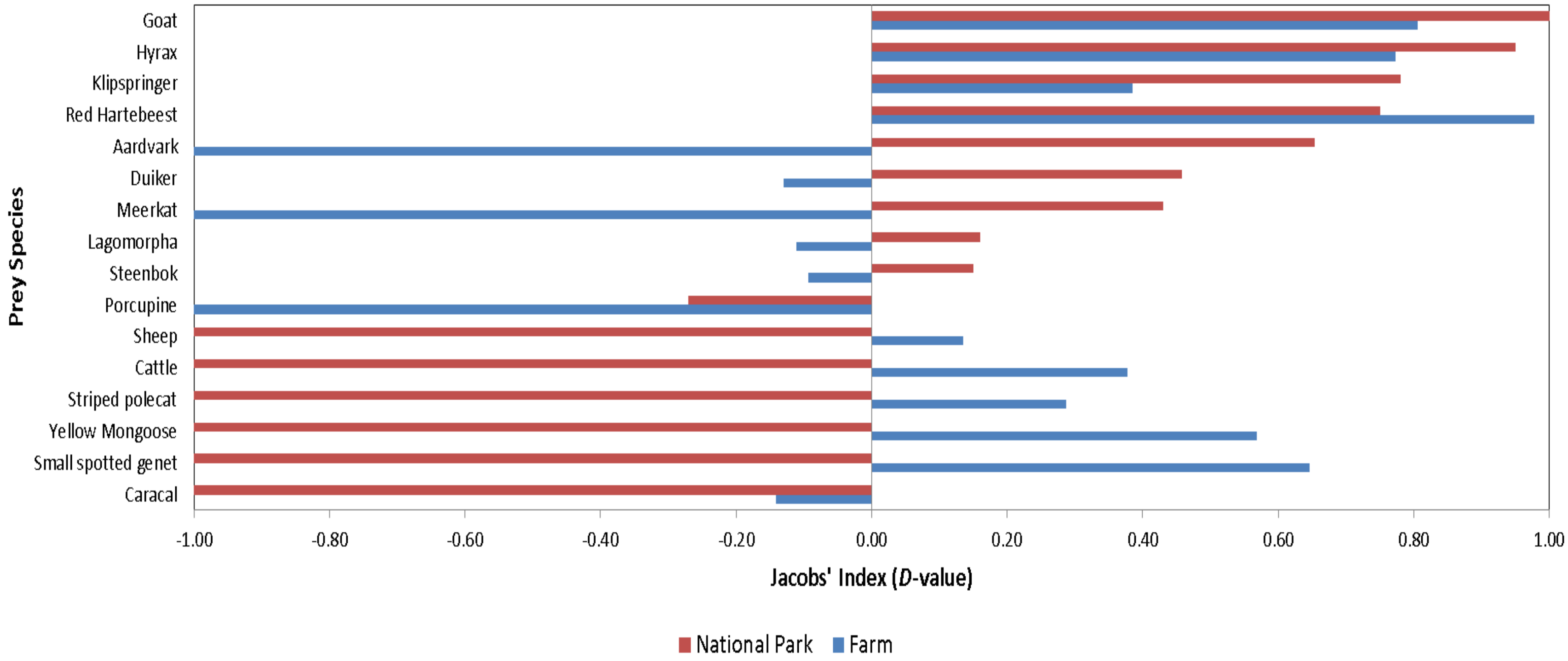
[c]Prey weight x Number of occurrences

[d]Correction factor x Prey items occurrence

Appendix 3G - Jacobs' Index (*D*-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqua National Park and the surrounding farmlands. *D*-values are based on corrected frequency of occurrence (%) of prey items from leopard scat.



Appendix 3H - Jacobs' Index (*D*-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqua National Park and the surrounding farmlands. *D*-values are based on the total biomass consumed of prey items from leopard scat.



Appendix 3I - Jacobs' index (*D*-value) of all prey items found in leopard scats collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. The corrected frequency of occurrence (CFO) % used in Jacobs' index calculation and the biomass consumed are included, as well as the Relative Abundance Index (RAI).

Prey species	RAI (%)	CFO (%)	Jacobs' Index (D)[a]	Biomass (%)	Jacobs' index (D)[b]
Hyrax	1.78	24.34	0.89	19.41	0.86
Yellow mongoose	0.21	1.99	0.81	0.70	0.54
Goat	3.13	17.70	0.74	22.09	0.80
Small spotted genet	0.21	1.33	0.73	0.80	0.59
Red hartebeest	0.45	2.66	0.72	5.83	0.86
Striped polecat	0.24	1.33	0.69	0.32	0.14
Klipspringer	1.95	7.08	0.59	7.10	0.59
Meerkat	0.30	0.66	0.38	0.31	0.01
Aardvark	0.64	1.33	0.35	1.48	0.40
Duiker	6.34	9.29	0.20	8.61	0.16
Steenbok	4.57	6.64	0.20	5.01	0.05
Sheep	9.42	10.62	0.07	11.44	0.11
Lagomorpha	10.61	11.72	0.06	9.59	-0.06
Cattle	2.91	1.99	-0.19	5.32	0.30
Caracal	1.81	0.66	-0.47	1.03	-0.28
Porcupine	4.36	0.66	-0.74	0.98	-0.64
Donkey	0.64	0	-1	0	-1
Horse	0.19	0	-1	0	-1
Aardwolf	1.66	0	-1	0	-1
Baboon	4.27	0	-1	0	-1
Bat-eared fox	1.11	0	-1	0	-1

Cape fox	0.24	0	-1	0	-1
Honey badger	0.07	0	-1	0	-1
Black-backed jackal	0.96	0	-1	0	-1
Grey mongoose	0.37	0	-1	0	-1
Oryx	3.87	0	-1	0	-1
Springbok	1.73	0	-1	0	-1
African wildcat	0.96	0	-1	0	-1

[a] D-values are based on CFO (%) of prey items from leopard scat.

[b] D-values are based on the total biomass consumed of prey items from leopard scat.

Chapter 4: The diet of caracal (*Caracal caracal*) in Namaqualand, South Africa

4.1. Abstract

Studies on caracal (*Caracal caracal*) ecology are sparse with most knowledge on caracal diet restricted to protected areas. Yet caracal are considered one of the predators responsible for high levels of livestock predation in Southern Africa and are therefore persecuted heavily on livestock farms, which make up the largest land use of this region. To elucidate the contribution of livestock in caracal diet, I collected and analysed caracal, scat sampling a large area that included both the Namaqua National Park and surrounding commercial small-stock farms. A total of 31 prey items were identified from 250 caracal scats. Rock hyrax (*Procavia capensis*) and lagomorpha [pooled Cape hare (*Lepus capensis*), scrub hare (*Lepus saxatilis*) and red rock rabbit (*Pronolagus rupestris*)] were the prey items occurring most frequently in caracal scats on both land-uses and also contributed the bulk of biomass consumed by caracal. Small mammals, in particular *Otomys* spp., the Namaqua rock mouse (*Aethomys namaquensis*), hairy-footed gerbil (*Gerbillurus paeba*) and striped mouse (*Rhabdomys pumillio*) occurred frequently in caracal diet. Sheep (*Ovis aries*) was consumed infrequently on farmlands, only occurring in 6.6% of scats analysed and contributing < 8% to the total biomass consumed on farmlands. Furthermore goat (*Capra hircus*) occurred in lower frequencies (2.5%) in caracal scat and contributed < 4% to the total biomass consumed on farmlands. Camera trap data showed wild prey to be more abundant in Namaqua National Park than on farmlands. These findings suggest that livestock are not an important contributor to the diet of this caracal population thereby challenging the traditional belief that this species is a main predator of small stock.

4.2. Introduction

Human-wildlife conflict involving mammalian carnivores has a tendency to occur in areas where carnivores inhabit human-dominated landscapes (Inskip and Zimmerman 2009). Competition between carnivores and humans over utilisation of the same resource(s) is cited as the main reason for conflict (Pettigrew *et al.* 2012). Carnivores are more prone to conflict with humans than are other species due to their vast movement patters, high dietary requirements and adaptability to changing environments (Linnell, Swenson and Anderson 2001; Treves and Karanth 2003; Inskip and Zimmerman 2009). In various cases human activities encroach into protected areas which remain a stronghold for various carnivore populations (Gusset *et al.* 2009). Buffer zones between protected and agricultural areas are becoming smaller, resulting in livestock representing the most abundant ungulate biomass inside and in the vicinity of some protected areas (Bagchi and Mischra 2006; Gusset *et al.* 2009; Li, Buzzard, Chen and Jiang 2013).

Wild felids have a complex relationship with humans. Being charismatic species most people admire felids and in some cultures they are even considered iconic figures (Loveridge, Wang, Frank and Seidensticker 2010). On the other hand felids have been known to predate on livestock and even threaten human lives (Thorn *et al.* 2012; Li *et al.* 2013). Larger felids (> 50 kg in weight) have been branded the main culprits for livestock losses (Loveridge *et al.* 2010). There are however the exceptions of the caracal (*Caracal caracal*) and the Eurasian lynx (*Lynx lynx*), both weighing < 30 kg which are also known to be responsible for livestock depredation. In regions where subsistence farming is practiced, the loss of livestock to depredation can be detrimental to the livelihoods of local communities (Schiess-Meier *et al.* 2007; Palmeira *et al.* 2008). In many cases, local people's desire to protect their livestock and families results in localised retaliatory killing of carnivores (Johansson *et al.* 2015). In some countries retaliatory killings have received government support and have led to the decrease and even extermination of various carnivore populations (Loveridge *et al.* 2010). As a result, mitigating human-carnivore conflict has become a main priority in carnivore conservation. Not only would appropriate solutions be beneficial to local biodiversity, but also to people affected by livestock losses. Various conservation organisations have promoted the use of historical livestock husbandry methods, such as kraaling animals at night, employing herders/shepherds and the use of livestock guarding animals such as dogs, donkeys and llamas (Graham, Beckerman and Thirgood 2005; Johansson *et al.* 2015).

In South Africa, farmers have been managing predators for years by implementing various predator control methods (Stadler 2006; Du Plessis 2013). Livestock farming on a large scale originated in

South Africa with the arrival of Dutch settlers in 1652 (Du Plessis 2013; Bergman *et al.* 2013). However, stock was vulnerable to free-roaming predators in the then Cape Province (now Western Cape, Northern Cape, North West and Eastern Cape) and in 1656 bounty systems were implemented to start controlling predators (Bergman *et al.* 2013). With the loss of large predators such as lion (*Panthera leo*) from the Cape Province, black-backed jackal (*Canis mesomelas*) and caracal became the primary predators of livestock, later being categorized as "vermin" (Stadler 2006; Du Plessis 2013). With the South African government supporting farmers with various predator management methods, more than 25 000 caracals were killed from 1914 – 1923 and an average of 2 200 caracals were killed in the Karoo region between 1931 and 1952 annually (Marker and Dickman 2005; Bergman *et al.* 2013). It is estimated that R1.39 billion is lost per annum in South Africa due to predation of livestock in (Van Niekerk 2010; De Waal 2012). Despite high levels of persecution, livestock losses are not decreasing and Bailey and Conradie (2013) reported that lethal persecution of caracal in some regions even resulted in an increase in livestock losses the following year. There is a great need to understand the ecology of predators responsible for livestock conflict in various areas (Li *et al.* 2013; Du Plessis, Avenant and De Waal 2015) as well as the extent to which conflict involving specific predators is real or perceived (Loveridge *et al.* 2010; Du Plessis *et al.* 2015). The availability of prey plays a vital role in structuring the diet of various carnivores (Karanth and Sunquist 1995; Woodroffe *et al.* 2005; Inskip and Zimmerman 2009). Many carnivores modify their diet to select for available prey species when a suitable range of wild prey is unavailable (Loveridge *et al.* 2010; Pettigrew *et al.* 2012). The diet of predators may therefore be influenced by the abundance of alternative prey species, in this case livestock (Pyke, Pulliam and Charnov. 1977). Studying carnivore feeding ecology on farmlands not only provides insights into the functioning of ecosystems subject to farming, but can also help to suggest means of managing livestock losses (Chattha *et al.* 2015).

Caracal are medium-sized felids and the largest of Africa's small cats (Estes 2012). The species is widespread occurring in most areas of the African continent, Central and South-West Asia and parts of India (Skinner and Chimimba 2005; Smith 2012). These secretive felids are solitary and mostly nocturnal (Skinner and Chimimba 2005; Estes 2012). In some areas where persecution is low they exhibit diurnal activity patterns, but limit their movement to areas with adequate cover (Avenant and Nel 1998). Caracal are known to travel vast distances before establishing a permanent home range (Norton and Lawson 1985). This contributes to their success across a wide range of habitats, along with their opportunistic diet. Avenant and Nel (2002) studied caracal diet in the West Coast National Park, Western Cape, and concluded that caracal feed on a wide range of prey with a weight range from 1 g (arthropods) to 31 kg (antelope). Despite the wide range of prey items utilised by caracal, mammals, especially rodents and medium mammals, have been recorded as the main prey items in this species' diet (Grobler 1981; Moolman 1984; Avenant and Nel 2002; Braczkowski *et al.* 2012). However, few of the aforementioned studies analysed caracal diet on small stock farms or accounted for fluctuations in diet due to seasons. Caracals rarely return to kills, especially in areas of high persecution. They are predominantly hunters, but have been noted to scavenge when resources are very low (Skinner and Chimimba 2005). Caracals are currently categorised by the International Union for Conservation of Nature (IUCN) as "Least Concern" (Breitenmoser-Wursten, Henschel and Sogbohossou 2008).

Caracals are rarely observed in the wild, especially outside protected areas (Estes 2012), and studying them by direct observation is thus difficult. The use of scat to analyse the diets of caracal and other secretive carnivores has been a successful method for understanding the feeding ecology of such carnivores (Moolman 1984; Norton, Lawson, Henley and Avery 1986; Bothma and Le Riche 1994; Avenant and Nel 2002; Hulsman *et al.* 2010; Klare, Kamler, Stenkewitz and Macdonald 2010; Davidson *et al.* 2013). However, dietary studies by means of scat analysis have been known to overestimate the importance of smaller prey items in a carnivore's diet (Klare *et al.* 2010). Similarly, camera traps have been useful tools for determining carnivore prey availability in rugged, isolated study areas (Martins and Harris 2013; Mann 2014) allowing sampling over vast areas (Swann, Kawanishi and Palmer 2011). Caracals also include prey items in their diet which are too small for cameras to detect (Avenant and Nel 2002). The use of live small mammal trapping in conjunction with camera trapping could be useful to provide insight into prey availability for caracal. Identifying which potential prey items are available to caracal across land-use types would refine understanding of caracal diet composition in the target study area.

4.2.1. Aims and Objectives

The main objective was to investigate caracal diet on farmland and a protected area (Namaqua National Park) in Namaqualand, Northern Cape, South Africa with the goal of understanding the role of caracal in this ecosystem particularly in connection with human-wildlife conflict over depredation. Such understanding can inform on whether caracal are a real or perceived threat to livestock, while facilitating the design of strategies for assisting conflict mitigation over depredation. This study hypothesises that land-use will influence prey composition in caracal diet, in addition to influencing prey categories occurring in caracal diet. Prey availability and preference were also determined and compared between the two land-uses. Accounting for prey availability according to land-use allowed me to assess if livestock consumption occurred in relation with decreased wild prey options.

4.3. Methods

4.3.1. Study Area

This study was conducted in Namaqua National Park (S 30. 16627 E017. 79619) and the surrounding farmlands, with study area encompassing a total of 810 km^2. The study period commenced in March 2014 and ended in April 2015. For a full description of the study area see Chapter 1, section 1.5.

4.3.2. Data Collection

For an in-depth description of scat collection see Chapter 2, section 2.1.1. For prey abundance estimation through camera trapping and small mammal trapping see Chapter 2, section 2.1.4 and section 2.1.5 respectively.

4.3.3. Data Analysis

4.3.3.1. Scat Analysis

See Chapter 2, section 2.2.1 for scat washing methods and methodology regarding the preparing of cross-sections and identification of mammalian hair.

The frequency of occurrence (per prey item) [FO], corrected frequency of occurrence (frequency of occurrence per scat) ([CFO)] and percentage biomass were calculated. For a more in-depth description of FO and CFO refer to Chapter 2, section 2.2.1.

To estimate the biomass of prey consumed by caracal I used Baker, Warren and James (1993)'s linear regression equation developed for bobcat (*Lynx rufus*) to calculate a correction factor for each prey item:

$$y = 16.63 + 4.09x$$

Where y is the weight of prey consumed per scat collected (kg/scat) and x is the average body weight of the prey item (kg) [Bacon *et al.* 2011]. This equation is only applied to prey weighing ≤ 4.5 kg as this is the weight at which a bobcat would ingest the entire prey item. This is similar for caracal. As with bobcats, caracals only feed on parts of larger prey species such as ungulates (Baker *et al.* 1993; Skinner and Chimimba 2005). For that reason Baker *et al.* (1993) used a set correction factor of 27 for larger prey items to account for bobcats only feeding on part of the prey item. A linear regression equation developed for bobcat was used as no data exists for caracal, and bobcat is a felid species closely related to the caracal with a comparable body size and prey range (Baker *et al.* 1993; Skinner and Chimimba 2005; Macdonald, Loveridge and Nowell 2010). When calculating biomass the FO was used and prey items occurring < 5% in the diet were excluded from biomass calculations (Bacon *et al.* 2011; Klare *et al.* 2010).

4.3.3.2. Prey Abundance and Preference Analysis

See Chapter 2, section 2.2.3 for more information.

4.3.4. Statistical Analysis

For diet statistical analysis please refer to Chapter 2, section 2.3.1 and for prey abundance and preference statistical analysis from camera trap and small mammal data please refer to Chapter 2, section 2.3.3.

4.4. Results

4.4.1. Caracal Diet

A total of 250 caracal scats were collected and analysed to determine caracal diet. Of these scats, 98 were collected in Namaqua National Park and 152 on the surrounding farmlands. Caracal diet consisted of 31 prey items (excluding unknown prey items), with mammals making up > 90% of the total diet according to the CFO. Hyrax (*Procavia capensis*) [31.2%], lagomorpha (18.7%), *Otomys* spp (8.3%) and Namaqua rock mouse (8.1%) were the four main prey items in caracal diet (Table 4.1). Medium mammals contributed > 50% to the diet, with small mammals contributing 29.1%. Together these two prey classes were consumed most frequently by caracal, with livestock only making up 6.9% of the diet. Reptiles (0.8%), invertebrates (2%), fruits/seeds (0.5%) and vegetation (1.9%) mostly occurred as trace amounts and made up < 6% of the total diet. No large mammals (> 40 kg) were present in caracal diet. The total biomass of all prey items analysed from caracal scats was 2344.9 kg (Table 4.2). Hyrax (35.9%), lagomorpha (19.6%) and Namaqua rock mouse (6.8%) were the three top prey items contributing to total biomass consumed. Sheep was the small stock type most consumed by caracal (5%) and contributed the fifth most overall to biomass consumed. Birds also contributed a substantial amount to total biomass consumed (4.6%). The importance of correction factors in biomass calculations can be illustrated by the low percentage that the Namaqua rock mouse contributed to total biomass consumed (0.1%) according to the calculated naïve biomass. However, with the inclusion of the CF the Namaqua rock mouse was the third most important prey item in caracal diet, contributing 6.8% to total biomass consumed.

Table 4.1. Prey items recorded in caracal scat (n=250) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. FO (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=327). CFO (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=250). For a full list of species analysed from scats see Appendix 4A.

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 327	FO (%)	Number of Occurrences (per scat) n = 250	CFO (%)
Medium- to large mammals (10-40 kg)		**10**	**3.1**	**8.3**	**3.3**
Medium mammals (1-10 kg)		**139**	**42.4**	**125.2**	**50.1**
Hyrax (*Procavia capensis*)	3.03	86	26.3	77.7	31.2
Lagomorpha	2.35	52	15.9	46.7	18.7
Small mammals (<1 kg)		**103**	**31.4**	**72.8**	**29.1**
Otomys spp	0.131	27	8.3	20.8	8.3
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	28	8.6	20.3	8.1
Striped mouse (*Rhabdomys pumillio*)	0.035	21	6.4	12.9	5.1
Livestock		**20**	**6.4**	**17.3**	**6.9**
Goat (*Capra hircus*)	50	7	2.1	5	2

Sheep (*Ovis aries*)	40	13	4	12	4.8
Birds	**1.57**	**14**	**4.3**	**6.7**	**2.7**
Reptiles		**6**	**1.8**	**2.1**	**0.8**
Invertebrates		**15**	**4.6**	**5**	**2**
Fruits/seeds	**0.002**	**3**	**0.9**	**1.2**	**0.5**
Vegetation	**0.001**	**11**	**3.4**	**5**	**2**
Unknown	**-**	**6**	**1.8**	**6**	**2.4**

Table 4.2. Biomass consumed calculated from caracal scat (n=250) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a full list of species analysed from scats and biomass consumed calculated see Appendix 4B.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=297)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	29	86	29	260.6	18	840.4	35.8
Lagomorpha	2.35	26.2	52	17.5	122.2	8.4	459.5	19.6
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	16.8	28	9.4	1.3	0.1	158.6	6.8
***Otomys* spp**	0.131	17.2	27	9.1	3.5	0.2	156.1	6.7
Sheep (*Ovis aries*)	40	27	13	4.4	520	35.8	118.2	5
Total	**182.2**	**528.6**	**297**	**100**	**1451.3**	**100**	**2344.9**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Baker *et al.* (1993), $Y = 16.63 + 4.09x$; only for prey < 4.5 kg

[c]Prey weight x Number of occurrences

[d]Correction factor x Prey item occurrence

4.4.2. Namaqua National Park versus surrounding farmlands

In Namaqua National Park, 24 different prey items were consumed and 25 prey items on the farmlands (excluding unknown items) (Table 4.3). In the national park, hyrax (33.5%), lagomorpha (15.8%) and *Otomys* spp (10.2%) occurred largely in caracal diet. Medium mammals (49.3%) were still the highest consumed prey class when assessing national park diet; however, in the national park small mammals (33%) were consumed more often than on surrounding farmlands (27%) (X^2 = 3.24, df = 1, p = 0.048). On the farmlands, the three prey items consumed most frequently were also hyrax (29.71%), lagomorpha (20.5%) and *Otomys* spp (7.1%). Sheep (*Ovis aries*) [2%] and goat (*Capra hircus*) [1%] were present in national park scat samples, possibly due to scat being collected close to the park borders. As expected there was a significant difference in livestock consumed between the national park (3%) and the farmlands (9.1%) [X^2 = 5.32, df = 1, p = 0.3].

In the national park, hyrax (38.6%), lagomorpha (16.5%), *Otomys* spp (8.9%), Namaqua rock mouse (8.7%) and birds (6.8%) contributed the largest amount of biomass (Table 3.4). The total biomass of prey items from caracal scats was 2294.5 kg for the national park and 2380.3 kg on the farms, however more scats were analysed from farmlands (n = 152) compared to the national park (n=98). Biomass calculated before the correction factor was used resulted in much higher biomass estimations of certain prey items and the three top prey items in the national park initially were sheep (32.8%), hyrax (29.8%) and goat (10.9%). This further emphasises why applying a correction factor is important when determining the actual biomass consumed, as a certain prey item's contribution to total biomass may be overestimated. On farmlands, hyrax (34.4%), lagomorpha (21.8%), sheep (7.1%), Namaqua rock mouse (5.6%) and *Otomys* spp (5.3%) contributed to the bulk of actual biomass consumed (Table 3.5). Hyrax and lagomorpha remained the two top prey items in caracal diet. Before correction factors were applied, sheep contributed > 50% to the total diet on farmlands, despite only occurring in 6.2% of the total scat samples analysed.

Table 4.3. Prey classes recorded in caracal scat collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. FO (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences. CFO (%) was calculated as the number of occurrences per scat divided by the total number of scats collected. For a table containing a full list of species identified see Appendix 4C (Namaqua National Park) and Appendix 4D (farmlands).

		Namaqua National Park				Farmlands			
Prey Item	**Prey Weight (kg)**	**Number of Occurrences (prey items) n = 130**	**FO (%)**	**Number of Occurrences (per scat) n = 98**	**CFO (%)**	**Number of Occurrences (prey items) n = 195**	**FO (%)**	**Number of Occurrences (per scat) n = 152**	**CFO (%)**
Medium- to large mammals (10-40 kg)		**3**	**2.3**	**2**	**2**	**7**	**3.6**	**6.3**	**4.2**
Medium mammals (1-10 kg)		**53**	**40.8**	**48.3**	**49.3**	**85**	**43.6**	**76.8**	**50.5**
Hyrax (*Procavia capensis*)	3.03	36	27.7	32.8	33.5	49	25.1	45.2	29.7
Lagomorpha	2.35	17	13.1	15.5	15.8	35	18.0	31.2	20.5
Small mammals (<1 kg)		**47**	**36.4**	**32.3**	**33**	**56**	**28.7**	**41**	**27**
Otomys spp	0.131	14	10.8	10	10.2	13	6.7	10.8	7.1
Namaqua rock mouse (*Aethomys*	0.047	14	10.8	10	10.2	14	7.2	10.3	6.8

namaquensis)									
Livestock		**3**	**2.3**	**3**	**3.1**	**16**	**8.2**	**13.8**	**9.1**
Goat (*Capra hircus*)	50	1	0.8	1	1	5	2.6	3.8	2.5
Sheep (*Ovis aries*)	40	2	1.5	2	2	11	5.6	10	6.6
Birds	**1.57**	**8**	**6.2**	**3.8**	**3.9**	**6**	**3.1**	**2.8**	**1.9**
Reptiles		**1**	**0.8**	**0.5**	**0.5**	**5**	**2.6**	**1.6**	**1.1**
Invertebrates		**5**	**3.9**	**2**	**2**	**10**	**5.1**	**3.1**	**2**
Fruits/seeds	**0.002**	**3**	**2.3**	**1.2**	**1.2**	**0**	**0**	**0**	**0**
Vegetation	**0.001**	**4.**	**3.1**	**1.8**	**1.9**	**7**	**3.6**	**3**	**2**
Unknown	**-**	**3**	**2.3**	**3**	**3.1**	**3**	**1.5**	**3**	**2**

Table 4.4. Biomass consumed calculated from caracal scat (n=98) collected in Namaqua National Park, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a full list of species analysed from scats and biomass consumed calculated see Appendix 4E.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=118)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	29	36	30.5	109.1	29.8	885.4	38.6
Lagomorpha	2.35	26.2	17	14.4	40	10.9	378.1	16.5
***Otomys* spp.**	0.131	17.2	14	11.9	1.8	0.5	203.7	8.9
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	16.8	14	11.9	0.7	0.2	199.6	8.7
Birds	1.57	23.1	8	6.8	12.6	3.4	156.3	6.8
Total	**3.03**	**528.6**	**118**	**100**	**366**	**100**	**2294.5**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Baker *et al.* (1993), $Y = 16.63 + 4.09x$; only for prey < 4.5kg

[c]Prey weight x Number of kills

[d]Correction factor x Prey item occurrence

Table 4.5. Biomass consumed calculated from caracal scat (n=152) collected on farmlands in Namaqualand, Northern Cape, South Africa Both the biomass consumed and the total biomass consumed is presented. For a full list of species analysed from scats and biomass consumed calculated see Appendix 4F.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey items occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	29	50	28.3	151.5	12.3	819.9	34.4
Lagomorpha	2.35	26.2	35	19.8	82.3	6.7	518.9	21.8
Sheep (*Ovis aries*)	40	27	11	6.2	660	53.4	167.8	7.1
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	16.8	14	7.9	0.7	0.1	133.1	5.6
***Otomys* spp**	0.131	17.2	13	7.3	1.7	0.1	126.1	5.3
Total	**3.03**	**528.58**	**177**	**100**	**1235.24**	**100**	**2380.29**	**100**

[a]From Skinner and Chimimba (2005)

[b] From Baker *et al.* (1993), $Y = 16.63 + 4.09x$; only for prey < 4.5kg

[c]Prey weight x Number of kills

[d]Correction factor x Prey item occurrence

4.4.4. Prey abundance and preference

For prey abundance results from camera trapping see Chapter 3, section 3.4.4. In Namaqua National Park, 35 sites were sampled and 59 on the farmlands. Total number of trap nights for small mammal trapping was 4 512, which included 1 680 trap nights in the national park and 2 832 on the farmlands. As the farmlands component of the study included a larger surface area, more small mammal sites were sampled on the farmlands. There was a significant difference between the Namaqua rock mouse RAI ($U = 698.5$, $df = 1$, $p < 0.05$) and the striped mouse RAI within the two land-uses ($U = 701$, $df = 1$, $p < 0.05$) [Figure 4.1].

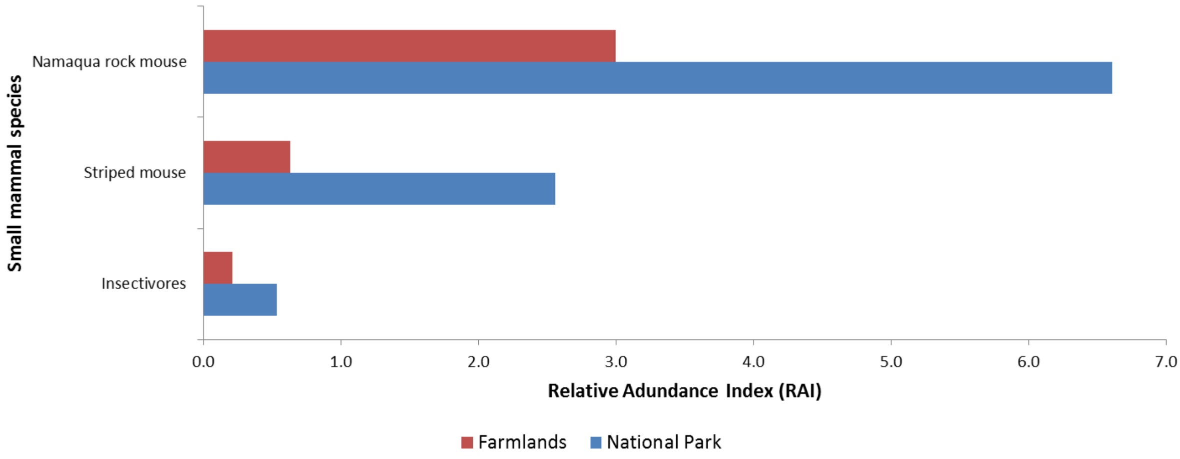


Figure 4.1. Prey relative abundance index (RAI) calculated from small mammal trapping data collected from September 2014 – November 2014. RAI was calculated as the total number of detections of a small mammal species, multiplied by 100 (to calculate the number of individuals captured per 100 trap nights), and divided by the total number of trap nights. Insectivores included *Elephantulus* spp., *Macroscelides proboscideus* and Soricidae.

For sampling effort results from camera data refer to Chapter 3, section 3.4.4.

During a total of 4512 small mammal trapping nights, only 8 small mammal species were sampled. Four species were grouped under “insectivores” for RAI analysis and 3 other species were discarded from the analysis due to only < 2 individuals of each species being captured. Each sampling occasion consisted of 48 trap nights, with 16 Sherman traps at each site, activated for 3 nights. The species accumulation curve did not reach an asymptote, however, the overall results illustrated that the curve was approaching an asymptote (ICE mean = 9.37) [Figure 4.2]. This suggests that 3.47 species were not sampled for the duration of our study.

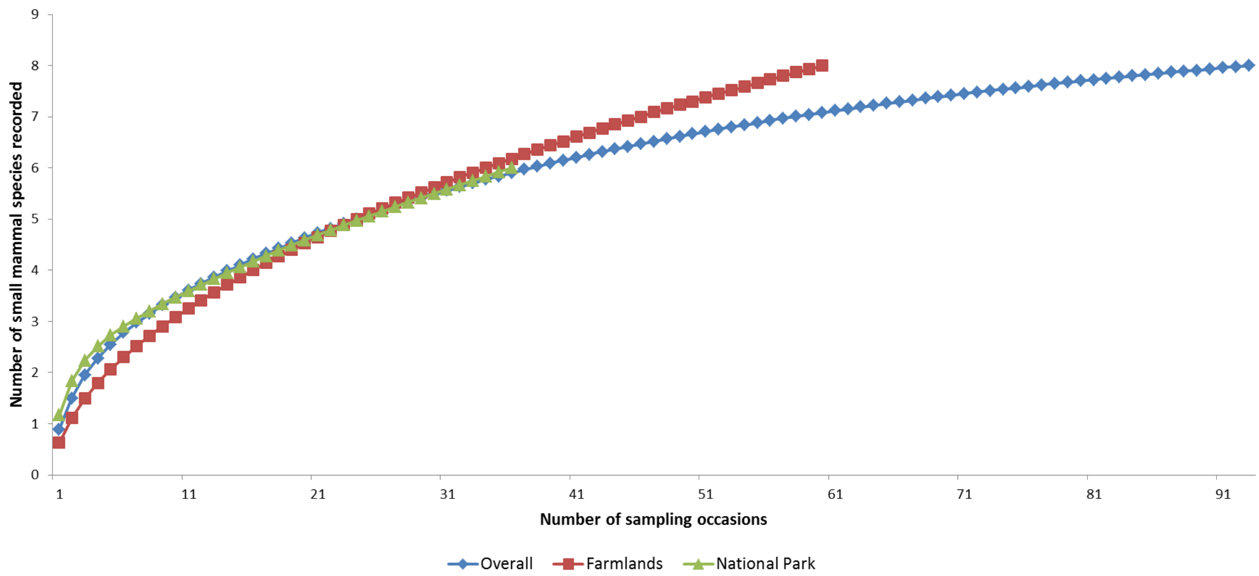


Figure 4.2. Species accumulation curve (100 randomised iterations) for small mammal trapping in the entire study area (ICE Mean = 9.37; ACE Mean = 10.24), in Namaqua National Park (ICE Mean = 12.47; ACE Mean = 14.93) and the surrounding farmlands (ICE Mean = 14.33; ICE Mean = 14.24) of the 8 small mammal species trapped in the study area. Sampling efficiency was recorded for all sampling occasions which included 16 traps per site trapping for 3 nights.

Prey preference was analysed using the camera data and small mammal trapping stations which were operated in spring. A Jacobs' index between 0.5 and 1 shows strong preference. Both the CFO and relative biomass consumed values were used to calculate the Jacobs' index for prey preference. Mammalian prey items that caracal preferred (*D* > 0.60) were hyrax, yellow mongoose and striped mouse (Figure 4.3). Previous studies (Klare *et al.* 2010) have recommended the exclusion of prey items occurring in < 5% of the total diet. A bias could exist for rare prey items occurring in scat; some prey items that only occur in scats once may have a *D*-value of +1 or close to +1. For a full comparison of all prey species recorded no prey items were excluded from the analysis. Goat, sheep, klipspringer (*Oreotragus oreotragus*), aardwolf (*Proteles cristatus*), springbok (*Antidorcas marsupialis*), steenbok (*Raphicerus campestris*) and duiker (*Sylvicapra grimmia*) were the prey species that had a *D*-value of < 0 for both CFO and biomass calculations.

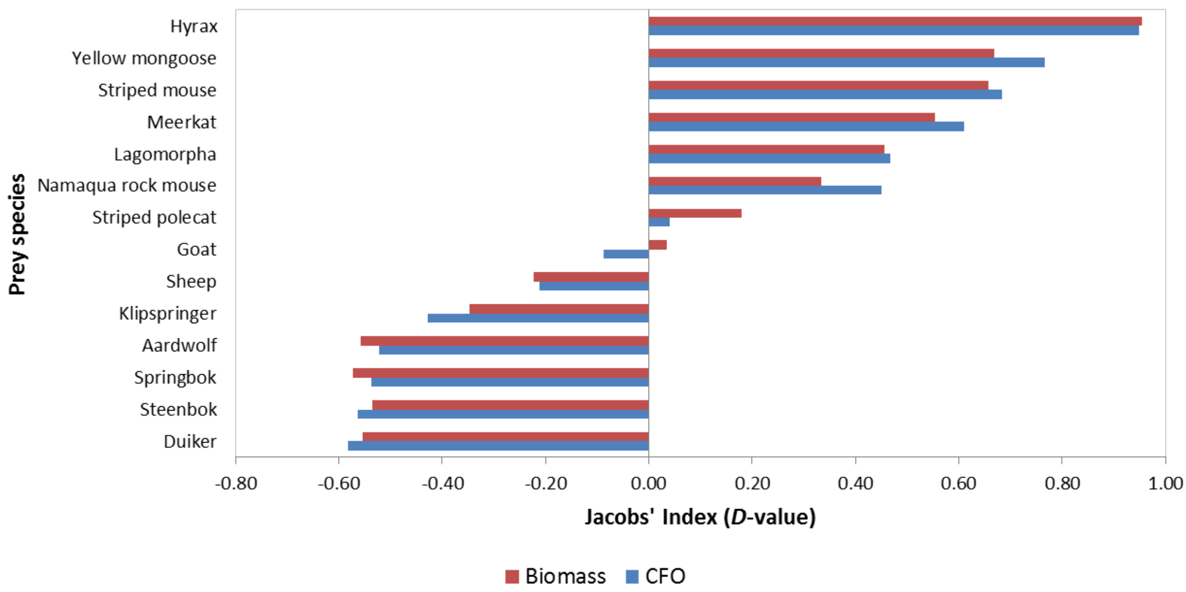


Figure 4.3. Jacobs' Index (*D*-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqualand, South Africa. Both the biomass and the corrected frequency of occurrence (%) used to calculate the *D*-value is illustrated.

As was expected, goat and sheep had a +1 *D*-value in the national park. This is as a result of stock remains found in caracal scat collected in the national park. However, due to livestock being absent in most parts of the national park resulting in 0% RAI there was a consequential positive *D*-value (Table 4.6). More importantly, hyrax, lagomorpha and striped mouse had a *D*-value of > 0.50, showing strong preference for these prey items, along with Namaqua rock mouse (0.39). Medium-sized ungulate species had negative *D*-values in both the national park and on the surrounding farmlands. On farmlands, hyrax, striped mouse and Namaqua rock mouse were prey items occurring frequently in caracal diet for which caracal also exhibited a strong preference according to the Jacobs' index value of > 0.50.

Table 4.6. Relative abundance index (RAI) of all mammalian species recorded on the camera traps in both Namaqua National Park and the surrounding farmlands in Namaqualand, Northern Cape. Namaqua rock mouse and striped mouse prey preference were also calculated from small mammal trapping data and scat analysis.The corrected frequency of occurrence (CFO) used in Jacobs' Index calculations for each separate land-use is also summarised. See Appendix 4G (CFO) and Appendix 4H (biomass consumed) for comparative figure of *D*-values calculated for the national park and farmlands.

Prey species	RAI (%) in Namaqua National Park	CFO (%) in Namaqua National Park	Jacobs' Index (*D*)	RAI (%) on farmlands	CFO (%) on farmlands	Jacobs' index (*D*)
Sheep	0.00	2.80	1	13.35	8.44	-0.25
Goat	0.00	1.40	1	4.43	3.23	-0.16
Hyrax	1.06	46.04	0.98	2.08	38.13	0.93
Yellow mongoose	0.04	1.40	0.95	0.29	1.69	0.71
Meerkat	0.39	1.87	0.66	0.26	0.84	0.53
Lagomorpha	6.07	21.74	0.62	12.51	26.31	0.43
Striped mouse	2.56	7.94	0.53	0.64	6.07	0.82
Namaqua rock mouse	6.61	14.01	0.39	3.00	8.68	0.51
Klipspringer	1.74	0.70	-0.43	2.04	0.84	-0.42
Duiker	6.98	1.40	-0.68	6.07	1.97	-0.53
Steenbok	7.05	0.70	-0.83	3.54	1.69	-0.36
Springbok	2.41	0	-1	1.45	0.84	-0.27
Aardwolf	2.81	0	-1	1.18	0.84	-0.17
Striped polecat	0.19	0	-1	0.26	0.42	0.23
Cattle	1.02	0	-1	3.7	0	-1
Oryx	10.83	0	-1	0.96	0	-1
Baboon	5.38	0	-1	3.81	0	-1

Black-backed jackal	1.64	0	-1	0.68	0	-1
African wildcat	1.41	0	-1	0.77	0	-1
Leopard	1.30	0	-1	0.63	0	-1
Bat-eared fox	1.28	0	-1	1.03	0	-1
Grey mongoose	0.37	0	-1	0.37	0	-1
Honey badger	0.18	0	-1	0.02	0	-1
Cape fox	0.16	0	-1	0.27	0	-1
Donkey	0.11	0	-1	0.86	0	-1
Horse	0.04	0	-1	0.25	0	-1
Red hartebeest	1.41	0	-1	0.05	0	-1
Aardvark	1.00	0	-1	0.49	0	-1
Porcupine	5.22	0	-1	4	0	-1
Caracal	1.35	0	-1	2	0	-1
Small spotted genet	0.09	0	-1	0.26	0	-1

4.5. Discussion

4.5.1. General diet of caracal in Namaqualand

A total of 31 prey items were identified in caracal diet in Namaqualand, Northern Cape. In Namaqualand caracals had two main prey items, hyrax and lagomorpha, irrespective of land-use type. In the Mountain Zebra National Park (MZNP) and farmlands in the area, hyrax were also a main prey item in caracal diet (Grobler 1981; Moolman 1984). In Namaqualand rodents also play an important role in caracal diet, especially the Namaqua rock mouse and *Otomys* spp. The striped mouse and hairy-footed gerbil were other important rodent species. In other caracal diet studies, rodents were the most preferred prey item, such as in the West Coast National Park, Robertson and the Karoo National Park, all study sites located in the Western Cape (Palmer and Fairall 1988; Stuart and Hickman 1991; Avenant and Nel 1997; Avenant and Nel 2002). Avenant and Nel (1997) found bush karoo rat (*Otomys unisulcatus*) to be the rodent occurring most frequently in caracal diet in the West Coast National Park, as well as the striped mouse. In 2002, the same authors studied prey availability in conjunction with caracal diet in the same study area and concluded that these two rodents were still the most important part of caracal diet in the West Coast National Park. Caracals tend to reside in areas with cover due to their secretive nature (Skinner and Chimimba 2005). Being part of the Succulent Karoo biome, my study area is characterised by low shrubs and succulents (Mucina and Rutherford 2006). It is thus expected that caracal in Namaqualand seek refuge in the rocky outcrops, or koppies, where shrub cover is thicker and rocks and boulders provide shelter. In these areas hyrax is an abundant prey item, along with Namaqua rock mouse which prefer crevices of rocky outcrops (de Graaff 1981; Moolman 1984; Skinner and Chimimba 2005).

Only one other study on caracal diet has been published in the Northern Cape. This study was undertaken by Mellville, Bothma and Mills (2004) in the Kgalagadi Transfrontier Park (KTP), an area with a different range of habitats (namely savannah) and prey than Namaqualand. Mellville *et al.* (2004) found rodents to be the main prey source for caracal in KTP, along with springhare (*Pedetes capensis*), a prey absent from the Namaqualand study area. Despite hyrax being an important prey source of caracal in Namaqualand, no hyrax remains were recorded from the KTP study. However, hyrax are very rare in the KTP and only a couple of small populations exist in the few small rocky outcrops present (Skinner and Chimimba 2005). The Mellville *et al.* (2004) study also reported larger prey items such as steenbok in the diet of caracal, along with smaller carnivores, including black-backed jackal. Few studies have reported medium-sized ungulates as a main prey item in caracal diet (Avenant and Nel 2002; Smith 2012). In the Free State province, diet studies primarily used stomach contents and not faecal analysis. Bester (1982) found mainly springhare and mountain reedbuck (*Redunca fulvorufula*) in caracal stomach remains, whereas Kok (1996) found sheep (*Ovis aries*) as the most prominent prey item in caracal diet. However, caution should be taken when inferring from these results as stomach contents were obtained from caracal persecuted due to preying on livestock on farms. Other studies using stomach contents to analyse caracal diet also found high percentages of domestic stock in the diet (Pringle and Pringle 1979; Bester 1982; Stuart and Hickman 1991; Bussiahn 1997). Kok (1996) also found larger antelope species from stomach content investigations, namely duiker and springbok. Caracal in Namaqualand did not prey on medium-sized ungulates as regularly as those in the Free State or some of the other study areas, despite a high availability of the prey items in the study area. According to camera trap data, a ready supply of medium-sized mammals was available in Namaqualand, decreasing the need to hunt ungulate species which may require higher energy to subdue (Smith 2012). Additionally, according to the Jacobs' index, only hyrax, striped mouse, lagomorpha and Namaqua rock mouse displayed a strong preference as prey items. In Namaqualand small and medium mammals were the main prey items of caracal, coinciding with past studies (Moolman 1984; Avenant and Nel 2002; Skinner and Chimimba 2005).

Like any diet estimation technique, scat analysis has a number of draw-backs, however the method has been readily used in many diet studies of medium- to small carnivore species (Mukherjee, Goyal, Johnsingh and Leite Pitman 2004; Klare *et al.* 2010; Kamler, Klare and Macdonald 2012). Caracal are secretive by nature and have mainly been observed hunting in savannah ecosystems (Skinner and Chimimba 2005). Past caracal diet studies have used scat or stomach contents analysis (Moolman 1984; Palmer and Fairall 1988; Stuart and Hickman 1991; Avenant and Nel 2002; Braczkowski *et al.* 2012). As scat analysis can overestimate the importance of smaller items in the diet of a carnivore, it is important to correct for these biases. No feeding trials have been performed for caracal and prior to this research no studies have made use of regression equations to calculate biomass consumed by caracal from caracal scat. Most frequently, FO and CFO are used, but Avenant and Nel (2002) also used the volumetric approach. An importance value is calculated by using the FO and multiplying it by prey weight. Klare *et al.* (2011) noted various biases regarding this method and suggested it only be used if a suitable BCM is unavailable. Baker *et al.* (1993) developed a regression equation from bobcat feeding trials. As various studies have used ecologically similar species for past BCM (Klare *et al.* 2010; Martins *et al.* 2011; Kamler *et al.* 2012; Mann 2014), it seems appropriate to utilise bobcat biomass models for caracal diet analysis.

4.5.2. Namaqua National Park diet versus surrounding farmlands

In Namaqua National Park hyrax and lagomorpha were the main prey items of caracal. Caracal diet in the national park also included a large percentage of small mammals and to some extent birds. Little variation was observed in caracal diet on the small-stock farms as hyrax and lagomorpha were still the two main prey items, despite the change in land-use type. The main difference between the diets of caracal as compared across the two land-uses was the minor addition of livestock (mainly sheep) on farmlands. Few recent studies on caracal diet have been undertaken in non-protected areas. Braczkowski *et al.* (2012) studied caracal diet in two coastal areas in the South-Western Cape which included a variety of habitats. Rodents were the most predominant prey item found in caracal scat and most prominently *Otomys irroratus*, the vlei rat. Bushbuck (*Tragelaphus scriptus*) was the second most prominent prey item in the diet. In the South-Western Cape study area caracal lived in close proximity to human settlements and frequently preyed on domestic cats. Although Braczkowski *et al.* (2012) sampled areas with available livestock, no small stock remains were found in scat remains. Another study, Moolman (1984) studied caracal diet in the Mountain Zebra National Park (MZNP) and surrounding farms, Eastern Cape, similar to the approach used in our study. Moolman (1984) found that hyrax was the prey item occurring most frequently in caracal diet both in and outside the MZNP. Hares were the second most important prey item in the park, followed by antelopes. After hyrax, rodents and domestic stock made up a large proportion of caracal diet on the farmlands surrounding MZNP. In contrast, I found that hyrax and lagomorpha remained the two main prey items in caracal diet across land-uses. Also in contrast with Moolman's (1984) study, small mammals in Namaqualand made up a higher percentage of caracal diet in the protected area than on farmlands. In the Eastern Cape study, domestic stock consumption was accompanied by decreased consumption of medium mammals and to some extent of antelope. Contrastingly in our study no loss of medium mammal consumption was recorded, however small mammals occurred less frequently in caracal diet with the addition of livestock as a prey item. However, this decrease could be attributed to lower small mammal abundance on the farmlands, rather than the inclusion of the alternate prey source.

In Namaqualand livestock occurred in only a small percentage of the scats collected. As there was no drastic change in caracal diet between the two land-uses, it can be suggested that caracals do illustrate an opportunistic feeding behaviour, only preying on livestock when it is advantageous. Past studies have reported caracal diet to be dependent on relevant prey items available (Grobler 1981, Avenant and Nel 2002) Wild prey remained an important part of caracal diet on farmlands, especially medium-sized mammals. When applying CFs to farmland samples, a change in ecologically important prey species was observed. Hyrax and lagomorpha remained the two main prey items, but sheep, an opportunistic prey item that only occurred in 6.6% of all scats analysed from the farmlands, contributed 7% to the total biomass consumed by caracals on farmlands when a CF was applied. Klare *et al.* (2011) warns that biases regarding livestock predation can exist when using BCM. As the age of the prey item is unknown, a mean weight of adult individuals is used. Caracal are known to prey on lambs and when older individuals fall prey only the hindquarters are typically fed on (Smith 2012). This can result in an overestimation of consumed biomass (Ciucci *et al.* 1996). When presenting livestock predation results, using CFO as the main method of diet analysis is advised.

Lagomorpha was a prey item which was abundant across both land-uses, but even more so on farmlands. Many hare species, such as the Cape and scrub hare, are known to prefer shorter grass and are a common occurrence around areas such as kraals where livestock occur (Skinner and Chimimba 2005). Despite additional prey species such as livestock on farmlands, and according to RAI results showing livestock to be the most abundant prey item on farms, caracal still selected for wild prey such as hyrax and lagomorpha. Small mammals was observed to be an important prey item in caracal diet, but occurred in higher frequencies in caracal diet in the national park According to small mammal trapping done in spring 2014, Namaqua rock mouse and striped mouse abundance was much higher in the national park than on farmlands. However, it would be expected for rodent abundance to be higher on farmlands due to a loss of natural predators as a result of carnivore persecution. Despite this, the intense utilisation of farmlands can also cause small mammal numbers to be lower than in protected areas (Avenant and du Plessis 2008). Van Deventer and Nel (2006) found an overall low abundance of rodent species in Namaqua National Park. The authors found that small mammal numbers correlated with food availability and cover. However, as the latter study was conducted in a time of drought, van Deventer and Nel (2006) suggested that the low rainfall was cause for low small mammal numbers. Carnivores that display opportunistic feeding behaviour can sometimes indicate the health of an ecosystem, as well as help to predict which prey species are available in the study area (Karanth and Sunquist 1995; Klare *et al.* 2011; Chattha *et al.* 2015). Compared to other small mammal studies in the Succulent Karoo such as van Deventer and Nel (2006), the small mammal numbers found in my study area were also low. Drought pressures and human activities are both factors which could have led to lower small mammal abundance on farmlands, resulting in fewer small mammal remains in caracal scat collected on farms (van Deventer and Nel 2006; Avenant and Nel 2008). However, with the higher abundance of lagomorpha and the addition of livestock on farmlands, caracal did not need to feed on as many small mammals on the farmlands as in the national park.

In Stuart and Hickman's (1991) study > 15 % livestock remains were found in scat. Their study was conducted in farming areas in the Karoo, Sandveld and Bedford area. Bush karoo rat was a prominent prey item in scat remains. Hyrax and hares were also found, but at lower occurrences than in both Moolman's study (1984) and in our Namaqualand study. Other studies reported that caracal preyed on smaller carnivores; with Mellville *et al.* (2004) even observing black-backed jackal remains in caracal scat. In Namaqualand caracal did not feed as frequently on smaller carnivores as other studies have cited. However, on the farmlands caracal did prey more on aardwolf, yellow mongoose (*Cynictis penicillata*) and striped polecat (*Ictonyx striatus*) than in the national park. Moolman (1984) found that caracal preyed on other carnivores only in the national park and not on the surrounding farmlands. Mellville *et al.* (2004) cited circumstantial reasons for caracal preying on more carnivores in the area sampled. The main area of study in the KTP had lower abundance of other larger carnivores, such as cheetah and leopard, making caracal the largest carnivore. Caracal would have then possibly killed other smaller carnivores to decrease competition (Mellville *et al.* 2004). Another reason the authors mentioned was that the lack of smaller ungulate species such as steenbok in the study region in KTP would have caused caracal to select for prey items in a similar prey weight class, such as black-backed jackal. Caracal killing and preying on other carnivores is not an unnatural occurrence, however carnivores are not an important prey item and are primarily preyed on opportunistically (Mills 1990; Mellville *et al.* 2004).

4.6. Conclusion

In Namaqualand, hyrax and lagomorpha were the main prey items in caracal diet, irrespective of land-use. Medium and smaller mammals, especially rodents were the main prey classes featured in caracal diet. *Otomys* spp., Namaqua rock mouse, hairy-footed gerbil and striped mouse were the four rodent species occurring most frequently in caracal diet. Birds were also consumed, particularly in Namaqua National Park. However, on farmlands wild prey was still consumed in high percentage, but livestock was also included opportunistically. The percentages that sheep and goat contributed to the total biomass in caracal diet could have been an overestimation, as an average of lamb, sub-adult and adult stock weights were used for calculations and the age structure of livestock as prey for caracal is unclear. A total of 31 prey items were identified in caracal diet, with > 90% of diet comprised of mammals.

Caracal are heavily persecuted throughout much of their range based on the belief that they predate heavily on livestock. Yet the results of this work suggest that this might not always be the case thereby questioning sustained persecution of this species on farmlands. Understanding the feeding ecology of under-studied carnivores such as caracal and the drivers behind their prey preference can potentially aid with possible mitigation solutions for farmer-predator conflict. Wild prey was more abundant in the national park than on the surrounding farmlands, with the bulk of prey biomass available on farmlands being made up of livestock. Lowered wild prey availability has been shown to be a primary driver of carnivore-human conflict over depredation. Even so, livestock was not a preferred prey item of caracal, whereas wild prey such as hyrax, lagomorpha and rodents were strongly preferred. Results from this study emphasize the opportunistic feeding behaviour of caracal in a seasonally variable environment and underline the importance of a suitable wild prey base on human-used landscapes to minimize carnivore-human conflict.

4.7. References

Avenant, N, L., and Du Plessis, J. J. 2008. Sustainable small stock farming and ecosystem conservation in southern Africa: A role for small mammals? *Mammalia* **72**: 258–263.

Avenant, N. L., and Nel, J. A. J. 1998. Home-range use, activity, and density of caracal in relation to prey density. *African Journal of Ecology* **36**: 347-359.

Avenant, N. L., and Nel, J. A. J. 2002. Among habitat variation in prey availability and use by caracal *Felis caracal*. *Mammal Biology* **67**: 18–33.

Avenant., N. L., and Nel, J. A. J. 1997. Prey use by four syntopic carnivores in a strandveld ecosystem. *South African Journal of Wildlife Research* **27:** 86-93.

Bacon, M. M., Becic, G. M., Epp, M. T., and Boyce, M. S. 2011. Do GPS Clusters Really Work? Carnivore Diet From Scat Analysis and GPS Telemetry Methods. *Wildlife Society Bulletin* **35**: 409-415.

Bagchi, S., and Mishra, C. 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). *Journal of Zoology* **268**: 217-224.

Bailey, A., and Conradie, B. 2013. *The Effect of Predator Culling on Livestock Losses: Caracal Control in Cooper Hunting Club, 1976 – 1981.* Centre for Social Science Research: University of Cape Town.

Baker, L. A., Warren, R, J., and James, W. E. 1993. Bobcat Prey Digestibility and Representation in Scats P*roceedings of 47th Annual conference of Southeastern Fish and Wildlife Agencies* **47**: 71-79.

Bergman, D. L., De Waal, H. O., Avenant, N. L., Bodenchuk, M. J., Marlow, M. C., and Nolte, D. L. 2013. The Need to Address Black-backed Jackal and Caracal Predation in South Africa. In: J. B. Armstrong and G. R. Gallagher, eds. 2013. *Proceedings of the 15th Wildlife Damage Management Conference* South Carolina.

Bester, J. L. 1982. *Die gedragsekologie en bestuur van die silwervos* Vulpes chama *(Smith, A.) met spesiale verwysing na die Oranje-Vrystaat.* Masters thesis, University of Pretoria, South Africa.

Bothma, J. du P., and Le Riche, E. A. N. 1994. Scat analysis and aspects of defaecation in Northern Cape leopards. *South African Journal of Wildlife Research* **24**: 21 – 25.

Braczkowski, A., Watson, L., Coulson, D., Lucas, J., Peiser, B., and Rossi, M. 2012. The diet of caracal, *Caracal caracal*, in two areas of the southern Cape, South Africa as determined by scat analysis. *South African Journal of Wildlife Research* **42**: 111–116.

Breitenmoser-Würsten, C., Henschel, P. and Sogbohossou, E. 2008. Caracal caracal. In: The IUCN Red List of Threatened Species 2008. [online] Available from: http://www.iucnredlist.org/details/3847/0 (Accessed 19 January 2016).

Bussiahn, F. E. C. 1997. *The diet of the black·backed jackal (*Canis mesomelas*) and caracal (*Felis caracal) *in the Eastern Cape, South Africa*. Masters thesis, Rhodes University, South Africa.

Cavallini, P., and Nel, J. A. J. 1990. The feeding ecology of the Cape grey mongoose, *Galerella pulverulenta* (Wagner 1839) in a coastal area. *African Journal of Ecology* **28:** 123-130.

Chattha, S. A., Hussain, S. M., Javid, A., Abbas, M. N., Mahmood, S., Barq, M. G., and Hussain, M. 2015. Seasonal Diet Composition of Leopard (*Panthera pardus*) in Machiara National Park, Azad Jammu and Kashmir, Pakistan. *Pakistan Journal of Zoology* **47**: 201 – 207.

Ciucci, P., Boitani, L., Pelliccioni, E. R., Rocco, M., and Guy, I. 1996. A comparison of scat-analysis methods to assess the diet of the wolf *Canis lupus*. *Wildlife Biology* **2**: 37–48.

Cloete, S. W. P., Snyman, M. A., and Herselman, M. J. 2000. Productive performance of Dorper sheep. *Small Ruminant Research* **36**: 119-135.

Davidson, Z., Valeix, M., Van Kesteren, F., Loveridge, A. J., Hunt, J. E., Murindagomo, F., and Macdonald, D. W. 2013. Seasonal Diet and Prey Preference of the African Lion in a Waterhole-Driven Semi-Arid Savanna *PLoS ONE* **8**: e55182.

de Graaff, G. 1981. *The rodents of southern Africa*. Pretoria: Buttersworth.

De Waal, H. O. 2012. Koördineer tog! *Landbouweekblad* **1738**: 32-34.

Du Plessis, J. J. 2013. *Towards the development of a sustainable management strategy for* Canis mesomelas *and* Caracal caracal *on rangeland*. Dissertation, University of the Free State, South Africa.

Du Plessis, J. J., Avenant, N. L., and De Waal, H. O. 2015. Quality and quantity of the scientific information available on black-backed jackals and caracals: contributing to human–predator conflict management? *African Journal of Wildlife Research* **45**: 138–157.

Estes, R. D. 2012. *The behaviour guide to African mammals*. Berkely: The University of California Press.

Graham, K., Beckerman, A. P., and Thirgood, S. 2005. Human-predator-prey conflicts: ecological correlates, prey losses and patterns of management. *Biological Conservation* **122**: 159-171.

Grobler, J. H . 1981. Feeding behaviour of the caracal *Felis caracal* Schreber 1776 in the Mountain Zebra National Park. *South African Journal of Zoology* **16**: 259- 262.

Gusset, M., Swarner, M. J., Mponwane, L., Keletile, K., and McNutt, J. W. 2009. Human–wildlife conflict in northern Botswana: livestock predation by Endangered African wild dog *Lycaon pictus* and other carnivores. *Oryx* **43**: 67-72.

Inskip, C., and Zimmerman, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. *Oryx* **43**: 18-34.

Johansson, O., McCarthy, T., Samelius, G., Andren, H., Tumursukh, L., and Mishra, C. 2015. Snow leopard predation in a livestock dominated landscape in Mongolia. *Biological Conservation* **184**: 251-258.

Kamler, J. F., Klare, U., and Macdonald, D. W. 2012. Seasonal diet and prey selection of black-backed jackals on a small-livestock farm in South Africa. *African Journal of Ecology* **50**: 299 – 307.

Karanth, K. U and Sunquist, M. E. 1995. Prey selection by tiger, leopard and dhole in tropical forests. *Journal of Animal Ecology* **64**: 439–450.

Klare, U., Kamler, J. F., and Macdonald, D. W. 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* **41**: 294–312.

Klare, U., Kamler, J. F., Stenkewitz, U., and Macdonald, D. W. 2010. Diet, prey selection, and predation impact of black-backed jackals in South Africa. *Journal of Wildlife Management* **74**: 1030–1042.

Kok, O. B. 1996. Die dieetsamestelling van enkele karnivoorsoorte in die Vrystaat, Suid-Afrika. *South African Journal of Science* **92**: 393–398.

Li, X., Buzzard, P., Chen, Y., and Jiang, X. 2013. Patterns of Livestock Predation by Carnivores: Human–Wildlife Conflict in Northwest Yunnan, China. *Environmental Management* **52**: 1334-1340.

Linnell, J .D. C., Swenson, J. E., and Anderson, R. 2001. Predators and people: Conservation of large carnivores is possible at high human densities if the management policy is favourable. *Animal Conservation* **4:** 345-349.

Loveridge, A. J., Wang, S. W., Frank, L. G., and Seidensticker, J. 2010. People and wild felids: conservation of cats and management of conflicts In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

Macdonald, D. W., Loveridge, A. J., and Nowell, K. 2010. Dramatis personae: an introduction to the wild felids. In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

Mann, G. 2014. *Aspects of the ecology of leopards (*Panthera pardus*) in the little Karoo, South Africa*. Dissertation, Rhodes University, South Africa.

Marker, L., and Dickman, A, J. 2005. Notes on the spatial ecology of caracals (*Felis caracal*), with particular reference to Namibian farmlands. *African Journal of Ecology* **43**: 73–76.

Martins, Q., and Harris, S. 2013. Movement, activity and hunting behaviour of leopards in the Cederberg mountains, South Africa. *African Journal of Ecology* **51**: 571-579.

Martins, Q., Horsnell, W. G. C., Titus, W., Rautenbach, T., and Harris, S. 2011. Diet determination of the Cape Mountain leopards using global positioning system location clusters and scat analysis. *Journal of Zoology* **283**: 81-87.

Mellville, H. I. A. S., Bothma, J. Du. P., and Mills, M. G. L. 2004. Prey selection by caracal in Kgalagadi Transfrontier Park. *South African Journal of Wildlife Research* **34:** 67-75.

Mills, M. G. L. 1990. *Kalahari hyaenas: comparative behavioural ecology of two species*. London: Unwin Hyman.

Moolman, L. C. 1984. ‘n Vergelyking van die voedingsgewoontes van die rooikat *Felis caracal* binne en buite die Bergkwagga Nasionale Park. *Koedoe* **27**: 121-129.

Mucina, L and Rutherford, M.C. eds. 2006. *The vegetation of South Africa, Lesotho and Swaziland.* Pretoria*:* South African National Biodiversity Institute.

Mukherjee, S., Goyal, S. P., Johnsingh, A. J. T., and Leite Pitman, M. R. P. 2004. The importance of rodents in the diet of jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and golden jackal (*Canis aureus*) in Sariska Tiger Reserve, Rajasthan, India. *Journal of Zoology* **262:** 405-411.

Norton, P. M., and Lawson, A. B. 1985. Radio tracking of leopards and caracals in the Stellenbosch area, Cape Province. *South African Journal of Wildlife Research* **15**: 17-24.

Norton, P. M., Lawson, A. B., Henley, S. R., and Avery, G. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *South African Journal of Wildlife Research* **16:** 47–52.

Palmeira, F.B.L., Crawshaw Jr, P. G., Haddad, C. M., Ferraz, K.M.P.M.B., and Verdade, L. 2008. Cattle depredation by puma (*Puma concolor*) and jaguar (*Panthera onca*) in central-western Brazil. *Biological Conservation* **141**: 118-125.

Palmer, R., and Fairall, N. 1988. Caracal and African wild cat diet in the Karoo National Park and the implications thereof for hyrax. *South African Journal of Wildlife Research* **18**: 30-34.

Pettigrew, M., Xie, Y., Kang, A., Rao, M., Goodrich, J., Liu, T., and Berger, J. 2012. Human–carnivore conflict in China: a review of current approaches with recommendations for improved management. *Integrative Zoology* **7**: 210–226.

Pringle, J. A., and Pringle, V. L. 1979. Observations on the lynx *Felis caracal* in the Bedford district. *South African Journal of Zoology* **14**: 1-4.

Pyke, G. H., Pulliam, H. R., and Charnov, E. L. 1977. Optimal foraging: a selective review of theory and tests. *The Quarterly Review of Biology* **52**: 137-154.

Samways, M, J. 2005. *Insect Diversity Conservation*. Cambridge: Cambridge University Press.

Schiess-Meier, M., Ramsauer, S., Gabanapelo, T., and Köning, B. 2007. Livestock predation — insights from problem animal control registers in Botswana. *Journal of Wildlife Management* **71**: 1267–1274.

Skinner, J. D., and Chimimba, C. T. 2005. *The mammals of the southern African subregion.* Cape Town: Cambridge University Press.

Smith, E, R. 2012. *An assessment of caracal population density and human-predator conflict in the Winterberg, Eastern Cape, South Africa.* Masters Thesis, Rhodes University, South Africa.

Stadler H. 2006. Historical perspectives on the development of problem animal management in the Cape Province. In: B. Daly, W. Davies-Mostert, S. Evans, Y. Friedmann, N. King, T. Snow and H. Stadler, eds. 2006. *Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa*. Johannesburg: Endangered Wildlife Trust.

Stuart, C. T. 1981. Notes on the mammalian carnivores of the Cape Province, South Africa. *Bontebok* **1**: 1-58.

Stuart, C. T., and Hickman, G. C. 1991. Prey of caracal *Felis caracal* in two areas of Cape Province, South Africa. *Journal of African Ecology* **105**: 373- 381.

Swann, D. E., Kawanishi, K., and Palmer, J. 2011. Evaluating Types and Features of Camera Traps in Ecological Studies: A Guide for Researchers In: A. F. O'Connell, J. D. Nichols and K. U. Karanth, eds. 2011. *Camera Traps in Animal Ecology: Methods and Analyses.* Tokyo: Springer.

Tambling, C. J., Laurence, S. D., Bellan, S. E., Cameron, E. Z., du Toit, J. T., and Getz, W. M. 2012. Estimating carnivoran diets using a combination of carcass observations and scats from GPS clusters. *Journal of Zoology* **286**: 102 – 109.

Thorn, M., Green, M., Dalerum, F., Bateman, P. W., and Scott, D. M. 2012. What drives human–carnivore conflict in the North West Province of South Africa? *Biological Conservation* **150**: 23–32.

Treves, A., and Karanth, K. U. 2003. Human-carnivore conflict and perspectives on carnivore management worldwide*. Conservation Biology* **17**: 1491–9.

Van Deventer, M., and Nel, J. A. J. 2006. Habitat, food, and small mammal community structure in Namaqualand. *Koedoe* **49:** 99-109.

Van Niekerk, H. N. 2010. *The cost of predation on small livestock in South Africa by medium-sized predators.* Maters thesis, University of the Free State, Bloemfontein.

Woodroffe, R., Thirgood, S., and Rabinowitz, A. 2005. Pe*ople and Wildlife, Conflict or Coexistence?* Cambridge: Cambridge University Press.

4.8. Appendices

Appendix 4A - Prey items recorded in caracal scat (n=250) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=327). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=250).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 327	Frequency of Occurrence (%)	Number of Occurrences (per scat) n = 250	Corrected Frequency of Occurrence (%)
Large Mammals (>40 kg)		**0**	**0**	**0**	**0**
Medium- to large mammals (10-40 kg)		**10**	**3.05**	**8.33**	**3.33**
Springbok (*Antidorcas marsupialis*)	34.48	1	0.31	1.00	0.40
Duiker (*Sylvicapra grimmia*)	16.1	4	1.22	3.33	1.33
Klipspringer *(Oretragus oreotragus)*	11.9	2	0.61	1.50	0.60
Steenbok (*Raphicerus campestris)*	11.1	3	0.92	2.50	1.00
Medium mammals (1-10 kg)		**139**	**42.38**	**125.15**	**50.06**
Aardwolf (*Proteles cristatus)*	8.8	1	0.31	1.00	0.40
Hyrax (*Procavia capensis*)	3.03	86	26.30	77.66	31.20
Lagomorpha	2.35	52	15.90	46.66	18.66
Small mammals (<1 kg)		**103**	**31.40**	**72.77**	**29.11**
Yellow Mongoose (*Cynictis penicillata)*	0.829	3	0.92	3.00	1.20
Striped polecat (*Ictonyx striatus*)	0.764	1	0.31	0.50	0.20
Meerkat (*Suricate suricate*)	0.728	3	0.92	2.33	0.93
Brant's whistling rat (*Parotomys brantsii*)	0.153	1	0.31	0.50	0.20
Otomys spp	0.131	27	8.26	20.83	8.33
Elephantulus spp	0.058	2	0.61	1.33	0.53

Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	1	0.31	1.00	0.40
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	28	8.56	20.27	8.11
Round-eared sengi (*Macroscelides proboscideus*)	0.038	1	0.31	1.00	0.40
Striped mouse (*Rhabdomys pumillio*)	0.035	21	6.42	12.85	5.14
Hairy-footed gerbil (*Gerbillrus paeba*)	0.025	12	3.67	8.33	3.33
Soricidae	0.011	2	0.61	0.83	0.33
Pygmy mouse (*Mus minutoides*)	0.006	1	0.31	0.50	0.20
Livestock		**20**	**6.40**	**17**	**6.80**
Goat (*Capra hircus*)	50	7	2.14	5	2
Sheep (*Ovis aries*)	40	13	3.98	12	4.80
Birds	**1.57**	**14**	**4.28**	**6.66**	**2.66**
Reptiles		**6**	**1.83**	**2.11**	**0.84**
Lizards	0.006	5	1.53	1.78	0.71
Snakes	0.006	1	0.31	0.33	0.13
Invertebrates		**15**	**4.57**	**5.04**	**2.02**
Coleoptera	0.004	6	1.83	2.19	0.88
Orthoptera	0.004	1	0.31	0.50	0.20
Scorpiones	0.004	7	2.14	2.10	0.84
Solifugae	0.004	1	0.31	0.25	0.10
Fruits/seeds	**0.002**	**3**	**0.92**	**1.16**	**0.46**
Vegetation	**0.001**	**11**	**3.36**	**4.99**	**2.00**
Unknown	**-**	**6**	**1.83**	**6.00**	**2.40**

Appendix 4B - Biomass consumed calculated from caracal scat (n=250) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=297)	Prey items occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	29.02	86	28.96	260.58	17.95	840.39	35.84
Lagomorpha	2.35	26.24	52	17.51	122.20	8.42	459.45	19.59
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	16.82	28	9.43	1.32	0.09	158.59	6.76
***Otomys* spp**	0.131	17.17	27	9.09	3.54	0.24	156.05	6.66
Sheep (*Ovis aries*)	40	27	13	4.38	520	35.83	118.18	5.04
Striped mouse (*Rhabdomys pumillio*)	0.035	16.77	21	7.07	0.74	0.05	118.60	5.06
Birds	1.57	23.05	14	4.71	21.98	1.51	108.66	4.63
Hairy-footed gerbil (*Gerbillrus paeba*)	0.025	16.73	12	4.04	0.30	0.02	67.61	2.88
Goat (*Capra hircus*)	50	27.00	7	2.36	350.00	24.12	63.64	2.71
Arthropods	0.004	16.65	8	2.69	0.03	0	44.86	1.91
Duiker (*Sylvicapra grimmia*)	16.1	27	4	1.35	64.40	4.44	36.36	1.55
Steenbok (*Raphicerus campestris)*	11.1	27	3	1.01	33.30	2.29	27.27	1.16
Yellow mongoose (*Cynictis*	0.829	20.02	3	1.01	2.49	0.17	20.22	0.86

penicillata)								
Meerkat (*Suricate suricate*)	0.728	19.61	3	1.01	2.18	0.15	19.81	0.84
Klipspringer (*Oreotragus oreotragus*)	11.9	27	2	0.67	23.80	1.64	18.18	0.78
Lizards	0.006	16.65	3	1.01	0.02	0	16.82	0.72
***Elephantulus* spp**	0.058	16.87	2	0.67	0.12	0.01	11.36	0.48
Soricidae	0.011	16.67	2	0.67	0.02	0	11.23	0.48
Aardwolf (*Proteles cristatus*)	8.8	27	1	0.34	8.80	0.61	9.09	0.39
Springbok (*Antidorcas marsupialis*)	34.48	27	1	0.34	34.48	2.38	9.09	0.39
Striped Polecat (*Ictonyx striatus*)	0.764	19.75	1	0.34	0.76	0.05	6.65	0.28
Brant's whistling rat (*Parotomys brantsii*)	0.153	17.26	1	0.34	0.15	0.01	5.81	0.25
Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	16.84	1	0.34	0.05	0	5.67	0.24
Round-eared sengi (*Macroscelides proboscideus*)	0.038	16.79	1	0.34	0.04	0	5.65	0.24
Pygmy mouse (*Mus minutoides*)	0.006	16.65	1	0.34	0.01	0	5.61	0.24
Total	**182.22**	**528.58**	**297**	**100**	**1451.3**	**100**	**2344.85**	**100**

[a]From Skinner and Chimimba (2005)
[b] From Baker *et al.* (1993), $Y = 16.63 + 4.09x$; only for prey < 4.5 kg
[c]Prey weight x Number of kills
[d]Correction factor x Prey items occurrence

Appendix 4C - Prey items recorded in caracal scat collected in Namaqua National Park, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=130). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=98).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n=130	Frequency of Occurrence (%)	Number of Occurrences (per scat) n=98	Corrected Frequency of Occurrence (%)
Large Mammals (>40 kg)		**0**	**0**	**0**	**0**
Medium- to large mammals (10-40 kg)		**3**	**2.31**	**2**	**2.04**
Springbok (*Antidorcas marsupialis*)	34.48	0.00	0.00	0.00	0.00
Duiker (*Sylvicapra grimmia*)	16.1	1.00	0.77	1.00	1.02
Klipspringer *(Oretragus oreotragus)*	11.9	1.00	0.77	0.50	0.51
Steenbok (*Raphicerus campestris)*	11.1	1.00	0.77	0.50	0.51
Medium mammals (1-10 kg)		**53**	**40.77**	**48.33**	**49.32**
Aardwolf (*Proteles cristatus)*	8.8	0.00	0.00	0.00	0.00
Hyrax (*Procavia capensis*)	3.03	36.00	27.69	32.83	33.50
Lagomorpha	2.35	17.00	13.08	15.50	15.82
Small mammals (<1 kg)		**47**	**36.43**	**32.31**	**32.97**
Yellow Mongoose (*Cynictis penicillata)*	0.829	1.00	0.77	1.00	1.02
Striped polecat (*Ictonyx striatus*)	0.764	0.00	0.00	0.00	0.00
Meerkat (*Suricate suricate*)	0.728	2.00	1.54	1.33	1.36
Brant's whistling rat (*Parotomys brantsii*)	0.153	1.00	0.77	0.50	0.51
Otomys spp	0.131	14.00	10.77	10.00	10.20

Elephantulus spp	0.058	0.00	0.00	0.00	0.00
Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	0.00	0.00	0.00	0.00
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	14.00	10.77	9.99	10.19
Round-eared sengi (*Macroscelides proboscideus*)	0.038	1.00	0.77	1.00	1.02
Striped mouse (*Rhabdomys pumillio*)	0.035	8.00	6.15	5.66	5.78
Hairy-footed gerbil (*Gerbillrus paeba*)	0.025	3.00	2.31	1.50	1.53
Soricidae	0.011	2.00	1.54	0.83	0.85
Pygmy mouse (*Mus minutoides*)	0.006	1.00	0.77	0.50	0.51
Livestock		**3**	**2.31**	**3**	**3.06**
Goat (*Capra hircus*)	50	1.00	0.77	1.00	1.02
Sheep (*Ovis aries*)	40	2.00	1.54	2.00	2.04
Birds	**1.57**	**8.00**	**6.20**	**3.83**	**3.91**
Reptiles		**1**	**0.77**	**0.50**	**0.51**
Lizards	0.006	1.00	0.78	0.50	0.51
Snakes	0.006	0.00	0.00	0.00	0.00
Invertebrates		**5**	**3.85**	**1.99**	**2.03**
Coleoptera	0.004	1.00	0.78	0.50	0.51
Orthoptera	0.004	1.00	0.78	0.50	0.51
Scorpiones	0.004	3.00	2.33	0.99	1.01
Solifugae	0.004	0.00	0.00	0.00	0.00
Fruits/seeds	**0.002**	**3.00**	**2.31**	**1.16**	**1.18**
Vegetation	**0.001**	**4.00**	**3.10**	**1.83**	**1.87**
Unknown	**-**	**3.00**	**2.33**	**3.00**	**3.06**

Appendix 4D - Prey items recorded in caracal scat collected on farmlands in Namaqualand, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=195). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=152).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n=195	Frequency of Occurrence (%)	Number of Occurrences (per scat) n=152	Corrected Frequency of Occurrence (%)
Large Mammals (>40 kg)		**0**	**0**	**0**	**0**
Medium- to large mammals (10-40 kg)		**7**	**3.59**	**6.33**	**4.16**
Springbok (*Antidorcas marsupialis*)	34.48	1.00	0.51	1.00	0.66
Duiker (*Sylvicapra grimmia*)	16.1	3.00	1.54	2.33	1.53
Klipspringer *(Oretragus oreotragus)*	11.9	1.00	0.51	1.00	0.66
Steenbok (*Raphicerus campestris)*	11.1	2.00	1.03	2.00	1.32
Medium mammals (1-10 kg)		**85**	**43.59**	**76.82**	**50.54**
Aardwolf (*Proteles cristatus)*	8.8	1.00	0.51	1.00	0.66
Hyrax (*Procavia capensis*)	3.03	49.00	25.13	45.16	29.71
Lagomorpha	2.35	35.00	17.95	31.16	20.50
Small mammals (<1 kg)		**56**	**28.72**	**40.96**	**26.95**
Yellow Mongoose (*Cynictis penicillata)*	0.829	2.00	1.03	2.00	1.32
Striped polecat (*Ictonyx striatus*)	0.764	1.00	0.51	0.50	0.33
Meerkat (*Suricate suricate*)	0.728	1.00	0.51	1.00	0.66
Brant's whistling rat (*Parotomys brantsii*)	0.153	0.00	0.00	0.00	0.00
Otomys spp	0.131	13.00	6.67	10.83	7.13
Elephantulus spp	0.058	2.00	1.03	1.33	0.88
Cape short-eared gerbil (*Desmodillus*	0.052	1.00	0.51	1.00	0.66

auricularis)					
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	14.00	7.18	10.28	6.76
Round-eared sengi (*Macroscelides proboscideus*)	0.038	0.00	0.00	0.00	0.00
Striped mouse (*Rhabdomys pumillio*)	0.035	13.00	6.67	7.19	4.73
Hairy-footed gerbil (*Gerbillrus paeba*)	0.025	9.00	4.62	6.83	4.49
Soricidae	0.011	0.00	0.00	0.00	0.00
Pygmy mouse (*Mus minutoides*)	0.006	0.00	0.00	0.00	0.00
Livestock		**16**	**8.21**	**13.83**	**9.10**
Goat (*Capra hircus*)	50	5.00	2.56	3.83	2.52
Sheep (*Ovis aries*)	40	11.00	5.64	10.00	6.58
Birds	**1.57**	**6.00**	**3.08**	**2.83**	**1.86**
Reptiles		**5**	**2.56**	**1.61**	**1.06**
Lizards	0.006	4.00	2.05	1.28	0.84
Snakes	0.006	1.00	0.51	0.33	0.22
Invertebrates		**10**	**5.13**	**3.05**	**2.01**
Coleoptera	0.004	5.00	2.56	1.69	1.11
Orthoptera	0.004	0.00	0.00	0.00	0.00
Scorpiones	0.004	4.00	2.05	1.11	0.73
Solifugae	0.004	1.00	0.51	0.25	0.16
Fruits/seeds	**0.002**	**0.00**	**0.00**	**0.00**	**0.00**
Vegetation	**0.001**	**7.00**	**3.59**	**2.99**	**1.97**
Unknown	**-**	**3.00**	**1.54**	**3.00**	**1.97**

Appendix 4E - Biomass consumed calculated from caracal scat (n=98) collected in Namaqua National Park, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=118)	Prey items occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	29.02	36	30.51	109.08	29.80	885.44	38.59
Lagomorpha	2.35	26.24	17	14.41	39.95	10.91	378.06	16.48
Namaqua rock mouse (*Aethomys namaquensis*)	0.131	17.17	14	11.86	1.83	0.50	203.66	8.88
***Otomys* spp**	0.047	16.82	14	11.86	0.66	0.18	199.59	8.70
Birds	1.57	23.05	8	6.78	12.56	3.43	156.28	6.81
Striped mouse (*Rhabdomys pumillio*)	0.035	16.77	8	6.78	0.28	0.08	113.72	4.96
Sheep (*Ovis aries*)	40	27	2	1.69	120.00	32.78	45.76	1.99
Hairy-footed gerbil (*Gerbillrus paeba*)	0.025	16.73	3	2.54	0.08	0.02	42.54	1.85
Arthropods	0.004	16.65	3	2.54	0.01	0.00	42.34	1.85
Meerkat (*Suricate suricate*)	0.728	19.61	2	1.69	1.46	0.40	33.23	1.45
Soricidae	0.011	16.67	2	1.69	0.02	0.01	28.26	1.23
Goat (*Capra hircus*)	50	27.00	1	0.85	40.00	10.93	22.88	1.00
Duiker (*Sylvicapra grimmia*)	16.1	27	1	0.85	16.10	4.40	22.88	1.00
Klipspringer (*Oreotragus*	11.9	27	1	0.85	11.90	3.25	22.88	1.00

oreotragus)								
Steenbok (*Raphicerus campestris)*	11.1	27	1	0.85	11.10	3.03	22.88	1.00
Yellow mongoose (*Cynictis penicillata)*	0.829	20.02	1	0.85	0.83	0.23	16.97	0.74
Brant's whistling rat (*Parotomys brantsii*)	0.153	17.26	1	0.85	0.15	0.04	14.62	0.64
Round-eared sengi (*Macroscelides proboscideus*)	0.038	16.79	1	0.85	0.04	0.01	14.22	0.62
Pygmy mouse (*Mus minutoides*)	0.006	16.65	1	0.85	0.01	0	14.11	0.62
Lizards	0.006	16.65	1	0.85	0.01	0	14.11	0.62
Springbok (*Antidorcas marsuplialis*)	34.48	27	0	0	0	0	0	0
Aardwolf (*Proteles cristatus*)	8.8	27	0	0	0	0	0	0
Striped polecat (*Ictonyx striatus*)	0.764	19.75	0	0	0	0	0	0
***Elephantulus* spp**	0.058	16.87	0	0	0	0	0	0
Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	16.84	0	0	0	0	0	0
Total	**3.03**	**528.58**	**118**	**100**	**366.06**	**100**	**2294.45**	**100**

[a]From Skinner and Chimimba (2005)
[b] From Baker *et al.* (1993), $Y = 16.63 + 4.09x$; only for prey < 4.5kg
[c]Prey weight x Number of kills
[d]Correction factor x Prey items occurrence

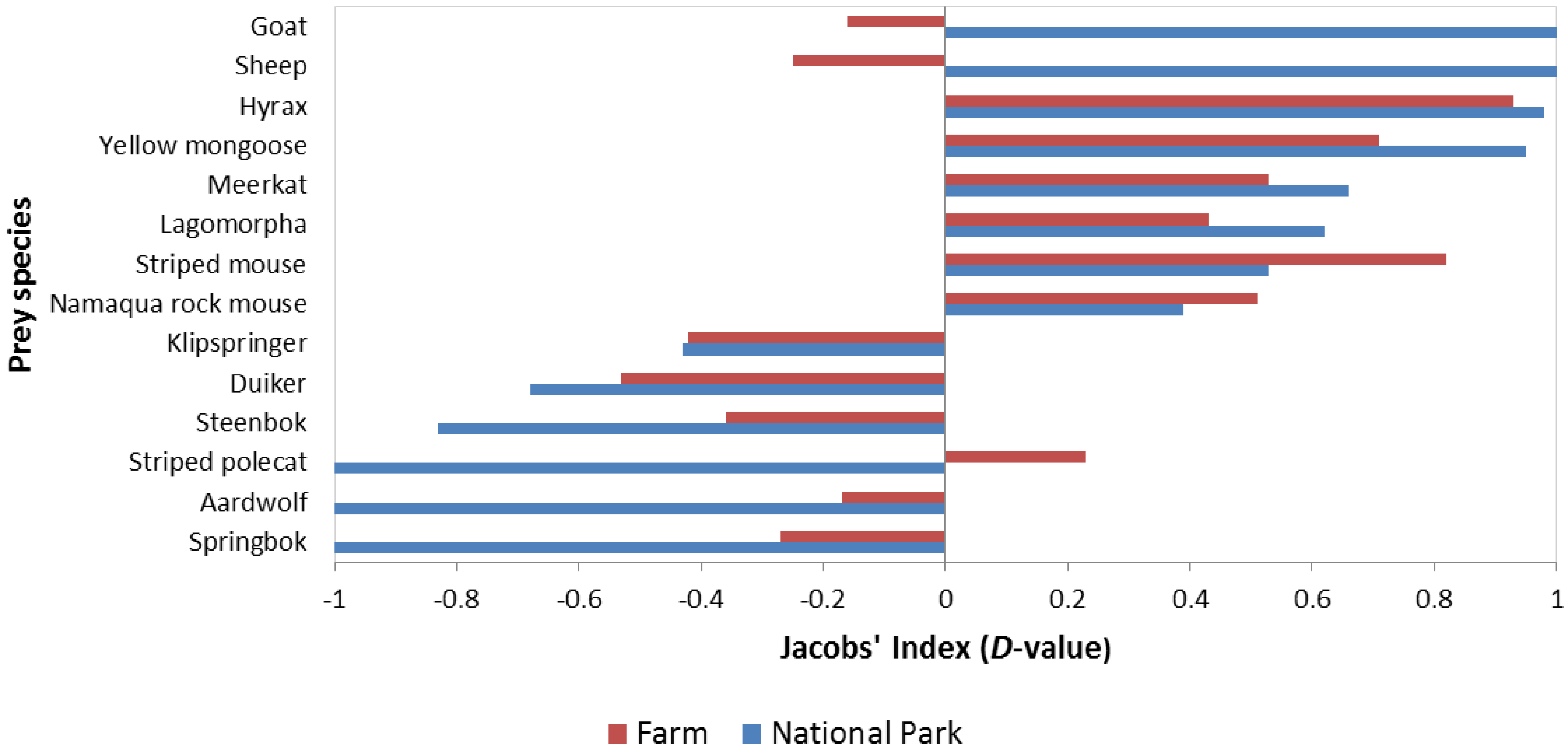
Appendix 4F - Biomass consumed calculated from caracal scat (n=152) collected on farmlands in Namaqualand, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey items occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Hyrax (*Procavia capensis*)	3.03	29.02	50	28.25	151.50	12.26	819.85	34.44
Lagomorpha	2.35	26.24	35	19.77	82.25	6.66	518.90	21.80
Sheep (*Ovis aries*)	40	27.00	11	6.21	660	53.43	167.80	7.05
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	16.82	14	7.91	0.66	0.05	133.06	5.59
***Otomys* spp**	0.131	17.17	13	7.34	1.70	0.14	126.08	5.30
Striped mouse (*Rhabdomys pumillio*)	0.035	16.77	13	7.34	0.46	0.04	123.19	5.18
Hairy-footed gerbil (*Gerbillrus paeba*)	0.025	16.73	9	5.08	0.23	0.02	85.08	3.57
Birds	1.57	23.05	6	3.39	9.42	0.76	78.14	3.28
Goat (*Capra hircus)*	50	27.00	5	2.82	200	16.19	76.27	3.20
Duiker (*Sylvicapra grimmia*)	16.1	27.00	3	1.69	48.30	3.91	45.76	1.92
Arthropods	0.004	16.65	4	2.26	0.02	0.00	37.64	1.58
Steenbok (*Raphicerus campestris)*	11.1	27.00	2	1.13	22.20	1.80	30.51	1.28
Yellow mongoose (*Cynictis*	0.829	20.02	2	1.13	1.66	0.13	22.62	0.95

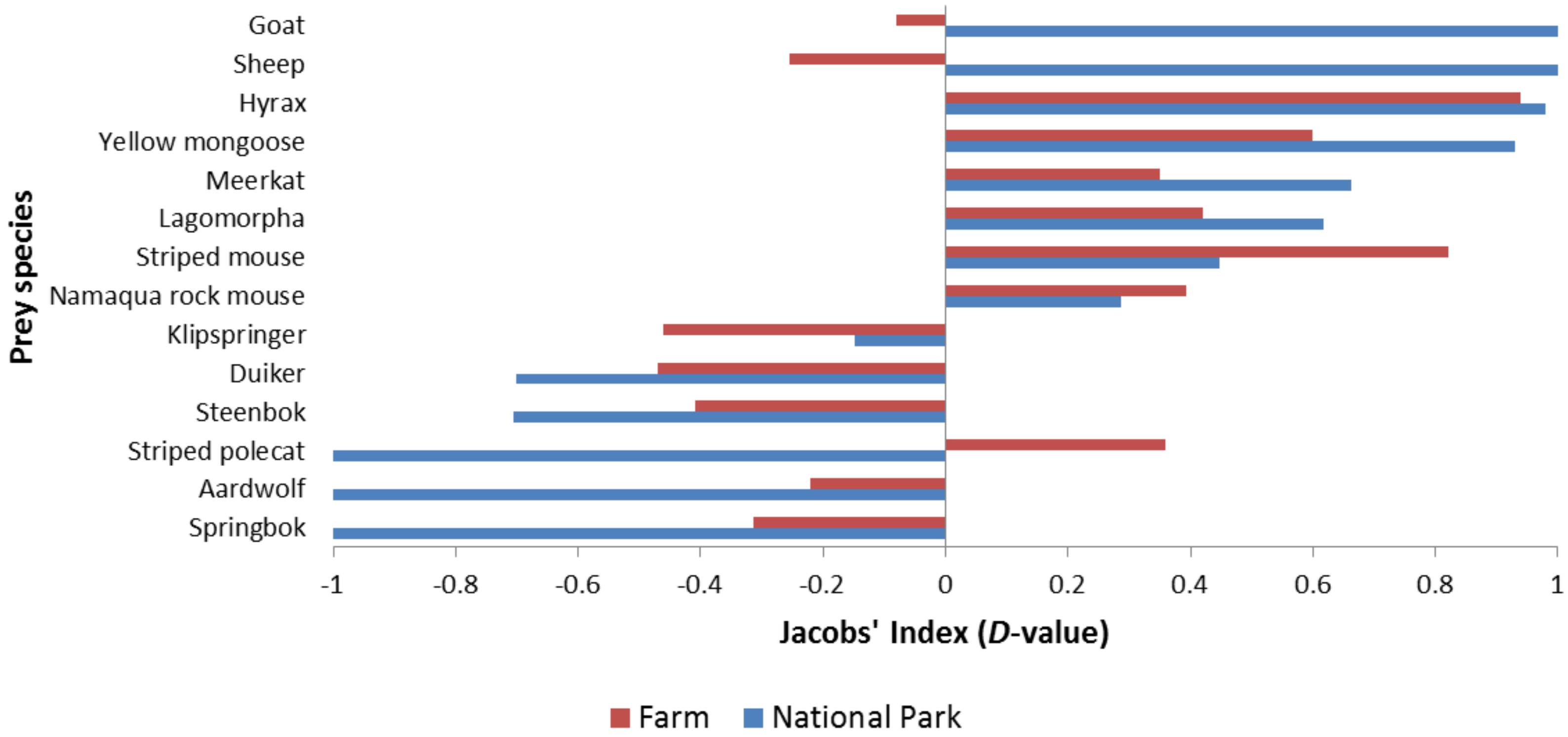
penicillata)								
***Elephantulus* spp**	0.058	16.87	2	1.13	0.12	0.01	19.06	0.80
Lizards	0.006	16.65	2	1.13	0.01	0.00	18.82	0.79
Aardwolf (*Proteles cristatus*)	8.8	27.00	1	0.56	8.80	0.71	15.25	0.64
Springbok (*Antidorcas marsupialis*)	34.48	27.00	1	0.56	34.48	2.79	15.25	0.64
Klipspringer (*Oreotragus oreotragus*)	11.9	27.00	1	0.56	11.90	0.96	15.25	0.64
Striped polecat (*Ictonyx striatus*)	0.764	19.75	1	0.56	0.76	0.06	11.16	0.47
Meerkat (*Suricate suricate*)	0.728	19.61	1	0.56	0.73	0.06	11.08	0.47
Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	16.84	1	0.56	0.05	0	9.52	0.40
Round-eared sengi (*Macroscelides proboscideus*)	0.038	16.79	0	0	0	0	0	0
Soricidae	0.011	16.67	0	0	0	0	0	0
Pygmy mouse (*Mus minutoides*)	0.006	16.65	0	0	0	0	0	0
Brant's whistling rat (*Parotomys brantsii*)	0.153	17.26	0	0	0	0	0	0
Total	**3.03**	**528.58**	**177**	**100**	**1235.24**	**100**	**2380.29**	**100**

[a]From Skinner and Chimimba (2005)
[b] From Baker *et al.* (1993), $Y = 16.63 + 4.09x$; only for prey <4.5kg
[c]Prey weight x Number of kills
[d]Correction factor x Prey items occurrence

Appendix 4G - Jacobs' Index (D-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqua National Park and the surrounding farmlands. The corrected frequency of occurrence (%) was used to calculate the D-values illustrated.



Appendix 4H - Jacobs' Index (D-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqua National Park and the surrounding farmlands. The Biomass was used to calculate the D-values illustrated.



Appendix 4I - Jacobs' index (D-value) of all prey items found in caracal scats collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. The corrected frequency of occurrence (CFO) used in Jacobs' index calculation and the biomass consumed is included.

Prey species	RAI (%)	CFO (%)	Jacobs' Index (*D*)[a]	Biomass (%)	Jacobs' index (*D*)[b]
Hyrax	1.78	40.96	0.95	44.10	0.96
Yellow mongoose	0.21	1.58	0.77	1.06	0.67
Striped mouse	1.35	6.78	0.68	6.22	0.66
Meerkat	0.30	1.23	0.61	1.04	0.55
Lagomorpha	10.61	24.61	0.47	24.11	0.46
Namaqua rock mouse	4.34	10.69	0.45	8.32	0.33
Striped polecat	0.24	0.26	0.04	0.35	0.18
Goat	3.13	2.64	-0.09	3.34	0.03
Sheep	9.42	6.33	-0.21	6.20	-0.22
Klipspringer	1.95	0.79	-0.43	0.95	-0.35
Aardwolf	1.66	0.53	-0.52	0.48	-0.56
Springbok	1.73	0.53	-0.54	0.48	-0.57
Steenbok	4.57	1.32	-0.56	1.43	-0.53
Duiker	6.34	1.76	-0.58	1.91	-0.55
Aardvark	0.65	0	-1	0	-1
African wildcat	0.96	0	-1	0	-1
Baboon	4.27	0	-1	0	-1
Bat-eared fox	1.11	0	-1	0	-1
Black-backed jackal	0.96	0	-1	0	-1
Cape fox	0.24	0	-1	0	-1
Caracal	1.81	0	-1	0	-1
Cattle	2.92	0	-1	0	-1
Donkey	0.64	0	-1	0	-1
Grey mongoose	0.37	0	-1	0	-1
Honey badger	0.07	0	-1	0	-1
Horse	0.19	0	-1	0	-1
Oryx	3.87	0	-1	0	-1
Porcupine	4.36	0	-1	0	-1
Red hartebeest	0.46	0	-1	0	-1
Small spotted genet	0.21	0	-1	0	-1

[a] D-values are based on CFO (%) of prey items from caracal scat.

[b] D-values are based on the total biomass consumed of prey items from caracal scat.

Chapter 5: The diet of black-backed jackal (*Canis mesomelas)* in Namaqualand, South Africa

5.1. Abstract

Black-backed jackals (*Canis mesomelas*) are considered "vermin" by many farmers and are responsible for a large part of livestock losses in South Africa. Black-backed jackal diet has been studied extensively in the past, primarily in protected areas, but research on small-stock farms is lacking. Black-backed jackal scats (n = 196) were collected on two different land-uses; namely the Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. The general diet of black-backed jackal in Namaqualand showed an opportunistic feeding behaviour exhibited by jackals in the study area with small mammals (40.3%), medium mammals (17.3%) and invertebrates (17.3%) being the prey classes occurring most frequently in black-backed jackal diet. In the national park jackal diet most frequently included coleoptera and diurnal rodent species such as *Otomys* spp. and the striped mouse (*Rhabdomys pumillio*). On farmlands the nocturnal Namaqua rock mouse (*Aethomys namaquensis*) was the rodent species contributing the most to the total biomass consumed, suggesting that black-backed jackals may alter their feeding strategies to decrease possible detection on farmlands. The high percentage occurrence of sheep (9.6%) in black-backed jackal diet on farmlands, relative to other prey items, suggest that jackals may contribute to livestock losses in Namaqualand. Steenbok (*Raphicerus campestris*) contributed > 20% to the total biomass consumed in the national park, compared to 25.2% contributed by sheep (*Ovis aries*) on the farmlands. According to camera trap data steenbok was the small ungulate with the highest abundance in the national park and sheep were the most abundant on the farmlands. This study confirms the generalist behaviour of black-backed jackals and further illustrates that land-use influences black-backed jackal diet.

5.2. Introduction

Human-wildlife conflict (HWC) is an ever increasing problem. It mostly occurs in areas where carnivores and humans occupy the same space or compete for similar resources (Inskip and Zimmerman 2009). Since the start of large-scale stock farming in South Africa in the nineteenth century, many carnivores have come into conflict with humans (Beinart 2003). Most carnivores are opportunistic hunters and with resultant easy-to-catch prey items, various carnivores have learnt to depredate on livestock (Loveridge, Wang, Frank and Seidensticker 2010). By the mid-nineteenth century many wildlife species had been eradicated in the Cape Province (now Northern Cape, Western Cape, Eastern Cape and North-West) to make way for pastoral growth (Van Sittert 1998; Beinart 2003). Various ungulate species also declined severely due to hunting for food as the human population increased and the need for food security became a priority (Beinart 2003; Du Plessis 2013). In the Cape Province, lions (*Panthera leo*), hyenas (*Crocuta crocuta*), cheetah (*Acinonyx jubatus*) and even wild dog (*Lycaon pictus*) were some of the first carnivore species to be eradicated by pastoralists (Van Sittert 1998; Skead 2011). The black-backed jackal (*Canis mesomelas*) has been labelled as a dominant mesocarnivore in South Africa and has persisted in the larger area of South Africa, despite intensive persecution (Bagniewska and Kamler 2013).

The black-backed jackal is a common resident in the arid regions of Southern Africa (Skinner and Chimimba 2005). Their range extends from south-western Angola, through Namibia, Botswana, south-west to east Zimbabwe, southern Mozambique and throughout South Africa. Black-backed jackal also occur in more northern parts of Africa from the Gulf of Aden southwards to the south of Tanzania (Loveridge and Nel 2004; Skinner and Chimimba 2005). These canids prefer open habitats and are absent from forested regions (Skinner and Chimimba 205).Black-backed jackals exhibit both diurnal and nocturnal activity patterns, depending on the land-use (Kaunda 2000; Loveridge and Nel 2004). Many of the jackal's prey are diurnal, such as striped mouse (*Rhabdomys pumillio*), and in protected areas where human presence is low, black-backed jackals are regularly observed in the day (Ferguson, Galpin and De Wet 1988; Loveridge and Nel 2004). Black-backed jackals are mostly observed moving in a trot and will only be witnessed walking, ears pricked when out foraging (Skinner and Chimimba 2005). In areas of heavy persecution these adaptablecanids have adopted a nocturnal activity pattern in an attempt to still persist in these areas of high human interference (Loveridge and Nel 2004).

The species are proficient hunters, either foraging singly, in pairs or in groups of three or more (Rowe-Rowe 1983; Skinner and Chimimba 2005). Scavenging is also an important part of black-backed jackal ecology, especially in areas where larger predators such as lion and leopard occur (Estes 2012). These canids are omnivores and display an opportunistic feeding behaviour in all habitats where they persist (Loveridge and Nel 2004; Skinner and Chimimba 2005). This opportunistic foraging behaviour means that black-backed jackals will often choose prey items which are most easily accessible (Estes 2012). Their diet is influenced by what is available and abundant in the certain type of habitat. Past studies conducted on the dietary behaviour of black-backed jackals have delivered contrasting results, with various studies concluding that ungulate species play an important part role jackal diet (Lamprecht 1978; Kok 1996; Do Linh San *et al.* 2009; Klare, Kamler, Stenkewitz and Macdonald 2010). However, other studies found rodents or even invertebrates to be the main prey items (Rowe-Rowe 1983; Smithers 1983; Stuart 1987; Van der Merwe *et al.* 2009). With so many contrasting studies on black-backed jackal diet it becomes clear that their prey range is influenced by the prey species available in a certain area. Their diet includes various invertebrates, vegetable matter such as fruit and seeds, rodents, other small carnivores, hyrax, lagomorphs, ungulates, domestic stock, carrion and at times even anthropogenic items (Rowe-Rowe 1976; Lamprecht 1978; Kok 1996; Nel *et al.* 1997; Loveridge and Macdonald 2003; Do Linh San *et al.* 2009; Kamler, Klare and Macdonald 2012). It is thus of no surprise that these jackals have been persecuted by farmers for years as a result of livestock depredation. With the increase of farming activities in arid areas in the country where black-backed jackals have persisted for years, the ungulate biomass in the form of livestock is increasing and in some cases this biomass is much higher than wildlife prey biomass (Bagchi and Mischra 2006; Gusset *et al.* 2009).

In the past, the South African government subsidised farmers with predator control methods which mostly included lethal control such as the use of indiscriminate traps (Du Plessis 2013). This continued persecution has had very little negative effect on black-backed jackal populations, but a potential increased loss of other mammalian species (non-target species) and biodiversity has been observed on farmlands (Loveridge and Nel 2004; Stadler 2006; Avenant and Du Plessis 2008). Many farmers claim that black-backed jackal numbers have increased over the years. Conradie and Piesse (2013) reported an increase in livestock losses the year after which lethal predator control was implemented on a farm in the Ceres region, Western Cape. Being so abundant across it range, the black-backed jackal has been categorised as “least concern” by the International Union for Conservation of Nature (IUCN) [Hoffmann 2014]. Despite the wide persistence of black-backed jackal across its range, it is still important to understand the ecology of these canids. Habitats vary across regions and the level of human influence in each area is different. With the persecution of jackals by humans various aspects of jackal biology have been observed to change, compensating for human interference (Skinner and Chimimba 2005). The most prominent is that of compensatory breeding where black-backed jackals deal with losses in the population with altered reproduction rates and litter sizes (Beinart 2003; Nattrass and Conradie 2013). As no two areas are the same, it is important to understand as much of each region, including black-backed jackal ecology per region (Du Plessis, Avenant and De Waal 2015).

Previous studies have validated the use of dietary studies in understanding predator ecology to aid the mitigation of HWC (Suryawanshi, Bhatnagar, Redpath and Mishra 2013; Chattha *et al.* 2015; Du Plessis *et al.* 2015). Many carnivores' range is influenced by the availability of suitable prey species (Stephens and Krebs 1986; Balme, Hunter and Slotow 2007). However, in the case of opportunistic carnivores which are not restricted in their range by the specific prey items available, understanding which prey items occur in the diet could give an indication of ecosystem health (Klare, Kamler and Macdonald 2011; Mann 2014). Damage-causing animals such as leopards and black-backed jackals are thought to be opportunistic predators. Most of the time when these animals prey on livestock it is as a result of the prey item being abundant or easily caught, resulting in less energy expenditure when hunting (Loveridge *et al.* 2010; Skinner and Chimimba 2005). The importance of mesocarnivores as part of an ecosystem has more recently been emphasised (Brassine 2011; Estes 2012; Bagniewska and Kamler 2013). Bagniewska and Kamler (2013) found that black-backed jackals can have adverse effects on smaller mammal diversity in a landscape.

Black-backed jackal foraging strategies have been witnessed on various occasions (Lamprecht 1978; Moehlman 1986; McKenzie 1990; Kamler, Foght and Collins 2009). However, as black-backed jackal diet has been found to be varied across different habitats and although mostly occurring in open habitats, very little is known of black-backed jackal foraging strategies on farmlands (Loveridge and Nel 2004; Bergman *et al.* 2013; Du Plessis *et al.* 2015). Scat analysis has proven to be a very useful method when studying secretive carnivore diets (Avenant and Nel 2002; Hulsman *et al.* 2010; Kamler *et al.* 2012; Stuart, Stuart and Pereboom 2013; Yihune and Bekele 2014). Although not necessarily secretive in protected areas, jackals are known to be adaptable and very little has been scientifically published on their diets in non-protected areas (Avenant and Nel 2002; Avenant and Du Plessis 2008; Du Plessis *et al.* 2015). The diet of these opportunistic predators can indicate the heath of the ecosystem and what prey items are available, both in Namaqua National Park and the surrounding farmlands. Camera traps have been used as a long-term monitoring tool in past studies where easy access is limited and observations of mammalian species are rare (Swann, Kawanishi and Palmer 2011). The understanding of black-backed jackal feeding ecology could further aid future mitigation strategies in Namaqualand. It could also help with understanding the ecosystem and what role each predator plays in the ecosystem.

5.2.1. Aims and Objectives

The main objective of this chapter was to provide a current account of black-backed jackal diet in Namaqualand to improve understanding the role of black-backed jackals in this system. Diet was compared between the Namaqua National Park and surrounding farmlands to further deepen understanding of black-backed jackal feeding ecology, especially the role of black-backed jackals on livestock predation in the area. This information will contribute to the compilation of a black-backed jackal management strategy for the region and assist with mitigation of conflict in the study area. This study hypothesises that land-use will influence prey composition in black-backed jackal diet, in addition to influencing prey categories occurring in black-backed jackal diet. Prey availability and prey preference were determined and compared between the two land-uses. Quantifying prey availability and preference will aid in understanding what effect prey availability has on diet choice of black-backed jackals in the region and whether livestock predation occurs as a response to decreased wild prey options.

5.3. Methods

5.3.1. Study Area

This study was conducted in Namaqua National Park (S30. 16627 E017. 79619) and the surrounding farmlands, encompassing a total of 810 km^2. For a full description of the study area see Chapter 1, section 1.5.

5.3.2. Data Collection

For an in-depth description of scat collection see Chapter 2, section 2.1.1. For prey abundance estimation through camera trapping and small mammal trapping see Chapter 2, section 2.1.4 and section 2.1.4 respectively.

5.3.3. Data Analysis

5.3.3.1. Scat Analysis

See Chapter 2, section 2. 2.1 for scat washing methods and methodology regarding the preparing of cross-sections and identification of mammalian hair.

The frequency of occurrence (per prey item) [FO], corrected frequency of occurrence (frequency of occurrence per scat) [CFO] and percentage biomass were calculated. For a more in-depth description of FO and CFO refer to Chapter 2, section 2.2.1.

The use of correction factors (CF's) to calculate the total biomass consumed by black-backed jackals have been used in past studies (Loveridge and Macdonald 2003; Klare *et al.* 2010; Kamler *et al.* 2012; Van de Ven, Tambling and Kerley 2013). The CFs used in this study was developed for red foxes (*Vulpes vulpes*). CFs does exist for the closely related side-striped jackal, however this species has a different prey range and does not include a CF for prey larger than Lagomorpha (Atkinson, Macdonald and Kamizola 2002). In the present study, the biomass ingested of larger mammals was included, especially since various studies have reported black-backed jackals to prey on ungulates and livestock (Klare *et al.* 2010). A biomass calculation model from Goszczyński (1974) was used and to some extent also from Jedrzejewska and Jedrzejewski (1998) who obtained CFs from feeding trials developed for red foxes. These small canids have a similar body mass to black-backed jackals and include a comparable prey range in their diet (Klare *et al.* 2010). When calculating biomass the FO was used, and prey items occurring < 5% in the diet were excluded from the calculations (Bacon *et al.* 2011; Klare *et al.* 2010). The use of biomass in dietary analyses of carnivores is an important factor as it is ecologically the most relevant parameter (Kamler *et al.* 2012).

5.3.3.2. Prey Abundance and Preference Analysis

See Chapter 2, section 2.2.3 for more information.

5.3.4. Statistical Analysis

For diet statistical analysis please refer to Chapter 2, section 2.3.1 and for prey abundance and preference statistical analysis from camera trap and small mammal data please refer to Chapter 2, section 2.3.3.

5.4. Results

5.4.1. Black-backed jackal Diet

A total of 196 black-backed jackal scats were analysed for this study; 94 collected in the Namaqua National Park and 102 on surrounding farmlands. Jackal tended to prey on smaller items which included a large proportion of invertebrates in their diet. Mammals made up > 60% of the total diet. A total of 35 different prey items were identified (excluding unknown items) from the 196 scat samples. Small mammals (40.3%), invertebrates (17.3%) and medium mammals (17.3%) were the three top prey classes occurring in the jackal diet. Coleoptera (10.9%), hyrax (*Procavia capensis*)

[10.2%], striped mouse (9.9%), Namaqua rock mouse (*Aethomys namaquensis*) [8.9%] and *Otomys* spp (8%) were the most frequently consumed prey items (Table 5.1).

Jackal diet included a combination of larger prey items such as ungulate species and smaller prey items such as insects and rodents. When analysing the total biomass consumed the use of CFs played an important role in calculating the true biomass consumed and the percentage each prey item contributed to black jackal diet. When assessing the total biomass consumed, larger prey items made up a higher percentage than that of smaller prey (Table 5.2). The total biomass of all prey items analysed from jackal scats was 3084.7 kg. Sheep (*Ovis aries*) [13.8%], hyrax (12.7%), steenbok (*Raphicerus campestris*) [11.5%], striped mouse (7.6%) and lagomorpha (7.3%) were the top prey items contributing to the total biomass consumed. Prey items such as the pygmy mouse (*Mus minutoides*), scorpiones, fruits/seeds, round-eared sengi (*Macroscelides proboscideus*), pygmy rock mouse (*Petromyscus collinus*), diplopoda, vegetation and orthoptra contributed 0% to the total biomass consumed before CFs were applied. However, after CFs were applied these prey items contributed > 0.05 % to the total biomass consumed.

Table 5.1. Prey items recorded in black-backed jackal scat (n=196) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. FO (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=336). CFO (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=196). For a full list of species analysed from scats see Appendix 5A.

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 336	FO (%)	Number of Occurrences (per scat) n = 196	CFO (%)
Medium- to large mammals (10-40 kg)		**21**	**6.3**	**16.2**	**8.2**
Medium mammals (1-10 kg)		**44**	**13.1**	**33.8**	**17.3**
Hyrax (*Procavia capensis*)	3.03	26	7.7	20	10.2
Small mammals (<1 kg)		**125**	**37.2**	**78.9**	**40.3**
Otomys spp.	0.131	25	7.4	15.6	8

Namaqua rock mouse (*Aethomys namaquensis*)	0.047	25	7.4	17.5	8.9
Striped mouse (*Rhabdomys pumillio*)	0.035	34	10.1	19.3	9.9
Livestock		**17**	**5.1**	**13.6**	**6.9**
Goat (*Capra hircus*)	50	5	1.5	3.8	2
Sheep (*Ovis aries*)	40	12	3.6	9.8	5
Birds	**1.57**	**7**	**2.1**	**2.9**	**1.5**
Reptiles		**22**	**6.6**	**7.8**	**4**
Invertebrates		**80**	**23.8**	**33.8**	**17.3**
Coleoptera	0.004	47	14	21.3	10.9
Fruits/seeds	**0.002**	**11**	**3.3**	**4.7**	**2.4**
Vegetation	**0.001**	**6**	**1.8**	**2.7**	**1.4**
Unknown	**-**	**3**	**0.9**	**1.5**	**0.8**

Table 5.2. Biomass consumed calculated from black-backed jackal scat (n=196) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a full list of species analysed from scats and biomass consumed calculated see Appendix 5B.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Sheep (*Ovis aries*)	40	118	12	3.6	480	38.2	425.2	13.8
Hyrax (*Procavia capensis*)	3.03	50	26	7.8	78.8	6.3	390.4	12.7
Steenbok (*Raphicerus campestris*)	11.1	118	10	3	111	8.8	354.4	11.5
Striped mouse (*Rhabdomys pumillio*)	0.035	23	34	10.2	1.2	0.1	234.8	7.6
Lagomorpha	2.35	50	15	4.5	35.3	2.8	225.2	7.3
Total	**216.01**	**1507**	**274**	**82.3**	**1257.1**	**100**	**3084.7**	**100**

[a]From Smithers and Chimimba (2005)

[b] From Goszczynski (1974) and Kamler *et al.* (2012)

[c]Prey weight x Number of kills

[d]Correction factor x Prey item occurrence

5.4.2. Namaqua National Park versus surrounding farmlands

A total of 94 scats were analysed from Namaqua National Park and 102 from the surrounding farmlands. From the 94 scats collected in the national park, 31 prey items were identified and from the 102 scats collected on the farmlands, 27 prey items were identified. Coleoptera occurred in a higher percentage in the national park diet (15.9%), than farm diet (6.2%) [X^2 = 12.50, df = 1, p = 0.050], as did lizards (NP = 4.2%; F = 1.1%) [X^2 = 7.05, df = 1, p = 0.014]. Steenbok and sheep occurred in higher frequencies in farm diet, than in national park diet (X^2 = 4.58, df = 1, $p < 0.05$; X^2 = 16.40, df = 1, $p < 0.05$). As expected there was a significant difference in the frequency of occurrence of livestock being consumed when compared between the two land-uses (X^2 = 1.06, df = 1, p = 0.002). Reptiles (X^2 = 5.31, df = 1, p = 0.036) and invertebrates (X^2 = 11.91, df = 1, p = 0.000) also differed significantly when comparing the national park diet to the farm diet.

In the national park, coleoptera (15.9%), striped mouse (9.2%), *Otomys* spp (9.2%), hyrax (8.3%) and lagomorpha (7.5%) were the most frequently consumed prey items (Table 5.3). Small mammals (36.6%), invertebrates (24.2%) and medium mammals (16.8%) were the three top prey classes consumed by jackals in the national park. On the surrounding farmlands, hyrax (11.9%), Namaqua rock mouse (11.4%), striped mouse (10.5%), sheep (9.6%) and *Otomys* spp (6.9%) were the top prey items consumed. Small mammals (42.8%), medium mammals (17.6%) and livestock (12.6%) were the three main prey classes consumed (Table 5.3).

The total biomass consumed by jackals in the national park was 3249 kg and 4294.7 kg on the farmlands. In the national park, steenbok (20.3%), hyrax (11.8%), striped mouse (8.9%), lagomorpha (8.6%) and springbok (*Antidorcas marsuplialis*) [7.6%] contributed the largest percentage to the total biomass consumed (Table 5.4). On the surrounding farmlands the prey items that contributed the most to the total biomass consumed was sheep (25.2%), hyrax (13.3%), duiker (*Sylvicapra grimmia*) [8.4%], Namaqua rock mouse (6.5%) and striped mouse (6.5%) (Table 5.5). The use of CFs meant that smaller prey items were not underestimated in terms of their ecological importance in black-backed jackal diet.

Table 5.3. Prey classes recorded in black-backed jackal scat collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. FO (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences. CFO (%) was calculated as the number of occurrences per scat divided by the total number of scats collected. For a table containing a full list of species identified see Appendix 5C (Namaqua National Park) and Appendix 5D (farmlands).

		Namaqua National Park				Farmlands			
Prey Item	**Prey Weight (kg)**	**Number of Occurrences (prey items) n = 182**	**FO (%)**	**Number of Occurrences (per scat) n = 94**	**CFO (%)**	**Number of Occurrences (prey items) n = 156**	**FO (%)**	**Number of Occurrences (per scat) n = 102**	**CFO (%)**
Medium- to large mammals (10-40 kg)		**13**	**7.1**	**9.3**	**9.9**	**8**	**5.1**	**6.8**	**6.7**
Medium mammals (1-10 kg)		**21**	**11.5**	**15.8**	**16.8**	**23**	**14.7**	**18**	**17.6**
Hyrax (*Procavia capensis*)	3.03	11	6.0	7.8	8.3	15	9.6	12.2	11.9
Lagomorpha	2.35	8	4.4	7	7.5	7	4.5	5.3	5.2
Small mammals (<1 kg)		**61**	**33.5**	**34.4**	**36.6**	**64**	**41**	**43.7**	**42.8**
Otomys spp.	0.131	15	8.2	8.6	9.2	10	6.4	7	6.9
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	9	5.0	5.9	6.2	16	10.3	11.7	11.4

Striped mouse (*Rhabdomys pumillio*)	0.035	18	9.9	8.6	9.2	16	10.3	10.7	10.5
Livestock		**2**	**1.1**	**0.8**	**0.9**	**15**	**9.6**	**12.8**	**12.6**
Goat (*Capra hircus*)	50	2	1.1	0.8	0.9	3	1.9	3	2.9
Sheep (*Ovis aries*)	40	0	0	0	0	12	7.7	9.8	9.6
Birds	**1.57**	**2**	**1.1**	**0.8**	**0.8**	**5**	**3.2**	**2.2**	**2.1**
Reptiles		**16**	**8.8**	**5.5**	**5.9**	**6**	**3.9**	**2.2**	**2.1**
Invertebrates		**56**	**30.8**	**22.8**	**24.2**	**26**	**16.7**	**11.1**	**10.8**
Coleoptera	0.004	33	18.1	15	15.9	14	9	6.3	6.2
Fruits/seeds	**0.002**	**6**	**3.3**	**2.3**	**2.5**	**5**	**3.2**	**2.4**	**2.3**
Vegetation	**0.001**	**3**	**1.7**	**1.2**	**1.2**	**3**	**1.9**	**1.5**	**1.5**
Unknown	**-**	**2**	**1.1**	**1**	**1.1**	**1**	**5.1**	**6.8**	**6.7**

Table 5.4. Biomass consumed calculated from black-backed jackal scat (n=94) collected in Namaqua National Park, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a full list of species analysed from scats and biomass consumed calculated see Appendix 5E.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Steenbok (*Raphicarus campestris*)	11.1	118	8	5.6	88.8	22.1	660.1	20.3
Hyrax (*Procavia capensis*)	3.03	50	11	7.7	33.3	8.3	384.6	11.8
Striped mouse (*Rhabdomys pumillio*)	0.035	23	18	12.6	0.6	0.2	289.5	8.9
Lagomorpha	2.35	50	8	5.6	18.8	4.7	279.7	8.6
Springbok (*Antidorcas marsupialis*)	34.48	118	3	2.1	103.4	25.8	247.6	7.6
Total	**226.01**	**1507**	**143**	**100**	**401.5**	**100**	**3249**	**100**

[a]From Smithers and Chimimba (2005)

[b] From Goszczynski (1974) and Kamler *et al.* (2012)

[c]Prey weight x Number of kills

[d]Correction factor x Prey item occurrence

Table 5.5. Biomass consumed calculated from black-backed jackal scat (n=102) collected on farmlands in Namaqualand, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented. For a full list of species analysed from scats and biomass consumed calculated see Appendix 5F.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Sheep (*Ovis aries*)	40	118	12	9.2	480	56.1	1080.9	25.2
Hyrax (*Procavia capensis*)	3.03	50	15	11.5	45.5	5.3	572.5	13.3
Duiker (*Sylvicapra grimmia*)	16.1	118	4	3.1	64.4	7.5	360.3	8.4
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	23	16	12.2	0.8	0.1	280.9	6.5
Striped mouse (*Rhabdomys pumillio*)	0.035	23	16	12.2	0.6	0.1	280.9	6.5
Total	**226.01**	**1507**	**131**	**100**	**855.6**	**100**	**4294.7**	**100**

[a]From Smithers and Chimimba (2005)

[b] From Goszczynski (1974) and Kamler *et al.* (2012)

[c]Prey weight x Number of kills

[d]Correction factor x Prey item occurrence

5.4.4. Prey abundance and preference

For prey abundance results from camera trapping see Chapter 3, section 3.4.3.

For prey abundance results from small mammal trapping see Chapter 4, section 4.4.4.

Prey preference was analysed using the camera data collected from the 159 camera traps which were set-out for the duration of a year (rotated once within each grid cell), along with the 94 (59 farms and 35 National Park) small mammal trapping stations which were active in spring. A Jacobs' index between 0.5 and 1 shows a strong preference (Jacobs 1974). Both the corrected frequency of occurrence and relative biomass consumed values were used to calculate the Jacobs' index for prey preference. Mammalian prey items that displayed a strong preference (> 0.60) were honey badger (*Mellivora capensis*), hyrax, striped mouse, steenbok, striped polecat (*Ictonyx striatus*) and springbok (Figure 5.1). Previous studies (Klare *et al.* 2010) have recommended the exclusion of prey items occurring in < 5% of the total diet. A bias could exist for rare prey items occurring in scat; some prey items that only occur in scats once may have a *D*-value of +1 or close to +1. For a full comparison of all prey species recorded in scats no prey items were excluded from the analysis. Bat-eared fox, baboon (*Papio ursinus*) and porcupine (*Hystrix africaeaustralis*) were the prey species that had a *D*-value of < 0 for both CFO and biomass calculations.

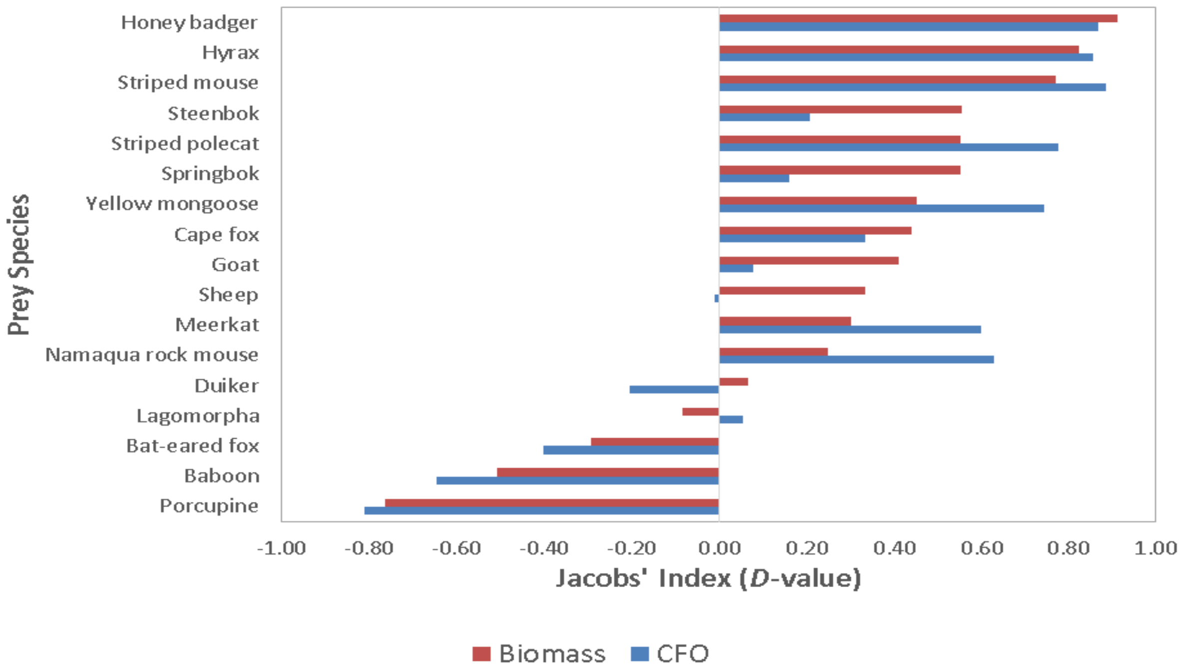


Figure 5.1. Jacobs' Index (*D*-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqualand, South Africa. Both the biomass and the corrected frequency of occurrence (%) were used to calculate the *D*-value for black-backed jackal prey preference. Please see Appendix 5I for a table comparing the both CFO and biomass as units used in Jacobs' index calculations.

Prey preference in black-backed jackal diet was also compared between the two land-uses (Table 5.6). No seasonal prey preference was calculated as no prey abundance data for seasonality was available. Goat remains were found in black-backed jackal scat collected in the national park, but due to livestock being absent in most parts of the national park, a resultant 0% RAI lead to a positive *D*-value for these prey items in the national park. Yellow mongoose (*Cynictis penicillata*), striped polecat, hyrax, honey badger, striped mouse, meerkat (*Suricate suricate*) and Cape fox had a *D*-value of > 0.50, showing strong preference for these prey items, along with lagomorpha (0.49), Namaqua rock mouse (0.37), steenbok (0.33) and springbok (0.18). Unfortunately abundance data was only available for Namaqua rock mouse and striped mouse. Yellow mongoose and Cape fox illustrated strong preference, despite only occurring in < 2% of the total scats analysed from the national park. This is as a result of low abundance of these prey items in the national park. Duiker and porcupine were the only two prey items which were avoided by black-backed jackals.

On farmlands, the striped mouse was the prey item with the highest *D*-value, representing the highest preference (0.94) in black-backed jackal diet. Hyrax, Namaqua rock mouse and yellow mongoose were the three prey items also showing a strong preference (> 0.60). Other prey items which also had a positive preference value on the farmlands were sheep, goat and springbok. More prey items were avoided on the farmlands, than in the national park. Baboon, steenbok, lagomorpha, bat-eared fox and duiker were all prey items which, according to the Jacobs' index, were avoided by black-backed jackals on the farmlands.

For sampling effort results from camera data refer to Chapter 3 and from small mammal trapping data refer to Chapter 4, section 4.4.4.

Table 5.6. Relative abundance index (RAI) of all mammalian species recorded on the camera traps and captured with small mammal trapping in both Namaqua National Park and on the surrounding farmlands in Namaqualand, Northern Cape. The corrected frequency of occurrence (CFO) used in Jacobs' index calculation for black-backed jackal on each separate land-use is also shown. For figures illustrating the difference in Jacobs' index compared between the two land-uses please see Appendix 5G (CFO) and Appendix 5H (biomass).

Prey species	RAI (%) in Namaqua National Park	CFO (%) in Namaqua National Park	Jacobs' Index (*D*)	RAI (%) on farmlands	CFO (%) on farmlands	Jacobs' index (*D*)
Goat	0.00	1.88	1	4.43	4.93	0.06
Yellow mongoose	0.04	1.13	0.94	0.29	1.64	0.71
Striped polecat	0.19	4.52	0.92	0.26	0.00	-1
Hyrax	1.06	17.70	0.91	2.08	19.97	0.84
Honey badger	0.18	2.26	0.86	0.02	0.00	-1
Striped mouse	2.56	19.53	0.80	0.64	17.51	0.94
Meerkat	0.39	2.83	0.76	0.26	0.00	-1
Cape Fox	0.16	1.13	0.76	0.27	0.00	-1
Lagomorpha	6.07	15.82	0.49	12.51	8.75	-0.20
Namaqua Rock Mouse	6.61	13.25	0.37	3.00	19.15	0.77
Steenbok	7.05	13.18	0.33	3.54	2.18	-0.24
Springbok	2.40	3.39	0.18	1.45	1.64	0.06
Duiker	6.98	2.26	-0.53	6.07	5.75	-0.03
Porcupine	5.22	1.13	-0.66	4.00	0.00	-1
Baboon	5.38	0.00	-1	3.81	1.64	-0.41
Bat-eared Fox	1.28	0.00	-1	1.03	0.82	-0.12
Sheep	0	0	-1	13.35	16.01	0.11

Horse	0.04	0	-1	0.25	0	-1
Red hartebeest	1.41	0	-1	0.05	0	-1
Aardvark	1.00	0	-1	0.49	0	-1
Klipspringer	1.74	0	-1	2.04	0	-1
Caracal	1.35	0	-1	2	0	-1
Small spotted genet	0.09	0	-1	0.26	0	-1
Aardwolf	2.81	0	-1	1.18	0	-1
Cattle	1.02	0	-1	3.7	0	-1
Oryx	10.83	0	-1	0.96	0	-1
Black-backed jackal	1.64	0	-1	0.68	0	-1
African wildcat	1.41	0	-1	0.77	0	-1
Leopard	1.30	0	-1	0.63	0	-1
Grey mongoose	0.37	0	-1	0.37	0	-1
Donkey	0.11	0	-1	0.86	0	-1

5.5. Discussion

5.5.1. General diet of black-backed jackal Namaqualand

A total of 35 different prey items were identified from the 196 scats analysed, concluding that black-backed jackals have a generalist diet in Namaqualand, Northern Cape, South Africa. Black-backed jackal diet was dominated by small mammal species, invertebrates and medium mammals and also included ungulate prey and livestock. The findings of this study support other studies which found that black-backed jackals are omnivorous (Bothma 1966; Smithers 1971; Rowe-Rowe 1976; Stuart 1987; Kok 1996; Kaunda and Skinner 2003; Loveridge and Macdonald 2003; Kok and Nel 2004; Do Linh San *et al.* 2009; Van der Merwe *et al.* 2009; Klare *et al.* 2010; Kamler *et al.* 2012; Van de Ven *et al.* 2013). Fruits/seeds and vegetation only occurred in < 5% of black-backed jackal diet in Namaqualand, but a future study on seasonal diet may further the understanding of how important plant matter are across seasons. When comparing black-backed jackal diet in Namaqualand to previous studies, it is important to remember that these canids are opportunistic in their feeding behaviour and will take prey which is the most abundant or the most accessible (Skinner and Chimimba 2005; Van de Ven *et al.* 2013). In general, black-backed jackal diet also varies seasonally and across different habitat types. In this study, the main prey item occurring most frequently in jackal diet was coleoptera (beetles). Invertebrate abundance was not sampled, but as black-backed jackals are opportunistic, we can assume that the high occurrence of beetles in jackal diet was as a result of their high abundance in the study area. Namaqualand forms part of the Succulent Karoo biome and is a region with high levels of endemism (Mucina and Rutherford 2006). The endemism and abundance of flora often spills over to invertebrate assemblages which have a resultant high abundance in such areas (Collville, Picker and Cowling 2002). Previous studies have found that arthropods occur frequently in jackal diet where abundance of these prey items is high (Smithers 1983; Kaunda and Skinner 2003; Loveridge and Macdonald 2003; Brassine 2011; Van de Ven *et al.* 2013).

Very few studies on black-backed jackal diet have been undertaken in the Northern Cape, however Stuart (1987) analysed 114 jackal stomachs collected from the Northern Cape, Eastern Cape and Western Cape. In 2010, a study on the diet and prey selection of black-backed jackals on 2 game reserves near Kimberley, Northern Cape was also undertaken (Klare *et al.* 2010). Du Plessis *et al.* (2015) reviewed all black-backed jackal studies in South Africa, emphasising the need for research in areas where applicable. In the Succulent Karoo black-backed jackal data was found to be lacking, with no previous studies undertaken in small-stock farming areas. The Succulent Karoo, along with the Nama Karoo biome, is the two most important small-stock farming areas in South Africa. In general, Du Plessis *et al.* (2015) concluded that most information on black-backed jackal ecology is dated. The general diet of black-backed jackal in Namaqualand not only included Coleoptera as a main prey item, but also hyrax, striped mouse, Namaqua rock mouse, *Otomys* spp. and lagomorpha. Past studies have emphasised the importance of rodents in jackal diet (Brassine 2011). Kok and Nel (2004) stated that black-backed jackal predation on rodents as a main prey source is mostly limited to certain habitats. As black-backed jackal dietary data is lacking in the Succulent Karoo, we can infer that the current study area is one of the areas where small mammals, primarily rodents, are considered a main prey item of black-backed jackals. Bothma (1966) found that invertebrates contribute the highest percentage to black-backed jackal diet, with rodents and potential carrion also being main prey items. Van der Merwe *et al.* (2009) concluded that rodents occur frequently in jackal diet in the North West province of South Africa. Grafton (1965) analysed black-backed jackal stomach contents obtained mostly from the then Transvaal region. Rodents were once again found to be the main prey item. Avenant and Du Plessis (2008) even reported that black-backed jackal play a vital role in controlling rodent numbers. Small-stock farms often have problems with rodents due to carnivores being lethally persecuted as a result of livestock depredation. On many other farms, such as crop farms which potentially do not practise stock farming, black-backed jackals may be absent due to past persecution. Crop farmers have also been noted to welcome the presence of black-backed jackal on their farms, as they aid with the control of rodents (Beinart 2003; Natrass and Conradie 2013).

Previous studies have found that black-backed jackal utilise larger ungulate species as a main prey item, suggesting that jackals prey on young ungulates or scavenge on carcasses of adult ungulates (Skinner and Chimimba 2005). Klare *et al.* (2010) was the first study in southern Africa to find that large ungulate species made up > 50% of black-backed jackal diet. With most jackal studies only reporting FO and not biomass, ungulate importance in past black-backed jackal diet studies could have been underestimated (Klare *et al.* 2010; Klare *et al.* 2011). Kamler *et al.* (2012) studied black-backed jackal diet on a small-stock farm in the Free State in relation to seasonality and found that in spring, when wild ungulates were fawning, wild ungulate percentage in diet was higher than livestock. Van de Ven *et al.* (2013) studied black-backed jackal diet in the Eastern Cape on a private game reserve. The authors found that large and small ungulates were the main prey items of black-backed jackal. In Namaqualand wild ungulates were consumed more frequently than livestock. Steenbok and duiker, both small ungulate species, were consumed most frequently, followed by springbok. It is not uncommon for springbok to occur in black-backed jackal diet. Both Klare *et al.* (2010) and Kamler *et al.* (2012) found that springbok was the ungulate species most consumed by jackals. Klare *et al.* (2010) also reported a preference for young ungulates by black-backed jackals. Kok (1996) found springbok, gemsbok (*Oryx gazella*), steenbok and duiker as the main prey items in black-backed jackal diet analysed from 321 stomachs collected in the Free State. It is near impossible, with scat analysis and stomach content analysis, to separate scavenging events from hunting events (Kok 1996; Klare *et al.* 2010). Whether black-backed jackal scavenged on these ungulate species in Namaqualand or hunted in groups, pairs or singularly is unknown. The age structure of the wild ungulates is also unknown, but black-backed jackals have a tendency to hunt ungulate fawns (Skinner and Chimimba 2005; Klare *et al.* 2010; Van de Ven *et al.* 2013). Regarding prey preference as calculated using the Jacobs' index, honey badger and hyrax were the prey items most preferred by jackals. Honey badger occurred in very low abundances in the study area, but as a result of occurring in one scat the Jacobs' index calculated a strong preference. Past studies have recommended to only utilise prey items which occur in >5% of the total scats to decrease the probability of encountering high *D*- values for rare prey items (Mann 2014).

Black-backed jackals are infamous killers of livestock and many farmers have labelled them as "vermin", functioning on a shoot-on-sight policy (Du Plessis 2013). In Namaqualand we found livestock to be the mammalian prey class which occured least frequently. However, sheep was the ungulate species occurring most frequently in black-backed jackal diet in Namaqualand and ultimately contributed the bulk to the total biomass consumed. These results could be an overestimation as the age structure of livestock prey is unknown. Sheep also occurred more frequently in the diet than goats; however on the farmlands sheep abundance was higher than goat abundance. Studies in other areas found livestock to feature prominently in jackal diet. Rowe-Rowe (1976) analysed 53 black-backed jackal stomachs collected in western Natal in a nature reserve and on farmlands. On the farmlands sheep was the main prey item occurring in black-backed jackal stomachs, compared to antelope carrion and fresh antelope remains which were more predominant in jackal stomachs collected in the nature reserve. Stuart (1987) also analysed stomach contents, and domestic stock was the second most frequently occurring mammalian prey class found after rodents. However, stomach contents can be cause for a bias towards livestock as samples are often obtained from predator control measures (Stuart 1981; Skinner and Chimimba 2005). In Kamler *et al.* (2012) seasonality was also assessed on a farm and it was found that in the lambing period sheep made up the bulk of black-backed jackal diet. In Namaqualand, livestock was not such an ecologically important prey item to jackals than found in other studies (Kamler *et al.* 2012). However, when assessing biomass sheep contributed the bulk to the total biomass consumed. Our results from Namaqualand suggests that black-backed jackals are responsible for livestock losses in the area, however natural prey still encompasses the bulk of jackal diet in the region.

5.5.2. Namaqua National Park versus surrounding farmlands

In the National Park, Coleoptera was the prey item occurring most frequently in jackal diet. However, Coleoptera occurred in lower frequencies in jackal diet on farmlands compared to other prey sources. Dean and Milton (1995) recorded a loss of beetle availability on cultivated fields. However, the abundance increased with the age of the fields. As a result of human-activity on farmlands in Namaqualand and the use of cultivated fields the coleopteran abundance may be lower on farmlands which in turn influences jackal to select an alternate prey source. However, jackal was also expected to exhibit both diurnal and nocturnal activity patterns in the national park, compared to mostly nocturnal on the farmlands. Most Coleopteran species display diurnal activity patterns (Picker *et al.* 2004), suggesting that as a result of a nocturnal behaviour pattern by jackal on farmlands, beetles were consumed less (Brassine 2011). Small mammals also made up a large percentage of jackal diet in the national park with the diurnal striped mouse and *Otomys* spp. being the two main prey items; similar to Rowe-Rowe (1983). *Otomys* spp. mostly exhibit diurnal activity and sometimes nocturnal activity patterns (de Graaff 1981; Brown and Willan 1991). This further confirms that black-backed jackals display both diurnal and nocturnal activity patterns in Namaqua National Park, according to the prey items consumed (Skinner and Chimimba 2005). On the farmlands Namaqua rock mouse occurred more frequently in jackal diet than in the national park. However, according to small mammal trapping Namaqua rock mouse abundance was lower on farmlands than in the national park. These rodent species are nocturnal and as suggested from past studies black-backed jackals restrict their activity to night-time (Ferguson *et al.* 1988; Skinner and Chimimba 2005). Feeding strategies and activity patterns of black-backed jackals may be altered to compensate for increased persecution in these areas (Skinner and Chimimba 2005). By decreasing possible detection by farmers, black-backed jackals can still persist on farmlands with lowered persecution rates (Ferguson *et al.* 1988). Therefore, their diet too reflects this shift in activity pattern, possibly explaining the higher occurrence of nocturnal species in black-backed jackal diet on farmlands.

Lagomorpha and hyrax were also prey items which occurred frequently in jackal diet. Black-backed jackal is not known to prey on hyrax in such large percentages, but this could indicate that hyrax is a plentiful resource in Namaqualand. Alternatively, hyrax was the main prey item occurring in jackal scats on the farmlands, with a reduced number of rodents found. Small mammal trapping in Namaqualand indicated a lower abundance of rodents on the farmlands than in Namaqua National Park; however more small mammals occurred in jackal scats collected on the farmlands than in the national park. Overgrazing on farmlands can be a cause for the resultant lower occurrence of rodent species on farmlands (Avenant and du Plessis 2008). Historically farmers have noticed an increase in hyrax numbers once carnivore numbers decreased on farms due to persecution (Beinart 2003). Hyrax competes with small stock for grazing resources and is often even considered a pest by many farmers (Wiid and Butler 2015). The camera data suggested that hyrax abundance was higher on the farmlands than in the national park. However, cameras were placed along roads and road networks were limited in the national park, possibly excluding more rocky outcrops when compared to the farmlands. Scorpions and reptiles were the other two non-mammalian prey items which also occurred more frequently in jackal diet in the national park than on the farmlands.

With livestock being consumed on the farmlands and absent in the national park, it is evident that jackals select for livestock, which is an abundant, accessible prey source. Livestock also contributes a substantial amount to total biomass consumed, rather than smaller prey items such as invertebrates and reptiles (Klare *et al.* 2010). It is clear that with the addition of livestock as a prey item in black-backed jackal diet, other natural prey items such as reptiles, invertebrates and even medium-sized ungulates decrease in occurrence. Steenbok was the wild ungulate prey item which contributed the most to total biomass consumed in the national park and was also the most abundant small ungulate in Namaqua National Park. However, on the farmlands duiker was the wild ungulate species which contributed the most to the total biomass consumed; in addition to having a significantly higher abundance than steenbok. Sheep contributed the bulk to the total biomass consumed on the farmlands, but was also the most abundant ungulate prey item on farmlands. While the age structure of livestock prey is unknown, past studies have found black-backed jackals to mostly feed on lambs (Kamler *et al.* 2012). Therefore the biomass estimation of sheep as a prey item may be an overestimation as the correction factor (CF) used was for adult ungulate prey and does not take age structure into account. An intense seasonal dietary study in Namaqualand could provide better insight into which time of the year livestock would be more vulnerable to black-backed jackal predation, increasing the knowledge to provide better solutions to prevent livestock losses. Furthermore this study, in conjunction with past literature on black-backed jackal, confirms that these canids merely prey on the most abundant and easy-to-catch prey source (Skinner and Chimimba 2005; Kamler *et al.* 2012). An increased natural prey base and an increased effort of livestock husbandry methods could decrease livestock losses and potentially deter black-backed jackals from livestock as an alternate prey source on farmlands.

5.6. Conclusion

Black-backed jackals in Namaqualand, Northern Cape, South Africa display a clear opportunistic, omnivorous diet. There was a clear difference in diet when comparing the protected area to the surrounding small-stock farmlands. Diet also varied according to season, as prey availability varied across seasons. Black-backed jackal selected for the most abundant and available prey items in Namaqualand, making them very adaptable. The general diet of jackal was mostly made up of small mammals, medium mammals and invertebrates. Coleoptera, striped mouse, hyrax, Namaqua rock mouse and *Otomys* spp. were the prey items occurring most frequently in jackal diet across the two land-uses and all seasons. However, when correction factors (CF) were taken into account to calculate the total biomass consumed, sheep was the prey item contributing the most to total biomass consumed. The CF does not take age structure into account and as most studies report jackals to mostly prey on lambs, this biomass estimation could be an overestimation. Hyrax is very rarely seen as an important prey item in black-backed jackal diet, but the high occurrence of hyrax in jackal diet in Namaqualand could point to a high abundance of hyrax in the study area. On the farmlands hyrax was the main prey item occurring most frequently in black-backed jackal diet. The increased use of cultivated fields in the study area to provide supplement feed to livestock could also be a drawing factor for hyraxes, increasing their abundance and activity in more open areas. Steenbok, striped mouse and lagomorpha were three prey items which also contributed a substantial amount to the total biomass. According to camera and small mammal trapping, all three of the last mentioned prey items were relatively common in the study area.

Prey items selected for in the national park by black-backed jackals mostly corresponded with a diurnal activity pattern. This illustrates that black-backed jackals are both diurnal and nocturnal in areas where human disturbance is low. Coleoptera were the main prey item in the national park. A higher abundance of Coleoptera were expected in the national park, as cultivated fields have been known to have a negative effect on coleoptera presence. Most Coleoptera species are diurnal, with some coleopterans displaying nocturnal behaviour. The striped mouse and *Otomys* spp. are both diurnal rodents, further suggesting that national park activity of jackals differs to that of farmlands. Rodent abundance was also higher in the national park than on the farmlands. The nocturnal Namaqua rock mouse was the rodent species occurring most frequently in black-backed jackal diet on the farmlands. When assessing biomass sheep was the prey item contributing > 20% of total biomass consumed. Duiker was the wild ungulate contributing the most to biomass consumed on the farmlands, whereas in the national park steenbok contributed the largest percentage to total biomass consumed. Duiker abundance on the farmlands was higher than steenbok abundance.

5.7. References

Adams, L. G., Farley, S. D., Stricker, C. A., Demma, J. D., Roffler, G. H., Miller, D. C., and Rye, R. O. 2010. Are inland wolf-ungulate systems influenced by marine – subsidies of Pacific salmon? *Ecological Applications* **20**: 251-262.

Atkinson, R. P. D., D. W. Macdonald., and R. Kamizola. 2002. Dietary opportunism in side-striped jackals *Canis adustus* Sundevall. *Journal of Zoology* **257**: 129–139.

Avenant, N, L., and Du Plessis, J. J. 2008. Sustainable small stock farming and ecosystem conservation in southern Africa: A role for small mammals? *Mammalia* **72**: 258–263.

Avenant, N. L., and Nel, J. A. J. 2002. Among habitat variation in prey availability and use by caracal *Felis caracal*. *Mammal Biology* **67**: 18–33.

Bacon, M. M., Becic, G. M., Epp, M. T., and Boyce, M. S. 2011. Do GPS Clusters Really Work? Carnivore Diet from Scat Analysis and GPS Telemetry Methods. *Wildlife Society Bulletin* **35**: 409-415.

Bagchi, S., and Mishra, C. 2006. Living with large carnivores: predation on livestock by the snow leopard (*Uncia uncia*). *Journal of Zoology* **268**: 217-224.

Bagniewska, J. M., and Kamler, J. F. 2013. Do black-backed jackals affect numbers of smaller carnivores and prey? *African Journal of Ecology* **52**: 564-567.

Balme, G., Hunter, L., and Slotow, R. 2007. Feeding habitat selection by hunting *leopards Panthera pardus* in a woodland savanna: prey catchability versus abundance. *Animal Behaviour* **74:** 589 – 598.

Beinart, W. 2003. *The rise of conservation in South Africa: settlers, livestock, and the environment 1770-1950*. Oxford: Oxford University Press.

Bergman, D. L., De Waal, H. O., Avenant, N. L., Bodenchuk, M. J., Marlow, M. C., and Nolte, D. L. 2013. The Need to Address Black-backed Jackal and Caracal Predation in South Africa. In: J. B. Armstrong and G. R. Gallagher, eds. 2013. *Proceedings of the 15th Wildlife Damage Management Conference:* South Carolina.

Bothma, J. Du P. 1966. Notes on the stomach contents of certain Carnivora (mammalia) from the Kalahari Gemsbok Park *Koedoe* **9:** 37-39.

Brand, D. J., and Nel, J. A. J. 1997. Avoidance of cyanide guns by black-backed jackal. *Applied Animal Behaviour Science* **55**: 177- 182.

Brassine, M. C. 2011. *The diet and ecological role of black-backed Jackals,* Canis mesomelas*, in two conservation areas in the Eastern Cape Province, South Africa*. Masters thesis, University of Rhodes, South Africa.

Chattha, S. A., Hussain, S. M., Javid, A., Abbas, M. N., Mahmood, S., Barq, M. G., and Hussain, M. 2015. Seasonal Diet Composition of Leopard (*Panthera pardus*) in Machiara National Park, Azad Jammu and Kashmir, Pakistan. *Pakistan Journal of Zoology* **47**: 201 – 207.

Collville, J., Picker, M. D., and Cowling, R. M. 2012. Species turnover of monkey beetles (Scarabaeidae: Hopliini) along environmental and disturbance gradients in the Namaqualand region of the succulent Karoo, South Africa. *Biodiversity and Conservation* **11**: 243–264.

Conradie, B.I., and Piesse, J. 2013. *The effect of predator culling on livestock losses: Ceres, South Africa, 1979 – 1987*. Centre for Social Science Research: University of Cape Town.

De Graaff, G. 1981. *The rodents of southern Africa*. Pretoria: Buttersworth.

Dean, W. R. J., and Milton, S. J. 1995. Plant and invertebrate assemblages on old fields in the arid southern Karoo, South Africa. *African Journal of Ecology* **33**: 1-13.

Do Linh San, E., Malongwe, N. B., Fike, B., Somers, M. J., and Walters, M. 2009. Autumn diet of black-backed jackals (*Canis mesomelas*) in the thicket biome of South Africa. *Wildlife Biology in Practice* **5**: 96-103.

Du Plessis, J. J. 2013. *Towards the development of a sustainable management strategy* for Canis mesomelas *and* Caracal caracal *on rangeland*. Dissertation, University of the Free State, South Africa.

Du Plessis, J. J., Avenant, N. L., and De Waal, H. O. 2015. Quality and quantity of the scientific information available on black-backed jackals and caracals: contributing to human–predator conflict management? *African Journal of Wildlife Research* **45**: 138–157.

Estes, R. D. 2012. *The behaviour guide to African mammals*. Berkely: The University of California Press.

Ferguson, J. W. H., Galpin, J. S., and De Wet, M. J. 1988. Factors affecting the activity patterns of black-backed jackals *Canis mesomelas*. *Journal of Zoology* **214**: 55-69.

Goszczyński, J. 1974. Studies on the food of foxes. *Acta Theriologica*. **19**: 1–18.

Grafton, R. N. 1965. Food of the black-backed jackal: a preliminary report. *Zoologica Africana* **1**: 41 – 53.

Gusset, M., Swarner, M. J., Mponwane, L., Keletile, K., and McNutt, J. W. 2009. Human–wildlife conflict in northern Botswana: livestock predation by Endangered African wild dog *Lycaon pictus* and other carnivores. *Oryx* **43**: 67-72.

Hoffman, M. 2014. *Canis mesomelas*. The IUCN Red List of Threatened Species 2014: e.T3755A46122476 [online] available from: http://dx.doi.org/10.2305/IUCN.UK.2014-1.RLTS.T3755A46122476.en. (accessed 26 October 2015).

Inskip, C., and Zimmerman, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. *Oryx* **43**: 18-34.

Jacobs, J. 1974. Quantitative measurement of food selection: a modification of the forage ratio and Ivlev's electivity index. *Oecologia* **14**:413–417.

Jedrzejewska, B., and Jedrzejewski, W. 1998. P*redation in Vertebrate Communities: The Białowież̇a Primeval Forest as a Case Study*. Germany: Springer.

Kamler, J. F., Foght, J. L., and Collins, K. 2009. Single black-backed jackal (*Canis mesomelas*) kills adult impala (*Aepyceros melampus*) *African Journal of Ecology* **48**: 847–848.

Kamler, J. F., Klare, U., and Macdonald, D. W. 2012. Seasonal diet and prey selection of black-backed jackals on a small-livestock farm in South Africa. *African Journal of Ecology* **50**: 299 – 307.

Kaunda, S. K. K. 2000. Activity patterns of black black-backed jackal at Mokolodi Nature Reserve, Botswana. *South African Journal of Wildlife Research* **30**: 157-162.

Kaunda, S. K. K., and Skinner, J. D. 2003. Black-backed jackal diet at Mokolodi Nature Reserve, Botswana. *African Journal of Ecology* **41**: 39-46.

Klare, U., Kamler, J. F., and Macdonald, D. W. 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* **41**: 294–312.

Klare, U., Kamler, J. F., Stenkewitz, U., Macdonald, D. W. 2010. Diet, prey selection, and predation impact of black-backed jackals in South Africa. *Journal of Wildlife Management* **74**: 1030–1042.

Kok, O. B. 1996. Die dieëtsamestelling van enkele karnivoorsoorte in die Vrystaat, Suid-Afrika. *South African Journal of Science* **92**: 393–398.

Kok, O. B., and Nel, J. A. J. 2004. Convergence and divergence in prey of sympatric canids and felids: opportunism or phylogenetic constraint? *Biological Journal of the Linnean Society* **83:** 527–538.

Lamprecht, J. 1978. On diet, foraging behaviour and interspecific food competition of jackals in the Serengeti National Park, East Africa*. Zeitschrift für Säugetierkunde* **43**: 210-223.

Loveridge, A. J., and Macdonald, D. W. 2003. Niche separation in sympatric jackals (*Canis mesomelas* and *Canis adustus*). *Journal of Zoology* **259**: 143-153.

Loveridge, A. J., and Nel, J. A. J. 2004. Black-backed jackal. In: C. Sillero-Zubiri, M. Hoffman and D. W. Mcdonald, eds. 2004. *Canids: foxes, wolves, jackals and dogs - 2004 status survey and conservation action plan.* Switzerland and United Kingdom: IUCN/SSC Canid Specialist

Group. [online]. Available: http://www.canids.org/cap/index.htm (accessed 12 February 2014).

Loveridge, A. J., Wang, S. W., Frank, L. G., and Seidensticker, J. 2010. People and wild felids: conservation of cats and management of conflicts In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

Mann, G. 2014. Aspects of the ecology of leopards (*Panthera pardus*) in the little Karoo, South Africa. Dissertation, Rhodes University, South Africa.

McKenzie, A. A. 1990. *Co-operative hunting in the black-backed jackal* Canis mesomelas. Dissertation, University of Pretoria, South Africa.

Moehlman, P. D. 1986. Ecology of cooperation in canids. In: D. I. Rubenstein and R. W. Wrangham, eds. 1986. *Ecological Aspects of Social Evolution*. New Jersey: Princeton University Press.

Mucina, L and Rutherford, M.C. eds., 2006. *The vegetation of South Africa, Lesotho and Swaziland.* Pretoria*:* South African National Biodiversity Institute.

Natrass, N., and Conradie, B. 2013. *Jackal Narratives and Predator Control in the Karoo, South Afric*a. Centre for Social Science Research: University of Cape Town.

Nel, J. A. J., Loutit, R., and Bothma, J. Du P. 1997. Prey use by black-backed jackals along a desert coast. *South African Journal of Wildlife Research* **27**: 100-104.

Picker, M. D., Griffiths, C., and Weaving, A. 2004. *Field guide to insects of South Africa*. Cape Town: Struik Nature.

Pyke, G. H., Pulliam, H. R., and Charnov, E. L. 1977. Optimal foraging: a selective review of theory and tests. *The Quarterly Review of Biology* **52**: 137-154.

Rowe-Rowe, D. T. 1976. Food of the black-backed jackal in nature conservation and farming areas in Natal. *African Journal of Ecology* **11**: 345–348.

Rowe-Rowe, D. T. 1983. Black-backed jackal diet in relation to food availability in the Natal Drakensberg. *South African Journal of Wildlife Research* **13**: 17-23.

Skead, C. J. 2011. *Historical incidence of the larger land mammals in the broader Western and Northern Cape provinces*, eds. A. Boshoff, G. Kerley and P. Lloyd. Port Elizabeth: Centre for African Conservation Ecology, Nelson Mandela Metropolitan University.

Skinner, J. D., and Chimimba, C. T. 2005. *The mammals of the southern African subregion.* Cape Town: Cambridge University Press.

Smithers, R. H. N 1971. *The mammals of Botswana*. *Museum Memoirs 4*. Salisbury: Trustees of the National Museums of Rhodesia.

Smithers, R. H. N. 1983. *The mammals of the southern African subregion.* South Africa: University of Pretoria.

Snyman, M.A., 2014. South African goat breeds : Boer goat. Info pack ref. 2014/002. Grootfontein Agricultural Development Institute. [online] http://gadi.agric.za/InfoPacks/2014002%20South%20African%20Goat%20breeds%20-%20Boer%20Goat.pdf (accessed 11 November 2015).

Stadler H. 2006. Historical perspectives on the development of problem animal management in the Cape Province. In: B. Daly, W. Davies-Mostert, S. Evans, Y. Friedmann, N. King, T. Snow and H. Stadler, eds. 2006. *Proceedings of a workshop on holistic management of human-wildlife conflict in the agricultural sector of South Africa*. Johannesburg: Endangered Wildlife Trust.

Stephens, D. W and Krebs, J. R. 1986. *Foraging Theory*. New Jersey: Princeton University Press.

Stuart, C. T. 1981. Notes on the mammalian carnivores of the Cape Province, South Africa. *Bontebok* **1**: 1-58.

Stuart, C. T. 1987. A comparison of the food of the black-backed jackal and caracal. *The Naturalist* **31**: 41–42.

Stuart, C. T., Stuart, T., and Pereboom, V. 2013. Diet of the bat-eared fox (*Otocyon megalotis*), based on scat analysis, on the Western Escarpment, South Africa. *Canid News* **6:** 2 [Online] http://www.canids.org/canidnews/6/Bat-eared_fox_diet_in_South_Africa.pdf (accessed 27 October 2015).

Suryawanshi, K. R., Bhatnagar, Y. V., Redpath, S., and Mishra, C. 2013. People, predators and perceptions: patterns of livestock depredation by snow leopards and wolves. *Journal of Applied Ecology*. **50**: 550-560.

Van de Ven, T. M. F. N., Tamblin, C, J., and Kerley, G. I. H. 2013. Seasonal diet of black-backed jackal in the Eastern Karoo, South Africa. *Journal of Arid Environments* **99**: 23-27.

Van der Merwe, I., Tambling, C. J., Thorn, M., Scott, D. M., Yarnell, R. W., Green, M., Cameron, E. Z., and Bateman, P. W. 2009. An assessment of diet overlap of two mesocarnivores in the North West Province, South Africa. *African Zoology* **44**: 288-291.

Van Deventer, M., and Nel, J. A. J. 2006. Habitat, food, and small mammal community structure in Namaqualand. *Koedoe* **49:** 99-109.

Van Sittert, L. 1998. Keeping the enemy at bay: the extermination of wild carnivora in the Cape Colony, 1889-1910. *Environmental History* **3**: 333-356.

Wiid, R. E., and Butler, H. J. 2015. Population management of rock hyraxes (*Procavia capensis*) in residential areas. *Pest Management Science* **2**:180-8.

Yihune, M., and Bekele, A. 2014. Feeding ecology of the Ethiopian wolf in the Simien Mountains National Park, Ethiopia. *African Journal of Ecology* **52**: 484–490.

5.8. Appendices

Appendix 5A - Prey items recorded in black-backed jackal scat (n=196) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=336). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=196).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 336	Frequency of Occurrence (%)	Number of Occurrences (per scat) n = 196	Corrected Frequency of Occurrence (%)
Large Mammals (>40 kg)		**0**	**0**	**0**	**0**
Medium- to large mammals (10-40 kg)		**21**	**6.25**	**16.16**	**8.24**
Springbok (*Antidorcas marsupialis*)	34.48	4	1.19	2.5	1.28
Baboon (*Papio ursinus*)	25	1	0.30	1	0.51
Duiker (*Sylvicapra grimmia*)	16.1	5	1.49	4.5	2.30
Honey badger (*Mellivora capensis*)	11.7	1	0.30	1	0.51
Steenbok (*Raphicerus campestris*)	11.1	10	2.98	7.16	3.65
Medium mammals (1-10 kg)		**44**	**13.10**	**33.82**	**17.26**
Porcupine (*Hystrix africaeaustralis*)	9.52	1	0.30	0.5	0.26
Bat-eared fox (*Otocyon megalotis*)	3.65	1	0.30	0.5	0.26
Hyrax (*Procavia capensis*)	3.03	26	7.74	19.99	10.20
Cape fox (*Vulpes chama*)	2.75	1	0.30	0.5	0.26
Lagomorpha	2.35	15	4.46	12.33	6.29
Small mammals (<1 kg)		**125**	**37.20**	**78.93**	**40.27**
Yellow Mongoose (*Cynictis*	0.829	2	0.60	1.5	0.77

penicillata)					
Striped Polecat (*Ictonyx striatus*)	0.764	3	0.89	2	1.02
Meerkat (*Suricate suricate*)	0.728	2	0.60	1.25	0.64
Otomys spp.	0.131	25	7.44	15.6	7.96
Common mole-rat (*Cryptomus hottentotus*)	0.089	3	0.89	1.83	0.93
Elephantulus spp	0.058	4	1.19	2.75	1.40
Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	3	0.89	2.33	1.19
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	25	7.44	17.52	8.94
Round-eared sengi (*Macroscelides proboscideus*)	0.038	1	0.30	0.33	0.17
Striped mouse (*Rhabdomys pumillio*)	0.035	34	10.12	19.3	9.85
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	16	4.76	10.36	5.29
Pygmy rock mouse (*Petromyscus collinus*)	0.019	1	0.30	1	0.51
Soricidae	0.011	4	1.19	2.33	1.19
Pygmy mouse (*Mus minutoides*)	0.006	2	0.60	0.83	0.42
Livestock		**17**	**5.10**	**13.58**	**6.93**
Goat (*Capra hircus*)	50	5	1.49	3.83	1.95
Sheep (*Ovis aries*)	40	12	3.57	9.75	4.97
Birds	**1.57**	7	2.08	2.86	1.46
Reptiles		**22**	**6.55**	**7.75**	**3.95**
Tortoise	1.9	7	2.08	2.57	1.31
Lizards	0.006	15	4.46	5.18	2.64
Invertebrates		**80**	**23.81**	**33.83**	**17.26**
Coleoptera	0.004	47	13.99	21.28	10.86
Orthoptera	0.004	1	0.30	0.95	0.48
Diplopoda	0.004	7	2.08	2.99	1.53
Scorpiones	0.004	25	7.44	8.61	4.39
Fruits/seeds	**0.002**	**11**	**3.27**	**4.7**	**2.40**
Vegetation	**0.001**	**6**	**1.79**	**2.65**	**1.35**
Unknown	**-**	**3**	**0.89**	**1.5**	**0.77**

Appendix 5B - Biomass consumed calculated from black-backed jackal scat (n=196) collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Sheep (*Ovis aries*)	40	118	12	3.60	480.00	38.18	425.23	13.79
Hyrax (*Procavia capensis*)	3.03	50	26	7.81	78.78	6.27	390.39	12.66
Steenbok (*Raphicerus campestris*)	11.1	118	10	3	111	8.83	354.35	11.49
Striped mouse (*Rhabdomys pumillio*)	0.035	23	34	10.21	1.19	0.09	234.83	7.61
Lagomorpha	2.35	50	15	4.50	35.25	2.80	225.23	7.30
Duiker (*Sylvicapra grimmia*)	16.1	118	5	1.50	80.50	6.40	177.18	5.74
Goat (*Capra hircus*)	50	118	5	1.50	250	19.89	177.18	5.74
Namaqua Rock Mouse (*Aethomys namaquensis*)	0.047	23	25	7.51	1.18	0.09	172.67	5.60
***Otomys* spp.**	0.131	23	25	7.51	3.28	0.26	172.67	5.60
Springbok (*Antidorcas marsupialis*)	34.48	118	4	1.20	137.92	10.97	141.74	4.60
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	23	16	4.80	0.40	0.03	110.51	3.58
Birds	1.57	35	7	2.10	10.99	0.87	73.57	2.39
Coleoptera	0.004	5	31	9.31	0.12	0.01	46.55	1.51
Lizards	0.006	18	7	2.10	0.04	0	37.84	1.23

Honey Badger (*Mellivora capensis*)	11.7	118	1	0.30	11.70	0.93	35.44	1.15
Baboon (*Papio ursinus*)	25	118	1	0.30	25.00	1.99	35.44	1.15
***Elephantulus* spp**	0.058	23	4	1.20	0.23	0.02	27.63	0.90
Soricidae	0.011	23	4	1.20	0.04	0.00	27.63	0.90
Tortoise	1.9	18	4	1.20	7.60	0.60	21.62	0.70
Striped Polecat (*Ictonyx striatus*)	0.764	23	3	0.90	2.29	0.18	20.72	0.67
Short-tailed gerbil (*Desmodillus auricularis*)	0.052	23	3	0.90	0.16	0.01	20.72	0.67
Common mole-rat (*Cryptomus hottentotus*)	0.089	23	3	0.90	0.27	0.02	20.72	0.67
Bat-eared Fox (*Otocyon megalostis*)	3.65	50	1	0.30	3.65	0.29	15.02	0.49
Cape Fox (*Vulpes chama*)	2.75	50	1	0.30	2.75	0.22	15.02	0.49
Porcupine (*Hystrix africaeaustralis*)	9.52	50	1	0.30	9.52	0.76	15.02	0.49
Suricate (*Suricate suricate*)	0.728	23	2	0.60	1.46	0.12	13.81	0.45
Yellow Mongoose (*Cynictis penicillata*)	0.829	23	2	0.60	1.66	0.13	13.81	0.45
Pygmy mouse (*Mus minutoides*)	0.006	23	2	0.60	0.01	0	13.81	0.45
Scorpiones	0.004	5	9	2.70	0.04	0	13.51	0.44
Fruits/seeds	0.002	14	3	0.90	0.01	0	12.61	0.41

Round-eared sengi (*Macroscelides proboscideus*)	0.038	23	1	0.30	0.04	0	6.91	0.22
Pygmy rock mouse (*Petromyscus collinus*)	0.019	23	1	0.30	0.02	0	6.91	0.22
Diplopoda	0.004	5	3	0.90	0.01	0	4.50	0.15
Vegetation	0.001	4	2	0.60	0	0	2.40	0.08
Orthoptera	0.004	5	1	0.30	0	0	1.50	0.05
Total	216.01	1507	274	82.28	1257.1	100	3084.68	100

[a]From Smithers and Chimimba (2005)

[b] From Goszczynski (1974) and Kamler *et al.* (2012)

[c]Prey weight x Number of kills

[d]Correction factor x Prey item occurrence

Appendix 5C - Prey items recorded in black-backed jackal scat collected in Namaqua National Park, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=182). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=94).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 182	Frequency of Occurrence (%)	Number of Occurrences (per scat) n = 94	Corrected Frequency of Occurrence (%)
Large Mammals (>40 kg)		**0**	**0**	**0**	**0**
Medium- to large mammals (10-40 kg)		**13**	**7.14**	**9.33**	**9.93**
Springbok (*Antidorcas marsupialis*)	34.48	3	1.65	1.50	1.60
Baboon (*Papio ursinus*)	25	0	0.00	0.00	0.00
Duiker (*Sylvicapra grimmia*)	16.1	1	0.55	1.00	1.06
Honey badger (*Mellivora capensis*)	11.7	1	0.55	1.00	1.06
Steenbok (*Raphicerus campestris*)	11.1	8	4.40	5.83	6.20
Medium mammals (1-10 kg)		**21**	**11.54**	**15.83**	**16.84**
Porcupine (*Hystrix africaeaustralis*)	9.52	1	0.55	0.50	0.53
Bat-eared fox (*Otocyon megalotis*)	3.65	0	0.00	0.00	0.00
Hyrax (*Procavia capensis*)	3.03	11	6.04	7.83	8.33
Cape fox (*Vulpes chama*)	2.75	1	0.55	0.50	0.53
Lagomorpha	2.35	8	4.40	7.00	7.45
Small mammals (<1 kg)		**61**	**33.52**	**34.38**	**36.57**
Yellow Mongoose (*Cynictis penicillata*)	0.829	1	0.55	0.50	0.53
Striped Polecat (*Ictonyx striatus*)	0.764	3	1.65	2.00	2.13
Meerkat (*Suricate suricate*)	0.728	2	1.10	1.25	1.33
Otomys spp.	0.131	15	8.24	8.61	9.16
Common mole-rat (*Cryptomus hottentotus*)	0.089	1	0.55	1.00	1.06
Elephantulus spp	0.058	1	0.55	1.00	1.06

Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	1	0.55	0.33	0.35
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	9	4.95	5.86	6.23
Round-eared sengi (*Macroscelides proboscideus*)	0.038	1	0.55	0.33	0.35
Striped mouse (*Rhabdomys pumillio*)	0.035	18	9.89	8.64	9.19
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	7	3.85	3.86	4.11
Pygmy rock mouse (*Petromyscus collinus*)	0.019	0	0	0	0
Soricidae	0.011	1	0.55	0.50	0.53
Pygmy mouse (*Mus minutoides*)	0.006	1	0.55	0.50	0.53
Livestock		**2**	**1.10**	**0.83**	**0.88**
Goat (*Capra hircus*)	50	2	1.10	0.83	0.88
Sheep (*Ovis aries*)	40	0	0	0	0
Birds	**1.57**	**2**	**1.10**	**0.75**	**0.80**
Reptiles		**16**	**8.79**	**5.51**	**5.86**
Tortoise	1.9	4	2.20	1.58	1.68
Lizards	0.006	12	6.59	3.93	4.18
Invertebrates		**56**	**30.77**	**22.78**	**24.23**
Coleoptera	0.004	33	18.13	14.96	15.91
Orthoptera	0.004	3	1.65	0.95	1.01
Diplopoda	0.004	4	2.20	1.83	1.95
Scorpiones	0.004	16	8.79	5.04	5.36
Fruits/seeds	**0.002**	**6**	**3.30**	**2.32**	**2.47**
Vegetation	**0.001**	**3**	**1.65**	**1.16**	**1.23**
Unknown	**-**	**2**	**1.10**	**1.00**	**1.06**

Appendix 5D - Prey items recorded in black-backed jackal scat collected on farmlands in Namaqualand, Northern Cape, South Africa. Frequency of occurrence (%) was calculated as the number of occurrences of each prey item divided by the total number of occurrences (n=156). Corrected frequency of occurrence (%) was calculated as the number of occurrences per scat divided by the total number of scats collected (n=102).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 156	Frequency of Occurrence (%)	Number of Occurrences (per scat) n = 102	Corrected Frequency of Occurrence (%)
Large Mammals (>40 kg)		**0**	**0**	**0**	**0**
Medium- to large mammals (10-40 kg)		**8**	**5.13**	**6.83**	**6.70**
Springbok (*Antidorcas marsupialis*)	34.48	1	0.64	1	0.98
Baboon (*Papio ursinus*)	25	1	0.64	1	0.98
Duiker (*Sylvicapra grimmia*)	16.1	4	2.56	3.50	3.43
Honey badger (*Mellivora capensis*)	11.7	0	0	0	0
Steenbok (*Raphicerus campestris*)	11.1	2	1.28	1.33	1.30
Medium mammals (1-10 kg)		**23**	**14.74**	**17.99**	**17.64**
Porcupine (*Hystrix africaeaustralis*)	9.52	0	0	0	0
Bat-eared fox (*Otocyon megalotis*)	3.65	1	0.64	0.50	0.49
Hyrax (*Procavia capensis*)	3.03	15	9.62	12.16	11.92
Cape fox (*Vulpes chama*)	2.75	0	0	0	0
Lagomorpha	2.35	7	4.49	5.33	5.23
Small mammals (<1 kg)		**64**	**41.03**	**43.68**	**42.82**
Yellow Mongoose (*Cynictis penicillata*)	0.829	1	0.64	1.00	0.98
Striped Polecat (*Ictonyx striatus*)	0.764	0	0	0	0
Meerkat (*Suricate suricate*)	0.728	0	0	0	0
Otomys spp.	0.131	10	6.41	6.99	6.85
Common mole-rat (*Cryptomus hottentotus*)	0.089	2	1.28	0.83	0.81
Elephantulus spp	0.058	3	1.92	1.75	1.72

Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	2	1.28	2	1.96
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	16	10.26	11.66	11.43
Round-eared sengi (*Macroscelides proboscideus*)	0.038	0	0	0	0
Striped mouse (*Rhabdomys pumillio*)	0.035	16	10.26	10.66	10.45
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	9	5.77	6.50	6.37
Pygmy rock mouse (*Petromyscus collinus*)	0.019	1	0.64	1	0.98
Soricidae	0.011	3	1.92	1.83	1.79
Pygmy mouse (*Mus minutoides*)	0.006	1	0.64	0.33	0.32
Livestock		**15**	**9.62**	**12.75**	**12.6**
Goat (*Capra hircus*)	50	3	1.92	3	2.94
Sheep (*Ovis aries*)	40	12	7.69	9.75	9.56
Birds	**1.57**	**5**	**3.21**	**2.16**	**2.12**
Reptiles		**6**	**3.85**	**2.15**	**2.11**
Tortoise	1.9	3	1.92	0.99	0.97
Lizards	0.006	3	1.92	1.16	1.14
Invertebrates		**26**	**16.67**	**11.05**	**10.83**
Coleoptera	0.004	14	8.97	6.32	6.20
Orthoptera	0.004	0	0.00	0.33	0.32
Diplopoda	0.004	3	1.92	1.16	1.14
Scorpiones	0.004	9	5.77	3.24	3.18
Fruits/seeds	**0.002**	**5**	**3.21**	**2.38**	**2.33**
Vegetation	**0.001**	**3**	**1.92**	**1.49**	**1.46**
Unknown	**-**	**1**	**0.64**	**0.50**	**0.49**

Appendix 5E - Biomass consumed calculated from black-backed jackal scat (n=94) collected in Namaqua National Park, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Steenbok (*Raphicarus campestris*)	11.1	118	8	5.59	88.80	22.12	660.14	20.32
Hyrax (*Procavia capensis*)	3.03	50	11	7.69	33.33	8.30	384.62	11.84
Striped mouse (*Rhabdomys pumillio*)	0.035	23	18	12.59	0.63	0.16	289.51	8.91
Lagomorpha	2.35	50	8	5.59	18.80	4.68	279.72	8.61
Springbok (*Antidorcas marsupialis*)	34.48	118	3	2.10	103.44	25.77	247.55	7.62
***Otomys* spp.**	0.131	23	15	10.49	1.97	0.49	241.26	7.43
Goat (*Capra hircus*)	50	118	2	1.40	100.00	24.91	165.03	5.08
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	23	9	6.29	0.42	0.11	144.76	4.46
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	23	7	4.90	0.18	0.04	112.59	3.47
Coleoptera	0.004	5	24	16.78	0.10	0.02	83.92	2.58
Honey badger (*Mellivora*	11.7	118	1	0.70	11.70	2.91	82.52	2.54

capensis)								
Duiker (*Sylvicapra grimmia*)	16.1	118	1	0.70	16.10	4.01	82.52	2.54
Lizards	0.006	18	6	4.20	0.04	0.01	75.52	2.32
Birds	1.57	35	2	1.40	3.14	0.78	48.95	1.51
Striped polecat (*Ictonyx striatus*)	0.764	23	3	2.10	2.29	0.57	48.25	1.49
Tortoise	1.9	18	3	2.10	5.70	1.42	37.76	1.16
Cape fox (*Vulpes chama*)	2.75	50	1	0.70	2.75	0.68	34.97	1.08
Porcupine (*Hystrix africaeaustralis*)	9.52	50	1	0.70	9.52	2.37	34.97	1.08
Meerkat (*Suricate suricate*)	0.728	23	2	1.40	1.46	0.36	32.17	0.99
Fruits/seeds	0.002	14	2	1.40	0.00	0.00	19.58	0.60
Yellow mongoose (*Cynictis penicillata*)	0.829	23	1	0.70	0.83	0.21	16.08	0.50
***Elephantulus* spp**	0.058	23	1	0.70	0.06	0.01	16.08	0.50
Round-eared sengi (*Macroscelides proboscideus*)	0.038	23	1	0.70	0.04	0.01	16.08	0.50
Soricidae	0.011	23	1	0.70	0.01	0.00	16.08	0.50
Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	23	1	0.70	0.05	0.01	16.08	0.50

Common mole-rat (*Cryptomus hottentotus*)	0.089	23	1	0.70	0.09	0.02	16.08	0.50
Pygmy mouse (*Mus minutoides*)	0.006	23	1	0.70	0.01	0.00	16.08	0.50
Scorpiones	0.004	5	4	2.80	0.02	0.00	13.99	0.43
Diplopoda	0.004	5	2	1.40	0.01	0.00	6.99	0.22
Vegetation	0.001	4	2	1.40	0.00	0.00	5.59	0.17
Orthoptera	0.004	5	1	0.70	0.00	0.00	3.50	0.11
Bat-eared Fox (*Otocyon megalotis*)	3.65	50	0	0	0.00	0.00	0	0
Baboon (*Papio ursinus*)	25	118	0	0	0.00	0.00	0	0
Pygmy rock mouse (*Petromyscus collinus*)	0.019	23	0	0	0.00	0.00	0	0
Sheep (*Ovis aries*)	40	118	0	0	0.00	0.00	0	0
Total	**226.007**	**1507**	**143**	**100**	**401.47**	**100**	**3248.95**	**100**

[a]From Smithers and Chimimba (2005)
[b] From Goszczynski (1974) and Kamler *et al.* (2012)
[c]Prey weight x Number of kills
[d]Correction factor x Prey item occurrence

Appendix 5F - Biomass consumed calculated from black-backed jackal scat (n=102) collected on farmlands in Namaqualand, Northern Cape, South Africa. Both the biomass consumed and the total biomass consumed is presented.

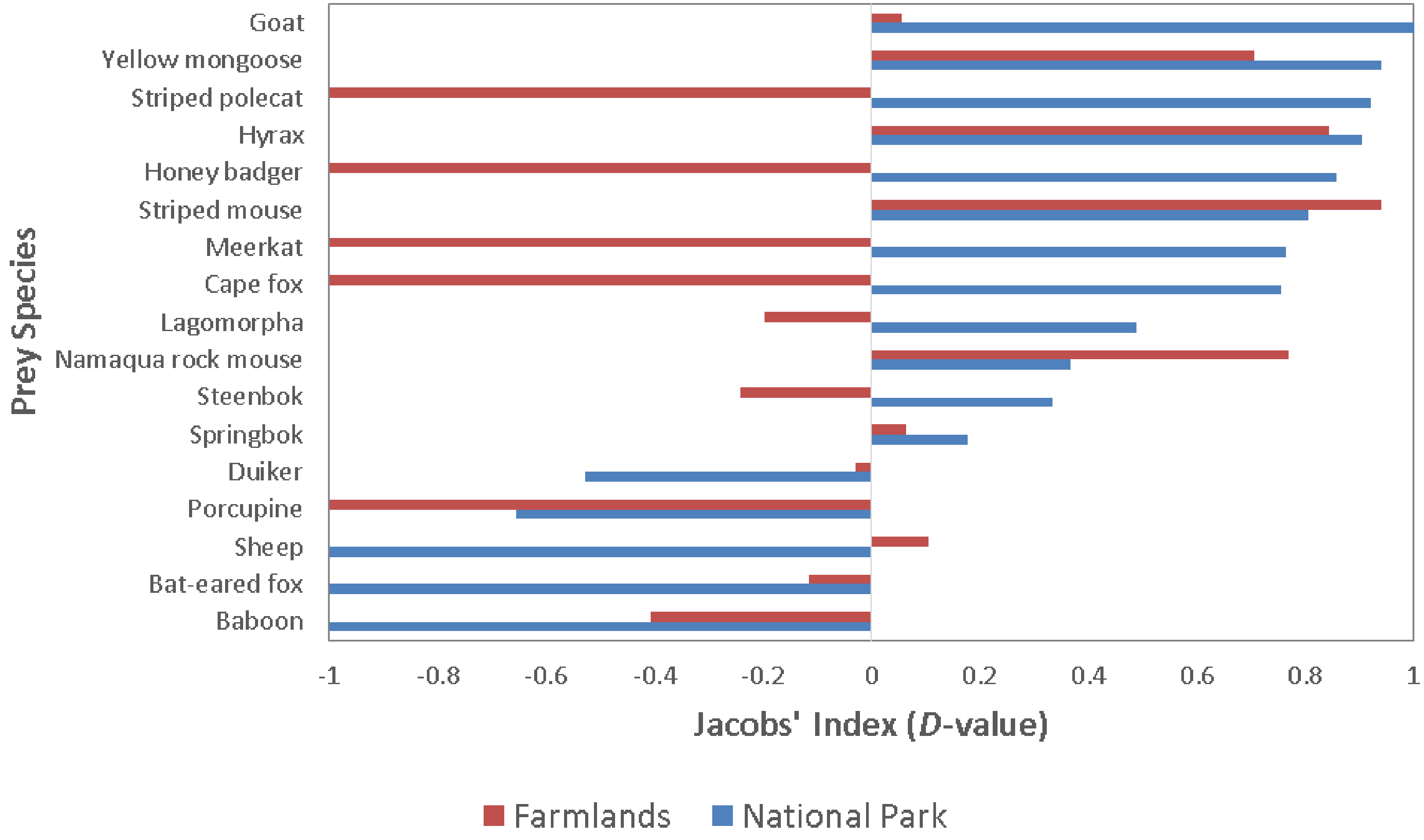
Prey Item	Prey Weight (kg)[a]	Correction factor (kg/scat)[b]	Number of Occurrences (n=177)	Prey item occurrence	Biomass consumed (kg)[c]	Biomass consumed as % of all scats	Total biomass consumed (kg)[d]	Relative biomass consumed (%)
Sheep (*Ovis aries*)	40	118	12	9.16	480.00	56.10	1080.92	25.17
Hyrax (*Procavia capensis*)	3.03	50	15	11.45	45.45	5.31	572.52	13.33
Duiker (*Sylvicapra grimmia*)	16.1	118	4	3.05	64.40	7.53	360.31	8.39
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	23	16	12.21	0.75	0.09	280.92	6.54
Striped mouse (*Rhabdomys pumillio*)	0.035	23	16	12.21	0.56	0.07	280.92	6.54
Goat (*Capra hircus*)	50	118	3	2.29	150.00	17.53	270.23	6.29
Lagomorpha	2.35	50	7	5.34	16.45	1.92	267.18	6.22
Steenbok (*Raphicerus campestris*)	11.1	118	2	1.53	22.20	2.59	180.15	4.19
***Otomys* spp.**	0.131	23	10	7.63	1.31	0.15	175.57	4.09
Hairy-footed gerbil (*Gerbillurus paeba*)	0.025	23	9	6.87	0.23	0.03	158.02	3.68
Birds	1.57	35	5	3.82	7.85	0.92	133.59	3.11

Springbok (*Antidorcas marsupialis*)	34.48	118	1	0.76	34.48	4.03	90.08	2.10
Baboon (*Papio ursinus*)	25	118	1	0.76	25.00	2.92	90.08	2.10
***Elephantulus* spp**	0.058	23	3	2.29	0.17	0.02	52.67	1.23
Soricidae	0.011	23	3	2.29	0.03	0.00	52.67	1.23
Bat-eared Fox (*Otocyon megalotis*)	3.65	50	1	0.76	3.65	0.43	38.17	0.89
Cape short-eared gerbil (*Desmodillus auricularis*)	0.052	23	2	1.53	0.10	0.01	35.11	0.82
Common mole-rat (*Cryptomus hottentotus*)	0.089	23	2	1.53	0.18	0.02	35.11	0.82
Coleoptera	0.004	5	7	5.34	0.03	0.00	26.72	0.62
Scorpiones	0.004	5	5	3.82	0.02	0.00	19.08	0.44
Yellow mongoose (*Cynictis penicillata*)	0.829	23	1	0.76	0.83	0.10	17.56	0.41
Pygmy mouse (*Mus minutoides*)	0.006	23	1	0.76	0.01	0.00	17.56	0.41
Pygmy rock mouse (*Petromyscus collinus*)	0.019	23	1	0.76	0.02	0.00	17.56	0.41
Tortoise	1.9	18	1	0.76	1.90	0.22	13.74	0.32

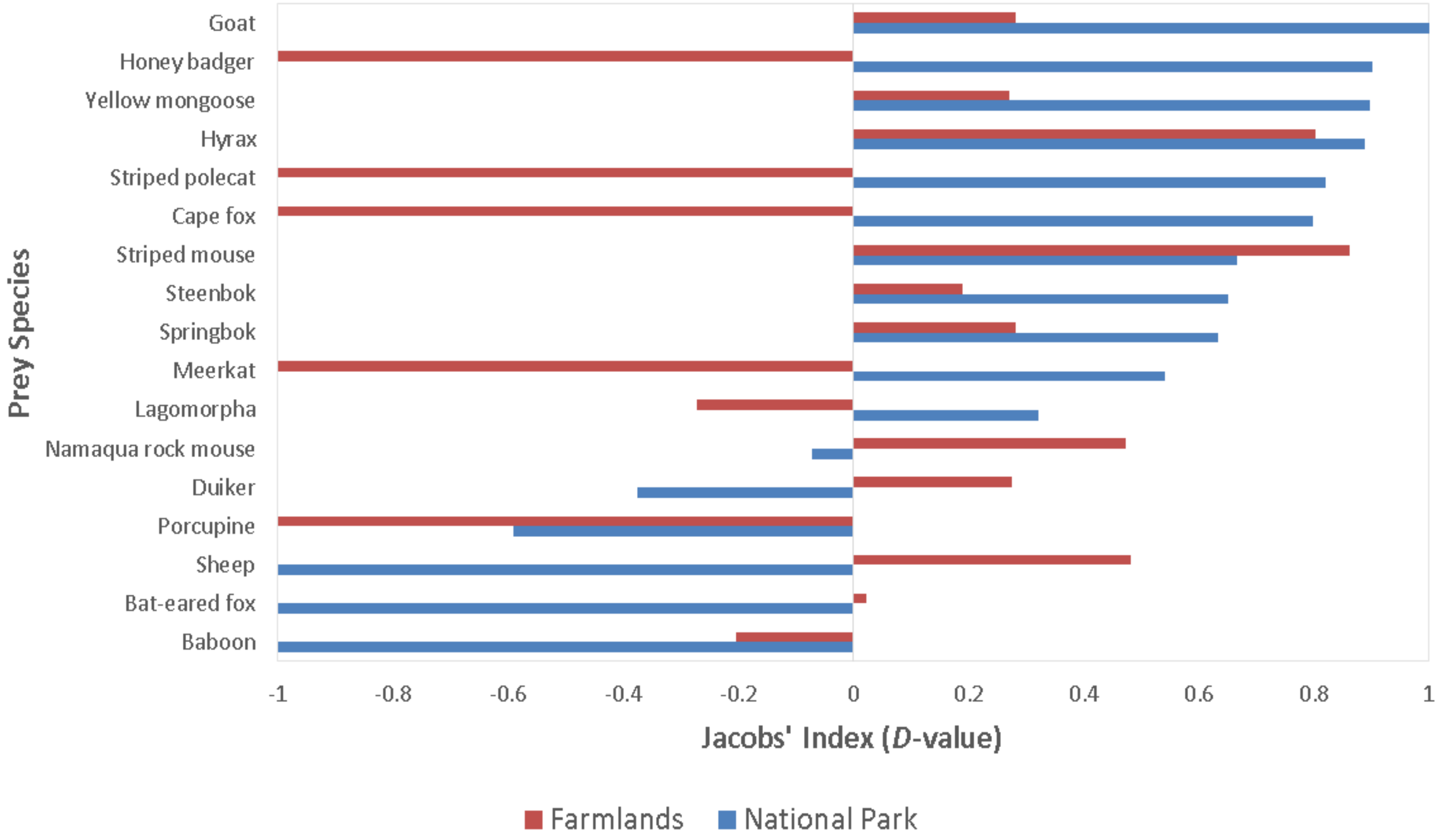
Lizards	0.006	18	1	0.76	0.01	0.00	13.74	0.32
Fruits/seeds	0.002	14	1	0.76	0.00	0.00	10.69	0.25
Diplopoda	0.004	5	1	0.76	0.00	0.00	3.82	0.09
Cape fox(*Vulpes chama*)	2.75	50	0	0.00	0.00	0.00	0.00	0.00
Striped Polecat (*Ictonyx striatus*)	0.764	23	0	0.00	0.00	0.00	0.00	0.00
Honey badger (*Mellivora capensis*)	11.7	118	0	0.00	0.00	0.00	0.00	0.00
Meerkat (*Suricate suricate*)	0.728	23	0	0.00	0.00	0.00	0.00	0.00
Porcupine (*Hystrix africaeaustralis*)	9.52	50	0	0.00	0.00	0.00	0.00	0.00
Round-eared sengi (*Macroscelides proboscideus*)	0.038	23	0	0.00	0.00	0.00	0.00	0.00
Orthoptera	0.004	5	0	0.00	0.00	0.00	0.00	0.00
Vegetation	0.001	4	0	0.00	0.00	0.00	0.00	0.00
Total	**226.007**	**1507**	**131**	**100**	**855.63**	**100.00**	**4294.66**	**100**

[a]From Smithers and Chimimba (2005)
[b] From Goszczynski (1974) and Kamler *et al.* (2012)
[c]Prey weight x Number of kills
[d]Correction factor x Prey item occurrence

Appendix 5G- Jacobs' Index (D-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqua National Park and the surrounding farmlands in black-backed jackal diet. The corrected frequency of occurrence (%) was used to calculate the D-values illustrated.



Appendix 5H - Jacobs' Index (D-value) showing preference (+ 1) and avoidance (- 1) for prey species in Namaqua National Park and the surrounding farmlands in black-backed jackal diet. The biomass was used to calculate the D-values illustrated.



Appendix 5I - Jacobs' index (*D*-value) of all prey items found in black-backed jackal scats collected in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. The corrected frequency of occurrence (CFO) used in Jacobs' index calculation and the biomass consumed is included.

Prey species	RAI (%)	CFO (%)	Jacobs' Index (*D*)[a]	Biomass (%)	Jacobs' index (*D*)[b]
Striped mouse	1.35	18.36	0.89	9.53	0.77
Honey badger	0.07	0.95	0.87	1.44	0.91
Hyrax	1.78	19.01	0.86	15.85	0.82
Striped polecat	0.24	1.90	0.78	0.84	0.55
Yellow mongoose	0.21	1.43	0.74	0.56	0.45
Namaqua rock mouse	4.34	16.67	0.63	7.01	0.25
Meerkat	0.30	1.19	0.60	0.56	0.30
Cape fox	0.24	0.48	0.33	0.61	0.44
Steenbok	4.57	6.81	0.21	14.39	0.56
Springbok	1.73	2.38	0.16	5.75	0.55
Goat	3.13	3.64	0.08	7.19	0.41
Lagomorpha	10.61	11.73	0.06	9.14	-0.08
Sheep	9.42	9.27	-0.01	17.26	0.33
Duiker	6.34	4.28	-0.20	7.19	0.07
Bat-eared fox	1.11	0.48	-0.40	0.61	-0.29
Baboon	4.27	0.95	-0.65	1.44	-0.51
Porcupine	4.36	0.48	-0.81	0.61	-0.76
Klipspringer	1.95	0	-1	0	-1
Aardwolf	1.66	0	-1	0	-1
African wildcat	0.96	0	-1	0	-1
Black-backed jackal	0.96	0	-1	0	-1
Aardvark	0.65	0	-1	0	-1
Caracal	1.81	0	-1	0	-1
Cattle	2.92	0	-1	0	-1
Donkey	0.64	0	-1	0	-1
Grey mongoose	0.37	0	-1	0	-1
Honey badger	0.07	0	-1	0	-1
Horse	0.19	0	-1	0	-1
Oryx	3.87	0	-1	0	-1
Porcupine	4.36	0	-1	0	-1
Red hartebeest	0.46	0	-1	0	-1
Small spotted genet	0.21	0	-1	0	-1

[a] D-values are based on CFO (%) of prey items from leopard scat.

[b] D-values are based on the total biomass consumed of prey items from leopard scat.

Chapter 6: Caracal (*Caracal caracal*) diet: scat analysis or GPS cluster visitation?

6.1. Abstract

The caracal (*Caracal caracal*) is the largest of Africa's small felids (< 20kg). Across much of Africa particularly where larger predators have been extirpated caracal are one of the main carnivores blamed for livestock predation. Caracal dietary studies are outdated with no studies in the Succulent Karoo and little research on small livestock farms. Studies on the diet of caracal and other small carnivores in Africa have relied on scat analysis with no study making use of Global Positioning System (GPS) cluster visitation. This study used a combination of scat analysis and GPS cluster visitations to estimate caracal diet in Namaqualand, Succulent Karoo biome. Based on both methods rock hyrax (*Procavia capensis*) was the main prey source for caracal in Namaqualand. Small mammals accounted for > 25% of the total biomass consumed by caracal according to scat analysis, however, this prey class was absent from GPS cluster analysis. Sheep (*Ovis aries*) biomass consumed was much higher (59.5%) according to the GPS cluster method compared to only 5% as concluded from scats analysed. Wild medium-to-large mammalian prey items were comparable between the two methods, with little variation observed. GPS telemetry data was biased towards large domestic prey not consumed entirely by caracal and did not detect small prey items (< 1 kg), but could provide valuable information regarding individual diet and kill rates of livestock and large wild prey. Scat analysis provided a broader representation of caracal diet, but scat investigations underestimated large prey because caracals ingest only small amounts of hair from large-bodied animals. I recommend a combination of GPS cluster visitation and scat analysis to determine caracal diet across a range of prey sizes.

6.2. Introduction

Historically various felid species have been in conflict with humans (Van Sittert 1998; Loveridge, Wang, Frank and Seidensticker 2010). With continuing increase in human populations, conflict between humans and felids is bound to increase even further (Inskip and Zimmerman 2009). Human-wildlife conflict (HWC) usually arises in areas where humans and wildlife compete for the same resources, such as space and food (Pettigrew *et al.* 2012). Felids are prone to HWC due to large home ranges and space requirements, high dietary needs and in some cases opportunistic feeding behaviour which enables them to persist on landscapes with human use (Cardillo *et al.* 2005; Inskip and Zimmerman 2009; Loveridge *et al.* 2010). Human-felid conflict occurs either when these cats predate on livestock hunted game species or fatally attack humans (Linnell *et al.* 1999; Ogada, Woodroffe, Oguge and Frank 2003; Inskip and Zimmerman 2009). Larger felids (> 50 kg) are responsible for losses of both larger-bodied livestock and smaller stock, as well as for fatal attacks on humans (Loveridge *et al.* 2010). Caracal, being considered small to medium-sized felids, along with the Eurasian lynx (*Lynx lynx*) can also cause great damage to small livestock farmers (Moolman 1984; Stahl, Vandel, Herrenschmidt and Migot 2001; Loveridge *et al.* 2010). In South Africa, encounters between farmers and caracal have mostly been negative (Beinart 2003). In the nineteenth century various carnivores, including caracal, were considered 'vermin' by the government (Van Sittert 1998). Subsidised control programs, which included dog hunting and poison clubs, were put into place and from 1914 – 1923 more than 25 000 caracals were killed (Beinart 2003; Bergman *et al.* 2013).

The caracal is a solitary felid and the largest of the smaller felids, with males weighing up to 15 kg and females up to 12 kg (Skinner and Chimimba 2005). Caracal are widespread throughout the African continent, occurring in the entire Southern African region and extending to Ethiopia, Somalia, Sudan, northern Niger, Mauritania, the Northern margins of the Sahara Desert and Morocco (Stuart 1982, Smith 2012). Their distribution also extends into parts of South Asia most notably the Middle East and certain areas of Armenia, Pakistan and India (Stuart 1982; Nowell and Jackson 1996). Caracal are categorised by the International Union for Conservation of Nature (IUCN) as "Least Concern" (Breitenmoser-Wursten, Henschel and Sogbohossou 2008). They are common throughout their distribution; however increasing anthropogenic pressures in Asia have led to population declines and the protection of some caracal populations (Ray, Hunter and Zigouris 2005). The success of these felids across a wide range of habitats can be attributed to their secretive nature, ability to exhibit both diurnal and nocturnal activity patterns and their generalist feeding behaviour (Stuart 1982; Avenant and Nel 1998; Ileman and Gürkan 2010; Estes 2012). Being efficient hunters, caracals will only scavenge when resources are limited (Skinner and Chimimba 2005). Their diet can range from arthropods to mammals weighing up to 31 kg (Grobler 1981; Moolman 1984; Palmer And Fairall 1988; Avenant and Nel 2002; Braczkowski *et al.* 2012a). Caracal have been reported to mostly prefer small- to medium sized mammalian prey, but a preference for birds as prey items has also been recorded (Stuart and Hickman 1991; Skinner and Chimimba 2005). As opportunistic predators, caracal select for prey high in abundance and readily available (Avenant and Nel 1997; Avenant and Nel 2002; Du Plessis, Avenant and De Waal 2015). This characteristic has made caracal one of the prime culprits for livestock predation (Du Plessis *et al.* 2015).

Management of damage-causing animals in South Africa, especially caracal and the black-backed jackal (*Canis mesomelas*), is often conducted on assumptions and traditional knowledge, with little scientific evidence contributing to management decisions (Avenant and Du Plessis 2008). Historically and still today, the belief has been that lethal persecution of these carnivores would decrease livestock losses. This belief has led to country-wide lethal control programs, with many not being monitored by the government (Avenant and Du Plessis 2008; Du Plessis *et al.* 2015). Bailey and Conradie (2013) reported that lethal persecution of caracal in some regions increased livestock losses experienced the following year. Past studies on coyote (*Canis latrans*) and other carnivores have found an increase in predator densities with increased lethal and indiscriminate control methods (Knowlton, Gese and Jaeger 1999; Avenant and Du Plessis 2008). The need to understand the ecology of damage-causing animals in Africa has been emphasised in various past studies (Avenant and Du Plessis 2008; Bergman *et al.* 2013; Du Plessis *et al.* 2015). The ecology of predators can be influenced by various factors, but prey availability plays a vital role (Balme, Hunter and Slotow 2007). Many opportunistic predators will shift their diet to select for available prey items when a suitable prey range is unavailable (Kok and Nel 2004; Loveridge *et al.* 2010; Pettigrew *et al.* 2012). Most carnivore studies have been carried out in the confines of protected areas with very few studies focusing on the ecology of carnivores outside protected land (Balme, Lindsey, Swanepoel and Hunter 2013; Du Plessis *et al.* 2015). Caracal diet studies on small stock farms, where these predators are believed to be responsible for large stock losses, are currently lacking and especially so in the Succulent Karoo biome (Bergman *et al.* 2013; Du Plessis *et al.* 2015). Studying the foraging ecology of these animals on both farmlands and in a national park will provide valuable insight to understanding caracal ecology under different conditions and how small stock farming has altered their foraging behaviour.

Previous caracal dietary studies used the highly invasive method of stomach content analysis, or alternatively the non-invasive means of scat analysis (Grobler 1981; Stuart 1982; Moolman 1984; Plamer and Fairall 1988; Avenant and Nel 1997; Avenant and Nel 2002; Braczkowski *et al.* 2012a). Hair identified from scats, bone fragments and other prey remains are used in scat analysis to identify prey items in a predator's diet (Ciucci *et al.* 1996; Klare, Kamler and Macdonald 2011). Scat analysis can overestimate the importance of smaller prey items, such as rodents and invertebrates, in a predator's diet (Klare *et al.* 2011). However, data analysis methods have been developed to decrease such biases (Ciucci *et al.* 1996; Marucco, Pletscher and Boitani 2008; Klare *et al.* 2011). Other methods used in dietary investigations include stable isotope and fatty acid analyses (Iverson, Field, Bowen and Blanchard 2004; Thompson *et al.* 2005; Bacon, Becic, Epp and Boyce 2011) but these cannot typically differentiate species-specific prey items for complex multi-prey systems. For larger predators VHF (Very High Frequency) radio-collars have also been used to locate kill sites and to then analyse prey remains collected at such sites (Norton and Lawson 1985; Beier, Choate and Barrett 1995). However, such methods have not been used in the past for medium-sized carnivores due to smaller prey items consumed by predators in this size class (Svoboda *et al.* 2013). Global Positioning System (GPS) technology has proven to be a useful tool for the advancement of carnivore research (Cagnacci, Boitani, Powell and Boyce 2010). GPS radio-collars have increased the accuracy of kill site identification (Bacon *et al.* 2011; Martins *et al.* 2011) as well as providing valuable insight into other aspects of carnivore ecology including movement (Martins and Harris 2013; Odden, Athreya, Rattan and Linnell 2014) and habitat selection (Knopff, Knopff, Bouyce and St. Clair 2014; Cristescu, Stenhouse and Boyce 2015a; Fattebert *et al.* 2015). Svoboda *et al.* (2013) is one of the few studies wherein GPS radio-collars have been used to determine and visit kill sites of medium-sized carnivores. The use of GPS cluster visitation as a method to estimate carnivore diet has been reported to be biased toward larger prey items (Tambling *et al.* 2012; Clark, Davidson, Johnson and Anthony 2014; Pitman, Swanepoel and Ramsay 2012). Studies in South Africa which utilised GPS clusters to determine carnivore diet have been restricted to large carnivores, such as leopards and lions (Tambling, Cameron, du Toit and Getz 2010; Martins *et al.* 2011; Pitman *et al.* 2012). The use of the GPS cluster technique for caracal diet assessment has not been tested or compared to the non-invasive scat analysis method.

6.2.1. Aims and Objectives

The main objective of this chapter was to investigate caracal diet as sampled across two land-uses; a protected area and surrounding small stock farms, as well as to compare diet estimation outputs from GPS cluster visitation and scat analysis. Using prey availability data collected simultaneously with predator diet records, I also tested whether caracal fed opportunistically (in accordance to prey availability), or selected specific prey (consuming it more than available). We hypothesis that the methods of sampling (scat versus GPS kill sites) will influence the outcome of caracal diet in the study area.

6.3. Methods

6.3.1. Study Area

This study was conducted in Succulent Karoo on commercial livestock farms neighbouring Namaqua National Park (S30. 16627 E017. 79619) and the Eastern section of the park. Farming occurs mostly with sheep and goats, with cattle raised to a lower extent. The 810 km² study area is part of the Namaqualand District, Northern Cape, South Africa. The study period commenced in March 2014 and ended in April 2015. For a full description of the study area see Chapter 1, section 1.5.

6.3.2. Data Collection

For an in-depth description of scat collection see Chapter 2, section 2.1.1. More information regarding caracal capture and immobilisation can be found in Chapter 2, section 2.1.2. Please also refer to Chapter 2, section 2.1.3 for a description of methods regarding GPS cluster visitation. For prey abundance estimation through camera trapping and small mammal trapping see Chapter 2, section 2.1.4 and section 2.1.5 respectively.

6.3.3. Data Analysis

6.3.3.1. Diet Estimation through Scat Analysis

For scat washing and analysing methodology see Chapter 2, section 2.2.1.

The frequency of occurrence (per prey item) [FO], corrected frequency of occurrence (frequency of occurrence per scat) [CFO] and percentage biomass were calculated. For a more in-depth description of FO and CFO refer to Chapters 2, section 2.2.1. A description of biomass calculation models (BCM) as used to determine biomass consumed by caracal can be found at Chapter 4, section 4.3.3.1.

6.3.3.2. Diet Estimation through GPS Radio-collar Cluster Visitation

For a more in-depth description of FO and CFO refer to Chapters 2, section 2.2.1. For more information on biomass estimation through GPS radio-collar cluster visitation please refer to Chapter 2, section 2.2.2.

6.3.3.3. Prey Preference Analysis

See Chapter 2, section 2.2.3 for more information.

6.3.4. Statistical Analysis

For analysis of diet as compared between scat and GPS radio-collar cluster visitation please refer to Chapter 2, section 2.3.2 and for prey abundance and preference statistical analysis from camera trap and small mammal data please refer to Chapter 2, section 2.3.3.

6.4. Results

6.4.1. Diet Estimation through Scat Analysis

For a full report on caracal diet estimated from scat analysis see Chapter 4, section 4.4.

6.4.2. Diet Estimation through GPS Radio-collar Cluster Visitation

From the 421 caracal GPS cluster sites visited between March 2014 and April 2015, prey remains were located at 91 sites where prey remains were found, resulting in a low success rate of identifying kills sites at GPS cluster visitations (21.6%). From the kill sites visited 7 prey species and 8 cases of "unknown" prey items were recorded. The main prey items which were recorded at kill sites were rock hyrax (39.6%), sheep (25.3%) and lagomorpha (pooled hares and rabbits) (15.4%) (Table 6.1). No small mammals (weighing < 1 kg) were recorded at kill sites; however one unknown small mammal was observed once (1.1%). Medium mammals were identified from hair remains that were found, or the rumen and digestive remains. Caracals consumed virtually the entire prey item when weighing < 4 kg. Ungulate remains were easily identified in the field, especially livestock remains, where caracals typically either fed on the hind-quarters, at the shoulder or at times on both these areas of the animal.

The biomass consumed at all kill sites investigated was 1069.2 kg, but when biomass was corrected to account for only a certain percentage of carcass consumed the total biomass consumed was 564.4 kg kg (Table 6.2). Sheep (59.5%) and hyrax (17.4%) contributed the bulk (> 70%) to total biomass consumed. Goat (subadult) was the largest prey item identified at kill sites. Despite adult sheep recorded at kill sites, the weight of these animals was still less than the weight of a subadult goat. The age for sheep remains was primarily YoY (> 60%) and occurring at 18.1% of all kill sites. The smallest prey items which could be identified from observed prey remains were lagomorpha. In the case of prey item weighing < 4.5 kg 90% of the total prey was consumed by caracals.

Table 6.1 Prey items recorded from GPS cluster visitations in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. FO (%) was calculated as the number of occurrences of the respective prey item across kill sites divided by the total number of kill sites identified (n=91).

Prey Item	Prey Weight (kg)	Number of Occurrences (prey items) n = 91	FO (%)
Medium- to large mammals (10-40 kg)		**5**	**5.5**
Duiker (*Raphicerus campestris*)	16.1	3	3.3
Klipspringer (*Oreotragus oreotragus*)	11.9	1	1.1
Unknown ungulate		1	1.1
Medium mammals (1-10 kg)		**53**	**58.2**
African wildcat (*Felis silvestris*)	4.25	1	1.1
Hyrax (*Procavia capensis*)	3.03	36	39.6
Lagomorpha	2.35	14	15.4
Unknown medium mammal		2	2.2
Small mammals (<1 kg)		**1**	**1.1**
Unknown small mammal		1	1.1
Livestock		**26**	**28.6**
Goat (*Capra hircus*)	50	3	3.3
Sheep (*Ovis aries*)	40	23	25.3
Birds	**1.57**	**2**	**2.2**
Unknown	**-**	**4**	**4.4**

Table 6.2. Biomass consumed calculated from caracal kill sites (n=82)* visited in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. Both the biomass consumed and the corrected biomass consumed is presented. See footnote for more details regarding calculations.

Prey Item	Prey age class	Estimated prey weight (kg)[a]	Number of kills	Biomass consumed (kg)[b]	Biomass consumed as % of all kill sites[c]	Prey consumption (%)[d]	Corrected biomass consumed (kg)[e]	Corrected biomass consumed as % of all kill sites[f]
Sheep (*Ovis aries*)			**23**	**698.9**	**65.4**		**336**	**59.5**
	YoY	21.7	15	325.5	30.4	60	195.3	34.6
	Subadult	39.4	1	39.4	3.7	40	15.8	2.8
	Adult	58	3	174	16.3	35	60.9	10.8
	Unknown	40	4	160	15	40	64	11.3
Hyrax (*Procavia capensis*)	**Unknown**	**3.03**	**36**	**109.1**	**10.2**	**90**	**98.2**	**17.4**
Goat (*Capra hircus*)			**3**	**178.8**	**16.7**		**71.5**	**12.7**
	YoY	22.8	1	22.8	2.1	40	9.1	1.6
	Subadult	78	2	156	14.6	40	62.4	11.1
Lagomorpha	**Unknown**	**2.35**	**14**	**32.9**	**3.1**	**90**	**29.6**	**5.2**
Duiker (*Raphicerus campestris*)			**3**	**38.1**	**3.5**		**20.1**	**3.6**
	Subadult	8	1	8	0.7	60	4.8	0.9
	Adult	16.1	1	16.1	1.5	60	9.7	1.7
	Unknown	14	1	14	1.3	40	5.6	1

African Wildcat (*Felis silvestris*)	**Adult**	**4.25**	**1**	**4.3**	**0.4**	**90**	**3.8**	**0.7**
Birds	**Unknown**	**1.57**	**2**	**3.1**	**0.3**	**90**	**2.8**	**0.5**
Klipspringer (*Oreotragus oreotragus*)	**YoY**	**4**	**1**	**4**	**0.4**	**60**	**2.4**	**0.4**
Total		313.2	83	1069.2	100		564.4	100

*Prey items that could not be identified to species level were not included in calculations

[a]From Schoeman (2000), Lu (2001) and Skinner and Chimimba (2005)

[b]Prey weight x Number of kills

[c](Prey weight x Number of kills)/Biomass consumed x 100

[d]Determined from photographs of kill at cluster visitations and Skinner and Chimimba (2005)

[e]Biomass consumed x Prey consumption (%)

[f](Biomass consumed x Prey consumption)/Corrected biomass consumed x 100

6.4.3. GPS Radio-collar Cluster Visitation versus Scat Analysis

A wider variety of prey items were identified from the 250 scat samples analysed than from the 91 kill sites visited. From scat analysis 31 prey items (excluding unknown prey items) were identified compared to only 7 prey items from kill sites (Figure 6.1). There was little variation in frequency of occurrence observed when comparing the main prey item, rock hyrax, between scat analysis (31.2%) and kill sites visited (39.6%) (Table 6.3). Sheep was the prey item occurring second most frequently at GPS cluster visits (25.3%). This percentage of occurrence was also significantly higher than what was identified from scat analysis (2%) [X^2 = 21.99, df = 1, p = 0.000]. Medium-large mammals which include duiker, steenbok and klipspringer showed no significant difference between the two sampling methods ($p > 0.05$).

Lagomorpha was the prey item which occurred second most frequently in caracal scats (18.7%) and third at kill sites (15.4%). No small mammals (< 1 kg) were identified at kill sites, but from scat analysis it was found that small mammals occurred in 29.1% of the 250 scats analysed. Small mammal remains would mostly be 100% consumed by caracals. In terms of scat analysis this was the second most important prey class, compared to GPS cluster visitations, where livestock (28.6%) was one of the two main prey classes after medium mammals (56%). There was also a significant difference in livestock occurrence between the two methods (X^2 = 22.72, df = 1, p = 0.000). Small mammal was completely absent from GPS cluster analysis (X^2 = 71.45, df = 1, p = 0.000). When comparing the frequency of occurrence between kill site analysis and scat analysis, it should be mentioned that the FO calculated for kill site analysis is comparable to the CFO for scat analysis.

Table 6.3. Prey classes recorded in caracal scat collected (n=250) in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa and kill sites visited (n=91). CFO (%) was calculated as the number of occurrences per scat or kill site divided by the total number of scats collected or kill sites visited. CFO for scat analysis is similar to the FO of kill sites.

Prey Item	Prey Weight (kg)	Scat Analysis		Kill sites	
		Number of Occurrences n = 250	CFO (%)	Number of Occurrences n = 91	FO (%)
Medium- to large mammals (10-40 kg)		**8.3**	**3.3**	**4**	**4.4**
Duiker (*Raphicerus campestris*)	16.1	3.33	1.33	3	3.3
Klipspringer (*Oreotragus oreotragus*)	11.9	1.50	0.60	1	1.1
Medium mammals (1-10 kg)		**125.2**	**50.1**	**51**	**56**
African wildcat (*Felis silvestris*)	**4.25**	**0**	**0**	**1**	**1.1**
Hyrax (*Procavia capensis*)	3.03	77.7	31.2	36	39.6
Lagomorpha	2.35	46.7	18.7	14	15.4
Small mammals (<1 kg)		**72.8**	**29.1**	**0**	**0**
Otomys spp	0.131	20.8	8.3	0	0
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	20.3	8.1	0	0
Striped mouse (*Rhabdomys pumillio*)	0.035	12.9	5.1	0	0
Livestock		**17**	**6.8**	**26**	**28.6**

Goat (*Capra hircus*)	50	12	4.80	3	3.3
Sheep (*Ovis aries*)	40	5	2	23	25.3
Birds	**1.57**	**6.7**	**2.7**	**2**	**2.2**
Reptiles		**2.1**	**0.8**	**0**	**0**
Invertebrates		**5**	**2**	**0**	**0**
Fruits/seeds	**0.002**	**1.2**	**0.5**	**0**	**0**
Vegetation	**0.001**	**5**	**2**	**0**	**0**
Unknown	**-**	**6**	**2.4**	**8**	**8.8**

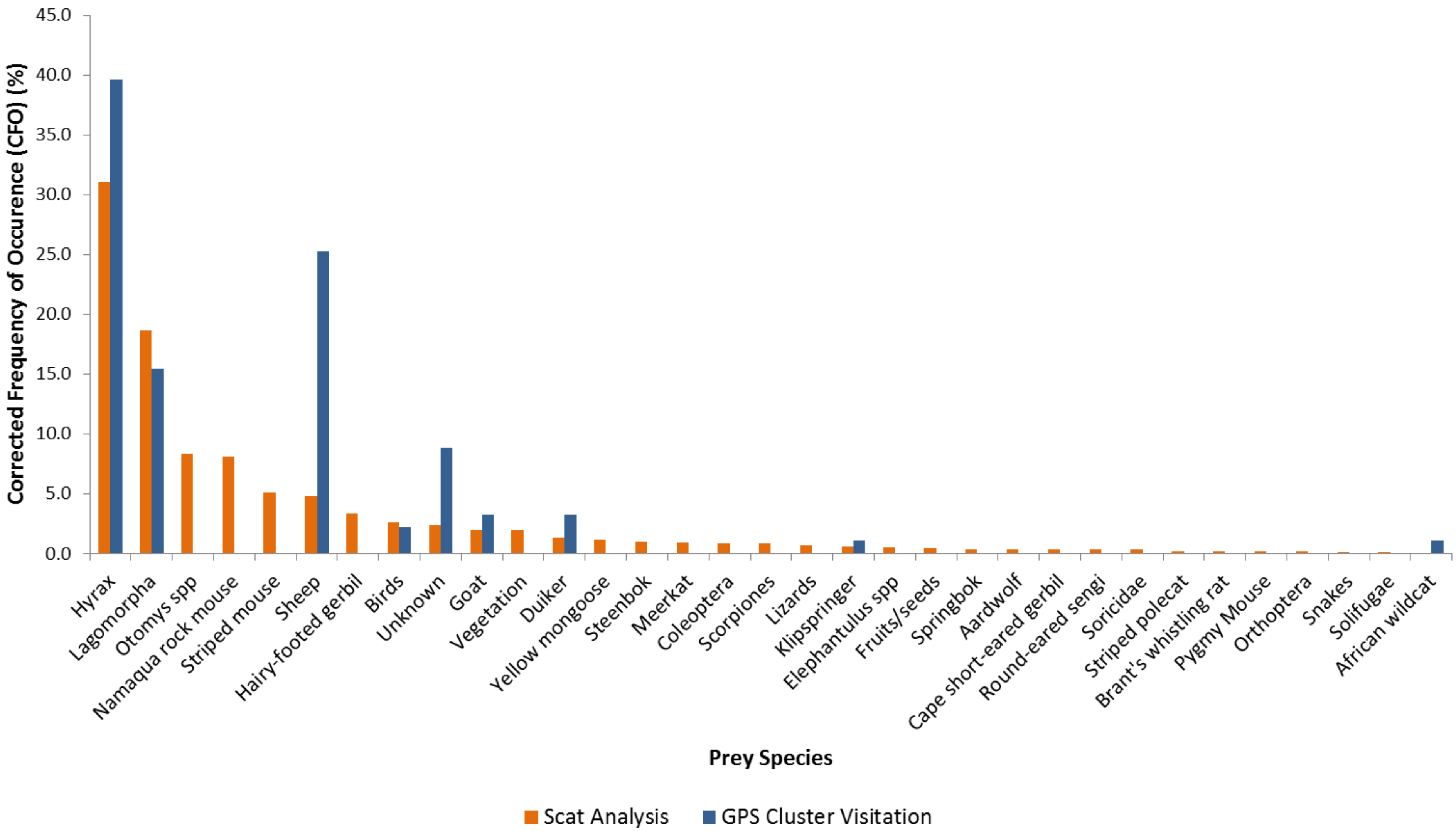


Figure 6.1. Corrected frequency of occurrence (CFO) % for all prey items identified from the 250 scats analysed and 91 kill sites visited in Namaqua National Park and surrounding farmlands, Namaqualand, Northern Cape, South Africa.

The total biomass consumed according to scats analysed was 2344.9 kg compared to GPS cluster visitations where the total biomass consumed was 564.4 kg. The prey item contributing the bulk to the total biomass consumed according to scat analysis was hyrax accounting for 35.8% of the total biomass consumed (Table 6.4). However, from kill site analysis hyrax only contributed 17.2% to the total biomass consumed. *Otomys* spp. and Namaqua rock mouse which contributed > 12% to the total biomass consumed analysed from scats were absent from the GPS cluster visitation analysis (Figure 6.3). While sheep only contributed 5% to the total biomass consumed from scat analysis, sheep contributed 59.5% as analysed from kill sites.

From the 250 scats collected and analysed, 89 (35.6%) scats were collected at GPS cluster sites (not just kill sites), 131 (52.4%) opportunistically across the study area and 32 (12.8%) along predetermined transects. Only 17 scats (6.8%) were collected at kill sites. Prey classes identified were generally evenly distributed (Figure 6.2). From the 89 scats collected from GPS cluster sites 36.1% of the prey classes identified were small mammals. Between all three scat collection methods caracal diet remained constant with medium mammals and small mammal primarily being the main prey classes consumed by caracals in the study area.

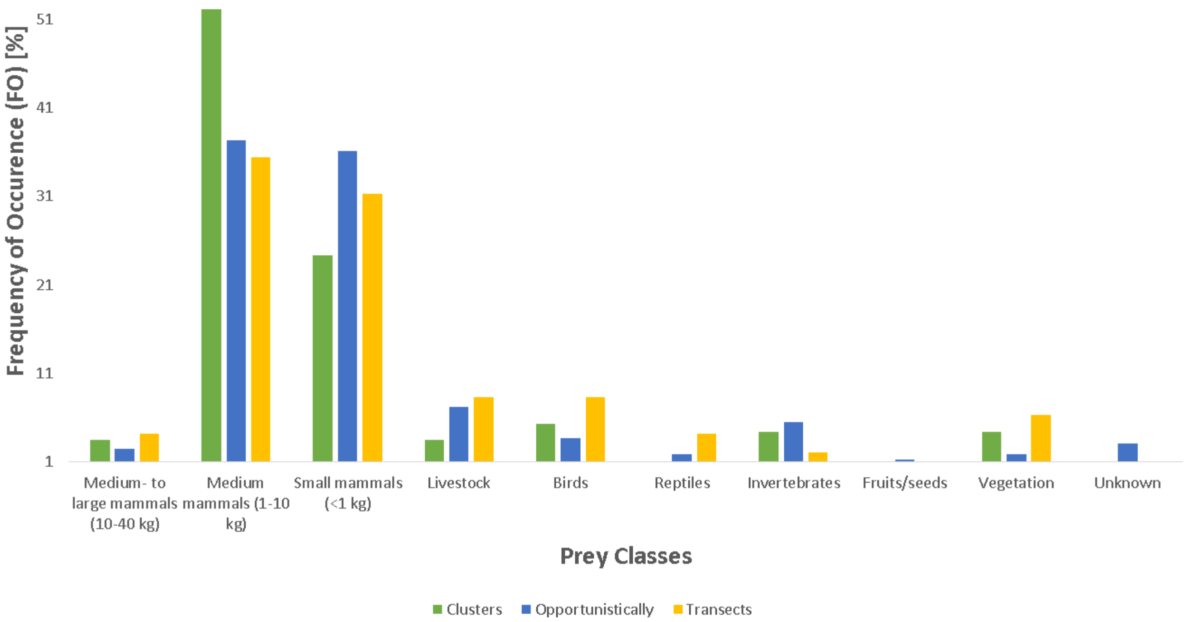


Figure 6.2. Comparison of scat collection methods showing the frequency of occurrence (FO) of all prey classes identified from the 250 scats analysed from Namaqua National Park and surrounding farmlands, Namaqualand, Northern Cape, South Africa.

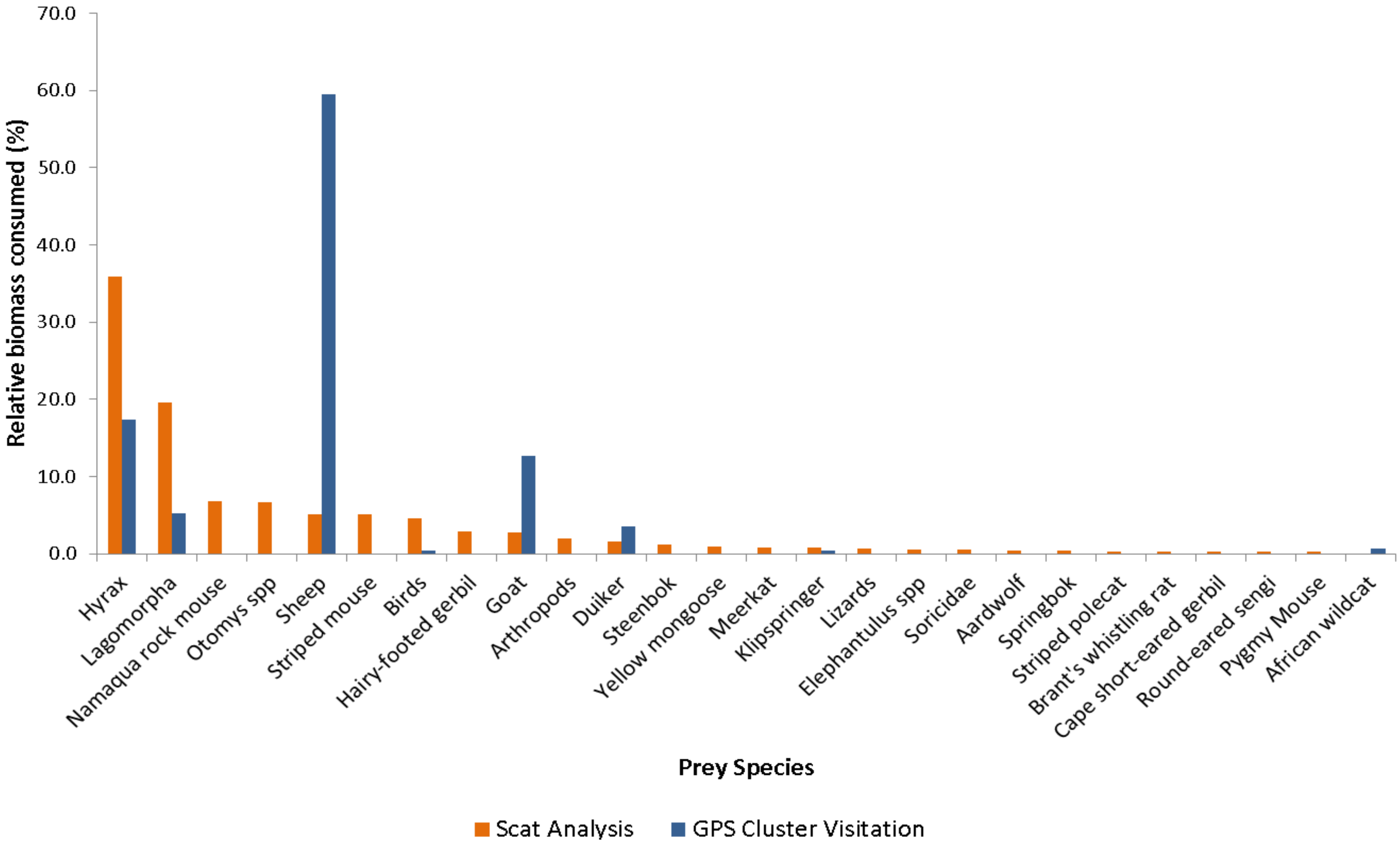


Figure 6.3. Relative biomass consumed (%) for all prey items identified from the 250 scats analysed and 91 kill sites visited in Namaqua National Park and surrounding farmlands, Namaqualand, Northern Cape, South Africa. The relative biomass consumed for scats analysed is the equivalent of corrected biomass consumed for kill site analysis.

Table 6.4. Biomass consumed calculated from caracal scat (n=250) collected and kill sites visited (n=91) in Namaqua National Park and on farmlands in Namaqualand, Northern Cape, South Africa. For a Table with all species and calculations based on scats analysed please see Appendix 4B, whereas for calculation based on kill sites see Table 6.2.

		Scat Analysis				GPS Cluster visitation		
Prey Item	**Prey Weight (kg)[a]**	**CF (kg/scat)[b]**	**Number of Occurrences**	**Biomass consumed as % of all scats[c]**	**Relative biomass consumed (%)[d]**	**Number of kills**	**Biomass consumed as % of all kill sites**	**Corrected biomass consumed (%)**
Hyrax (*Procavia capensis*)	3.03	29.0	86	18.0	35.8	36.0	10.2	98.2
Lagomorpha	2.35	26.2	52	8.4	19.6	14.0	3.1	29.6
Namaqua rock mouse (*Aethomys namaquensis*)	0.047	16.8	28	0.1	6.8	0.0	0.0	0.0
***Otomys* spp**	0.131	17.2	27	0.2	6.7	0.0	0.0	0.0
Sheep (*Ovis aries*)	40	27.0	13	35.8	5.0	23.0	65.4	59.5
Goat (*Capra hircus*)	50	27.0	7	24.1	2.7	3.0	16.7	12.7
Duiker (*Sylvicapra grimmia*)	16.1	27.0	4	4.4	1.6	3.0	3.5	3.6
Klipspringer (*Oreotragus*	11.9	27.0	2	1.6	0.8	1.0	0.4	0.4

oreotragus)								
African wildcat (*Felis sylvestris*)	4.25	34.0	0	0.0	0.0	1.0	0.4	0.7
Total	186.5	562.6	297	100	100	83	100	100

[a]From Skinner and Chimimba (2005)

[b] From Baker *et al.* (1993), $Y = 16.63 + 4.09x$; only for prey < 4.5kg

[c]Prey weight x Number of occurrences

[d]Correction factor x Prey item occurrence

6.4.4. Prey Preference

Prey preference was only calculated for mammalian species which were captured on the camera traps and in small mammal traps. All unknown prey items and birds were excluded from the analysis. For prey preference calculated from scats analysed, see Chapter 3. Hyrax was the most preferred prey item at kill sites according to calculations using CFO (0.96) [Figure 6.4] and biomass (0.61) [Figure 6.5]. Sheep was a prey item for which a strong preference existed (*D* > 0.50), according to the *D*-value calculated from CFO for kill sites, however when applying corrected biomass sheep was an avoided prey item (-0.59). Sheep was also an avoided prey item according to scat analysis (-0.21). Furthermore lagomorpha, African wildcat and goat were also prey species which were preferred, having a positive *D*-value according to CFO calculations form kill sites analysed. According to prey preference calculated from scat analysis and kill sites, klipspringer and duiker were both prey items avoided by caracal. With both methods lagomorpha was a preferred prey item. Both Namaqua rock mouse (*Aethomys namaquensis*) and striped mouse (*Rhabdomys pumillio*) weren't observed at kill sites due to their small body weight, however according to Jacobs' index calculated from scats analysed both these two rodent species are preferred prey items of caracal (*D*-value > 0.40).

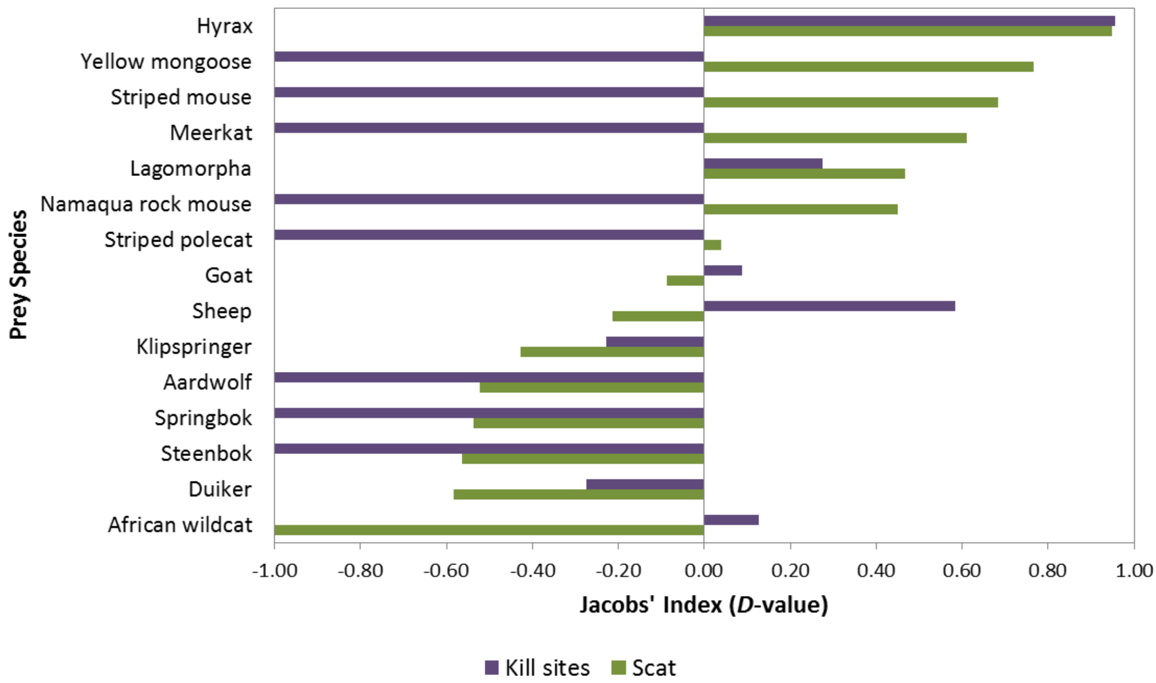


Figure 6.4. Jacobs' Index (*D*-value) showing preference (+ 1) and avoidance (- 1) for prey species identified from caracal kill sites in Namaqua National Park and the surrounding farmlands, Namaqualand, Northern Cape, South Africa. *D*-values are based on corrected frequency of occurrence (CFO) % of prey items from caracal scat and caracal kill sites.

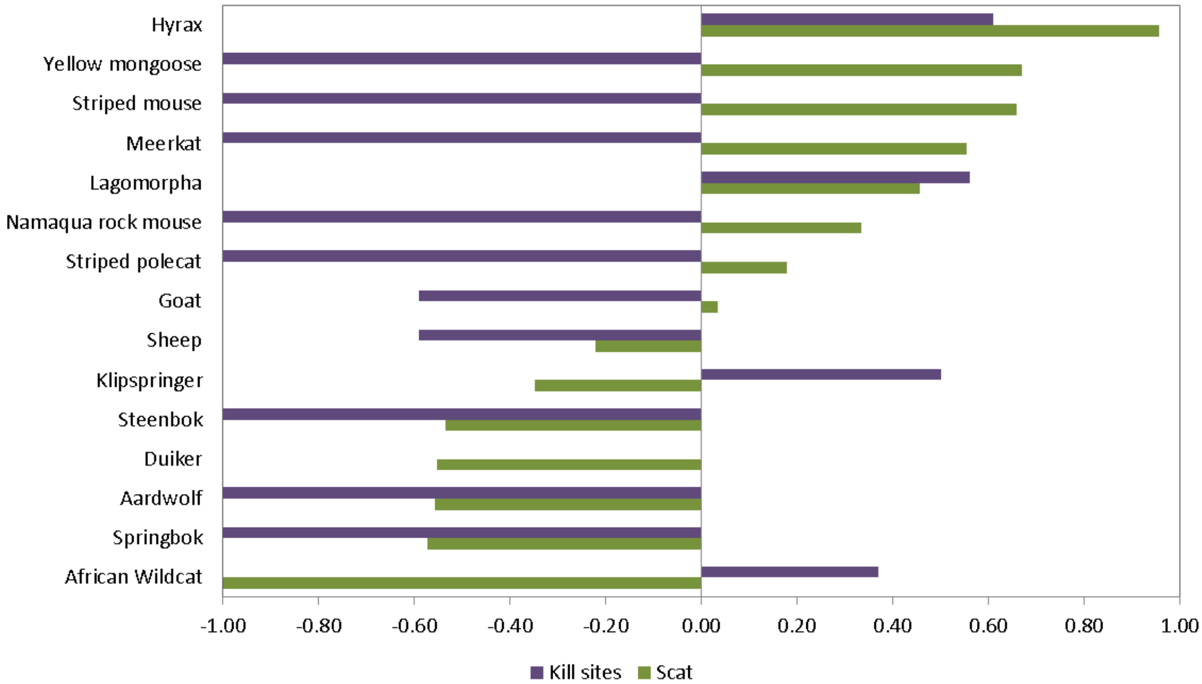


Figure 6.5. Jacobs' Index (*D*-value) showing preference (+ 1) and avoidance (- 1) for prey species identified from caracal kill sites in Namaqua National Park and the surrounding farmlands, Namaqualand, Northern Cape, South Africa. *D*-values are based on the relative and corrected biomass consumed (%) of prey items from caracal scat and caracal kill sites.

6.5. Discussion

Prey composition identified from scat analysis and GPS cluster visitations differed significantly, with a higher number of prey items identified from scat analysis. Kill sites were adequate to determine larger-bodied prey items and even medium-sized prey items, such as hyrax (*Procavia capensis*) and lagomorpha, but smaller prey items were not observed. From scat analysis a more complete idea of prey composition in caracal diets was identified. When analysing scat collected according to collection methods, very little difference was observed. Despite the method of scat collection, caracal diet remained constant across the entire study area according to scats analysed. This broader picture allows for a more comprehensive understanding of the ecology of these medium-sized felids and illustrates the opportunistic feeding behaviour displayed across two different land-uses in Namaqualand. Whereas kill site prey identification was biased towards prey items which were not consumed entirely by caracal, scat analysis has been known to be biased towards smaller prey items (Martins *et al.* 2011). However, the use of a corrected biomass consumed decreases that bias and provides insight into which prey items are of ecological importance to the caracal (Klare *et al.* 2011). When applying biomass calculation models (BCM) to small mammals identified from scat analysis this prey class contributed > 25% to the total biomass consumed, making it the second most important prey class contributing to the total biomass consumed by caracal. This was a prey class which was completely absent in kill site analyses. Past studies found that small mammals, especially rodents, are prominent prey items in caracal diet (Palmer and Fairall 1988; Stuart and Hickman 1991; Avenant and Nel 1997; Avenant and Nel 2002; Mellville, Bothma and Mills 2004). Other studies confirmed that small mammals were present in caracal diet, but these prey items were not necessarily one of the main items. Studies on leopard diet using both scat and GPS cluster analysis have been done in South Africa (Martins *et al.* 2011; Pitman *et al.* 2013). Leopards in certain regions of South Africa have smaller body sizes and as such could potentially also include smaller prey items in their diets, such as rodents (Norton, Lawson, Henley and Avery 1986; Ott, Kerley and Boshoff 2007; Martins 2010). In the Southern Cape, South Africa, researchers found the vlei rat *(Otomys irroratus)* to be the second most frequently occurring prey items in leopard scats analysed (Braczkowski, Watson, Coulson and Randall 2012b). However, when the aforementioned study applied BCM the vlei rat contributed < 1% to the total biomass consumed. In Martins *et al.* (2011)'s study on leopard diet in the Western Cape, South Africa which included both scat analysis and GPS cluster analysis, rodents were concluded to contribute < 1% to the total biomass consumed. Despite leopards in the Western and Southern Cape having smaller body sizes, they are still considered apex predators in the ecosystems where they persist and are not completely comparable to caracals. Each area is different and with a difference in prey availability and abundance a difference in caracal diet can be observed (Avenant and Nel 2002). The use of scat analysis would thus be crucial to determine caracal diet if all prey classes were to be included.

Several recent studies on large carnivore diet have used a combination of GPS cluster visitation and scat analysis (Bacon *et al.* 2011; Morehouse and Boyce 2011; Martins *et al.* 2011; Tambling *et al.* 2012; Pitman *et al.* 2013; Cristescu *et al.* 2015b). However, most dietary analysis focusing on small felid species have only either used scat analysis or the more invasive technique of stomach contents analysis (Moolman 1984; Stuart and Hickman 1991; Kok 1996; Avenant and Nel 2002; Braczkowski *et al.* 2012a). The first study to test GPS cluster (kill site analysis) for a small felid species, the bobcat (*Lynx rufus*) was recently carried out by Svoboda *et al.* (2013). However, this study focussed solely on bobcat predation on white-tailed deer (*Odocoileus virginianus*), but did manage to apply a model which allowed for prey detection of deer fawns weighing < 5 kg. This specific method from the aforementioned study would not have been beneficial for this study as a wide variety of prey items from caracal clusters was required. Caracals are known to feed on a variety of prey items which include small mammals (1-10 kg and ≤ 1 kg). Svoboda *et al.* (2013) did conclude that rapid visitation of cluster sites should be priority, especially to account for smaller prey species, such as white-tailed fawns. The success of finding kill sites when visiting GPS clusters for this study in Namaqualand was higher than what Svoboda *et al.* (2013) found for bobcats. No other studies utilising GPS cluster visitation methods to determine the diet of medium-sized felids have been published. Caracal are also known to prey on small ungulate species such as steenbok (*Raphicerus campestris*) [Mellville *et al.* 2004]. Identifying ungulate carcasses at kill sites is expected to be easier than finding hyrax or lagomorpha carcasses of which only the rumen, intestines or hair tufts would not be consumed by caracal (Estes 2012). When feeding on ungulates caracal are known to only consume select parts of the animals which would result in a larger part of the carcass being left behind to be identified by researchers (Skinner and Chimimba 2005). With the low occurrence of wild ungulates in both scat analysis and kill site analysis it can be concluded that in Namaqualand caracal do not have a particularly high preference for small ungulates as a prey species, a statement which is supported by the Jacobs' index calculated for this study. Most of the scats analysed containing small ungulate remains were collected opportunistically, with the exception of one scat which could have been from the same feeding event at one of the kill sites analysed.

This study was designed to provide baseline data for a larger project focused on assisting human-carnivore conflict mitigation in Namaqualand. According to kill site analysis, sheep contributed > 60% to the total biomass consumed, compared to only 5% as analysed from scats. If GPS cluster visitation would have been used as the sole method for dietary analysis, the importance of livestock as a prey item could have been overestimated. All caracal monitored with GPS radio-collars were male. Male felids have been found to be more predisposed to livestock predation than females (Loveridge *et al.* 2010). Females tend to be more wary of human-dominated landscapes, especially when raising kittens (Bunnefeld *et al.* 2006). Bunnefeld *et al.* (2006) found that female Eurasian lynx (*Lynx lynx*) avoided areas of human habitation, compared to males which were found to persist in close proximity to humans. Male felids also hold larger territories with a higher need to disperse to establish an adequate home range, making them more predisposed to contact with livestock (Linnell, Swenson and Andersen 2001; Loveridge *et al.* 2010). Compared to Namaqua National Park where wild prey is available in the higher abundances, prey availability on farmlands mostly consisted of livestock, which are possibly easier to catch than wild prey. Linnell *et al.* (1999) found that animals dispersing from protected areas could possibly become 'problem animals'. Of the 8 collared caracal, 87.5% were trapped on farmlands, potentially also allowing for a bias towards livestock. Individuals could also 'specialise' in a certain prey item which could lead to higher instances of livestock recorded at kill sites (Linnell *et al.* 1999). Scat analysis provides a broader and more complete representation of the diet of caracal and possibly of other felids because of inclusion of a variety of prey size categories. However, the use of GPS telemetry methods allows opportunities for multiple insights into felid ecology beyond only documenting prey composition.

6.6. Conclusion

Caracal in semi-arid Namaqualand, South Africa have a broad prey base ranging from arthropods to medium-sized ungulates. When assessing the general diet of caracal, GPS cluster visitations had a bias towards larger-bodied prey items which were not consumed entirely. Small mammals were found to contribute > 25% to the total biomass consumed as analysed from the 250 scats. This prey class was never encountered during GPS cluster visitation. Both scat and kill site analysis allowed for the same occurrence of wild ungulates in caracal diet, emphasizing the appropriateness of GPS cluster visitations when focusing on larger-bodied prey items. Even relatively small prey such as rock hyrax, hares and rabbits (lagomorpha) were detected during cluster visitation suggesting that the method has good potential for caracal diet estimation when the focus is on prey weighing > 1 kg. Sheep remains were found more frequently at kill sites than in scats suggesting that large prey might be underestimated by the scat method, possibly because scats deposited after livestock consumption include more flesh and only small amounts of hair. Scat analysis provided a broad representation of caracal diet at lower cost and effort compared to GPS collaring and cluster visitation, however care should be taken to decrease biases towards smaller prey items associated with scat analysis. The use of GPS cluster visitations for small felids, such as the caracal, which has such a wide prey spectrum, should be undertaken with caution or in conjunction with scat analysis. The latter combined approach would allow for lower bias in diet estimation and additionally individual caracal diet can be assessed, as well as other behaviours of the focal study animals.

6.7. References

Avenant, N, L., and Du Plessis, J. J. 2008. Sustainable small stock farming and ecosystem conservation in southern Africa: A role for small mammals? *Mammalia* **72**: 258–263.

Avenant, N. L., and Nel, J. A. J. 1998. Home-range use, activity, and density of caracal in relation to prey density. *African Journal of Ecology* **36**: 347-359.

Avenant, N. L., and Nel, J. A. J. 2002. Among habitat variation in prey availability and use by caracal *Felis caracal*. *Mammalian Biology* **67**: 18–33.

Avenant., N. L., and Nel, J. A. J. 1997. Prey use by four syntopic carnivores in a strandveld ecosystem. *South African Journal of Wildlife Research* **27:** 86-93.

Bacon, M. M., Becic, G. M., Epp, M. T., and Boyce, M. S. 2011. Do GPS Clusters Really Work? Carnivore Diet From Scat Analysis and GPS Telemetry Methods. *Wildlife Society Bulletin* **35**: 409-415.

Bailey, A., and Conradie, B. 2013. The Effect of Predator Culling on Livestock Losses: Caracal Control in Cooper Hunting Club, 1976 – 1981. Centre for Social Science Research: University of Cape Town.

Balme, G., Hunter, L., and Slotow, R. 2007. Feeding habitat selection by hunting *leopards Panthera pardus* in a woodland savanna: prey catchability versus abundance. *Animal Behaviour* **74:** 589 – 598.

Balme, G., Lindsey, P. A., Swanepoel, L. H., and Hunter, L. T. B. 2013. Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study. *Conservation Letters* **00**: 1 – 9.

Beier, P., D. Choate, and R. H. Barrett. 1995. Movement patterns of mountain lions during different behaviors. Journal of Mammalogy **76**: 1056–1070.

Beinart, W. 2003. The rise of conservation in South Africa: settlers, livestock and the environment. Oxford: Oxford University Press.

Bergman, D. L., De Waal, H. O., Avenant, N. L., Bodenchuk, M. J., Marlow, M. C., and Nolte, D. L. 2013. The Need to Address Black-backed Jackal and Caracal Predation in South Africa. In: J. B. Armstrong and G. R. Gallagher, eds. 2013. *Proceedings of the 15th Wildlife Damage Management Conference* South Carolina

Braczkowski, A., Watson, L., Coulson, D., and Randall, R. 2012b. Diet of leopards in the southern Cape, South Africa. *African Journal of Ecology* **50**: 377 – 380.

Braczkowski, A., Watson, L., Coulson, D., Lucas, J., Peiser, B., and Rossi, M. 2012a. The diet of caracal, *Caracal caracal*, in two areas of the southern Cape, South Africa as determined by scat analysis. *South African Journal of Wildlife Research* **42**: 111–116.

Bunnefeld, N., Linnell, J. D. C., Odden, J., Van Duijn, M. A. J., and Andersen, R. 2006. Risk taking by Eurasian lynx (*Lynx lynx*) in a human-dominated landscape: effects of sex and reproductive status. *Journal of Zoology* **270**: 31–39.

Cagnacci, F., Boitani, L., Powell, R. A., and Boyce, M. S. 2010. Animal ecology meets GPS-based radiotelemetry: a perfect storm of opportunities and challenges. *Philosophical Transactions of the Royal Society of London B Biological Sciences* **365**: 2157–2162.

Cardillo, M., G. M. Mace, K. E. Jones, J. Bielby, O. R. Bininda-Emonds, W. Sechrest, C. D. L. Orme, and A. Purvis. 2005. Multiple causes of high extinction risk in large mammal species. *Science* **309**: 1239-1241.

Ciucci, P., Boitani, L., Pelliccioni, E. R., Rocco, M., Guy, I. 1996. A comparison of scat-analysis methods to assess the diet of the wolf *Canis lupus*. *Wildlife Biology* **2**: 37–48.

Clark, D. A., Davidson, G. A., Johnson, B. K., and Anthony, R. G. 2014. Cougar Kill Rates and Prey Selection in a Multiple-Prey System in Northeast Oregon. *The Journal of Wildlife Management* **78**: 1161–1176.

Cristescu, B., Stenhouse, G. B., and Boyce, M. S. 2015a. Predicting multiple behaviors from GPS radiocollar cluster data. *Behavioral Ecology* **26**: 452-464.

Cristescu, B., Stenhouse, G. B., and Boyce, M. S. 2015b. Grizzly bear diet shifting on reclaimed mines. *Global Ecology and Conservation* **4**: 207-220.

Du Plessis, J. J., Avenant, N. L., and De Waal, H. O. 2015. Quality and quantity of the scientific information available on black-backed jackals and caracals: contributing to human–predator conflict management? *African Journal of Wildlife Research* **45**: 138–157.

Estes, R. D. 2012. *The behaviour guide to African mammals*. Berkely: The University of California Press.

Fattebert, J., Robinson, H. S., Balme, G., Slotow, R., & Hunter, L. 2015. Structural habitat predicts functional dispersal habitat of a large carnivore: how leopards change spots. *Ecological Applications* **25**: 1911–1921.

Grobler, J. H. 1981. Feeding behaviour of the caracal *Felis caracal* Schreber 1776 in the Mountain Zebra National Park. *South African Journal of Zoology* **16**: 259- 262.

Ilemin Y. and Gürkan B. 2010. Status and activity patterns of the Caracal, *Caracal caracal* (Schreber,1776), in Datca and Bozburun Peninsulas, Southwestern Turkey. *Zoology in the Middle East* **50**: 3-10.

Inskip, C., and Zimmerman, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. *Oryx* **43**: 18-34.

Breitenmoser-Würsten, C., Henschel, P. and Sogbohossou, E. 2008. Caracal caracal. In: The IUCN Red List of Threatened Species 2008. [online] Available from: http://www.iucnredlist.org/details/3847/0 (Accessed 19 January 2016).

Iverson, S. J., C. Field, W. D. Bowen, and W. Blanchard. 2004. Quantitative fatty acid signature analysis: a new method of estimating predator diets. Ecological Monographs **74**: 211–235.

Klare, U., Kamler, J. F., and Macdonald, D. W. 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* **41**: 294–312.

Knopff, A. A., Knopff, K. H., Boyce, M. S., & Clair, C. C. S. 2014. Flexible habitat selection by cougars in response to anthropogenic development. *Biological Conservation* **178**: 136-145.

Knowlton, F. F., Gese, E. M., and Jaeger, M. M. 1999. Coyote depredation control: an interface between biology and management. *Journal of Range Management* **52**: 398–412.

Kok, O. B. 1996. Die dieetsamestelling van enkele karnivoorsoorte in die Vrystaat, Suid-Afrika. *South African Journal of Science* **92**: 393–398.

Kok, O. B., and Nel, J. A. J. 2004. Convergence and divergence in prey of sympatric canids and felids: opportunism or phylogenetic constraint? *Biological Journal of the Linnean Society* **83:** 527–538.

Linnell, D. C., Odden, J., Smith, M. E., Aanes, R., and Swenson, J. E. 1999. Large Carnivores That Kill Livestock: Do "Problem Individuals" Really Exist? *Wildlife Society Bulletin* **27**: 698 – 705.

Linnell, J. D. C., Swenson, J. E., and Andersen, R. 2001. Predators and people: conservation of large carnivores is possible at high human densities if management policy is favourable. *Animal Conservation* **4**: 345–349.

Loveridge, A. J., Wang, S. W., Frank, L. G., and Seidensticker, J. 2010. People and wild felids: conservation of cats and management of conflicts In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

Lu, C. D. 2001. Boer Goat Production: Progress and Perspective. *Proceedings of the 2001 International Conference on Boer Goats in China.*

Martins, Q. 2010. *The ecology of the leopard* Panthera pardus *in the Cederberg Mountains*. Dissertation, University of Bristol, United Kingdom.

Martins, Q., and Harris, S. 2013. Movement, activity and hunting behaviour of leopards in the Cederberg mountains, South Africa. *African Journal of Ecology* **51**: 571-579.

Martins, Q., Horsnell, W. G. C., Titus, W., Rautenbach, T., and Harris, S. 2011. Diet determination of the Cape Mountain leopards using global positioning system location clusters and scat analysis. *Journal of Zoology* **283**: 81-87.

Marucco, F., Pletscher, D. H., and Boitani, L. 2008. Accuracy of Scat Sampling for Carnivore Diet Analysis: Wolves in the Alps as a Case Study. *Journal of Mammalogy* **89**: 665-673.

Mellville, H. I. A. S., Bothma, J. Du. P., and Mills, M. G. L. 2004. Prey selection by caracal in Kgalagadi Transfrontier Park. *South African Journal of Wildlife Research* **34:** 67-75.

Moolman, L. C. 1984. 'n Vergelyking van die voedingsgewoontes van die rooikat *Felis caracal* binne en buite die Bergkwagga Nasionale Park. *Koedoe* **27**: 121-129.

Morehouse, A. T., and Boyce, M. S. 2011. From venison to beef: seasonal changes in wolf diet composition in a livestock grazing landscape. *Frontiers in Ecology and the Environment* **9**: 440–445.

Norton, P. M., and Lawson, A. B. 1985. Radio tracking of leopards and caracals in the Stellenbosch area, Cape Province. *South African Journal of Wildlife Research* **15**: 17-24.

Norton, P. M., Lawson, A. B., Henley, S. R., and Avery, G. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *South African Journal of Wildlife Research* **16:** 47–52.

Nowell, K., and Jackson, P. 1996. Wild cats: Status survey and conservation action plan. Switzerland: IUCN/SSC Cat Specialist Group.

Odden, M., Athreya, V., Rattan, S., & Linnell, J. D. 2014. Adaptable neighbours: movement patterns of GPS-collared leopards in human dominated landscapes in India. *PLoS ONE* **9**: e112044. doi:10.1371/journal.pone.0112044.

Ogada, M. O., Woodroffe, R., Oguge, N. O., and Frank, L. G. 2003. Limiting Depredation by African Carnivores: the Role of Livestock Husbandry. *Biological Conservation* **17**: 1-10.

Ott, T., Kerley, G. I. H., and Boshoff, A. F. 2007. Preliminary observations on the diet of leopards (*Panthera pardus*) from a conservation area and adjacent rangelands in the Baviaanskloof region, South Africa. *African Zoology* **42**: 31–37.

Palmer, R., and Fairall, N. 1988. Caracal and African wild cat diet in the Karoo National Park and the implications thereof for hyrax. *South African Journal of Wildlife Research* **18**: 30-34.

Pettigrew, M., Xie, Y., Kang, A., Rao, M., Goodrich, J., Liu, T., and Berger, J. 2012. Human–carnivore conflict in China: a review of current approaches with recommendations for improved management. *Integrative Zoology* **7**: 210–226.

Pitman, R. T., Mulvaney, J., Ramsay, P. M., Jooste, E., and Swanepoel, L. H. 2013. Global Positioning System-located kills and faecal samples: a comparison of leopard dietary estimates. *Journal of Zoology* **292**: 18-24.

Pitman, R. T., Swanepoel, L. H., and Ramsay, P. M. 2012. Predictive modelling of leopard predation using contextual Global Positioning System cluster analysis. *Journal of Zoology* **288**: 222-230.

Ray, J. C., Hunter, L. and Zigouris, J. 2005. *Setting conservation and research priorities for larger African carnivores.* New York: Wildlife Conservation Society.

Schoeman, S. J. 2000. A comparative assessment of Dorper sheep in different production environments and systems. *Small Ruminant Research* **36**: 137-146.

Skinner, J. D., and Chimimba, C. T. 2005. *The mammals of the southern African subregion.* Cape Town: Cambridge University Press.

Smith, E, R. 2012. *An assessment of caracal population density and human-predator conflict in the Winterberg, Eastern Cape, South Africa.* Masters Thesis, Rhodes University, South Africa.

Stahl, P., Vandel, J. M., Herrenschmidt, V., and Migot, P. 2001. The effect of removing lynx in reducing attacks on sheep in the French Jura Mountains. *Biological Conservation* **101**:15–22.

Stuart, C. T. 1982. Aspects of the biology of the caracal (*felis caracal* schreber 1776) in the Cape Province, South Africa. Masters thesis, University of Natal, South Africa.

Stuart, C. T., and Hickman, G. C. 1991. Prey of caracal *Felis caracal* in two areas of Cape Province, South Africa. *Journal of African Ecology* **105**: 373- 381.

Svoboda, N. J., Belant, J. L., Beyer, D. E., Duquette, J. F., and Martin, J. A. 2013. Identifying bobcat *Lynx rufus* kill sites using a global positioning system. *Wildlife Biology* **19**: 78-86.

Tambling, C. J., Laurence, S. D., Bellan, S. E., Cameron, E. Z., du Toit, J. T., and Getz, W. M. 2012. Estimating carnivoran diets using a combination of carcass observations and scats from GPS clusters. *Journal of Zoology* **286**: 102 – 109.

Thompson, D. R., S. J. Bury, K. A. Hobson, L. I. Wassenaar, and J. P. Shannon. 2005. Stable isotope in ecological studies. Oecologia **144**: 517– 519.

Van Sittert, L. 1998. Keeping the enemy at bay: the extermination of wild carnivora in the Cape Colony, 1889-1910. *Environmental History* **3**: 333-356.

6.8. Appendices

Appendix 6A- Jacobs' index (D-value) of all prey items found at caracal kill sites in Namaqua National Park and surrounding farmlands, Northern Cape, South Africa. The corrected frequency of occurrence (CFO) % used in Jacobs' index calculation and the biomass consumed are included, as well as the relative abundance index (RAI).

Prey species	RAI (%)	CFO (%)	Jacobs' Index (D)[a]	Biomass (%)	Jacobs' index (D)[b]
Hyrax	1.78	44.4	0.96	15	0.61
Sheep	9.42	28.4	0.58	62	-0.59
Lagomorpha	10.61	17.3	0.28	4.5	0.56
African wildcat	0.96	1.2	0.13	0.6	0.37
Goat	3.13	3.7	0.09	13.2	-0.59
Klipspringer	1.95	1.2	-0.23	0.4	0.50
Duiker	6.34	3.7	-0.28	3.7	0
Yellow mongoose	0.21	0	-1	0	-1
Striped mouse	1.35	0	-1	0	-1
Meerkat	0.3	0	-1	0	-1
Namaqua rock mouse	4.34	0	-1	0	-1
Striped polecat	0.24	0	-1	0	-1
Aardwolf	1.66	0	-1	0	-1
Springbok	1.73	0	-1	0	-1
Steenbok	4.57	0	-1	0	-1
Aardvark	0.65	0	-1	0	-1
Baboon	4.27	0	-1	0	-1
Bat-eared fox	1.11	0	-1	0	-1
Black-backed jackal	0.96	0	-1	0	-1
Cape fox	0.24	0	-1	0	-1
Caracal	1.81	0	-1	0	-1
Cattle	2.92	0	-1	0	-1
Donkey	0.64	0	-1	0	-1
Grey mongoose	0.37	0	-1	0	-1
Honey badger	0.07	0	-1	0	-1
Horse	0.19	0	-1	0	-1
Oryx	3.87	0	-1	0	-1
Porcupine	4.36	0	-1	0	-1
Red hartebeest	0.46	0	-1	0	-1
Small spotted genet	0.21	0	-1	0	-1

[a] D-values are based on CFO (%) of prey items from caracal kill sites.

[b] D-values are based on the total biomass consumed of prey items from caracal kill sites

Chapter 7: Integrated discussion of results and proposed management implications

7.1. Predator diet in Namaqualand - what have we learnt from this study?

Livestock farming in South Africa contributes a substantial amount annually to the country's economic growth. In 2013 the total income earned by the commercial farming sector was R182 980 million, with animal and animal product farming contributing the bulk to the total (R87 291 million) [Statistics South Africa 2013]. Livestock are vulnerable to many factors such as disease and drought, but the most controversial and pressing issue is that of depredation on livestock by predators (Dickman, Macdonald and Macdonald 2011). Conflict between farmers and predators in South Africa has been an ongoing battle. Despite the extirpation of many predators in certain areas of South Africa by intense lethal control measures, many predators still persist in most parts of the country (Van Sittert 1998; Du Plessis, Avenant and De Waal 2015). Understanding diet composition of carnivores can provide important knowledge to effectively conserve ecosystems, especially in areas where these animals are responsible for livestock losses (Valeix *et al.* 2012; Du Plessis *et al.* 2015). Predator-prey interactions lie at the core of human-carnivore conflict in many areas, especially South Africa (Thorn, Green, Scott and Marnewick 2013). Past studies have claimed that a loss in abundance of wild prey species due to human interference could be driving human-carnivore conflict (Woodroffe, Thirgood and Rabinowitz 2005; Valeix *et al.* 2012). Dietary analyses can help to understand the extent of depredation; however other factors such as herding practises, environmental factors and behavioural ecology should also be taken into account (Suryawanshi, Bhatnagar, Redpath and Mishra 2013).

Past dietary studies on leopard (*Panthera pardus*), caracal (*Caracal caracal*) and black-backed jackal (*Canis mesomelas*) have usually been undertaken within the confines of game reserves and protected areas (Kaunda and Skinner 2003; Mellville, Bothma and Mills 2004; Balme, Lindsay, Swanepoel and Hunter 2013). Comparing diet across the Namaqua National Park and surrounding farmlands provides insight into how the presence of small stock farming and human practices alters prey populations, which in turn influences predator diet (Ott, Kerley and Boshoff 2007; Du Plessis *et al.* 2015). Many farmers in Namaqualand make use of indiscriminate lethal traps. On various occasions other carnivores such as African wildcat (*Felis sylvestris*), bat-eared fox (*Otocyon megalotis*), aardwolf (*Proteles cristatus*) and digging animals such as aardvark (*Orycteropus afer*) have been recorded in these traps (The Cape Leopard Trust 2011). These animals are important ecosystem engineers and the loss of the latter could have negative effects on ecosystem functioning in the area (Davidson, Detling and Brown 2012; Fleming *et al.* 2014). Small ungulate species also fall victim to these traps, however, it is unknown to what extent. Camera data showed wildlife numbers to be higher in Namaqua National Park, than on the farmlands. Various studies have claimed that farming practises negatively influence rodent populations which could be one of the reasons why predator species such as black-backed jackals tend to prey on alternate prey sources such as livestock (Avenant and Du Plessis 2008). However, many studies also report that prey abundance is the driver behind human-carnivore conflict suggesting that the influx of an alternate prey source such as livestock promotes depredation by carnivores (Woodroffe *et al*. 2005; Inskip and Zimmerman 2009).

In Namaqualand leopards are the largest remaining carnivore in the ecosystem, making these animals the apex predator (Skead 2011). Leopards had a more specific prey range in Namaqualand than the two mesocarnivores. From the leopard scats analysed in this study, 24 prey items were identified, compared to 31 prey items for caracal and 35 for black-backed jackal. Hyrax (*Procavia capensis*) was the main prey item for both felids in this study. On the farmlands hyrax was also a main prey species occurring frequently in black-backed jackal diet. Past studies have claimed that the diet of an opportunistic predator can provide insight into abundant prey items (Karanth and Sunquist 1995; Chattha *et al.* 2015). With hyrax occurring in the diet of all three of the study animals, it can be assumed that this prey item is abundant in the rocky outcrops. Leopards and caracals are well adapted to rugged and mountainous terrains and their distribution overlaps with hyrax in Namaqualand (Skinner and Chimimba 2005). Past ecological information on the study area is lacking, but high persecution of natural predators of hyrax could have led to an increase in the hyrax population. Hyrax competes with livestock for resources and past studies have emphasised the intense herbivory impacts of hyrax in an ecosystem (Davies 1999; Davies and Ferguson 2000). All three of the study animals provide an important service to farmers, as an influx of hyrax in the ecosystem could be detrimental in the form of competition with livestock for food (Fourie 1983; Davies 1999).

Caracal mostly selected for natural prey, especially hyrax, lagomorpha and rodents such as *Otomys* spp. and Namaqua rock mouse (*Aethomys namaquensis*). Black-backed jackal primarily included natural prey in their diet and of the three focal species preyed the most on non-mammalian prey, especially beetles, scorpions and even tortoises. This illustrates their opportunistic foraging behaviour, as these animals included a wide range of prey species in their diet. The generalist diet of jackals further illustrates their importance in an ecosystem. Bagniewska and Kamler (2013) suggested that in some systems where apex predators have been decimated, mesocarnivores can fill the role of apex predators and have even been found to increase in numbers. This is often referred to as "mesopredator release". Past studies have found that an increase in jackals could lead to a negative effect on other carnivore species. For farmers this could be a great problem, as these other species such as bat-eared fox and Cape fox (*Vulpes vulpes*) do not depredate on livestock. These small canids feed primarily on arthropods (bat-eared fox) and rodents (Cape fox) [Kamler et *al.* 2012]. Arthropods and rodents, if not controlled by natural predators, can become a problem for livestock farmers in Namaqualand due to their reliance on the success of crops for supplementary feed for stock (Avenant and Du Plessis 2008; Blaum, Tietjen and Rossmanith 2009). Our results also suggest that a potential "mesopredator release" could increase livestock losses, as black-backed jackals were responsible for the most sheep losses. Maintaining a healthy leopard population in Namaqualand could prevent such a "mesopredator release" from occurring.

Black-backed jackal diet is known to vary seasonally and even spatially (Klare, Kamler, Stenkewitz and Macdonald 2010). Even though one the main objectives of this study was to analyse jackal diet in Namaqualand, it is also crucial to assess their ecology nationwide to better understand what the impact of these mesocarnivores are on the small stock industry. Ecological data on both caracal and black-backed jackal is lacking and surprisingly very little is known about their feeding ecology on small stock farms, despite claims that these animals depredate heavily on livestock (Du Plessis *et al*. 2015). The preferred rodent prey of jackal were *Otomys* spp. and striped mouse (*Rhabdomys pumillio*), both of which are diurnal species. Studies report that jackals display both diurnal and nocturnal activity patterns in protected areas, switching to a primarily nocturnal pattern of behaviour in human dominated landscapes (Ferguson, Galpin and De Wet 1988; Skinner and Chimimba 2005). Namaqua rock mouse, a nocturnal rodent species, occurred in higher frequencies in jackal scats on the farmlands than in the national park. The preferred rodent species by jackals on the two contrasting land-uses supports these claims and as such confirmed that in Namaqualand jackals are nocturnal in farmland areas.

Leopards were the main predator of goats (*Capra hircus*) in the study area, with a very small percentage of goat remains analysed from caracal and black-backed jackal scats. As expected, the bulk of goat remains were found in leopard scats collected on the farmlands. However, in the national park leopard diet consisted mainly of hyrax and small antelope species such as steenbok (*Raphicerus campestris*), duiker (*Sylvicapra grimmia*) and klipspringer (*Oreotragus oreotragus*). The three antelope species were found to occur frequently in leopard diet according to other studies in similar ecosystems (Norton, Lawson, Henley and Avery 1986; Ott *et al.* 2007; Martins *et al.* 2011; Mann 2014). Livestock replaced the small antelope species in leopard diet on the farmlands. It can be challenging for farmers to confine goat herds to a certain area. Goats prefer to roam vast areas, soften unprotected (Lu 1988), and they fall within the preferred prey range of leopards (10 – 40kg), as found by Hayward *et al.* (2006).

Leopards are not the main concern of small stock farmers, but rather caracal and black-backed jackal (Thorn *et al.* 2013; Du Plessis *et al.* 2015). These two mesocarnivores are smaller than leopards and as such prey on smaller stock. Both these animals are known to prefer lambs; however adult sheep carcasses were also identified at caracal kill sites (see Chapter 6). As mentioned previously the persistence of leopards in the system could prevent a "mesopredator release". Despite also contributing to livestock losses, especially goat, leopard depredation on livestock can be managed (see section 7.2). According to scat analysis, caracal was responsible for the least of the livestock losses and black-backed jackal depredated on livestock more often than caracal. The two main prey items in caracal diet (hyrax and lagomorpha) remained the same, irrespective of the land-use. However, the number increased when assessing caracal diet from GPS cluster visitations. As stated in Chapter 6, a bias could have existed as only male caracal were captured and fitted with collars. In Namaqualand we found leopard to feed on other carnivores to a greater extent than both caracal and black-backed jackal. The influx of an available prey source (livestock) on farmlands could increase the occurrence of carnivores on farmlands, leading to an increase in competition for natural prey items. Such a factor could also result in increased livestock predation, further emphasising that a suitable natural prey base on farmlands could decrease livestock losses.

7.2. Possible solutions to decrease livestock depredation In Namaqualand

With the Succulent Karoo biome being one of only two arid biodiversity hotspots in the world, the conservation of this area is of importance (Mucina and Rutherford 2006; Du Plessis *et al.* 2015). However, as stated above, agriculture especially livestock farming forms an important part of South Africa's economic growth and many people depend on the practise for subsistence (Thorn *et al.* 2013). Farmers have been implementing lethal strategies to control predators on farms for decades (Beinart 2003; Marker and Dickman 2005; Bailey and Conradie 2013). Despite the increasing conflict experienced between farmers and predators in South Africa, very little scientific effort has contributed to understanding the dynamics of predators on farms (Bergman *et al*. 2013; Du Plessis *et al*. 2015). Holistic solutions have been recommended without proper understanding of the rationale behind such solutions and the effort required to successfully executing such solutions. This has resulted in disappointment from farmers regarding such methods, with many claiming they do not work (Li, Buzzard, Chen and Jiang 2013; Thorn *et al.* 2013). However, lethal persecution has also been implemented without proper knowledge and has resulted in the collapse of ecosystems in some areas (Pettigrew *et al.* 2012). As each system does not function to the same extent as the next, it is important to study each area individually. What works for one farmer will not necessarily work for another. Lethal persecution of predators on farms includes spot-light hunting, lethal and indiscriminate traps, poison, hunting with dogs and many others (Beinart 2003). In many cases spot-light hunting is less indiscriminate, however, there are instances when a farmer will shoot anything within range. The greatest concern is the use of indiscriminate traps. With the increase of public awareness regarding animal persecution on farms and continuous pressures from conservation organisations, many farmers have felt the pressure to alter their predator management strategies to more holistic methods (Loveridge, Wang, Frank and Seidensticker, 2010).

The use of livestock guarding dogs (LGD) such as Anatolian shepherd dogs and maluti dogs has been successful in some areas (Marker, Dickman and Schumann 2005). Many farmers have also used llamas (*Lama glama)* and donkeys (*Equus asinus*) as guarding animals (Crawshaw 2004). Although the use of LGDs has been successful in decreasing livestock losses in certain areas, many farmers also report problems with LGDs (Marker *et al.* 2005; Gehring, Vercauteren and Landry 2010). These animals need to be fed regularly and trained properly to prevent behavioural problems such as dogs hunting game, returning home and leaving the stock unattended, playing too roughly with lambs and sometimes even killing stock (Marker *et al.* 2005). Often farmers do not have the time to properly train a LGD or they are reluctant to invest time and effort in the LGD's development (Smith 2012). It is in such cases where the use of LGD's fails. Many studies suggest the alternative use of shepherds/herders (Inskip and Zimmerman 2009; Pettigrew *et al*. 2012). In an ideal scenario herders should be used, alongside a LGD. This will allow for the correct training period and the dogs will be adequately fed. There is currently a larger study being conducted in Namaqualand to test lethal persecution versus the use of LGDs and the use of LGDs in combination with herders (K. J Teichman and B. Cristescu unpublished data).

Actively persecuting jackals on farms is a controversial issue, as black-backed jackals can adapt their ecology to human influences such as their diet, activity patterns and even reproductive rates and litter sizes (Beinart 2003; Skinner and Chimimba 2005; Nattrass and Conradie 2013). The best method would rather be prevention, but keeping in mind the cunning behaviour of jackals it is advised to continuously change methods or use a combination of methods. Historical pastoral methods such as herding and kraaling require a lot of effort especially in vast areas such as Namaqualand. However, past studies have recommended the use of such practices as the most practical way to decrease livestock losses (Gusset *et al.* 2009). In the early 1900s fencing was coined as the new solution to reduce livestock losses, as well as decrease the spread of disease (Beinart 2003; Bergman *et al.* 2013). Kraaling animals constantly caused excessive trampling of areas which resulted in erosion. Diseases were also spread more easily in the tightly packed kraals (Beinart 2003). With the new "vermin-proof" fencing, farmers abandoned kraaling. However, today better disease-management and camp-rotation systems are available and a few farmers have thus started to kraal animals once again at night. Kraaling animals require man-power to round up all individuals and many farmers have herds which can travel vast distances (Benjaminsen *et al.* 2006). However, with stock wandering off these animals can more readily fall victim to attacks by predators, especially by leopards. If the kraaling system could again be applied in Namaqualand, farmers may lose less stock to predators. With the low occurrence of livestock remains in caracal scats it can be assumed that these animals prey on livestock opportunistically. Such depredations can be limited by increasing the effort needed to catch stock. Black-backed jackals depredate on lambs and are known to target young animals in the lambing season (Kamler *et al.* 2012). Adapting management strategies to decrease losses in this time can be advantageous. Black-backed jackals rarely depredate on adult stock, so if a farmer can implement an effective strategy, such as increasing herding efforts and kraaling close to the farmstead, to safe-guard lambs from jackal, fewer losses can be experienced.

Scat analysis has shown to be a very effective method to determine the diet of predators. It is also a non-invasive technique and requires few resources (Avenant and Nel 2002; Klare *et al.* 2010; Klare, Kamler and Macdonald 2011). In comparison, capturing and collaring animals is expensive and can cause unnecessary stress to an animal (Bacon, Becic, Epp and Boyce 2011). Making use of GPS collars can provide valuable information with regards to carnivore ecology in a specific region. For example, fitting leopards with GPS radio-collars will provide better insights as to how, where and potentially why goat is found in leopard diet in such high numbers. The home range size and population dynamics of leopards in Namaqualand is not known. It could be that only one or two individuals are responsible for livestock depredation. As these animals are the apex predators in this system it is expected that they occur in much lower densities than the two mesocarnivores, increasing the probability of having only one or two "problem individuals" in the region. Arid areas also have reportedly low leopard densities and persecuting even only one individual may have drastic effects on the ecosystem functioning (Martins 2010; Mann 2014). Many studies have found leopards not to respond positively to relocation and many times the predator has returned to its original home range (Athreya *et al.* 2010).

Ensuring leopard persistence in Namaqualand could be the key to keeping livestock losses at a low level. As mentioned in section 7.1, the loss of an apex predator from a system could lead to a "mesopredator release" in which smaller predator (thought to be responsible for larger livestock losses) numbers increase. However, the first step would be to limit leopard depredation on livestock. To prevent leopard depredation it would be best to have guarding animals or shepherds/herders accompany animals into the veld in the day and not leave animals out at night. Leopards are known to exhibit surplus killing where a large number of livestock are killed, but not fed on. This behaviour has not as yet been recorded in Namaqualand and keeping animals guarded at night and not in the koppies and out in the open would be a step in the right direction. To further maximise the protection of livestock and avoid high levels of depredation, stock should also be protected from black-backed jackals and caracal. In the case of the mesocarnivores it is mostly the lambs which are depredated on and increasing guarding in lambing periods could ensure that losses of lambs are decreased. By maintaining a solid natural prey base and in turn deceasing the negative human influence on the ecosystem, along with implementing a combination of livestock guarding/herding and other holistic methods, livestock losses in Namaqualand could be controlled and farmers could experience fewer losses annually.

7.3. References

Athreya, V., Odden, M., Linnell, J. D., And Karanth, K. U. 2010. Translocation as a Tool for Mitigating Conflict with Leopards in Human-Dominated Landscapes of India. *Conservation Biology* **25**: 133–141.

Avenant, N, L., and Du Plessis, J. J. 2008. Sustainable small stock farming and ecosystem conservation in southern Africa: A role for small mammals? *Mammalia* **72**: 258–263.

Avenant, N. L., and Nel, J. A. J. 2002. Among habitat variation in prey availability and use by caracal *Felis caracal*. *Mammal Biology* **67**: 18–33.

Bacon, M. M., Becic, G. M., Epp, M. T., and Boyce, M. S. 2011. Do GPS Clusters Really Work? Carnivore Diet from Scat Analysis and GPS Telemetry Methods. *Wildlife Society Bulletin* **35**: 409-415.

Bagniewska, J. M., and Kamler, J. F. 2013. Do black-backed jackals affect numbers of smaller carnivores and prey? *African Journal of Ecology* **52**: 564-567.

Bailey, A., and Conradie, B. 2013. *The Effect of Predator Culling on Livestock Losses: Caracal Control in Cooper Hunting Club, 1976 – 1981*. Centre for Social Science Research: University of Cape Town.

Balme, G., Lindsey, P. A., Swanepoel, L. H., and Hunter, L. T. B. 2013. Failure of research to address the rangewide conservation needs of large carnivores: leopards in South Africa as a case study. *Conservation Letters* **00**: 1 – 9.

Beinart, W. 2003. *The rise of conservation in South Africa: settlers, livestock and the environment.* Oxford: Oxford University Press.

Benjaminsen, T. A., Rohde, R., Sjaastad, E., Wisborg, P., and Lebert, T. 2006. Land reform, range ecology, and carrying capacities in Namaqualand, South Africa. *Annals of the Association of American Geographers* **96**: 524-540.

Bergman, D. L., De Waal, H. O., Avenant, N. L., Bodenchuk, M. J., Marlow, M. C., and Nolte, D. L. 2013. The Need to Address Black-backed Jackal and Caracal Predation in South Africa. In: J. B. Armstrong and G. R. Gallagher, eds. 2013. *Proceedings of the 15th Wildlife Damage Management Conference* South Carolina.

Blaum, N., Tietjen, B., and Rossminth, E. Impact of Livestock Husbandly on Small- and Medium-Sized Carnivores in Kalahari Savannah Rangelands*. The Journal of Wildlife Management* **73**: 60-67.

Chattha, S. A., Hussain, S. M., Javid, A., Abbas, M. N., Mahmood, S., Barq, M. G., and Hussain, M. 2015. Seasonal Diet Composition of Leopard (*Panthera pardus*) in Machiara National Park, Azad Jammu and Kashmir, Pakistan. *Pakistan Journal of Zoology* **47**: 201 – 207.

Cowling, R. M., Esler, K. J., and Rundel, P. W. 1999. Namaqualand, South Africa – an overview of a unique winter-rainfall desert ecosystem. *Plant Ecology* **142**: 3-21.

Crawshaw, P. G. 2004. Depredation of domestic animals by large cats in Brazil. *Human Dimensions of Wildlife* **9**: 329–30.

Davidson, A. D., Detling, J. K., and Brown, J. H. 2012. Ecological roles and conservation challenges of social, burrowing, herbivorous mammals in the world's grasslands. *Frontiers in Ecology* **10**: 477-486.

Davies, R. A. G. 1999. Extent, cost and control of livestock predation by eagles with a case study on Black Eagles (*Aquila verreauxii*) in the Karoo. *Journal of Raptor Research* **33**: 67-72.

Davies, R. A. G., and Ferguson, J. W. H. 2000. The influence of predation by Black Eagles *Aquila vereaxii* on Rock Hyrax numbers in the arid Karoo. In: R, D. Chancellor and B-U Meyburg, eds. 2000. *Raptors at risk.* United Kingdom: Hancock House.

Dickman, A. J., Macdonald, E. W., and Macdonald, D. W. 2011. A review of financial instruments to pay for predator conservation and encourage human–carnivore coexistence. *PNAS* **108**: 13937–13944.

Du Plessis, J. J., Avenant, N. L., and De Waal, H. O. 2015. Quality and quantity of the scientific information available on black-backed jackals and caracals: contributing to human–predator conflict management? *African Journal of Wildlife Research* **45**: 138–157.

Estes, R. D. 2012. *The behaviour guide to African mammals*. Berkely: The University of California Press.

Ferguson, J. W. H., Galpin, J. S., and De Wet, M. J. 1988. Factors affecting the activity patterns of black-backed jackals *Canis mesomelas*. *Journal of Zoology* **214**: 55-69.

Fleming, P. A., Anderson, H., Pendergast, A. S., Bretz, M. R., Valentine, L. E., and Hardy, G, E, StJ. 2014. Is the loss of Australian digging mammals contributing to a deterioration in ecosystem function? *Mammal Review* **44**: 94–108.

Fourie, L. J. 1983. *The population dynamics of the rock hyrax* Procavia capensis *(Pallas, 1766) in the Mountain Zebra National Park*. Dissertation, University of Rhodes, South Africa.

Gehring, T. M., Vercauteren, K. C., and Landry, J-M. 2010. Livestock Protection Dogs in the 21st Century: Is an Ancient Tool Relevant to Modern Conservation Challenges? *BioScience* **60**: 299-308.

Gusset, M., Swarner, M. J., Mponwane, L., Keletile, K., and McNutt, J. W. 2009. Human–wildlife conflict in northern Botswana: livestock predation by Endangered African wild dog *Lycaon pictus* and other carnivores. *Oryx* **43**: 67-72.

Hayward, M. W., Henschel, P., O'Brien, J., Hofmeyr, M., Balme, G and Kerley, G. I. H. 2006. Prey preferences of the leopard (*Panthera pardus*). *Journal of Zoology* **270**: 298-313.

Inskip, C., and Zimmerman, A. 2009. Human-felid conflict: a review of patterns and priorities worldwide. *Oryx* **43**: 18-34.

Kamler, J. F., Stenkewitz, U., Klare, U., Jacobsen, N, F., and Macdonald, D. W. 2012. Resource Partitioning Among Cape Foxes, Bat-Eared Foxes, and Black-Backed Jackals in South Africa. *The Journal of Wildlife Management* **76**: 1241–1253.

Karanth, K. U and Sunquist, M. E. 1995. Prey selection by tiger, leopard and dhole in tropical forests. *Journal of Animal Ecology* **64**: 439–450.

Kaunda, S. K. K., and Skinner, J. D. 2003. Black-backed jackal diet at Mokolodi Nature Reserve, Botswana. *African Journal of Ecology* **41**: 39-46.

Klare, U., Kamler, J. F., and Macdonald, D. W. 2011. A comparison and critique of different scat-analysis methods for determining carnivore diet. *Mammal Review* **41**: 294–312.

Klare, U., Kamler, J. F., Stenkewitz, U., and Macdonald, D. W. 2010. Diet, prey selection, and predation impact of black-backed jackals in South Africa. *Journal of Wildlife Management* **74**: 1030–1042.

Li, X., Buzzard, P., Chen, Y., and Jiang, X. 2013. Patterns of Livestock Predation by Carnivores: Human–Wildlife Conflict in Northwest Yunnan, China. *Environmental Management* **52**: 1334-1340.

Loveridge, A. J., Wang, S. W., Frank, L. G., and Seidensticker, J. 2010. People and wild felids: conservation of cats and management of conflicts In: D. W. Macdonald and A. J. Loveridge, eds. 2010. *Biology and conservation of wild felids.* New York: Oxford University Press.

Lu, C. D. 1988. Grazing behavior and diet selection of goats. *Small Ruminant Research* **1**: 205-216.

Mann, G. 2014. *Aspects of the ecology of leopards (*Panthera pardus*) in the little Karoo, South Africa.* Dissertation, Rhodes University, South Africa.

Marker, L., and Dickman, A, J. 2005. Notes on the spatial ecology of caracals (*Felis caracal*), with particular reference to Namibian farmlands. *African Journal of Ecology* **43**: 73–76.

Marker, L., Dickman, A., and Schumann, M. 2005. Using Livestock Guarding Dogs as a Conflict Resolution Strategy on Namibian Farms. *Carnivore Damage Prevention News* **5**: 28-32.

Martins, Q., Horsnell, W. G. C., Titus, W., Rautenbach, T., and Harris, S. 2011. Diet determination of the Cape Mountain leopards using global positioning system location clusters and scat analysis. *Journal of Zoology* **283**: 81-87.

Mellville, H. I. A. S., Bothma, J. Du. P., and Mills, M. G. L. 2004. Prey selection by caracal in Kgalagadi Transfrontier Park. *South African Journal of Wildlife Research* **34:** 67-75.

Mucina, L and Rutherford, M.C. eds., 2006. *The vegetation of South Africa, Lesotho and Swaziland.* Pretoria*:* South African National Biodiversity Institute.

Nattrass, N., and Conradie, B. 2013. *Jackal Narratives and Predator Control in the Karoo, South Africa*. Centre for Social Science Research: University of Cape Town.

Norton, P. M., Lawson, A. B., Henley, S. R., and Avery, G. 1986. Prey of leopards in four mountainous areas of the south-western Cape Province. *South African Journal of Wildlife Research* **16:** 47–52.

Ott, T., Kerley, G. I. H., and Boshoff, A. F. 2007. Preliminary observations on the diet of leopards (*Panthera pardus*) from a conservation area and adjacent rangelands in the Baviaanskloof region, South Africa. *African Zoology* **42**: 31–37.

Pettigrew, M., Xie, Y., Kang, A., Rao, M., Goodrich, J., Liu, T., and Berger, J. 2012. Human–carnivore conflict in China: a review of current approaches with recommendations for improved management. *Integrative Zoology* **7**: 210–226.

Skead, C. J. 2011. *Historical incidence of the larger land mammals in the broader Western and Northern Cape* In: A. F. Boshoff, G. I. H. Kerley, and P. H. Lloyd, eds. Centre for African Conservation Ecology, Nelson Mandela Metropolitan University, Port Elizabeth.

Skinner, J. D., and Chimimba, C. T. 2005. *The mammals of the southern African subregion.* Cape Town: Cambridge University Press.

Smith, E, R. 2012. *An assessment of caracal population density and human-predator conflict in the Winterberg, Eastern Cape, South Africa.* Masters Thesis, Rhodes University, South Africa.

Statistics South Africa. 2013. *Statistical release, P1101: Agricultural Survey 2013*. Pretoria: Statistics South Africa.

Suryawanshi, K. R., Bhatnagar, Y. V., Redpath, S., and Mishra, C. 2013. People, predators and perceptions: patterns of livestock depredation by snow leopards and wolves. *Journal of Applied Ecology*. **50**: 550-560.

The Cape Leopard Trust (CLT). 2011. *The Cape leopard trust annual report 2011*. Cape Town: The Cape Leopard Trust.

Thorn, M., Green, M., Scott, D., and Marnewick, K. 2013. Characteristics and determinants of human-carnivore conflict in South African farmland. *Biodiversity Conservation* **22**: 1715–1730.

Valeix, M., Hemson, G., Loveridge, A. J., Mills, G., and Macdonal, D. W. 2012. Behavioural adjustments of a large carnivore to access secondary prey in a human-dominated landscape. *Journal of Applied Ecolog*y **49**: 73–81.

Van Sittert, L. 1998. Keeping the enemy at bay: the extermination of wild carnivora in the Cape Colony, 1889-1910. *Environmental History* **3**: 333-356.

Woodroffe, R., Thirgood, S., and Rabinowitz, A. 2005. *People and Wildlife, Conflict or Coexistence?* Cambridge: Cambridge University Press.