Mesopredator abundances, prey interactions and diet of *Caracal caracal* and *Canis mesomelas* in the Gamkaberg, Western Cape

by

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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 owner of the copyright 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: December 2018

Abstract

Carnivore conservation is considered a priority due to a rise in conflict between involved species and humans. Conservation strategies are thus essential in ensuring the persistence of carnivores in carnivore-human conflict. This conflict affects many livestock farmers, whose main concern is the loss of income due to livestock deaths from predators. Reported incidences of depredations could intensify the human-wildlife conflict in an area, which could potentially result in predators being killed by, for example, trapping and through sport hunting. This measure-for-measure retaliatory response can drive predators to local and regional extirpation, often resulting in an increase of wild herbivore densities. Small stock farmers in South Africa regard leopard, caracal (*Caracal caracal*) and black-backed jackal (*Canis mesomelas*) as vermin. In the Gamkaberg region of South Africa's Western Cape Province, the diet of the Cape leopard has been studied quite extensively, but research on the diets of the black-backed jackal and the caracal in the area is lacking. Consequently, this study focussed on the distribution and diet of caracal and black-backed jackal using camera traps and scat and stomach content analyses.

The first part of this thesis focuses on the diets of the two species and compares dietary preferences on farmland and in conservation areas. Results pose a clear contrast to livestock farmers' view on these predators' natural diet. Both focal species were found to prey upon predominately smaller prey and were opportunistic. Insects were found in approximately 10% of both the jackal and caracal scats. Other invertebrates were also identified in the scats of both species, including scorpions and Solifugae. The stomachs of 11 black-backed jackal contained Solifugae and egg remnants; the softer nature of such diets makes it difficult to detect them in scats. Stomach content analyses thus indicated more recent and detailed diet results, in particular for the opportunistic black-backed jackal that ingests many soft-tissue prey items, such as carrion and Arthropoda that rarely persist through the digestive tract. Mammals, especially rodents, are a very important food source for mesopredators and were found in most of the samples for both jackal and caracal. In this study, 83.3% and 88.1% of jackal and caracal scat samples, respectively, contained rodent parts. Rodents, therefore, account for a significant part of both mesopredators' diets in the Little Karoo. The large variation found in both the caracal and black-backed jackal diets confirmed their opportunistic feeding nature in the Gamkaberg. This flexibility in diet, especially for the black-backed jackal, makes it difficult to determine a prey-specific preference pattern. The diets of the focal species in this study are adaptable to time, space and prey availability.

The second part of the thesis focuses on estimating population density based on camera trapping. Population size and density estimates are informative to conservation and management planning but are difficult to estimate, especially if the species is rare or elusive. This study used estimators based on relative abundance and presence-absence records to assess the relative abundance of caracal and black-backed jackal in the study area. Camera traps were used for a 10 month period (June 2014-April 2015) in farmlands and conservation areas, whilst also testing different sampling efforts. Graphs were produced to illustrate activity periods of the focal species throughout the year. In particular, caracal and black-backed jackal were found to roam in overlapping areas, preying on similar species and showing similar activity patterns. A significant difference was found between prey diversity of the two land-uses (P=0.001). Significant differences were also found between randomised and intensive sampling (P=0.03) as well as between randomised and extensive sampling (P=0.05). However, there were no significant differences in prey diversity between intensive and extensive sampling. In total, 28 caracal and 115 black-backed jackal occurrences were recorded on camera traps, with less caracal and black-backed jackal detected on farmlands than in conservation areas, indicating their preference for natural prey in reserves over prey on farmlands. This also corroborates the results from the scat samples found on farmlands and in conservation areas for both focal species.

Opsomming

Karnivoorbewaring word as `n prioriteit beskou as gevolg van ‘n styging in konflik tussen mense en die betrokke spesies. Bestuursstrategieë is dus baie belangrik omdat dit die aanhoudende teenwoordigheid van karnivore verseker. Veëboere se grootste bekommernis is die verlies van inkomste weens veë afnames veroorsaak deur roofdiere. Voorbeelde soos hierdie kan ‘n styging in mens-roofdier konflik veroorsaak en kan daartoe lei dat roofdiere doodgemaak word met lokvalle en sportjag. Die nagevolge hiervan is die uitwissing van roofdiere wat die natuurlike herbivoor populasies in toom hou. Veëboere beskou luiperde, rooikatte en rooijakkalse as peste en hierdie roofdiere veroorsaak veral mense-dier konflik in die area van die Gamkaberg in the Wes-Kaap in Suid-Afrika. Hierdie tesis poog daarom om rooikatte en rooijakkalse deeglik te bestudeer omdat daar min oor hulle huidige ruimtelike ekologie verken is. Diëetstudies is al in diepte breedvoerig onderneem vir die Kaapse luiperd, egter is daar `n tekort aan studies wat op die diëet van rooijakkalse en rooikatte in die Gamkaberg area fokus. In hierdie studie gaan rooikatte en rooijakkalse in meer diepte bestudeer word met gebruik van diëetanalise en kamera lokvalle.

Die eerste gedeelte van hierdie tesis fokus op die diëte van die rooikat (*Caracal caracal*) en die rooijakkals (*Canis mesomelas*). Dit word gedoen om kennis te bekwaam oor die rooikat en rooijakkals se diëetvoorkeure tussen plaaslande en natuurreservate. Hierdie kan vir veëboere ‘n nuwe perspektief bied oor karnivore se natuurlike diëet. Albei fokusspesies het op kleiner prooi gevoer en was veelsydig in hul prooikeuse. Insekte is ook in baie stoelgang monsters vir beide die rooikat en rooijakkals gevind (omtrent 10% vir elk). Ander ongewerweldes soos skerpioene en geleedpotiges is gevind in albei fokusspesies. Dit is merkwaardig dat daar baie sagte prooi gevind is in die 11 rooijakkals maaginhoude wat bestudeer is. Die rooijakkals neem baie sagte voedingstowwe in soos aas en geleedpotiges wat vernietig word binne-in die spysverteringskanaal. Dié sagte materiaal sal glad nie, of baie selde, teenwoordig wees in die harde stoelgang monsters. Dus bied maaginhoudanalise meer volledige resultate, veral vir die veelsydige rooijakkals. Soogdiere, veral knaagdiere, is ‘n baie belangrike voedselbron vir kleiner roofdiere en is in meeste van die monsters vir die rooijakkals en rooikat opgemerk. In hierdie studie het 83.3% en 88.1% van die jakkals en rooikat se stoelgang onderskeidelik knaagdierinhoud bevat. Knaagdiere vorm dus ‘n beduidende deel van albei fokusspesies se diëte in die Klein Karoo. Die wye verskeidenheid in albei fokusspesies se diëte bevestig hulle wye habitat omvang in Suidelike Afrika. Hul diëet verskeidenheid, veral dié van die rooijakkals, maak dit moeilik om ‘n spesifieke prooikeuse-patroon te bepaal. Die jakkals en rooikat toon dat hulle diëte maklik aanpasbaar is tot tyd, ruimte en wat beskikbaar is.

Die tweede gedeelte van die tesis handel oor die beraming van bevolkingsdigtheid vir die bogenoemde fokusspesies. Bevolkingsgrootte- en digtheidberamings bied belangrike inligting vir bewarings- en bestuursplanne. Ongelukkig is dit soms moeilik om dié inligting te verg as die spesies skaars en ontwykend is. Die relatiewe oorvloed en teenwoordig-afwesig beramings word gebruik om die rooikatte en rooijakkalse se getalle te bepaal. Kamera lokvalle is opgestel om vir tien maande (Junie 2014 - April 2015) tussen plaaslande en nattuurreservate inligting te versamel, asook verskillende steekproefpogings te toets. Grafieke is getrek om die fokusspesies se aktiwiteitspatrone deur die loop van die jaar te illustreer, wat hul aktiwiteit sal wys. In hierdie studie is dit gevind dat die rooikatte en rooijakkalse in soortgelyke areas voorgekom het, voedsel gekies het en dat hulle dieselfde tye aktief was. ‘n Beduidende verskil (P=0.001) is gevind tussen prooidiversiteit op plaaslande en in natuurreservate. Beduidende verskille is ook gevind tussen die lukrake- en intensiewe steekproefpogings (P=0.03) asook die lukrake en ekstensiewe steekproefpogings (P=0.05). Daar is egter geen beduidende verskille gevind in prooiverskeidenheid tussen intensiewe en ekstensiewe steekproefpogings nie. ‘n Somtotaal van 28 rooikatte en 115 rooijakkalse is deur al die kamera lokvalle afgeneem. Daar het minder rooikatte en rooijakkalse op plaaslande voorgekom in vergelyking met natuurreservate. Dit kan beteken dat hulle natuurlike prooi verkies in natuurreservate bo veë in plaaslande. Dit korreleer met die aantal stoelgang monsters wat gevind is op plaaslande en op natuurreservate vir beide fokusspesies.

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Chapter One: Introduction

1.1. Human-wildlife conflict

There is a delicate asymmetry that exists in nature. Everything is connected and interwoven and, for better or for worse, our species has influenced this delicate balance. Whether we realise the scale of our footprint on this planet or not, certain events have been put into motion that, for the time being at least, now cannot be undone. As a species, we share the earth with countless others. We have emerged as the dominant species and as such, we have caused damage. Our environmentally indelicate actions have pushed the environments around us to the limits of sustainability and extinction. Species extinctions have been part of the ecological process since creation: adapt, or die. Presently, conservationists are concerned about the sudden rise in extinction rates and the effect it can have on ecological systems (Martins 2010). Terborgh & Estes (2010) state that over the last 50 000 years, a significant amount of megafauna has been lost. The increase in the human population has resulted in the increased loss of natural resources. Schipper *et al.* (2008) state that humans have contributed to the extinction or endangerment of more than a quarter of the world's mammals in the last 500 years. Due to a rise in conflict between carnivore species and humans, the conservation of these species is considered a priority. Management strategies are thus essential to ensure the persistence of carnivores. Hunter & Hinde (2005) predict that by 2050, most species will only survive in places where people choose to tolerate them. The biggest threats to increased extinction rates of predators are fragmentation, anthropogenic threats, destruction of corridors and climate change (Martins 2010). Additional threats to predators include hunting/trophy hunting and traps set by farmers (Turnbull-Kemp 1967, Packer *et al.* 2009, Mann 2014). Research has also indicated that non-target species are also killed by poisoned baits set out to kill a specific species (Brown 1988, Martins 2010). Carnivore conservation depends on measures that can be implemented outside of protected areas (Balme *et al.* 2010). In this study, carnivores were studied inside and outside of conservation areas to discern whether there was a difference in predator abundance and variety.

Carnivores exhibit a top-down ecosystem effect, suggesting that lower trophic levels such as secondary consumers and primary producers are held intact by carnivores (Hairston *et al.* 1960, Oksanen *et al.* 1980, Miller *et al.* 2001). Some believe that the removal of plants would cause a greater disruption to the ecosystem, as this would cause a decrease in herbivore numbers and, subsequently, a decrease in carnivores would ultimately result (Hunter and Price 1992). Regardless, bottom-up and top-down processes occur simultaneously (Seidensticker 2002). If an apex predator, such as the Cape leopard (*Panthera pardus*), is removed from an ecosystem, mesopredator release can occur. Mesopredator release describes the process through which an ecosystem's lower-tier predators become dominant in the ecosystem due to the absence of the apex predator (Martins 2010, Brook *et al.* 2012). Top-down influences usually have a major effect on the abundance and species composition of vegetation, which can lead to regime shifts or alternative states of ecosystems (Estes *et al.* 2011). This theory suggests that carnivores act as keystone species, regulating the number of herbivores and consequently, the pressure herbivores exert on plants, so that diversity is maintained in the ecosystem (Miller *et al.* 2001). If the caracal (*Caracal caracal*) or black-backed jackal (*Canis mesomelas*) go extinct, the surviving species could promote intra-species competition, ultimately leading to the overpopulation of certain prey (Miller *et al.* 2001, Estes *et al.* 2011). This is why it is important to protect, manage and recover threatened predator populations. For instance, Crête (1999) claimed that ungulate biomass was five to seven times higher in areas where wolves (*Canis lupus*) were absent compared to areas where they were present. This suggests that wolves historically had an impact on the abundance of ungulates in an ecosystem. This again refers to the top-down ecosystem effect, meaning that without the presence of this apex predator, the ungulate population would have dominated the area in numbers.

Livestock farmers' most pressing concerns include the loss of income due to livestock deaths, presumably related to predators (Naughton-Treves *et al.* 2003). In the Cape Province, between 1977 and 1982, an average of 690 leopard-related stock deaths were reported annually (Esterhuizen & Norton 1985). Predator-related livestock deaths can cause an increase in human-wildlife conflict in an area and result in predators being killed in retaliatory killings by, for example, gin traps and through sport hunting (Packer *et al.* 2009). Ultimately, this human-wildlife conflict may lead to a total extirpation of predators, which control natural herbivore densities in an area. These native herbivores will often outcompete introduced livestock herbivore species, being better evolutionarily equipped to survive the landscape (Odden *et al*. 2002).

Until the late 1960s, bounties were payable for Cape leopard, as detailed in the Cape Problem Animal Ordinance No. 26 of 1957 (Martins 2010). This encouraged hunting clubs and farmers to kill leopard that caused damage to livestock (Norton 1986, Martins 2010). Ultimately, in 1974, the leopard was declared a protected animal, after which a permit was required to trap or kill the species (Nature Conservation Ordinance No. 19 of 1974; Norton 1986). After this act protecting the leopard was implemented, action was taken to minimise the number of leopard killed and to increase research effort (Norton & Lawson 1985, Norton 1986). In contrast to leopard, one is still allowed to kill or trap caracal and black-backed jackal without a permit (Martins 2010). However, traps for these mesopredators can kill non-targeted animals, including leopard and other species (Martins 2010). Therefore, methods used to trap caracal and black-backed jackal should be reconsidered in order to avoid causing harm to any other animals (AFWA 2009).

The prey of predators usually choose a habitat that gives them the highest energetic return, whilst predators choose a habitat that maximises their expected fitness (Hugie & Dill 1994). The authors state that a negative feedback loop occurs in the case of habitat selection by predators and prey. In particular, like prey, predators will choose a habitat that provides more resources (i.e. more prey present), which will lead to a higher predation risk in these areas. This causes prey species to redistribute and predator species to subsequently do the same. It is thought that livestock is a preferred prey due to their closed/protected habitats and the minimised energy expenditure needed for a predator to prey on livestock (Linnel *et al.* 1996). As such, predators may choose to hunt livestock rather than expending more energy hunting wildlife, thus skewing wild predator-prey networks (Linnel *et al.* 1996) and leading to intensified farmer-predator conflicts.

Small stock farmers regard leopard, caracal and black-backed jackal as problem animals (Avenant & Nel 1998, Marker & Dickman 2005). They are also regarded as problem animals in the Gamkaberg region (Mann 2014). Nguni cattle, goat and ostrich farming are the main livestock farms present in the study area (See Appendix 6). According to Mann (2014), farmers in the Little Karoo and more specifically Gamkaberg, have classified baboons (56%), black-backed jackal (51%), caracal (21%), porcupines (19%) and leopard (17%) as the most problematic animals in accordance to livestock depredation and human-wildlife conflict.

In this study, caracal and black-backed jackal were the focal species, as little was known about their whereabouts and preferred diet (Stuart 1982; Marker & Dickman 2005, Klare *et al.* 2011). The information required to map mesopredator distribution can be difficult to obtain due to their wide-ranging habits and low densities (Thorn *et al.* 2009). Detailed diet studies have been extensively undertaken for the Cape leopard (Norton 1986, Rautenbach 2010, Mann 2014); however, there is a lack of data with regards to the diet of black-backed jackal and caracal, particularly in the Gamkaberg area. Similar diet studies for mesopredators have been carried out in the following areas, among others: the Kalahari (Bothma 1966, Drouilly *et al. 2018*), the Addo Elephant National Park (Hall-Martin and Botha 1980); the Robertson Karoo, the Coastal Sandveld (Stuart 1982), the Karoo National Park (Palmer & Fairall 1988), the West Coast National Park (Avenant 1993) as well as in Namibia (Mellville *et al.* 2004).

1.2. Study area

1.2.1 Study area

This study was conducted in the Little Karoo, Western Cape (ca. 23 500 km^2), a semiarid, intermontane basin that includes three biodiversity hotspots: Succulent Karoo, Maputoland-Pondoland-Albany and the Cape Floristic Region (Mittermeier *et al.* 2005; Vlok & Schutte-Vlok 2010) (Fig. 1.1). The Little Karoo stretches from the eastern town of Uniondale to the western town of Barrydale, also including the Swartberg, Langeberg and Outeniqua Mountains (Vlok & Schutte-Vlok 2010).

Predator abundance was measured on farmlands and in conservation areas in the surrounding Gamkaberg (21.25, -33.83333 to 22.08333, -33.5) in the Western Cape, South Africa. Rotating camera stations were allocated for this study, surrounding the Gamkaberg Nature Reserve as well as the Rooiberg Mountain Catchment Area and Groenfontein Nature Reserve.

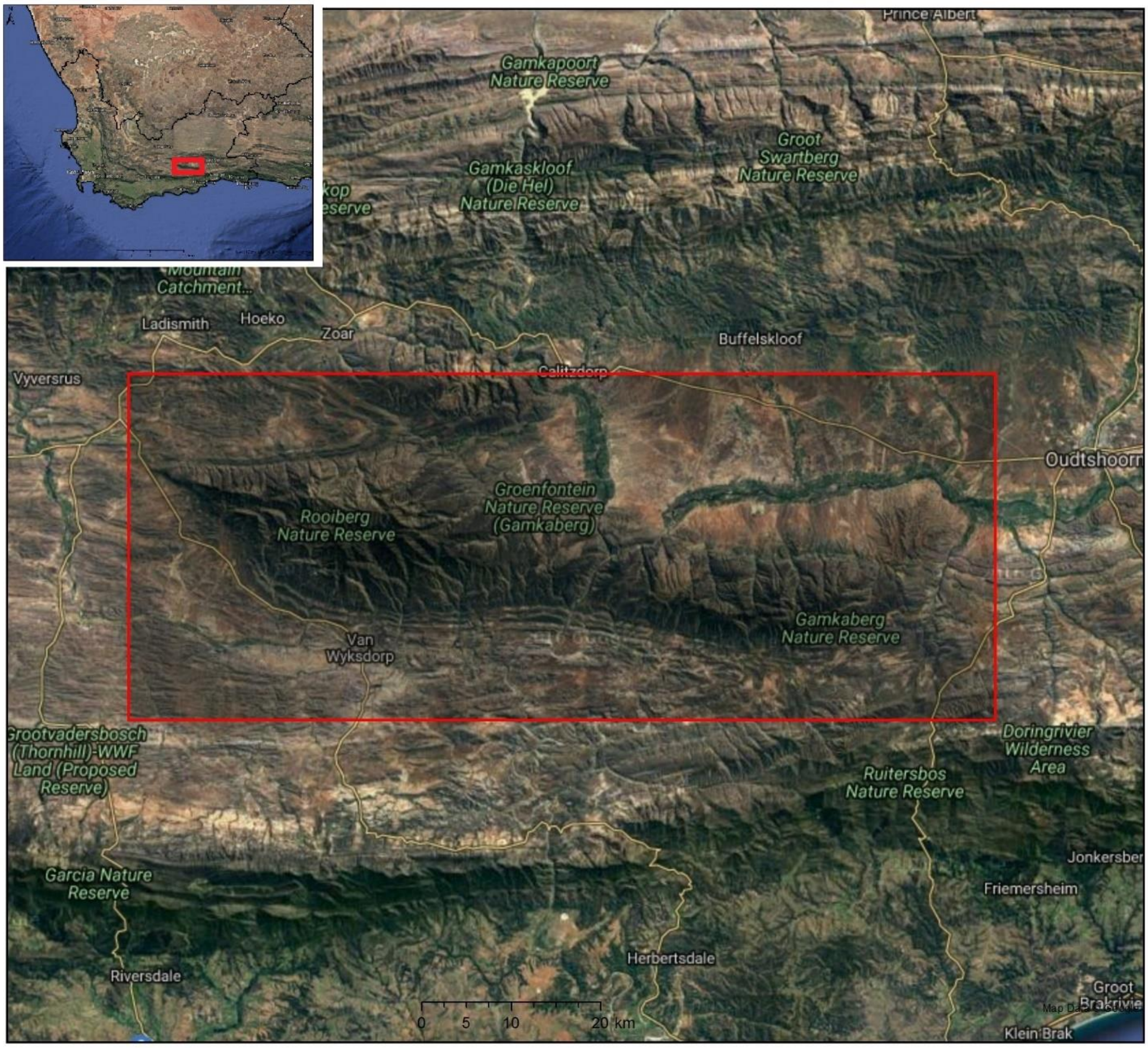

Figure 1.1: Study area within the little Karoo, Western Cape, South Africa (Google Maps).

According to Rautenbach (2010), there are 57 mammal species present in the Gamkaberg that are potential prey for the focal predators, including both small and medium species. The Gamkaberg is surrounded by farmlands. The west side includes ostrich farming and agricultural crops, mostly lucerne (*Medicago sativa*) and the east side consists mainly of sheep farming as well as Boer goat and ostrich farming (Cupido 2005, Rautenbach 2010). The Gamkaberg Nature Reserve (9 428 ha) serves as an important conservation area for indigenous fauna and flora. However, livestock in this area tends to be free-ranging, which increases the potential risk for human-wildlife conflict, involving predators such as leopard, caracal and black-backed jackal (Rautenbach 2010, Cape Nature 2013).

1.2.2 Climate

Summer average temperatures range between 20.1 °C and 22.5 °C and winter average temperatures range between 7.5 ºC and 12.5 ºC (Walton *et al.* 1984). The average annual rainfall ranges between 150 and >1200mm at high altitudes, with primarily winter rainfall, although rain can be distributed throughout the year (Cupido 2005, Reyers *et al.* 2009, Rautenbach 2010).

The climatic data were retrieved from the South African Weather Service using the weather stations at Ladismith and Oudtshoorn. During the study (May 2014-April 2015), the average daily maximum temperature varied between 20.0 °C and 34.0 °C (Fig. 1.2) and the average daily minimum temperature varied between 4.5 °C and 17.0 °C (Fig. 1.3) (SA Weather Service 2015). Rainfall patterns were random with periods of drought which results in a region of water scarcity (Cupido 2005, Reyers *et al.* 2009, Rautenbach 2010). The average monthly daily rain (mm) varied between 37.2 mm in the spring of September 2014 to 1.3 mm in the summer of December 2014 (Fig. 1.4) (SA Weather Service 2015).

The Little Karoo is a winter rainfall region where cold, rainy weather may endure for several days. However, unpredictable summer storms provide occasional rainfall. The Little Karoo differs from the Great Karoo, which receives most of its annual rainfall during summer thunderstorms.

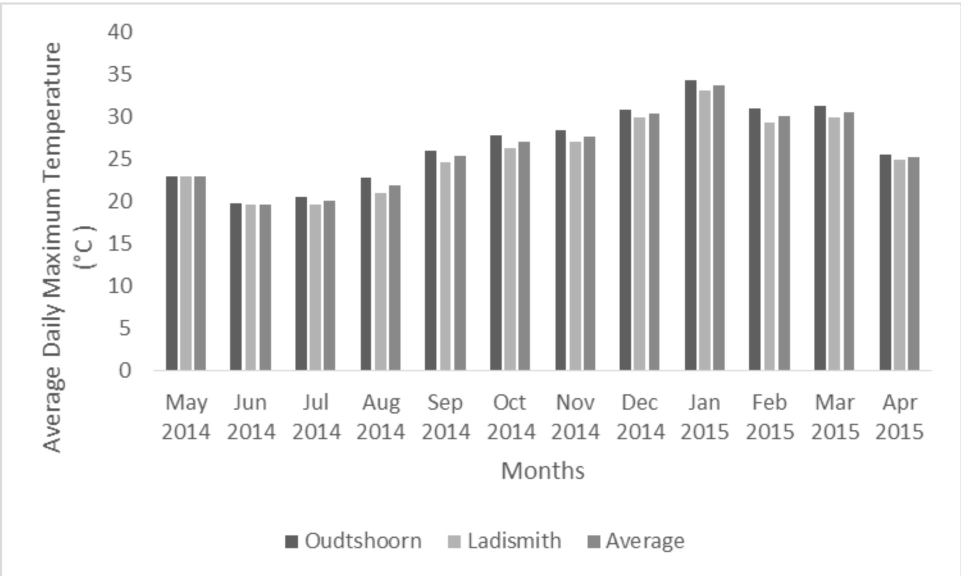

Figure 1.2: Average daily maximum temperature (°C) for Ladismith and Oudtshoorn and averages from May 2014 to April 2015 (SA Weather Service 2015).

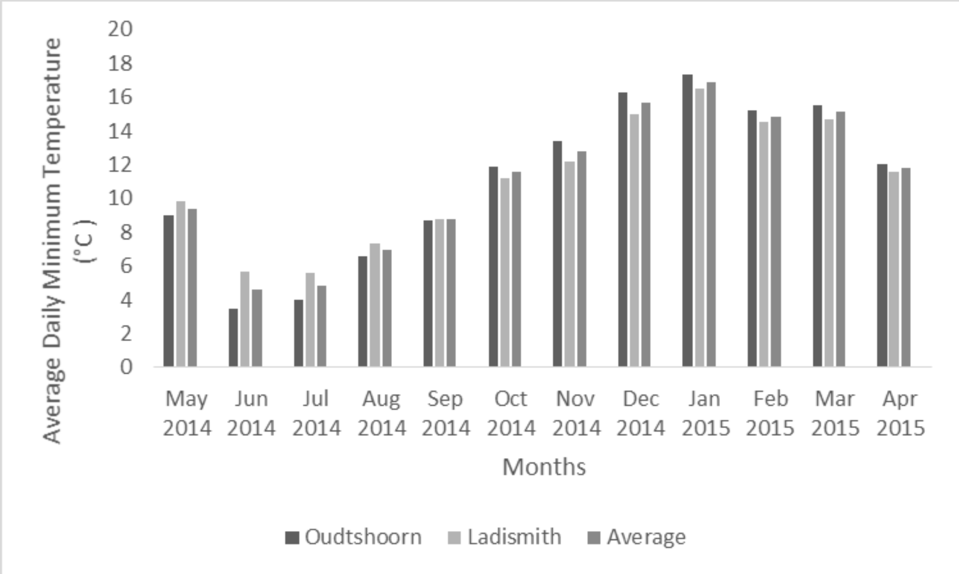

Figure 1.3: Average daily minimum temperature (°C) for Ladismith and Oudtshoorn and averages from May 2014 to April 2015 (SA Weather Service 2015).

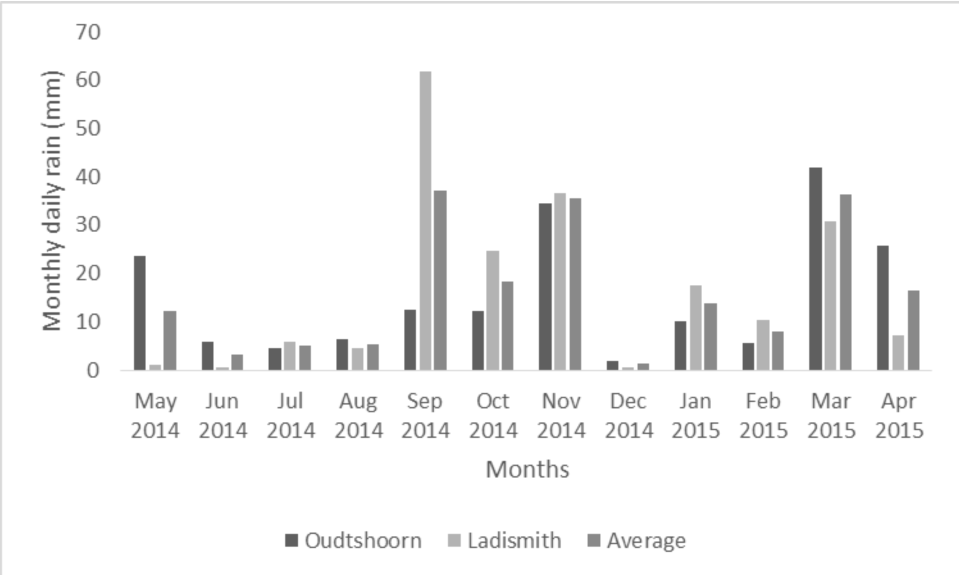

Figure 1.4: Monthly daily rain (mm) for Ladismith and Oudtshoorn and averages from May 2014 to April 2015 (SA Weather Service 2015).

1.2.3 Vegetation

The main vegetation type in the Gamkaberg is mountain fynbos. Additionally, thicket vegetation is present to the east and Karoo vegetation to the west (Mucina & Rutherford 2006). The Little Karoo includes three international biodiversity hotspots including the Cape Floral Region, Succulent Karoo and Maputoland-Pondoland Albany Thicket (Fig. 1.5) (Myers *et al.* 2000 & Mittermeier *et al.* 2005). According to Vlok *et al.* (2005), six distinct biomes were identified in the study area: perennial stream, river and floodplain, subtropical thicket, succulent Karoo, renosterveld and fynbos. The Little Karoo's vegetation is strongly influenced by topography and rainfall, and this results in more complex habitats in and around the mountains (Vlok *et al.* 2005). Fire regimes also play an important role in regulating the regional fauna and flora (Cowling *et al.* 1997).

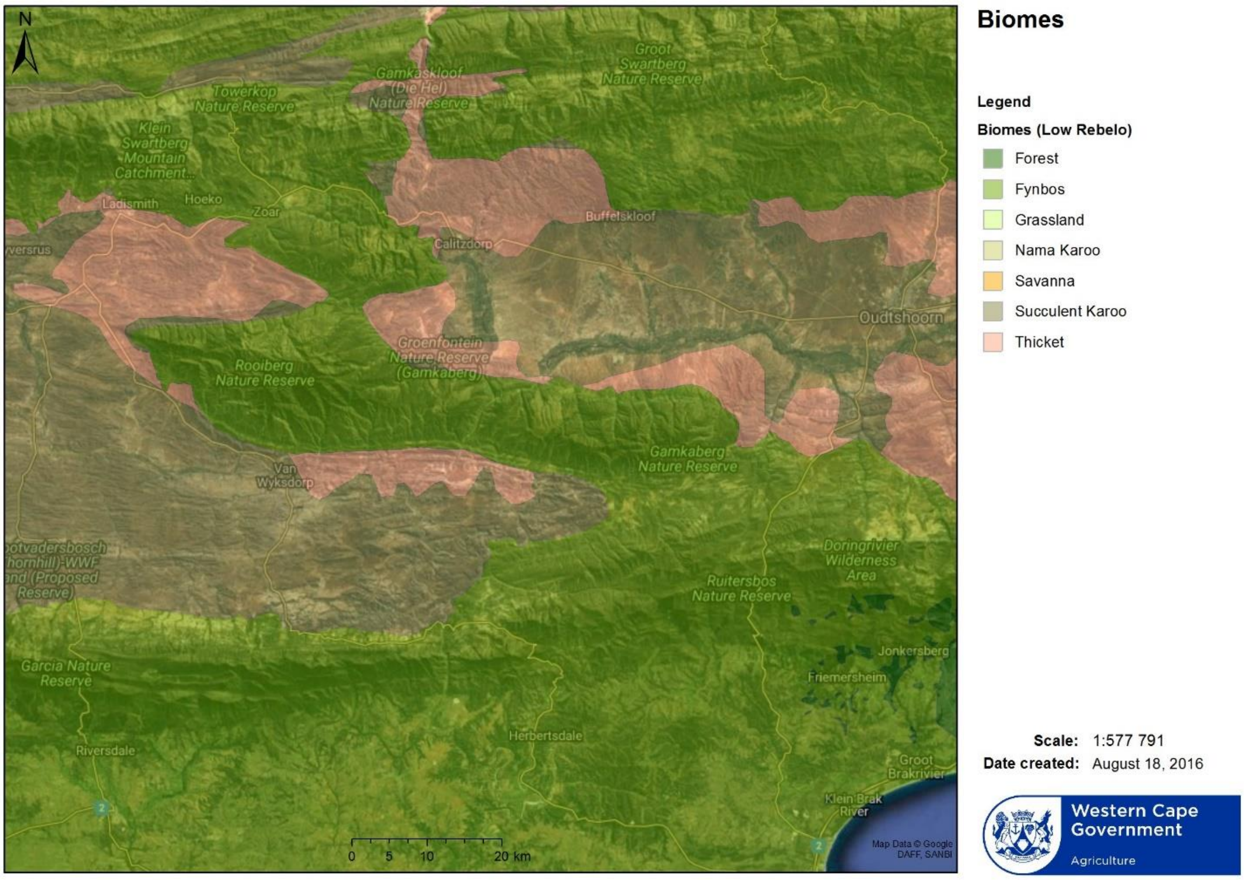

Figure 1.5: The various biomes in the study area.

1.2.4 Geology

The Gamkaberg mountain range includes three isolated mountains adjacent to one another in the Little Karoo region, namely: Sandberg, Rooiberg and the Gamkaberg (Walton *et al.* 1984, Rautenbach 2010). It includes several non-adjacent nature reserves, the oldest of is the Gamkaberg Nature Reserve (9600 ha), which was declared to protect the endangered Cape Mountain Zebra (*Equus zebra zebra*). The reserve was later expanded to include the Rooiberg Nature Reserve (12 800 ha), Groenfontein Nature Reserve (5200 ha), Paardenberg Nature Reserve (1500 ha) and Vaalhoek Nature Reserve (1200 ha). The mountains have a rugged topography with a mean altitude of 1 496 m above sea level (Walton *et al.* 1984, Rautenbach 2010). The Rooiberg and Gamkaberg are distinguished by deep-cut, narrow gorges surrounded by upright, rocky cliffs. These mountains' surroundings are flat with open plains mostly used for agricultural purposes.

The rock stratum consists of sedimentary rocks from the Cape Supergroup, including the Witteberg Group, the Bokkeveld Group and the Table Mountain sandstone group that includes sandy, thin, nutrient-poor soil with high content of limestone (Cowling *et al.* 1997, Reyers *et al.* 2009). The Little

Karoo formed part of a shallow marine shelf between the Early Ordovician and Early Carboniferous period, which resulted in an extensive deposition of fossil-rich sandstone, mudstone and shale sediments (Fourie *et al.* 2011, Mann 2013). The sedimentary mountains in the Little Karoo cover the Cape Granite Suite, which is an enormous granitic extrusion (Scheepers & Armstrong 2002).
The flat valley surrounding the Rooiberg- and Gamkaberg is part of the Oudtshoorn Basin, which is part of the Uitenhage Group of Mesozoic sedimentary deposits (Newton *et al.* 2006). The soil of these valleys is red in colour, basic, loosely organised and easily drained (Ellis & Lambrecths 1986).
The Gamka-Olifants-Gouritz river system is an essential perennial water source in the study area (Fig. 1.6). The river system starts in the Swartberg Mountain as the Gamka river and flows south to the Huisriver Pass, where it links with the Huisriver flowing westward from Calitzdorp. The Olifants River joins the Gamka and forms the Gouritz River, which separates the Gamkaberg and Rooiberg Mountains. The Groot River is south of Rooiberg and joins the Gouritz river.

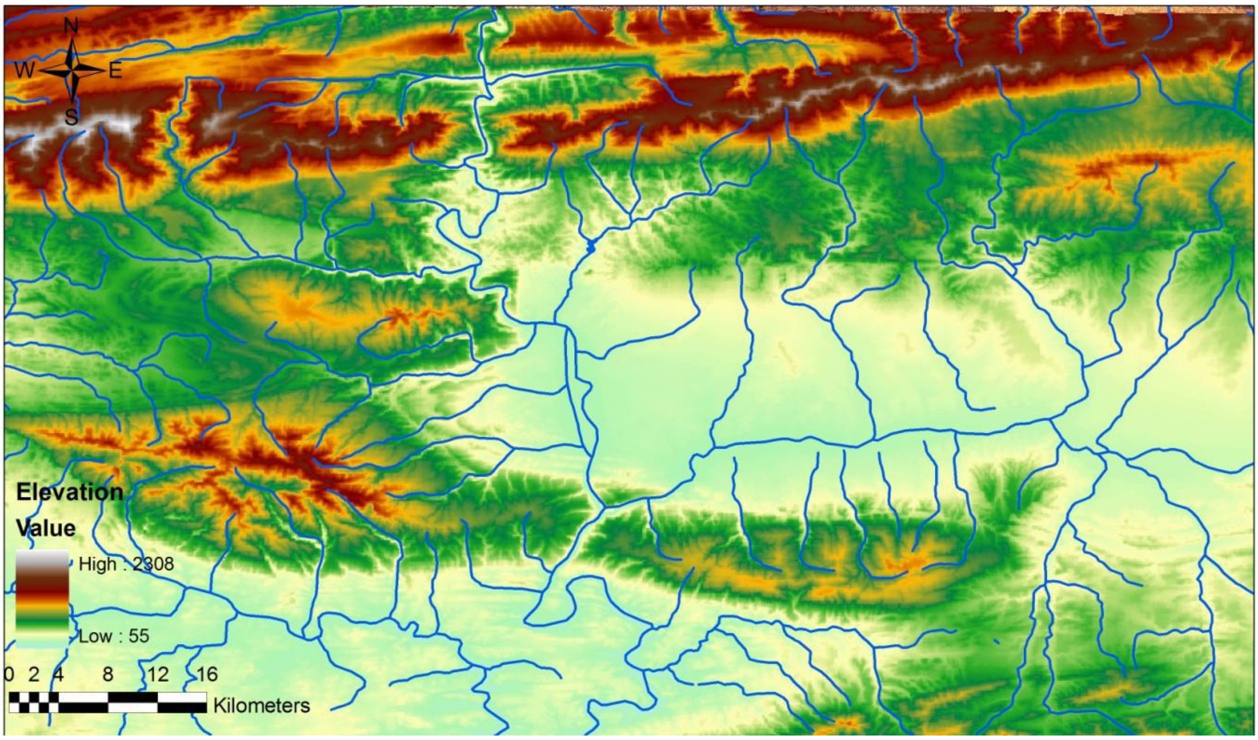

Figure 1.6: Elevation and drainage map of the study area obtained from Mann (2014).

In the Little Karoo, the main cause of land-cover change and biodiversity loss is overgrazing that results in degradation of vegetation and soil (Reyers *et al.* 2009). The area is mostly overstocked with cattle, horses, donkeys, sheep, goats and ostriches (Cupido 2005). This degradation as well as clearing for croplands have resulted in a decline in biodiversity in the Little Karoo (Rouget *et al.* 2006, Gallo *et al.* 2009).

1.3. Focal species

A recent questionnaire-based study concluded that farmers tend to kill carnivores they encounter more often, and not the species they think to inflict the costliest damage (Mann 2014). Martins (2010) found that leopard are known to make larger kills during winter than in the summer, possibly due to the summer heat adding to their level of exhaustion and discomfort. This is likely to also be the case for the mesopredators in this study, indicating that the black-backed jackal and the caracal kill more livestock in the summer than any other prey, for the same reasons as that of the leopard. This study focused on two main mesopredators, namely the black-backed jackal and the caracal, as extensive studies have already been carried out on the Cape leopard in the region (Rautenbach 2010, Mann 2015).

1.3.1 Caracal (*Caracal caracal*)

The caracal is the largest (8.9-13.8 kg) of all the smaller cats occurring in the Cape region and has been classified as a mesopredator (Stuart 1982, Skinner & Chimimba 2005). The caracal has a wide distribution on the African continent and can withstand arid conditions. They are associated with open country, savanna woodland, vlei and grassland areas (Skinner & Chimimba 2005). Home-range sizes for males (27.0±0.750 km^2) are larger than for females (7.39±1.68 km^2) (Avenant 1993, Skinner & Chimimba 2005). The caracal is listed as “least concern” according to the IUCN Red Data list (IUCN 2013). African caracal are listed in Appendix II by CITES which means that their populations are currently stable (CITES 2013). As they have become increasingly perceived as a problem animal. The caracal utilises various prey species, including small- to medium-sized mammals, and ranging from insects to antelope, but are known to focus primarily on rodents (Avenant 1993, Mellville *et al.* 2004, Mellville *et al.* 2006). Caracal are in some situations involved in livestock predation on sheep and goats (Stuart 1982, Avenant & Nel 1998, Mellville *et al.* 2006). They are solitary and mainly nocturnal animals (Avenant & Nel 1998, Skinner & Chimimba 2005). In the Karoo, caracal compete for prey with the black-backed jackal, another mesopredator (Stuart 1982, Moolman 1986, Skinner & Smithers 1990, Martins unpublished data 2014).

1.3.2 Black-backed Jackal (*Canis mesomelas*)

The black-backed jackal is a medium-sized (6-10 kg) canid widely distributed in South Africa, except in developed and forested areas such as Cape Town, Paarl and Knysna for example (Skinner & Chimimba 2005). Their home-range size is between 2 and 181.9 km^2 (Brand 1993) and they prefer drier, open terrain habitat even though they have a wide habitat tolerance (Skinner & Smithers 1990). Black-backed jackal are opportunistic feeders and have a wide food range including antelope, rodents, birds, reptiles, insects, wild fruits and berries (Skinner & Smithers 1990, Klare *et al.* 2010). They are solitary animals but also live in pairs. They are primarily nocturnal but are often seen during the day (Ferguson 1980, Skinner & Smithers 1990). The black-backed jackal is currently listed as "least concern" according to the IUCN (IUCN 2013). They are extremely difficult to trap because of their developed smell and their tendency to pick up any small changes in the surrounding landscape (Skinner & Chimimba 2005). The black-backed jackal is perceived as a problem mesopredator in sheep and goat farming areas (Brand 1993, Klare *et al.* 2011).

1.4. Problem statement, aim and objectives

In the Gamkaberg area, farmers farm primarily with livestock, such as cattle (*Bos taurus*), ostrich (*Struthio camelus*), sheep (*Ovis aries*) and goats (*Capra hircus*). In the Little Karoo, there is ample and recent data available on the Cape leopard's diet, home- and core ranges (Mann 2014). It has been found that farmers in the area still regard the caracal and black-backed jackal as the culprits for most of their livestock losses (pers. comm.). Few studies on the species' diet have been undertaken in this area to help farmers understand their ecology better. Studies on black-backed jackal have been undertaken in the Kalahari Gemsbok Park (Bothma 1966); Kimberley (Klare *et al.* 2011); Grahamstown (Forbes 2011); Namib Desert (Nel *et al.* 1997, Goldenberg 2010), Addo Elephant National Park (Hall-Martin & Botha 1980); Eastern Cape (Busshian 1997); Botswana; Zimbabwe (Smithers 1983), Northern, Western and Eastern Cape (Stuart, 1987); Free State (Kok 1996) and the uKhahlamba-Drakensberg Park (Rowe-Rowe1983, Drouilly *et al.*2018). Caracal ecology has been studied in the Eastern Cape (Busshian 1997); the Karoo National Park (Palmer & Fairall 1988); the Mountain Zebra National Park (Grobler 1981, Moolman 1984); the Kgalagadi Transfrontier Park (Mellville *et al.* 2004); Northern, Western and Eastern Cape (Stuart & Hickmann 1991); the West Coast National Park (Avenant & Nel 1997); Botswana (Smithers 1971); the Karoo (Drouilly *et al.* 2018) and in the Free State (Bester 1982). Most of these studies made use of stomach content analysis. To date, no study on the ecology of these mesopredators has been undertaken in the Little Karoo region. The primary aim of this project was, therefore, to attempt to fill this knowledge gap.

Objective 1: To determine the diets of both the black-backed jackal and the caracal in the Gamkaberg area of the Little Karoo.

Objective 2: To estimate the relative abundance of the mesopredators and prey comparing protected areas to farmland.

Chapter Two: Diet of Caracal (*Caracal caracal*) and black-backed Jackal (*Canis mesomelas*) in the Gamkaberg

2.1. Abstract

Extensive studies on carnivore diet have been carried out for large carnivores within South Africa. However, there is a major gap in the knowledge of diet of mesopredators such as black-backed jackal and caracal. Large carnivores and mesopredators are vulnerable to anthropogenic threats and habitat fragmentation, due to the majority of their natural habitat consisting of farmlands. This results in human-wildlife conflict with farmers who perceive these carnivores as vermin. Scat samples were collected opportunistically from June 2014 to April 2015 in both conservation and farmland areas in the Gamkaberg region. Stomach contents of jackal were also provided by a local hunter. Frequency of occurrence (%) of food items was determined to assess the diet composition of the two mesopredators. Species accumulation curves were produced to determine if the scat sample sizes were large enough for a representative description of diet. Prey preference or avoidance was calculated using the Jacobs' Index. The most frequently found prey for the caracal and black-backed jackal was the *Otomys spp.*; 19.4% and 20.95% respectively. The most important food source derived from total biomass of prey consumed by the black-backed jackal, included livestock such as goat, sheep, ostrich and donkeys, together making up more than half of the jackal's diet (55.3%). The black-backed jackal's most preferred prey was Rodentia and Insecta in all areas. Goats and vlei rats were the main food sources for the caracal, making up 42% of the corrected biomass of prey consumed. The caracal's most preferred prey in all areas included: Rodentia, Reptilia and Insecta. The stomach content analysis of the jackal showed that only 15.5% of all prey species were small mammals (<1 kg) and Dorper sheep and ostrich accounted for 74% of the total biomass of prey. This implies that prey selection may be biased towards livestock; however, these livestock animals were consumed in farmland areas. The two mesopredators were found to predate on smaller prey and were also very opportunistic towards other food items. Mammals, especially rodents, were an important food source for the mesopredators and were present in the majority of the scat and stomach samples of both jackal and caracal.

2.2. Introduction

Gathering information on carnivore diets can assist in understanding the role of carnivores in ecosystem functioning and help to identify competitors and their possible impact on prey populations (Mills 1992, Klare *et al.* 2011). Furthermore, diet analyses can aid future carnivore-related management, especially if it benefits the economy and the species become endangered (Klare *et al.* 2011). Several methods have been used to study the composition of carnivore diets, including the extremely invasive stomach content analysis (Bothma 1966), direct observations (Mills & Shenk, 1992), non-invasive scat analysis (Mann 2014) and stable isotope analysis (Darimont & Reimchen 2002).

More recent diet studies have been carried out on the Cape Leopard, the apex predator in the study area, but there is a major gap with regards to the diet of the perceived problem carnivores in the area, namely: black-backed jackal and caracal (Rautenbach 2010, Mann 2014). In order to understand why farmers classify some predators as vermin, it is important to compare their diet in nature reserves/conservation areas and farming areas. Most nature reserves in South Africa are small, fragmented and surrounded by agricultural areas and, therefore, the predators living in and around these areas have a much wider diet choice between livestock and/or wildlife (Bothma & Le Riche 1984).

In contrast with large carnivores, mesopredators predate on relatively small prey that correlates with their own body weight (Rautenbach 2010). Mesopredators such as the caracal and black-backed jackal, with a mean mass of 12.1 kg and 7.8 kg respectively, would then be more dependent on small mammals and invertebrate species (Skinner & Chimimba 2005). That said, black-backed jackal have been recorded to consume a broad range of prey items in Sub-Saharan Africa ranging from arthropods to the greater kudu which weighs about 270 kg (Forbes 2011). The most common prey are small sized mammals weighing between 0-5 kg (Bothma 1966, Hall-Martin & Bothma 1980, Bussiahn 1997, Nel *et al.* 1997, Skinner & Chimimba 2005, Goldenberg 2010, Klare *et al.* 2010, Forbes 2011). According to Carbone & Gittleman (2002), the carnivore population density usually has an interrelationship with the available prey biomass; therefore, it is possible that the black-backed jackal and caracal population densities would be low in the Little Karoo because of the limited food availability present.

Stuart & Hickmann (1991) found that only 16.8% of the scats of caracal contained hair of small livestock including sheep and goats and that consumed antelopes were less than 15 kg in mass. This is very similar to the body weight of a caracal itself. Rock hyraxes, hares, rabbits and rodents were also substantial food items for the caracal (Palmer & Fairall 1988). Avenant & Nel (1997) found that mammals occurred in 100% of the West Coast National Park caracals' diet, where the most important prey species were the Karoo bush rat (*Otomys unisulcatus*) and the striped mouse (*Rhabdomys pumilio).* From nine stomach contents collected in Botswana, 89% contained mammal remains, with the largest mammal recorded being a juvenile impala (Smithers 1971). Reptiles and birds were also present. Two studies undertaken in the Free State found contrasting results: Bester (1982) only found remains of wild mammals in the stomach, whereas Kok (1996) found a 28% occurrence of sheep in 85 stomach samples. This difference may be due to seasonal changes over the years or a small sample size in Bester's study. In several studies, it was found that caracal were responsible for domestic stock killings (Stuart and Hickman 1991, Bester 1982, Pringle & Pringle 1979, Skinner 1979). Stuart (1982) recorded that an average of 2 219 caracals were killed in the period from 1931-1952 in controlled operations in the Karoo.

According to many studies, black-backed jackal are opportunistic omnivores with mammals, insects, carrion, vegetable matter, birds and reptiles present in their diet (Bothma 1966, Klare *et al.* 2010, Forbes, Grobler 1981, Mellville *et al.* 2004, Hall-Martin & Botha 1980, Loveridge & Macdonald, 2003, Nell *et al.* 1997, Goldenberg 2010, Bussiahn 1997). Black-backed jackal are known to consume prey that is in great abundance or the easiest to capture. Nel *et al.* (1997) compared the diet of black-backed jackal at four different sites – three in Namibia and one in South Africa – to determine whether diet differed significantly. They found that jackal predominantly fed on birds except when seal colonies with pups were present. These results differ significantly from the traditional jackal studies, where the species often feeds on an unusual, but abundant prey source, namely sea mammals. It is clear that jackal are extremely adaptable and can survive in many environments as they are able to feed on a wide range of prey and other food items. Stuart (1987) analysed 114 jackal stomach contents from the Northern, Eastern and Western Cape. The author found that the highest percentage of occurrence belonged to mammals (57%), including rodents, domestic stock and carrion, followed by plant material, birds, invertebrates and reptiles. Kok (1996) collected 321 stomachs in the Free State and found that jackal also fed primarily on mammals, mainly antelope, and seldom on domestic stock. Rowe-Rowe (1983) sampled 477 scats and found that in the high rainfall Ukhahlamba-Drakensberg Park, more than half of the jackals' diet contained small mammals, mainly *Otomys irroratus* and *Rhabdomys pumilio*. An insignificant amount of their diet comprised of domestic mammals.

Smithers (1983) and Kok (1996) emphasised that it is difficult to separate carrion from captured prey in stomach contents, but that direct observations have confirmed that black-backed jackal are efficient hunters of mammals up to the size of hares (Ferguson 1978).

Many diet studies have been carried out on mammals. These include methodologies such as scat-analyses, stomach content analysis, molecular and isotope analysis, each of which has unique positives and negatives. As this study was carried out from a conservation standpoint, the non-invasive method of scat collection was used. Scat analysis is a well-established technique for assessing carnivore diet, and has been widely used, both in South Africa and abroad (Norton *et al.* 1986; Karanth & Sunquist 1995; Ramakrishnan *et al.* 1999; Ott *et al.* 2007; Aryal & Kreigenhofer 2009; Rautenbach 2010; Harihar *et al.* 2011; Braczkowski *et al.* 2012). When possible, stomach contents were retrieved from a legalised hunter.

Klare *et al.* (2011) did a comparative study to determine which diet sampling method would be the most accurate when studying a specific animal. They concluded that with scat analysis, using biomass calculation models, would provide the most trustworthy estimation of the actual diet of carnivores. The authors recommended combining frequency of occurrence methods with biomass models. This was because with frequency of occurrence alone, large food items were underestimated and thus no reliable conclusions could be drawn about the relevance of different food categories, especially when the impact of predation on livestock and niche overlap with another carnivore were addressed.

In this study, scat and stomach content analysis methods were used to determine the dietary biomass of the mesopredators. These methods were employed for several reasons, including the low cost of scat and stomach content analysis as well as the accessibility of the technology required. (Chame 2003). Additionally, the frequency of occurrence was used to obtain further information about rare food items in order to distinguish whether the predator was a specialist or an opportunist. Scats were identified based on shape, size, surrounding spoor tracks and signs, as well as prey content. Carnivore species, such as the black-backed jackal, use scat to mark their territory in conspicuous areas such as at trail junctions, rocky outcrops, trunks of trees or termite nests (Chame 2003). Therefore, in this study, complete scats were not collected.

2.3. Materials and methods

2.3.1 Scat analysis

Caracal and black-backed jackal scat samples were collected opportunistically whilst driving and walking in the study area from June 2014 to April 2015. Scat was collected on farmlands and in conservation areas. The collection effort was biased towards hiking trails and gravel roads, and may have resulted in scat samples being collected from the same animals. These data were not collected for seasonality or abundance tests, but purely to determine prey preference and diet of caracal and black-backed jackal in the area. Caracal scat and black-backed jackal scat both have distinct appearances that serve as a clear indication of which animal it originates from. Caracal scats (Fig. 2.1) were identified by the approximate diameter of 20-25 mm (Stuart & Stuart 2013); the content of the scat consists primarily of bones and hair and is spherical-shaped (tapered at one end and segmented) in appearance. The scat of the black-backed jackal (Fig. 2.1) is approximately 20mm in diameter (Walker 1996; Stuart & Stuart 2013), its appearance is spherical shaped (one pointed end) and it often contains arthropods, vegetation and fruit, as well as bones, feathers and hair. Black-backed jackal scat is unique in that it contains a wider variety of prey items and the animal is prone to leaving its scat in specific locations for territorial purposes. Differentiation between the scats of caracal and that of other felines, as well as between black-backed jackal scats and that of other canines needed to be made since the scats from caracal and black-backed jackal have similar appearances to their counterparts including leopard, aardwolf and bat-eared foxes that are also present in the study area. Leopard scat generally larger and contains more complete bone remains with the scat having an average diameter size of 26 mm. Aardwolf scat consists primarily of termites and ants with an even larger diameter of 40-50 mm. Bat-eared fox scat consists of insect remains as well as fruit remnants and measures 18 mm in diameter (Stuart & Stuart 2013).

Figure 2.1: Caracal (left) and black-backed jackal (right) scats.

Once the scat was collected in either the conservation or farmland areas, the date and GPS coordinates were recorded, scats were identified and numbered. The scats were then placed in an envelope and air dried until further analysis in the laboratory.

Once in the laboratory, each scat sample was placed in a sealed foil container and put into an autoclave (Labtech, Model no.: LAC 20605) for 20 minutes at 120 ºC for sterilization purposes. The scat was left to cool down. Once cool, the scat was placed in a sieve (3 mm) and washed with running water until only prey remains were left (bones, hair, insect remnants, etc.). These remains were then placed in a petri-dish, with an ID card, to dry in a fume hood (Pelmanco Ltd.). When dry, each scat sample was sifted through to sort all possible prey remnants and then categorised (hair, teeth, bone, etc.). Teeth were identified to family level using reference samples (De Graaff 1981, Pocock 1987, Reed 2011). A tweezer tip full of hairs (approx. 10-50 hairs) from each scat sample were randomly selected and put into the tip of a disposable plastic pipette (3 ml). Boiling paraffin wax (Sigma-Aldrich Paraplast Plus) was then slowly sucked into the pipette, surrounding the hairs. The pipette was then immediately placed into an ice bucket. Thin cross-sections (about 2 mm) of the pipette tip were made using a surgical scalpel and then mounted onto microscopic slides using transparent nail polish. The hair cross-sections were photographed using a Leica DM2000 light microscope equipped with a Leica DCF295 camera at 40x magnification, using LAS software (Leica Application Suite, Version 3.5.0) with live measurement. The hairs were identified using reference samples provided by Rhodes University (Parker, D., Department of Zoology and Entomology, Rhodes University) and Keogh (1979, 1983). Cuticle imprints were made for samples containing too few hairs to identify using cross-section samples. Transparent nail polish was applied to microscopic slides, upon which the hairs were placed horizontally. When dry, the hairs were removed slowly, leaving scale imprints behind. Cuticle imprints are keratinised overlapping scales along the length of the hair which forms different patterns for different species and are therefore useful for identification purposes (Keogh 1979).

2.3.2 Stomach content analysis

Eleven black-backed jackal stomachs were collected. These were provided by a licensed hunter who was hired by landowners to control jackal that were possibly responsible for livestock predation. Actual stomach samples can provide a more complete diet analysis than scat analysis as they contain soft-tissue food particles, such as scorpions, egg remnants, fruits, snakes and spiders. A similar methodology to scat sampling was followed in the laboratory. Once a jackal was shot, the belly was cut open to remove the stomach. The contents were placed into a sieve (3 mm) and rinsed under running water. The rinsed contents were then placed in a jar containing 70% ethanol to kill off any parasites and to preserve the sample for further analysis. Numerous morphometric measurements of the hunted jackal were recorded (see Appendix 4).

In the laboratory, the stomach contents were rinsed with water and dried in a fume hood before identification. The identification process of the stomach contents was identical to that of the scat samples.

2.3.3 Data analysis

During the analysis, frequency of occurrence (%) of a food item was determined for the diet composition of the focal species (Lockie 1959, Norton *et al.* 1986, Ott *et al.* 2007, Rautenbach 2010, Mann 2014). The percentage for each individual prey species was calculated by dividing the number of occurrences of a particular prey species (in total) by the total number of prey items obtained in all scats, multiplied by 100. (Lockie 1959, Rautenbach 2010). Certain prey species may have appeared more than once in a single scat but in the current study, this was not measured. The frequency of occurrence estimator has been associated with other diet estimators based on the frequency of prey items to indicate how frequently a prey species occurs in a predator's diet and how important these species are as a food item to the associated predator (Klare et al. 2011, Loveridge & Macdonald 2003). Klare *et al.* (2011) stated that this model tends to overestimate the importance of smaller food types and, therefore, other indices, such as biomass, should be combined with this method to obtain more accurate results. To produce a corrected frequency of occurrence (%), each food item found in a scat was given a weighting (Karanth & Sunquist 1995, Mann 2014). For example, if a scat sample contained two prey species, a weighting of 0.5 was assigned to each and for a scat sample containing four prey items a weighting of 0.25 was assigned to each.

Other dietary analysis methods include the measuring of volume or mass of the prey items present in the scats and calculating biomass intake using conversion factors (Loveridge & Macdonald 2003, Klare *et al.* 2011). Therefore, to convert the frequency of occurrence of prey items to valid prey biomass results for the focal species, conversion factors were necessary (Ackerman 1984, Klare *et al.*2011). Kamler *et al.* (2012) produced conversion factors (CF) based on a biomass calculation model for the black-backed jackal. CF converts the mass of the different prey remains in scats into the biomass ingested of different prey species (Goszczynksi 1974, Kamler *et al.*2012). This CF is necessary as the frequency of occurrence overestimates small animals and underestimates large animals. These conversion factors were used for both focal species as black-back jackal and caracal have similar body sizes. However, the digestibility rates of a felid and canid differs, possibly influencing results (Wyse *et al.* 2003). Conversion factors have been produced for larger felids (Ackerman *et al.* 1984, Marker *et al.* 2003). Marker *et al.* (2003) found that, similar to caracal consumption, smaller prey species account for 70% of cheetah consumption. However, with a body mass of 21-72 kg, cheetah weigh more than caracal.

Species accumulation curves were produced using EstimateS (v.9.1.0) to determine if scat sample sizes were large enough for a complete description of caracal and jackal diet in the Gamkaberg (Willot 2001, Colwell 2005, Rautenbach 2010). If an asymptote is not reached, the Incidence-based Coverage Estimator (ICE) mean can be used to determine how many species were not included in the analysis (Colwell 2005, Rautenbach 2010).

Prey relative abundances were estimated opportunistically in a camera-trapping survey (see Chapter 3 for a detailed description on camera-trapping activities). Together with the scat analysis data, this was used to estimate selection for specific food items. Caracal and black-backed jackal lack distinctive features such as stripes and spots; therefore, mark-recapture methods are more invasive and time-intensive and were not used for abundance estimation in this study (Oliveira-Santos 2010). Funston *et al.* (2010) suggest that species with low densities and cryptic features need an alternative estimation of population densities; for example, game counts or transect counts. The relative abundance of each species (prey and carnivores) was filtered, based on the assumption that one individual of a species could be photographed more than once per day (Sanderson 2004, Martins *et al.* 2007), unless individuals can be distinguished based on sex or the presence of more than one individual on one photograph (Sanderson 2004, Martins *et al.* 2007).

The Relative Abundance Index (RAI) was calculated by dividing the number of photographs recorded for each species by the total number of useable photographs recorded (Martins *et al.* 2007, Rautenbach 2010, Mann 2014). Overestimation was avoided by only counting photographs of the same species that were more than an hour apart as separate photographic events (Yasuda 2004, Mann 2014), but can result in the underestimation of group-living species such as baboons. All photographs containing irrelevant data – such as people, vehicles and empty content – were excluded from the study.

Prey preference or avoidance was calculated using Jacobs' Index, which specifies a measure of prey preference by comparing the species preyed upon by the focal species (using scat) to their relative availability (using photographs) (Jacobs 1974, Mann 2014). This index has been widely used in carnivore research to measure prey preference for species such as lions, tigers, wolves, black-backed jackal and leopard (Hayward & Kerley 2005, Hayward *et al.* 2011, Wagner *et al.* 2012, Klare *et al.* 2010, Rautenbach 2010, Mann 2014). The following equation was used for the calculation of the Jacobs' Index:

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

Utilisation is represented by "r"; r_i is the proportion of all scats containing species *i*. Availability is represented by "p", with p_i being the relative abundance of species *i* from camera trapping. Jacobs' Index gives a range between +1 (maximum avoidance) and -1 (maximum preference) (Jacobs 1974). The diet preferences of caracal and black-backed jackal were determined with the inclusion of all species. Confidence intervals for the dietary data were used to determine significant preference and avoidance of prey for both data sets (Quinn & Keough 2002, Rautenbach 2010).

2.4. Results

A total of 59 caracal scats and 84 black-backed jackal scats were collected; however, some scats contained only a few strands of hair, or none at all. Scats for black-backed jackal contained other identifiable remains, including egg shell remnants, invertebrates, reptiles and vegetation. All were used in the analysis. A total of 16 prey species were found in caracal scats and 21 prey species in jackal scats, using the cross-section method. Cuticle-scale imprints were made for scats that contained only a few hair strands to aid in identification.

2.4.1. Frequency of occurrence and biomass calculations

Vlei rats (*Otomys* spp. – 19.1%), vegetation (16.7%), striped mouse (*Rhabdomys pumilio* – 14.2%) and beetles (Coleoptera – 8.0%) were the most frequently found prey items for caracal (Table 2.1). Small mammals (<1 kg) accounted for 80.9% of all prey species. A total of 2 584.6 kg of biomass of all prey items was estimated from the caracal scats. Goats and aardvark were the main food sources, making up 74.0% of the total biomass of prey items.

The caracal's most frequently consumed prey was the vlei rat but this species only accounted for 1.2% of total prey biomass (see Table 2.1).

Based on the amount of biomass consumed using Ackerman's (1984) formula, goat (22.2%) and vlei rat (19.3%) were the two most important food sources for the caracal, while small mammals such as hares and rodents accounted for a far larger percentage of biomass consumed (Table 2.1).

Vegetation (seeds, grass, etc. – 21.9%), vlei rat (21.0%), beetles and striped mouse (8.57%) were the most frequently found prey items for the black-backed jackal (Table 2.2). Small mammals (<1 kg) accounted for 79.5% of all the prey species consumed. Overall, the black-backed jackal scats accounted for 2 595.21 kg of biomass of all the prey items consumed. The most dominant prey biomass for black-backed jackal was donkey (24.5%), goat (16.8%), ostrich (14.0%) and duiker (12.9%), together contributing 77.5% to the total. The donkeys found in the area originated from a feral population in conservation areas that were previously farmland.

The most frequently consumed prey item for the black-backed jackal was also the vlei rat and vegetation (seeds and berries), but these accounted for less than 1% of total biomass (Table 2.2). The most important food sources included livestock (donkey, goat and ostrich), contributing to more than half of the black-backed jackal's diet (55.3%).

The corrected prey biomass shows a difference in the importance of biomass consumed for black-backed jackal, with the vlei rat (21.2%) and other rodents, duiker and grysbok being most prevalent. The livestock in this case contributed <8.0%.

Table 2.1: Prey items recorded in caracal scats (n=59) collected in Gamkaberg in the Little Karoo, Western Cape, South Africa. Number of occurrences shows the number of scats in which each prey item was found. Frequency of occurrence is the percentage of each prey species relative to the total number of prey items identified. Corrected frequency of occurrence shows the percentage of each prey species after occurrence totals were corrected to account for the presence of multiple prey items in some scats. The percentage prey biomass shows the percentage of each prey item of the estimated total biomass of all prey items found in scat samples using the corrected frequency of occurrence. The corrected prey biomass is the biomass of prey consumed, converted using the formula developed by Ackerman (1984).

Prey species	**Prey mass (kg)**	**Number of occurrences (total=162)**	**Frequency of occurrence (%)**	**Corrected frequency of occurrence (%)**	**Total biomass of all prey items (%)**	**Corrected prey biomass (%)**
Elephant Shrew (*Elephantulus spp.*)	0.0582	2	1.23	1.39	0.04	1.23
Round-eared Sengi (*Macroscelidus probiscensis*)	0.0382	2	1.23	0.97	0.01	0.86
Vlei Rat (*Otomys spp.*)	0.131	31	19.14	21.65	1.24	19.27
Brants' Whistling Rat (*Parotomys brantsii)*	0.1258	2	1.23	1.10	0.04	0.98
Hairy-footed Gerbil (*Gerbillurus paeba)*	0.025	4	2.47	2.36	0.02	2.10
Striped Mouse (*Rhabdomys pumilio*)	0.0404	23	14.20	14.78	0.18	13.15
Namaqua Rock Mouse (*Aethomys namaquensis*)	0.0475	3	1.85	3.06	0.04	2.72
Common Molerat (*Cryptomus hottentotus*)	0.07025	1	0.62	0.42	0.01	0.37

Hare (*Lepus spp.*)	2.72	8	4.94	6.54	6.67	12.65
Aardvark (*Orycteropus afer)*	43.25	1	0.62	0.84	13.25	3.82
Mongoose (*Galarella pulverulenta*)	0.7271	4	2.47	2.27	0.89	2.02
Small-spotted Genet (*Genetta genetta*)	1.9	1	0.62	0.84	0.58	0.74
Grysbok (*Raphicerus melanotis*)	10.25	1	0.62	0.42	3.14	1.91
Klipspringer (*Oreotragus oreotragus*)	11.9	1	0.62	0.55	2.01	2.52
Duiker (*Sylvicapra grimmia*)	17.4	1	0.62	0.42	5.33	1.91
Goat (*Capra aegagrus hircus*)	**40**	**5**	**3.09**	**4.87**	**61.28**	**22.21**
Insecta	0.004	4	2.47	1.94	0.00	0.38
Beetles (Coleoptera)	0.004	13	8.02	6.84	0.02	1.32
Millipedes (Myriapoda)	0.004	3	1.85	1.17	0.00	0.23
Scorpiones	0.004	9	5.56	4.77	0.01	0.92
Birds (Aves)	0.9	3	1.85	1.52	0.83	2.06
Reptilia	1	8	4.94	3.95	2.45	2.75
Tortoise (*Chersina angulata*)	1.25	5	3.09	2.19	1.91	1.53
Vegetation	0.004	27	16.67	15.16	0.03	2.35

Table 2.2: Prey items recorded in black-backed jackal scats (n=84) collected in Gamkaberg in the Little Karoo, Western Cape, South Africa.

Prey species	Prey mass (kg)	Number of occurences (total=210)	Frequency of occurrence (%)	Corrected frequency of occurrence (%)	Total biomass of all prey items (%)	Corrected prey biomass (%)
Elephant Shrew (*Elephantulus spp.*)	0.0582	6	2.86	2.90	0.05	2.57
Vlei Rat (*Otomys spp.*)	**0.131**	**44**	**20.95**	**23.93**	**0.81**	**21.21**
Brants' Whistling Rat (*Parotomys brantsii*)	0.1258	2	0.95	1.69	0.04	1.50
Hairy-footed Gerbil (*Gerbillurus paeba*)	0.025	3	1.43	0.97	0.01	0.86
Striped Mouse (*Rhabdomys pumilio*)	0.0404	18	8.57	9.17	0.10	8.13
Namaqua Rock Mouse (*Aethomys namaquensis*)	0.0475	4	1.90	7.89	0.03	6.99
Common Molerat (*Cryptomus hottentotus*)	0.07025	1	0.48	0.37	0.01	0.33
Rodentia	0.0683	2	0.95	1.41	0.02	1.25
Hare (*Lepus spp.*)	2.715	8	3.81	4.44	3.04	8.55
Bush Pig (*Potamochoerus larvatus*)	70.6	1	0.48	0.56	9.88	2.56

Cape Grey Mongoose (*Galerella pulverulenta*)	0.7271	2	0.95	1.35	0.20	1.20
Grysbok (*Raphicerus melanotis*)	10.25	5	2.38	2.15	7.17	9.78
Steenbok (*Raphicerus campestris*)	11.1	1	0.48	0.23	1.55	1.02
Klipspringer (*Oreotragus oreotragus*)	11.9	1	0.48	0.56	1.67	2.56
Duiker (*Sylvicapra grimmia*)	17.4	5	2.38	2.20	12.18	9.99
Springbok (*Antidorcas marsupialus*)	34.5	1	0.48	0.56	4.83	2.56
Goat (*Capra aegagrus hircus*)	40	3	1.43	1.16	16.80	5.28
Donkey (*Equus africanus asinus*)	**175**	**1**	**0.48**	**0.56**	**24.49**	**2.56**
Egg	1.42	2	0.95	0.51	0.40	0.10
Insecta	0.004	4	1.90	1.72	0.00	0.33
Termites (Isoptera)	0.004	1	0.48	0.37	0.00	0.07
Beetles (Coleoptera)	0.004	18	8.57	6.17	0.01	1.19
Millipedes (Myriapoda)	0.004	1	0.48	0.23	0.00	0.04
Scorpiones	0.004	10	4.76	3.29	0.01	0.63
Birds (Aves)	0.9	5	2.38	1.44	0.63	1.94
Ostrich (*Struthio camelus*)	100	1	0.48	0.28	14.00	0.38
Reptilia	1	10	4.76	3.49	1.40	2.42
Lizard (Squamata)	1	1	0.48	0.56	0.14	0.39
Tortoise (*Chersina angulata*)	1.25	3	1.43	1.03	0.52	0.71
Vegetation	0.004	46	21.90	18.81	0.03	2.90

2.4.2. Species accumulation curves

The species accumulation curve for the caracal scat samples did not reach an asymptote (Figure 2.2). This may be a result of the small sample size. The Incidence-based Coverage Estimator (ICE) used the occurrence of prey species in scats, and the Abundance-based Coverage Estimator (ACE) used prey mass in scats and species richness (Chazdon *et al.* 1998), and had means of 28.40 and 28.35 (S(est)SD=2.18), respectively, implying that four to five prey species may not have been detected in the scat samples.

The accumulation curve for the black-backed jackal also did not reach an asymptote, visualizing an increase that suggests that samples collected for jackal were not sufficient (Figure 2.3). The ICE- and ACE means were 40.27 and 40.23 (S(est)SD=2.96) respectively, implying that 10 to 11 prey items were not found in the scat analysis.

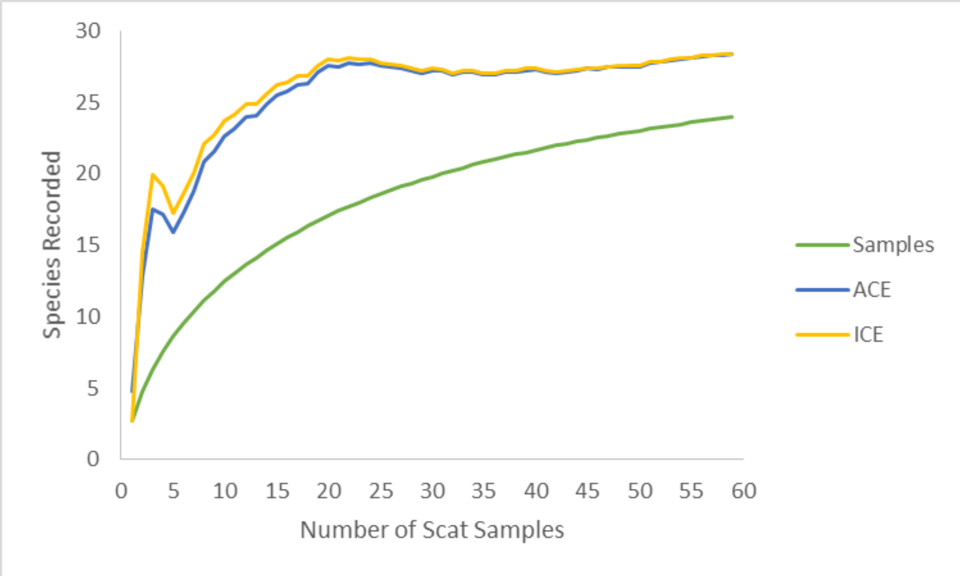

Figure 2.2: Sample-based Incidence Data Accumulation Curve (100 randomised repetitions; ACE mean 28.35, ICE mean 28.4) for 24 prey types recorded in 59 caracal scat samples collected in the Little Karoo for all land-use types. ACE and ICE provided estimates of the number of species at which the curve is likely to reach an asymptote, and thus represented an estimate of the total number of species likely to be present in caracal scats in the area.

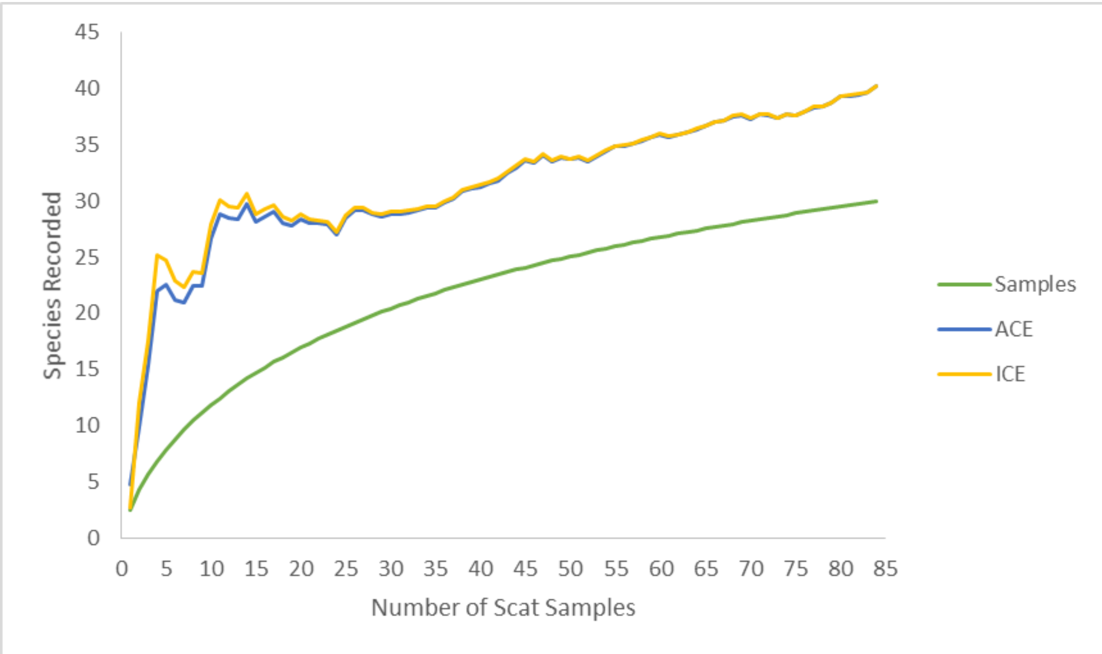

Figure 2.3: Sample-based Incidence Data Accumulation Curve (100 randomised repetitions; ACE mean 40.23, ICE mean 40.27) for 30 prey types recorded in 84 black-backed jackal scat samples collected in the Little Karoo for all land-use types.

2.4.3. Stomach content analysis

In addition to the scat samples, 11 black-backed jackal stomachs were retrieved from a local licensed hunter. A total of 25 identifiable prey items were found in these stomachs and were identified using the same methodology as was used for the scats. Vegetation (14.0%), scorpions (14.0%) and beetles (8.5%) were the most frequently found prey items (Table 2.3). Only 15.5% of all the prey species in the stomach contents were small mammals (<1 kg). The biomass of all prey items found was 1 984.85 kg in total. Dorper sheep and ostrich were the main food source, making up 74.0% of the total biomass of prey items. This food selection may be biased towards livestock as all of the black-backed jackal that were shot were presumed to be retaliatory killings. Livestock were the most important food source regarding stomach contents, accounting for 86.0% of total biomass of prey (Dorper sheep, ostrich and goat) consumed by black-backed jackal.

With regards to the importance of corrected prey biomass to the black-back jackal's diet, the stomach content analysis did not differ from the scat analysis. With both methods, the hairy-footed gerbil (13.7%), the round-eared sengi and the elephant shrew dominated (Table 2.3). This corresponds more with the scat analysis data for the black-backed jackal excluding the fact that all of the jackal were retrieved from farmlands. Correction factors were used, as previously explained.

Table 2.3: Prey items recorded in black-backed jackal stomach contents (n=11) collected in Gamkaberg in the Little Karoo, Western Cape, South Africa.

Prey Species	**Prey Mass (kg)**	**Number of occurrences (total=71)**	**Frequency of occurrence (%)**	**Corrected frequency of occurrence (%)**	**Total biomass of all prey items (%)**	**Corrected prey biomass (%)**
Elephant Shrew (*Elephantulus spp.*)	0.0582	1	1.41	1.15	0.01	10.80
Round-eared Sengi (*Macroscedilus probiscensis*)	0.0382	1	1.41	1.01	0.01	12.89
Vlei Rat (*Otomys spp.*)	0.131	3	4.23	3.78	0.09	7.84
Hairy-footed Gerbil (*Gerbillurus paeba*)	**0.025**	**1**	**1.41**	**1.32**	**0.01**	**13.71**
Striped Mouse (*Rhabdomys pumilio*)	0.0404	2	2.82	4.61	0.02	7.20
Common Molerat (*Cryptomus hottentotus*)	0.07025	1	1.41	1.32	0.02	1.07
Hare (*Lepus spp.*)	2.715	2	2.82	2.86	1.27	1.18
Meerkat (*Suricata suricatta*)	0.734	1	1.41	0.92	0.17	3.42
Cape Grey Mongoose (*Galerella pulverulenta*)	0.7271	1	1.41	1.01	0.17	7.84
Grysbok (*Raphicerus melanotis*)	10.25	1	1.41	2.31	2.40	1.75
Springbok (*Antidorcas marsupialus*)	34.5	1	1.41	1.32	8.08	1.03
Goat (*Capra aegagrus hircus*)	40	1	1.41	1.32	9.37	0.98

Dorper Sheep (*Ovis aries*)	60	2	2.82	2.17	28.11	4.26
Egg	1.42	4	5.63	5.56	1.33	0.84
Termites (Isoptera)	0.004	3	4.23	3.87	0.00	1.20
Crickets, grasshoppers (Orthoptera)	0.004	4	5.63	4.10	0.00	1.40
Beetles (Coleoptera)	0.004	6	8.45	6.96	0.01	3.58
Sun Spider (Solifugae)	0.004	5	7.04	6.41	0.00	1.61
Scorpiones	0.004	10	14.08	14.21	0.01	2.12
Birds (Aves)	0.9	5	7.04	6.12	1.05	1.34
Ostrich (*Struthio camelus*)	**100**	**2**	**2.82**	**1.94**	**46.85**	**4.38**
Reptilia	1	1	1.41	1.32	0.23	1.53
Tortoise (*Chersina angulata*)	1.25	1	1.41	0.92	0.29	5.34
Snake (Serpentes)	1	2	2.82	2.33	0.47	1.18
Vegetation	0.004	10	14.08	21.13	0.01	1.53

The accumulation curve for the stomach contents collected for the black-backed jackal did not reach an asymptote (Figure 2.4). The ICE- and ACE means were 41.56 and 39.61 (S(est)SD = 2.76), respectively, implying that between 14 to 17 prey items were not found in these samples. Even though the stomach content analysis of the black-backed jackal only consisted of 11 samples, the difference in species was clear. The stomach content analysis included more soft-bodied prey (such as, egg, Solifugae, Scorpiones, Serpentes and Orthoptera) than the scat analysis.

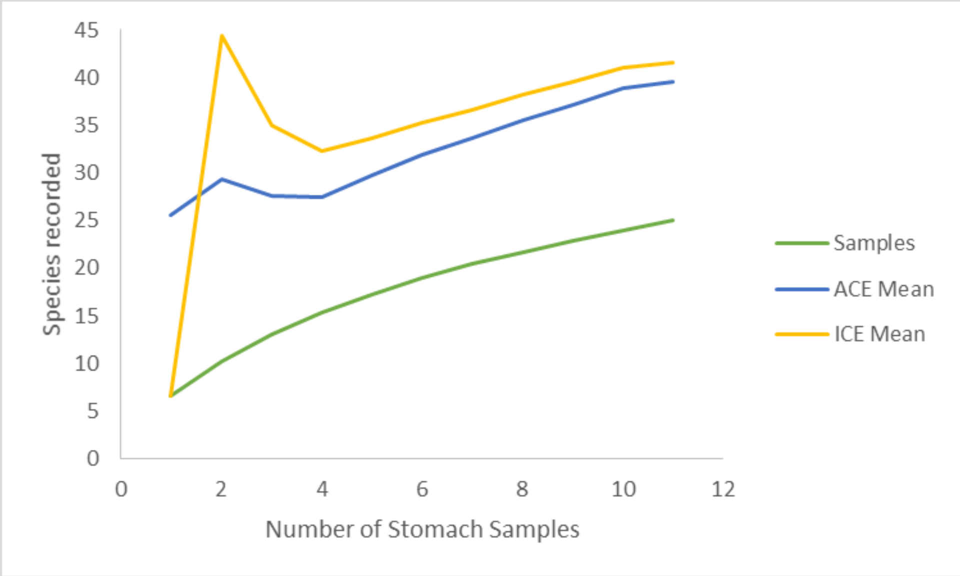

Figure 2.4: Sample-based Incidence Data Accumulation Curve (100 randomised repetitions; ACE mean 39.61 ICE mean 41.27) for 25 prey types recorded in 11 stomach samples from black-backed jackals collected in Gamkaberg in the Little Karoo, Western Cape, South Africa.

2.4.4. Relative abundance and Jacobs' Index

Relative abundances of prey species for each mesopredator species was calculated using 66 camera-trap sites within areas classified as caracal and black-backed jackal habitats, split equally into farmland and conservation areas. These areas were chosen based on mountain slopes, plains and scats found. It was visible that photos taken were skewed toward large animals excluding Rodentia species. This could create biases that caracal and jackal do not prefer large animals.

The Jacobs' Index for the caracal indicated that the most preferred prey species (>0.5) were quite extensive, including all rodents, millipedes, klipspringer, vegetation, tortoises, scorpions, reptiles, insects, genets and mongoose (Figure 2.5). All livestock falls under least-preferred prey, apart from when caracal live on or near livestock (goat) farms. Jacobs' Index scores of <-0.5 represent a significant avoidance of a particular prey species (Hayward *et al.* 2006). Most of the species that fall in this range were posing a possible threat or was less palatable to the caracal, especially if body size is considered.

The most preferred prey species for the black-backed jackal, using the Jacobs' Index, was more extensive than that of the caracal, most probably because of the jackal's wider opportunistic diet that includes rodents, reptiles, termites, springbok, millipedes, klipspringer, egg, vegetation, scorpions, insects, beetles, grysbok and mongoose (Figure 2.6). The only form of livestock that was preferable in the black-backed jackal's diet was ostrich eggs.

Many of the species recorded on camera that were not consumed by the mesopredators were found at low densities within the study areas (Table 2.4 & 2.5). A relative abundance percentage of <1% for a species suggests that they were rarely found in caracal and jackal habitat and could therefore be less preferable prey. This included animals such as the bush pig, mongoose and meerkat.

Jacobs' Index values based on scat analysis for the caracal showed strong preferences for rodents, reptiles, insects, scorpions and the klipspringer (Figure 2.5). The majority of the animals considered as the least preferable prey were recorded on camera, which included genet, mongoose, grysbok and hares, all with low abundances (0.03%, 0.3%, 0.3% and 5.8%, respectively). For black-backed jackal, the Jacobs' Index showed a strong preference for rodents, insects, vegetation, reptiles, klipspringer, springbok and egg shells (Figure 2.6). None of these were recorded on camera but were found in scat. Grysbok, mongoose, bush pig, hare, duiker and donkeys were identified in photographs, but had low abundances (0.3%, 0.3%, 0.2%, 5.8%, 3.7% and 1.0%, respectively).

Table 2.4: Summary of the Relative Abundance Indices (RAI) of potential prey species and caracal in the study area in the Little Karoo. Jacobs' Indices were calculated for each species based on the corrected frequency of occurrence (CFO) of species in 59 scats collected in the area.

*: These species were not expected to be detected by the camera.

Species	Photos	RAI	Scat CFO	Jacobs' Index
Aardvark	71	2.10	0.84	-0.44
Aardwolf	8	0.24	0.00	-1.00
Baboon	295	8.74	0.00	-1.00
Beetles*	0	0.00	6.84	1.00
Bird	91	2.70	1.52	-0.28
Brants' Whistling Rat*	0	0.00	1.10	1.00
Bush Pig	7	0.21	0.00	-1.00
Cape Mountain Zebra	2	0.06	0.00	-1.00
Caracal	28	0.83	0.00	-1.00
Cattle	101	2.99	0.00	-1.00
Common Molerat*	0	0.00	0.42	1.00
Domestic Dog	45	1.33	0.00	-1.00
Donkey	32	0.95	0.00	-1.00
Dorper Sheep	61	1.81	0.00	-1.00
Duiker	123	3.65	0.42	-0.80
Elephant Shrew*	0	0.00	1.39	1.00
Genet	1	0.03	0.84	0.93
Goat	511	15.15	4.87	-0.55
Grysbok	11	0.33	0.42	0.12
Hairy-footed Gerbil*	0	0.00	2.36	1.00
Hare	196	5.81	6.54	-0.06
Honey Badger	18	0.53	0.00	-1.00
Insects*	0	0.00	1.94	1.00
Jackal	115	3.41	0.00	-1.00
Klipspringer*	0	0.00	0.55	1.00
Large Ungulate	51	1.51	0.00	-1.00
Meerkat	13	0.39	0.00	-1.00
Millipedes*	0	0.00	1.17	1.00
Mongoose	11	0.33	2.27	0.75

Namaqua Rock Mouse*	0	0.00	3.06	1.00
Ostrich	1149	34.05	0.00	-1.00
Polecat	3	0.09	0.00	-1.00
Porcupine	194	5.75	0.00	-1.00
Reptiles*	0	0.00	2.19	1.00
Round-eared Sengi*	0	0.00	0.97	1.00
Scorpions*	0	0.00	4.77	1.00
Steenbok	183	5.42	0.00	-1.00
Striped Mouse*	0	0.00	14.78	1.00
Tortoise*	0	0.00	2.19	1.00
Vegetation*	0	0.00	15.16	1.00
Vlei Rat*	0	0.00	21.65	1.00
Wild Cat	54	1.60	0.00	-1.00

Figure 2.5: Jacobs' Index scores (Conservation, Farmland, and all areas) for potential caracal prey species in the Little Karoo, based on corrected frequency of occurrence of prey items in caracal scats and the relative abundance of these prey species within areas of caracal habitat. Scores of less than -0.5 indicated that caracal avoided preying on those species, whereas scores above 0.5 were preferred prey.

Table 2.5: Summary of the Relative Abundance Indices (RAI) of prey species and black-backed jackal in the study area in the Little Karoo. Jacobs' Indices were calculated for each species based on the corrected frequency of occurrence (CFO) of species in 84 scats collected in the area.

*: These species were not expected to be detected by the camera.

Species	Photos	RAI	Scat CFO	Jacobs' Index
Aardvark	71	2.10	0.00	-1.00
Aardwolf	8	0.24	0.00	-1.00
Baboon	295	8.74	0.00	-1.00
Beetles	0	0.00	6.17	1.00
Bird	91	2.70	1.44	-0.31
Brants' Whistling Rat	0	0.00	1.69	1.00
Bush Pig	7	0.21	0.56	0.46
Cape Mountain Zebra	2	0.06	0.00	-1.00
Caracal	28	0.83	0.00	-1.00
Cattle	101	2.99	0.00	-1.00
Common Molerat	0	0.00	0.37	1.00
Domestic Dog	45	1.33	0.00	-1.00
Donkey	32	0.95	0.56	-0.26
Dorper Sheep	61	1.81	0.00	-1.00
Duiker	123	3.65	2.20	-0.25
Egg	0	0.00	0.51	1.00
Elephant Shrew	0	0.00	2.90	1.00
Genet	1	0.03	0.00	-1.00
Goat	511	15.15	1.16	-0.88
Grysbok	11	0.33	2.15	0.74
Hairy-footed Gerbil	0	0.00	0.97	1.00
Hare	196	5.81	4.44	-0.14
Honey Badger	18	0.53	0.00	-1.00
Insects	0	0.00	1.72	1.00
Jackal	115	3.41	0.00	-1.00
Klipspringer	0	0.00	0.50	1.00
Large Ungulate	51	1.51	0.00	-1.00
Lizard	0	0.00	0.56	1.00
Meerkat	13	0.39	0.00	-1.00

Millipedes	0	0.00	0.23	1.00
Mongoose	11	0.33	1.35	0.61
Namaqua Rock Mouse	0	0.00	7.89	1.00
Ostrich	1149	34.05	0.28	-0.99
Polecat	3	0.09	0.00	-1.00
Porcupine	194	5.75	0.00	-1.00
Reptile	0	0.00	3.49	1.00
Rodent	0	0.00	1.41	1.00
Scorpions	0	0.00	3.29	1.00
Springbok	0	0.00	0.56	1.00
Steenbok	183	5.42	0.23	-0.92
Striped Mouse	0	0.00	9.17	1.00
Termites	0	0.00	0.37	1.00
Tortoise	0	0.00	1.03	1.00
Vegetation	0	0.00	18.81	1.00
Vlei Rat	0	0.00	23.93	1.00
Wild Cat	54	1.60	0.00	-1.00

Figure 2.6: Jacobs' Index scores (Conservation-, Farmland- and all areas) for potential black-backed jackal prey species in the Little Karoo, based on corrected frequency of occurrence of prey items in black-backed jackal scats and the relative abundance of these prey species within areas of black-backed jackal habitat. Scores of less than -0.5 indicated that black-backed jackals avoided preying on those species, whereas scores above 0.5 were preferred prey.

2.5. Discussion and conclusion

Finding food is a very difficult task for animals in dry areas such as the Little Karoo. Two possible survival strategies include, to either specialise and prey upon a single vulnerable resource, or to diversify over multiple types of resources (Logan & Sweanor 2001). Previous research shows that black-backed jackal and caracal are flexible in prey choice and the ability to practice different foraging methods allows them to survive in different habitat types (Bussiahn 1997). In comparison to other predator diet studies, this study only provided a first-order indication of the diet of the focal species in the Little Karoo. Unlike most studies, seasonal diet tendencies were not taken into account due to a small sample size and two-month intervals between sampling efforts.

In the Little Karoo, large- and medium-sized prey are not as abundant as in other regions of South Africa. Mann (2014) found that the apex predator, the Cape leopard, is more opportunistic and has a larger prey base in this area compared to other studies. The focal mesopredators were found to predate on smaller prey and were also very opportunistic, finding prey that is high in protein. In periods of low prey abundance, jackal preferred highly nutritional and protein-rich food sources such as insects. Similar results were found for coyotes (*Canis latrans*) in the Chihuahuan Desert (Hernandez *et al.* 2002). Insects, especially beetles and locusts, are easy to catch and high in protein; therefore, an ample variety of insects were found in the jackal and caracal diet (approximately 10% of samples) for each species. Goldenberg (2010) found that the giant longhorn beetle, *Acanthophorus capensis*, was found in jackal scat throughout the year, concluding that they search for this beetle because of its high nutritional value. Other invertebrates, including scorpions and Solifugae, were also found in both focal species' scat samples.

Interestingly, in the 11 black-backed jackal stomachs contents examined, Solifugae and egg were found. Being soft in nature, they would be hard to find or non-existent in scats. For this reason, stomach contents are assumed to be more complete in content than scat content. However, stomach contents are difficult to obtain for obvious legal and ethical reasons. Bothma (1966) also found a high content of insects, followed by rodents and carrion; whereas in other studies, artiodactyls and rodents were found to be more important. This may be because most diet studies are scat-based. In many ways, stomach content analyses produce much more recent and detailed diet results, especially for the opportunistic black-backed jackal that ingests many soft-tissue prey, such as Insecta, egg and Arthropoda that rarely persist through the digestive tract. The scat-analysis methodology can, therefore, be biased towards harder food particles, especially in the black-backed jackal's diet.

Mammals, in particular rodents, are a very important food source for the mesopredators and were found in most of the samples for both species. Stuart (1976) found rodent remains in 13.3% of samples and Goldenberg (2010) in 11.0% of samples. In this study, 83.3% and 88.1% of jackal and caracal scat samples contained rodent parts, respectively. Rodents therefore account for a significant part of both mesopredators' diets in the Little Karoo. The abundance of these species could be high due to a cyclical outburst in peak years (Krebs & Myers 1974). In contrast, Goldenberg (2010) stated that more nutritional prey are easier to catch than less nutritional prey, for example, a longhorn beetle when compared to a rodent. This suggests that mesopredator diets can vary in different habitats. The large variation in both caracal and black-backed jackal diets found in this study confirms their opportunistic feeding patterns. This flexibility in diet, especially for the black-backed jackal, makes it difficult to determine a specific prey preference pattern.

The low density of the Cape leopard in the study area increases the availability of all prey for caracal and jackal. As caracal and jackal in this area mainly preyed on *R. pumilio* and *Otomys spp*, it indicates a trend of diurnal behaviour similar to other studies (Rowe-Rowe 1983). Jackal consumed more *Otomys spp* than *R. pumilio* because their activity patterns were more aligned despite the fact that *R. pumilio* is more commonly found in traps (Rowe-Rowe 1983). This is supported by observations of their activity in daylight hours from camera traps.

For both focal species this study showed that black-backed jackal and caracal scats found on farmland had a much higher count and dependency of livestock remains in comparison to the scats found in or around conservation areas. This indicates that mesopredators consume what is in the vicinity of where they are at that time. Mellville *et al.* (2004) found a caracal scat containing livestock remains 23.3km away from a farm which indicates that caracal do transgress from conservation areas into bordering farmlands. The mesopredator diets were very similar to each other if one takes into account the most frequently preyed upon items, however the black-backed jackal has a much more varied diet than the caracal, as found in other studies (Busshian 1997).

Of the invertebrates consumed, scorpions and beetles were the most prominent in both mesopredator diets. Insects have a low biomass and most probably have little contribution to the diet, but can act as a supplement when taken opportunistically. Similar to this study, Moolman (1984) also found scorpions in small amounts of scats analysed. Palmer & Fairall (1988) suggested that mesopredators predate on insects in some areas. This could be true in arid areas where prey abundances are low and where animals feed on prey items that they do not usually consume in other circumstances.

Plant material was also prominent in both diets (Palmer & Fairall 1988, Avenant & Nel 1997, Mellville *et al.* 2004). Caracal are more likely to ingest plant material while grooming or through the consumption of other food (secondary ingestion). These prey items can contribute to the moisture intake of carnivores.

The most abundant prey for caracal in this study were rodents. Caracal are also opportunistic feeders and consumed prey that were most abundant and most frequently encountered when hunting (Melville

2010, Bothma & Walker 1999). Studies in the Kgalagadi Transfrontier Park and in the West Coast National Park also had high rodent remains in the scat – up to 89.1% (Avenant & Nel 1997, Mellville *et al.* 2004); whereas other studies vary in percentage occurrence from 5.3% (Grobler 1981) to 50% (Stuart & Hickman 1991). In most of the caracal studies elsewhere, diets included a higher percentage of artiodactyls >10 kg. In most areas, the rock hyrax forms a large part of the caracal's diet, yet in this study, they were not captured on any camera-trap photographs or found in the scats of the focal species. As per Moolman's (1986) study in the Mountain Zebra National Park, only two species of carnivores were found in the caracal diet in this study. This is less than what Mellville *et al.* (2004) found in the Kgalagadi Tranfrontier Park, including the genet and the mongoose. The possible low density of smaller carnivores in the Gamkaberg area creates the opportunity for smaller artiodactyls to fill this prey category for caracal.

The black-backed jackal's diet in southern Africa is exceptionally adaptable and opportunistic, according to this study and many others, and they live on whatever is most abundant and most easily obtainable (Stuart, 1976, Bothma 1966, Rowe-Rowe 1974, Palmer & Fairall 1988, Mellville *et al.* 2004). At times, the black-backed jackal has been identified as a hunter of small prey such as small mammals and insects; a pursuer killing larger prey such as hares and young antelope; or even a scavenger, supplementing its diet with vegetation matter. Stuart (1976) sampled 772 scats to differentiate jackal diet among three sites to determine if diet differed in each area. He found that the scats from the coastal site primarily contained bird material, and the riverine and plains sites contained predominantly plant material. In the highland areas of Natal, Rowe-Rowe (1974) found that animal material was the primary food source, with plant material barely present.

Mukherjee *et al.* (1994) found that remains of more than one prey were usually present in one scat; therefore, a large enough hair sample should be taken for each scat to include all the prey present. This should especially be done for opportunistic feeders such as the focal species in this study in order to assess how their diet is adaptable through time, space and availability.

Chapter Three: Estimating mesopredator activity, the intensity of sampling efforts and prey diversity between land-uses in the Little Karoo using camera traps

3.1. Abstract

Population size and density estimates are fundamental data for conservation and management plans, but are difficult to gather if the species are rare or elusive. Studying larger carnivores or mammals is difficult due to population densities that are often low, large home ranges and difficulties in capturing or observing them. Camera trapping has been used successfully globally to produce information about an area and its species, such as species presence, activity patterns and behaviour, spatial patterns, habitat use and capture-recapture data on individually recognisable species. Camera trapping also contributes to the awareness of conservation issues. However, fewer studies have been undertaken on unmarked species using occupancy and relative abundance estimates. Infrared remote camera trapping has been used as a research tool to identify predator and prey abundance in a number of carnivore studies. This study used camera traps to estimate caracal and black-backed jackal relative abundances in the Little Karoo. Camera traps were set for 10 months in total (June 2014-April 2015) in farmland and conservation areas, whilst also testing different sampling efforts around the Gamkaberg mountain range. Statistical tests were conducted using abundance data to test the similarity between the land-use types and the sampling efforts using the pairwise Permutational Multivariate Analysis of Variance (PERMANOVA). Graphs were produced to illustrate activity periods of the focal species throughout the year and show when they were most active. This determined whether the black-backed jackal and caracal competed temporally in activity patterns. Additionally, statistical tests were conducted using abundance data to test the similarity between land-use types and the sampling efforts. In the study area, it was found that caracal and black-backed jackal and prey species were active at similar times. However, a significant difference (P=0.001) was found between prey diversity and the two land-uses. Significant differences were found between the randomised and intensive sampling methods (P=0.03) as well as the randomised and extensive sampling methods (P=0.05). However, no significant differences were found in prey diversity between the intensive and extensive sampling methods. A total of 28 caracals and 115 black-backed jackals were recorded on all the camera traps, with fewer caracal and jackal on farmlands than in conservation areas. This could mean that they prefer natural prey in reserves more than the prey in farmland areas, or it could be indicative of persecution. This correlates with the number of scat samples found on farmlands and in conservation areas for both focal species. The Cape leopard's habitat differs from the mesopredators habitat, indicating that they most likely avoided areas where

the Cape leopard roamed to evade unnecessary conflict. This was supported by the camera data which did not capture any photographs of the Cape leopard.

3.2. Introduction

While population size and density estimates are fundamental data for conservation and management plans, they are difficult to gather if the species are rare or elusive (Creel *et al.* 2003). Collecting such data can be difficult, time-consuming and expensive, but remains necessary for effective conservation planning and to monitor a species' threatened status for the IUCN Red List database (Linkie *et al.* 2007, Mann 2014). Many studies focus on large apex predators for conservation purposes and lack information on other, smaller species that might sometimes be problematic to livestock farmers (Estes *et al.* 2011).

Studying larger carnivores or mammals in particular is difficult due to their low population densities, large home ranges and the difficulties encountered in capturing or observing them (Terborgh 1988, Mills *et al.* 2000). Management and conservation of many African carnivores is further impeded by a lack of accurate distribution and abundance data (Wiesel 2006, Thorn *et al.* 2009). Brand & Nel (1997) mentioned that neophobia of novel stimuli in canids and acquired behavioural patterns like avoidance of poisoned bait can explain avoidance of novel stimuli like camera-traps or man-made objects (Mahut 1958, Van Der Merwe 1953). Direct counts of such animals can be very time-consuming and data is therefore usually gathered through indirect methods such as spoor or animal sign counts (Balme *et al.* 2009), transects (Silveira *et al.* 2003) and camera-trap surveys (Karanth & Nichols 1998). The advancement of new technologies is alleviating these challenges and allowing for more precise and accurate monitoring strategies. Improved techniques include camera-trapping, DNA analysis, scat detection by trained dogs as well as the interpretation of this data using satellite imagery and ecological modelling, among others.

Camera trapping is advantageous when a study is conducted over a large sampling area using equipment that is operable during both day and night hours to detect cryptic and rare species. A study by Mann (2014) concluded that better results for leopard densities were obtained from the non-invasive camera-trapping techniques and scat samples rather than GPS collar data. This method is also useful in increasing sampling efficiency in inaccessible areas where daily visits of sampling sites are not possible (Ancrenaz *et al.* 2012). Camera trapping has been used globally to produce a wide range of information about an area and its species, such as the presence-absence of species, activity patterns and behaviour, spatial patterns, habitat use and capture-recapture data on individually recognisable species. Camera trapping also contributes to the awareness of conservation issues (Cutler & Swann 1999; Wilson & Delahay 2001, Ancrenaz *et al*. 2012). Early studies using camera traps focused on density estimations of naturally marked species, but there is a growing interest in examining the whereabouts of unmarked species (Burton *et al.* 2015). If patches occupied by a certain species need to be calculated, camera trapping is the most efficient sampling method to use for most secretive medium- to large-sized species (Karanth *et al.* 2004). Burton *et al.* (2015) reviewed 266 camera-trapping studies between 2008 and 2013, of which most estimated density by using capture-recapture models on marked species. In contrast, very few studies were completed on unmarked species using occupancy and relative abundance estimates (Thorn *et al*. 2009, Linkie *et al*. 2007, MacKenzie *et al*. 2005). Magoun *et al.* (2011) is an example of a study that used a very creative way of studying unmarked species and collecting hairs for DNA identification.

There are many biological- and non-biological constraints regarding camera-trapping, including species-specific data where aquatic mammals, arboreal species and small mammals like rodents are not detected. For this reason, scat samples were also analysed in this study to broaden the prey-preference scale of each focal species (Ancrenaz *et al*. 2012). Camera trapping is also habitat-specific; animals are not easily detected in open habitats as they have large roaming areas outside the detection zones. Environmentally influenced cameras work well in drier conditions with low humidity. Non-biological constraints include high initial and running costs (cameras, batteries, memory cards, storage equipment with card readers, etc.), logistics and personnel (appropriate transport and people monitoring the camera traps), and data processing (Ancrenaz *et al.* 2012). These constraints need to be kept to a minimum.

It is a particularly challenging to estimate abundance of unmarked species with camera traps, but occupancy modelling has been suggested to estimate detection probabilities and provide an index of abundance (O'Brien *et al.* 2010, O'Connell & Bailey 2011). Camera-trap data have been analysed using Relative Abundance Indices (Carbone *et al.* 2001); this can contribute to camera-trap count statistics that is attributable towards animal abundance or detection probabilities, or both (Nichols *et al.* 2010).

In this study, the Relative Abundance Index (RAI) was applied to estimate Jacobs' Index and the species' presence-absence. Raw presence-absence is also referred to as naïve occupancy because it is likely to underestimate the true occurrence of a species when the detection probability is less than one (Burton *et al.* 2015). The activity patterns of the focal species were determined to see whether they were competing with each other and whether they avoided the activity patterns of the apex predator, the Cape leopard. Different sampling efforts using the camera traps were compared in order to determine how much effort was needed for camera sampling and if there was a major difference in species between farmland and conservation areas.

3.3. Materials and methods

3.3.1 Camera trapping

Infrared remote camera-trapping was used as a research tool to identify predator and prey abundance and has been useful in previous carnivore studies (Carbone *et al.* 2001, Henschel & Ray 2003). Leopards are easily identifiable by the rosette markings on their coat, which are unique to each individual (Loveridge & Macdonald 2003). In contrast, caracal and black-backed jackal are more difficult to survey and can only be identified by natural markings or scars. This is a challenging identification method that would be much more effort-intensive and difficult to apply to these predators (Loveridge & Macdonald 2003). Therefore, this study was restricted to estimating relative abundances of caracal and black-backed jackal.

Cameras (Cuddeback^{TM}) were installed to run for 10 months in total (June 2014-April 2015) in farmlands and conservation areas, whilst also testing different sampling efforts around the Gamkaberg mountain range. Resources only allowed for a total of 36 cameras, with two cameras set up at each sample site to ensure proper identification of predators (two photographs to be taken on either side of the predator) and to ensure that possible camera failure would not have an impact on the data collected (Karanth & Nichols 1998).

Randomized Sampling Effort

For the first two months (June 2014-July 2014), 36 cameras were placed randomly across the study area, equally split between six farmland sites and six conservation sites. Three single cameras were placed on each site. Hartebeesvlakte, Triangle, Fontein, Vaalhoek, Greens, Rooiolifantskloof are conservation areas and Bruce, Matthee, Oosthuizen, Ellis, Laubscher, Britz are farmland areas (Figure 3.1).

Figure 3.1: Sample 1 Randomised sites around the Gamkaberg and Rooiberg mountain ranges.

Intensive Sampling Effort

Of the randomised sites, the three conservation areas and three farmland areas that provided the most sufficient data with regards to the focal species were selected in order to determine the second, more intensive sampling effort. This was determined by sites that showed mesopredator activity from the previous randomised sampling effort.

This intensive sampling effort included nine farmland- and nine conservation area camera sites within each opposing grid, using 18 cameras each for two months: August 2014-October 2014; October 2014-December 2014; December 2014-February 2015. Grids (16 km^2) for the camera study were designed to be no further than 15 km from each other to prevent the risk of under sampling (Henschel & Ray 2003). This was done three times on different paired sites over a period of six months (Figure 3.2).

Extensive Sampling Effort

The third sampling effort included an extensive approach by setting up cameras all around the sites of the second sampling effort, choosing three subsites in each site (six sites shown in Figure 3.2) and using paired cameras at every camera location to observe whether it was necessary to sample meticulously for caracal and black-backed jackal. This sampling effort was active from February 2015 to April 2015.

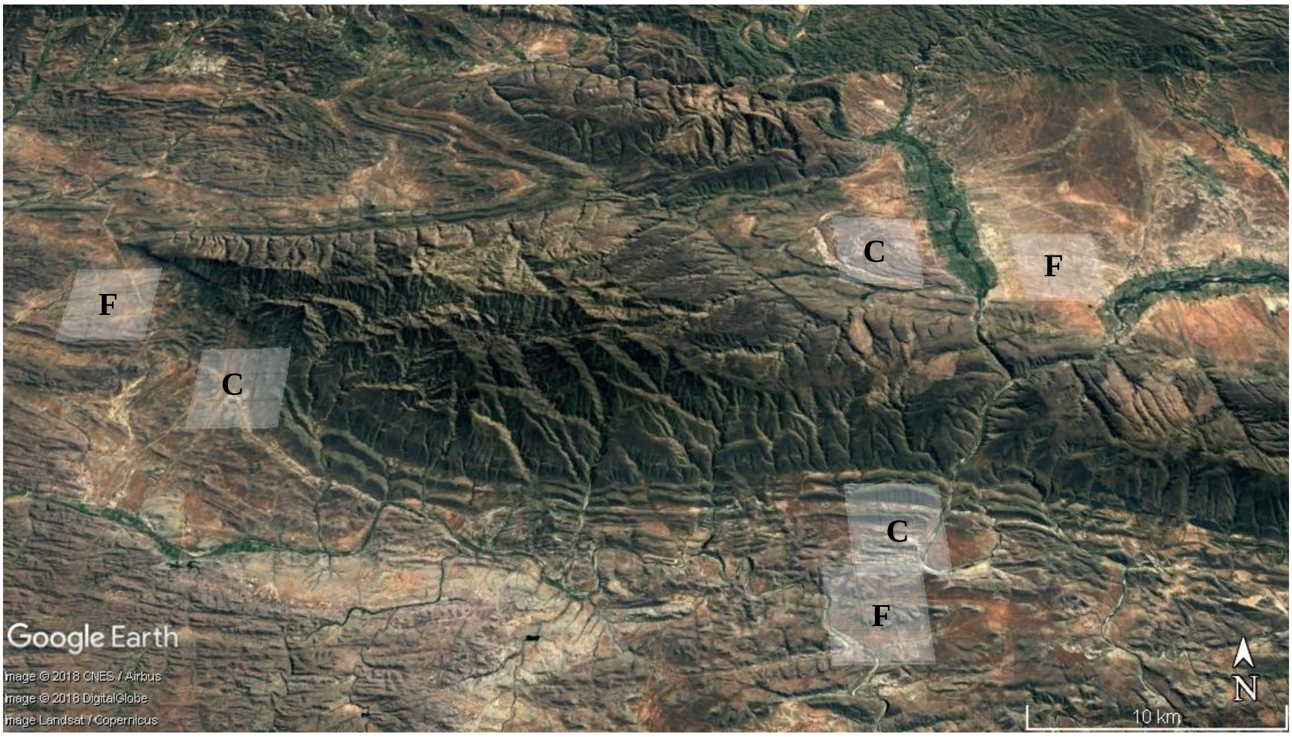

Figure 3.2: Sample 2 and 3 Conservation- (C) and Farmland sites (F) with nine subsites within each grid.

Ancrenaz *et al.* (2012) suggested that the following factors should be taken into consideration and recorded when choosing camera sites: photographs of the camera station and its surroundings, canopy height and canopy closure, the distance of the camera to roads and trails, and the distance to the closest water source. Using the average home ranges of black-backed jackal and caracal is vital in establishing sampling designs and area (Burton *et al.* 2015). Monthly data collection and checking of the camera traps ensured that data loss through mechanical failure was kept to a minimum. Cameras were placed 3 m away from, and perpendicular to tracks or trails to ensure full body photographs of the animals (Silver *et al.* 2004). The cameras were placed approximately 30 cm above the ground, and attached to steel fence posts with cable ties to prevent tampering of the cameras. There was an equal number of cameras in farmlands and conservation areas that functioned simultaneously in order to ensure consistency in the collection of all possible species present, so that data were comparable.

The first photograph on each memory card served as an identification card that contained the date, camera station and GPS coordinates. Cameras were set on 60-second delays to avoid drainage of battery life and to preserve memory card space. Additionally, a timeframe of 60 seconds between consecutive photos was used to decrease the chance of oversampling a specific individual that might use the same trail within the said timeframe, especially if individual caracal and black-backed jackal are difficult to differentiate (Thorn *et al.* 2009, Burton *et al.* 2015). Camera traps were serviced monthly and batteries and SD cards replaced when necessary.

3.3.2 Data analysis

The abundance of the species present at every camera site was compiled in an Excel spreadsheet using the Timelapse Image Analyzer. Photographs downloaded from the memory cards were renamed and organised using this program, providing information for every photograph including time and date captured, location, photo name, species present and the number of individuals present. The GPS coordinates of each camera site and the land-use type for each photograph were also included. Using this information, the Relative Abundance Index detailed in Chapter Two was calculated, and thus a comparison between the sampling efforts and land-use types could be made.

Predator activity was tested to discern whether there was a seasonal difference between the mesopredators in the Gamkaberg. A Shapiro-Wilk W test was carried out to determine whether there was a normal distribution in the data. Graphs were prepared to illustrate the activity periods of the different species throughout the year. The graphs illustrate at which time(s) of the day/night the species were most active, known as an activity budget (Hanya 2004). This determined whether the black-backed jackal and caracal competed temporally for space and potentially for similar prey species.

Additionally, statistical tests were conducted using abundance data to test the similarity between the land-use types and the sampling efforts. This will also give an indication on prey diversity in the different land-use areas. For both tests, the pairwise Permutational Multivariate Analysis of Variance (PERMANOVA) was computed in Primer 6 (Anderson 2001). PERMANOVA produces t-test and p-values for the similarity tests between land-use and sampling efforts. The pairwise PERMANOVA tests produced a clustering analysis to visualise Bray-Curtis similarity measures (Curtis & Bray 1957), where the land-use type produced a PCO (Principal Coordinates) plot and the sampling efforts produced a CAP (Canonical Analysis of Principal Coordinates) analysis.

3.4. Results

A total of 28 caracal and 115 black-backed jackal were recorded on all the camera traps that were in place from June 2014 to April 2015. Of the black-backed jackal, 68 were recorded in conservation areas and 47 on farmlands. Only three caracals were recorded on farmlands compared to 25 in conservation areas.

3.4.1. Activity

Figure 3.3 illustrates that caracal were primarily nocturnal with some exceptions where they were photographed during the mornings and day. Black-backed jackal were also found to have a predominance to nocturnal traits. However, the caracal and black-backed jackal roamed similar areas, consumed the same food and were active within similar timeframes.

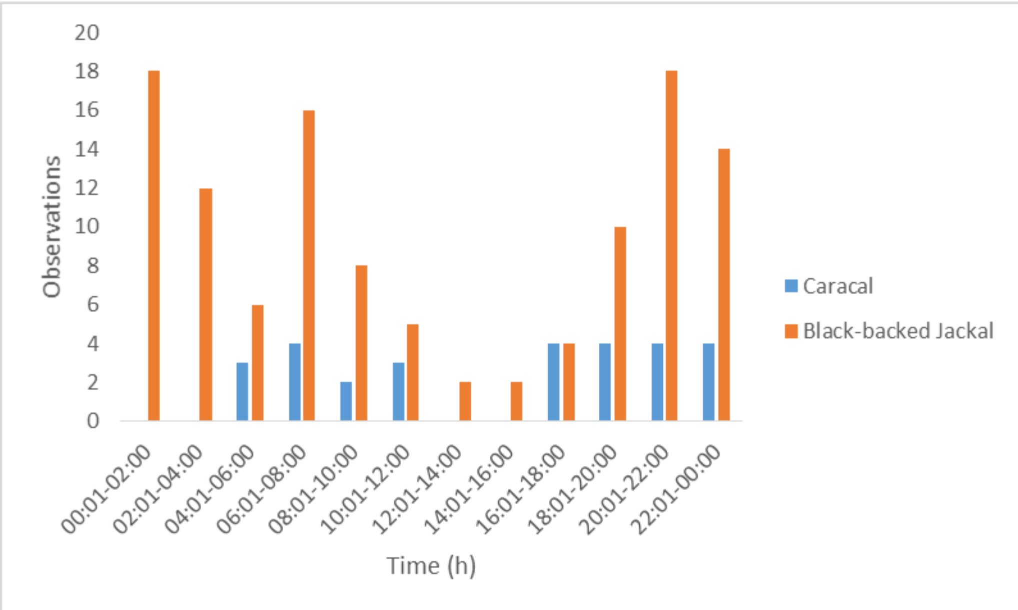

Figure 3.3: Activity for focal species recorded between May 2014 and April 2015.

3.4.2. PERMANOVA tests between sampling methods and land-uses

The goal of this study was to test whether there was a difference in prey diversity between conservation areas and farmlands using camera traps. It endeavoured to illustrate possible significant differences in the different sampling techniques used, and to test the necessity of using many camera traps closely spaced or selecting key spots to produce the same sufficient information required to carry out a diversity analysis.

The Principal Coordinates (PCO plot) from a Permutational MANOVA test was used to show the similarity between prey diversity in conservation and farmland sites (Figure 3.2). This plot clearly shows that there was a significant difference (P=0.0001) between prey diversity and these two land-uses (Table 3.1). This can primarily be due to farmlands having livestock that do not naturally occur in conservation areas. A Canonical Analysis of Principal Coordinates (CAP plot) from a Permutational MANOVA test was used to show the similarity between sampling efforts using potential prey (Figure 3.5). Significant differences were found between the randomised and intensive sampling method (P=0.03) as well as the randomised and extensive sampling methods (P=0.05). However, no significant differences were found in prey diversity between the intensive and extensive sampling methods, meaning that either method will produce sufficient data. Using the extensive method would be most preferable as it is cost-, energy- and, ultimately, more time-efficient.

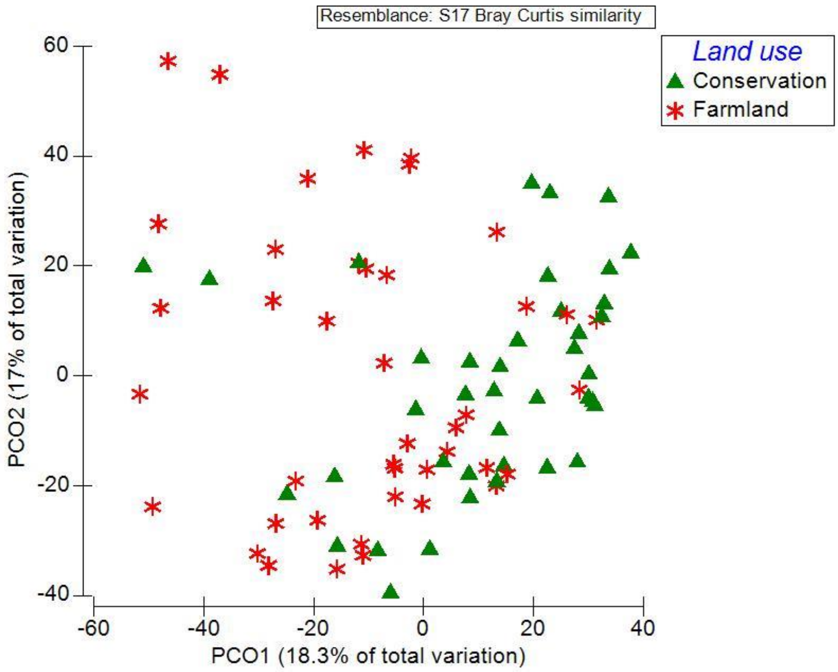

Figure 3.4: Principal Coordinates (PCO) plot from a Permutational MANOVA test showing the similarity in prey diversity between conservation and farmland sites.

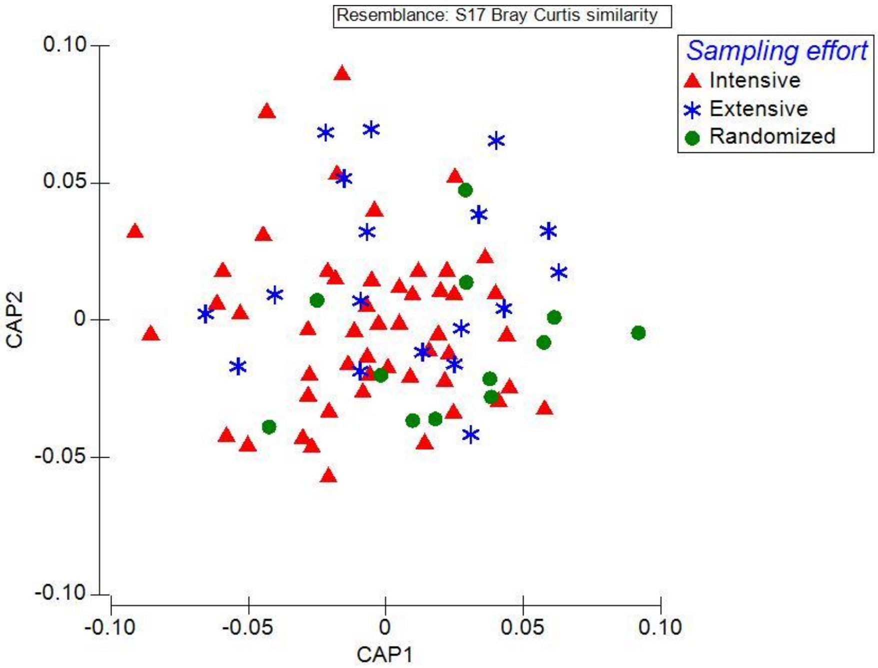

Figure 3.5: Canonical analysis of principal coordinates (CAP plot) from a Permutational MANOVA test showing the similarity in prey diversity between sampling efforts – Intensive, Extensive and Randomised.

Table 3.1: P(perm) values show whether there was a significant difference (P=<0.05) in prey diversity between land-use, sampling efforts and pairwise tests for sampling efforts.

Source of variation	df	SS	MS	Pseudo-F	P(perm)
Land-use	1	17477	17477	6.17	0.0001
Sampling effort	2	9332	4666	1.57	0.074
Pairwise tests	**t**	**P(perm)**			
Intensive, Extensive	0.95	0.52			
Intensive, Randomised	1.44	0.03			
Extensive, Randomised	1.46	0.05			

3.5. Discussion and conclusion

The data shows that jackal were more abundant than caracal on the farmlands where camera traps were installed. Jackal tend to utilise plains (Rautenbach 2010) whereas caracal prefer rocky, mountainous areas. Both focal species occurred less on farmlands than in conservation areas, hypothesizing that they prefer natural prey in reserves over the prey found in farmlands. This correlates to the difference between the number of scats found on farmlands and the number found in conservation areas for both focal species. The scat results for both species confirmed this in Chapter Two and indicated that the mesopredators preferred rodents as their primary food source. An improvement on this study for the future would be to include Sherman trapping to study where different species of rodents occur and to determine if they are more abundant in nature reserves than on farmlands.

Carnivore species are influenced by competition with other carnivores, which in this case is the Cape leopard, the caracal and the black-backed jackal. As mentioned, the caracal and black-backed jackal feed predominantly on smaller prey, indicating a more rapid response in change of habitat and prey availability than the apex predator that prefers mountainous areas for refuge from persecution in the lower farmlands (Mann 2014). Even though the diets of the focal species are very similar, it is their different choice of habitat and timing of activity that allow them to co-exist. In this study, the activity of both focal species peaked at dawn, at dusk and at night, meaning that they tend to be nocturnal. There were, however, instances where black-backed jackal were recorded during the day and records also indicated that caracal often roamed around until 11:44 in the morning. Thus, the relationship of these carnivores with their predominant prey, the rodents, must have an influence on their activity throughout the diurnal stages of the day (Carbone & Gittleman 2002). The authors also state that prey density is a determinant of carnivore density within and between species, being a critical factor to the future of stable carnivore populations. Rowe-Rowe (1983) found similar results as to the timeframes (09:00 to 14:59) in which jackal were inactive.

Some studies described *Otomys irrotatus* as crepuscular, whereas another study found them to be active throughout the day and night (Davis 1973, Perrin 1981), which supports the fact that this was a preferred species by both caracal and black-backed jackal. Shortridge (1934) and Avenant & Nel (1998) seem to be the only authors stating that caracal appear to hunt by day. In the current study, caracal also appeared to have longer diurnal activity patterns when compared to other studies; this could be solely due to prey activity in the Little Karoo that the mesopredators have adapted to.

Increasing the density of camera traps can improve the probability of detecting a study animal (Karanth & Nichols 1998). This is detecting at least one individual of a species in a sampling area (O'Brien *et al.* 2003). A limited number of cameras were available for this study; therefore, a higher trap density reduced the area that could be surveyed. Additionally, areas used frequently by the focal species can increase detection probability (Karanth & Nichols 1998). Camera sites were chosen carefully to accommodate both caracal and jackal, staying close to farmland plains and mountainous slopes. There was no significant difference between the extensive and intensive sampling methods, which means a larger area could be used with limited cameras to study black-backed jackal and caracal. There was, however, a difference when the latter two sampling methods were compared to randomised sampling. This indicates that there still needs to be some form of uniformity or structure when deciding to place cameras in certain areas. This knowledge can influence the observation rates of the black-backed jackal on camera traps. Additionally, the flash of a camera-trap may prevent the use of a specific area in the future by the individual (Karanth *et al*. 2010).

The result from the different land-uses, conservation areas and farmland areas were fairly different with respect to prey species present. This makes sense as the farmlands had very little or no natural

vegetation due to goats, ostriches or cattle roaming the area. On the other hand, the nature reserves had dense vegetation and overlapping biomes. One significant spot in Triangle reserve had many Brants' whistling rats in between the succulents and this was found nowhere else. Loveridge *et al.* (2003) found that dietary overlaps between two sympatric species, *Canis mesomelas* and *Canis adustus* were different between seasons with the hot season overlapping more due to food scarcity.
Mellville & Bothma (2006) studied caracal using spoor counts to determine density and the prey species they were most likely feeding on. They found increased spoor density in the colder seasons, suggesting the caracal have to search for prey for extended periods and are most likely to eat lambs in the lambing seasons. Seasonal preference would be interesting to investigate in future studies on the caracal and black-backed jackal in the Gamkaberg region.
Prey can be caught opportunistically or can be hunted because of evolutionary adaptations. This irreconcilable difference in the way of obtaining prey can be useful when comparing competing predator species such as the caracal and the black-backed jackal. There may be minor differences in habitat-use, activity and the sharing of a few prey taxa, but this dichotomy can help explain the coexistence of sympatric competing carnivores (Kok *et al.* 2004). Generally, caracal are defined as being more specialised than the findings of this study, thus the non-availability of a particular prey taxon could have forced the caracal to be less selective in the Gamkaberg region. As prey availability decreases, carnivores become less selective and their prey choice broadens. In southern Africa, rodent numbers tend to fluctuate. When the rodents are at low levels of abundance, canids and even felids switch to a higher invertebrate diet (Palmer & Fairall 1988).

The mesopredators preferred species differs much from the apex predator's prey choice. The Cape leopard in the area feeds primarily on rock hyrax (17.3%), kudu (11.5%) and vlei rats (9.6%), according to Mann (2014). The focal species' diets did not show any evidence of rock hyrax and large prey such as kudu in their diet. This could be because the areas that leopards prefer are different to that of the mesopredators. The leopards in the Little Karoo prefer steep slopes at lower altitudes, typical of foothills and deeply incised valleys (Mann 2014). This habitat differs from the mesopredators habitat, indicating that they avoided where the Cape leopard roamed to avoid unnecessary conflict. This was supported by the camera data which did not capture one image of a Cape leopard.

Chapter Four: Conclusion and recommendations

4.1. Introduction

Ecosystem management has developed as an important practice for conservation and wildlife biology and as a substitute for the traditional method of species-level management. This approach became popular because species persist or disappear; populations increase or decline because of transformations in their habitats (Estes 1996). On the contrary, conservation and management of a specific species is reliant on the identification of conservation threats as well as the knowledge and understanding of their biology and ecology (Caughley 1994). To establish the relationship between the three main predators – the caracal, the black-backed jackal and the Cape leopard – and their corresponding prey, diet and population estimate, studies need to be conducted for the participating species. This will, in turn, determine their co-existence and the competitive nature among each other to aid in understanding the population structure in the Little Karoo. Mann (2014), Rautenbach (2010) and Norton (1986) did extensive studies on the home range and diet of the Cape leopard in this area, overlooking the importance of the mesopredators that also have a huge impact on population dynamics in the Little Karoo. The farmers in this area identified the top five damage-causing animals as baboons (56% of respondents), black-backed jackal (51%), caracal (21%), porcupines (19%) and leopards (17%) (Mann 2014). This encourages the fact that it is important for caracal and black-backed jackal diets to be studied alongside that of the leopard.

The aim of this study was to provide a preliminary assessment of the prey preference of the black-backed jackal and the caracal, respectively. Camera trapping and scat analysis were used jointly to determine prey preference and possible competition between these co-existing species. These data were also used to determine the importance of livestock as part of the diet by comparing farmland and conservation areas and whether the Cape leopard's diet and home range affects the focal species significantly.

4.2. Conservation status

Many ecologists have realised that removing predators from an environment can result in population explosions of the subordinate species, such as the prey (Prugh *et al.* 2009). Soulé *et al.* (1988) was the first to establish the idea of mesopredator release, which is the process of mammalian carnivores of medium to small size being more dominant in the absence of a large carnivore. Mesopredator release usually has negative cascading effects on prey species but can also lead to intraguild predation among the mesopredators – this is a combination of predation and competition between two species that rely on the same prey resources and also benefit from preying upon each other. In the Klein Karoo, this could become a reality for either the caracal or the black-backed jackal if leopard are extirpated. Historically, caracal are more likely to predate on black-backed jackal (Mellville *et al.* 2004), which could lead to them dominating in the Gamkaberg area.

In 2008, leopard status on the IUCN Red list was changed from Least Concern to Near Threatened and specifically in the Western Cape, they are listed as 'Protected' species since the declaration of the Nature Conservation Ordinance No. 19 of 1974 (Henschel *et al.* 2009). In the Gamkaberg region, the Cape leopard is the only apex predator still existing in the area, followed by two mesopredators – the black-backed jackal and the caracal. Human persecution has led to the fact that the leopard is now declining in numbers and, consequentially, ecological trophic cascades can take place (Estes *et al.* 2011, Brook *et al.* 2012). If mesopredator release takes place, especially with the two species in this study area, a rapid decline in prey abundance and diversity could follow suite. Therefore, maintaining a Cape leopard population may indirectly protect vulnerable prey and maintain biodiversity. In the Gamkaberg, the Cape mountain zebra (*Equus zebra zebra)* is a highly vulnerable species with a population of less than 100 that needs to be protected from natural predators. Leopard are the most likely to prey on them, so if a variety of diet choice remains for the Cape leopard, predation on the Cape Mountain zebra will, in turn, also be less likely. Maintaining a healthy, natural ecosystem including all trophic levels will result in more vulnerable species and livestock being predated on less by the apex and mesopredators.

4.3. Camera trapping

Camera-trapping is a very popular method used to study wildlife, especially cryptic species such as tigers, ocelots, leopard, Cape mountain zebras, etc. It is the perfect setup to be used for long periods of time over large study areas for as long as the batteries and storage unit permit. For non-uniquely identifiable species like most ungulates, caracal and black-backed jackal, it is more difficult to determine an accurate density of species. Nonetheless, some individuals can be identified by placing two cameras opposite each other to photograph right and left flanks to capture their unique 'fingerprint' markings. Capture-recapture models and Spatially Explicit Capture-Recapture (SECR) models accurately distinguish between individuals and have been used on tigers (Karanth & Nichol 1998, 2004, Wang & Macdonald 2009), ocelots (Trolle & Kerry 2003), leopard (Chauhan *et al.* 2005, Martins 2010, Rautenbach 2010, Mann 2014) and jaguars (Silver *et al.* 2004)

It was very difficult to estimate numbers and density for the focal mesopredator species in this study. Estimates using Occupancy, Relative Abundance Indices (RAIs) and DNA sampling are main options that can be used to accurately identify the abundance of these species. The best method to use for individual identification of caracal and black-backed jackal is a DNA-based study (Ancrenaz *et al.* 2012). However, this was not the aim of the current study. RAIs were used as they are easy to calculate and have been used in many previous studies.

It is suggested that future studies employ occupancy models or DNA-based studies as these provide more individually correct data (Mackenzie *et al.* 2006, Negroes *et al.* 2010). Another suggestion would be to take seasonal trends into account for the black-backed jackal and the caracal as their diet, abundance and reproductive trends can differ across seasons.

Compared to the diet findings, the camera traps seriously lacked in providing data on the smaller prey species such as the rodents that were prominent in both focal species' diets. It would be advisable to include Sherman traps in future studies for more accurate results. Camera traps are favourable for detecting medium to large ground-dwelling mammals and excluding information on reptiles, small mammals, many birds, aquatic species, invertebrates and arboreal species (Ancrenaz *et al.* 2012).

In this study, camera stations were also biased towards open travel routes such as two-track 4x4 routes and trails. If these were not present, other open animal travel routes were picked, such as holes under fences and faeces/territory markings of the focal species. The Klein Karoo is also the ideal environment in which to do camera trapping when compared with moister areas as the possible water-damage risks to the cameras and problems with the equipment's battery life are lessened (Wang & Macdonald 2009, Ancrenaz *et al.* 2012). Thus, the most effective method to use would be by combining techniques for more accurate results. Possible additional methods to use include tracks and visual observations as well as the genetic analysis of scats, urine and hair.

4.4. Diet

Diet studies can provide an interesting perspective on the livelihoods of secretive carnivores to better understand their role in the ecosystem, to identify competitors and to determine their impact on local prey populations. There are several ways of acquiring dietary information, including non-invasive methods – such as scat analysis, stable isotope analysis and carcass observations – as well as the invasive method of stomach content analysis.

Many studies have been done on leopard diet, whereas mesopredator diet studies have been understudied, even though they sometimes pose high risks to the income of livestock farmers (Rautenbach 2010, Mann 2014). To better assess the relationship of mesopredators with the surrounding environment, be it farmland or conservation areas, both these environments need to be studied to understand the corresponding mesopredators. This was done by comparing the caracal and black-backed jackal diets in these environments.

Mesopredators flexible prey choice, which ranges from plant matter to insects and mammals, allow them to adapt very easily to changing environments (Busshian 1997). Interestingly, a fairly high number of insects– mainly beetles and locusts – were found in the jackal and caracal diets, providing a good subsidiary source of protein and nutrients. A number of scorpions and Solifugae were also present in both diets. The low numbers of black-backed jackal and caracal individuals can be explained by limited food availability, as they will be more dependent on smaller prey such as small mammals and invertebrates (Skinner & Chimimba 2005).

A few improvements can be made for future studies by including seasonal input, increased stomach content studies and a larger sample size. Seasonal input can be used to do a more diet-specific study by looking at the different preferable prey species in winter versus summer. Stomach content analysis also produced a more detailed diet analysis as it included a lot softer food items such as egg. More samples would include a better ratio of preferable prey and food items that could have been missed by a smaller sample of scat and stomach content alone.

4.5. Human-wildlife conflict management

Carnivores sometimes prey on species that are valuable to humans, which, in turn, results in economic losses for farmers focused on livestock and wild game (Treves & Karanth 2003; Graham *et al*. 2005). Additional to this is the fact that carnivores are sensitive to habitat fragmentation, especially because their home ranges are large, which forces them to travel outside the protected areas and into regions where human-wildlife conflict occurs (Woodroffe & Ginsberg 1998). Most carnivores are still declining in numbers globally (Breitenmoser 1998).

Early studies provided solutions for human-wildlife conflict that are mutually effective for farmers and predators. Green et al. (1984) studied 70 sheep and goat producers from 16 states in America and two provinces in Canada, where 89% of the producers saw livestock guard dogs as an economic asset, and 109 out of 137 dogs were considered to be effective guardians. Linhart *et al*. (1979) found that livestock-predation dogs were effective against predators on sheep farms and small- and medium-sized cattle farms. Another tested management tool was introduced by Hawley *et al*. (2007), using shock collars on grey wolves. They found that wolves shifted 0.7 km further away from the centre zone after the shock treatment had been applied, which was crucial for the calving season. An 80% reduction in wolf visits to this area was seen, although the trapping and collaring of the wolves could have contributed to an increased level of fear and human awareness. Kamler *et al*. (2008) conducted a study using soft catch traps to trap smaller carnivores that are not effectively caught using cage traps. In the livestock industry, this non-lethal capture method can be used as an alternative to catch problem animals such as black-backed jackal in order to relocate them from farm areas rather than killing them (Linnel et al. 1997). However, the method of translocation has also been problematic as the animals tend to leave the site of release and travel hundreds of kilometres back home (Hamilton 1981, Vidya 2006). Due to the mesopredators extensive distribution range this method is not very realistic. Odden *et al*. (2002) and Burns *et al*. (1996) suggested that toxic livestock protection collars mounted on sheep was a good method to target the local predators like the lynx. If husbandry techniques can be improved, land-types can be zoned to prevent or reduce future depredation events.

It is impossible to eliminate black-backed jackal and caracal due to their wide geographic distribution and quick population recovery rate. However, encounters can be minimised by increasing the natural ecosystem functioning in combination with carnivore proof methods including carnivore-proof pens, maternity pens and herding guard dogs. Another solution can be to limit permits for carnivore control to small, domestic livestock producers, in turn following an ecosystem-friendly approach to husbandry with methods to prevent depredation (Bothma 2012). The financial and ecological management plans should accompany the applications. Therefore, it is advised that a multi-faceted approach should be used to minimise depredation by the black-backed jackal and caracal. These two mesopredators are beneficial in that they control the natural herbivorous prey, which, in turn, reduces grazing potential.

4.6. Conclusion

The goal of this study was to provide knowledge on the diets and whereabouts of the mesopredators in the Little Karoo to gain a better understanding of their dynamics. Using two non-invasive techniques, namely camera trapping and scat analysis, as well as stomach content analysis, black-backed jackal and caracal diet and relative abundances were determined in conservation areas and farmlands of the Little Karoo.

Local extinctions of predators are linked to the increase in human population, signifying that as human densities rise, carnivore populations decrease (Woodroffe 2000). Therefore, it is essential to compare mesopredator ecology between conservation areas and farmlands to better understand them. The problem in South Africa is fragmentation, where most conservation areas are surrounded by farmlands and are relatively small and far from each other (Bothma & Le Riche 1984). Therefore, it is critical to protect conservation areas and privately owned land – the most suitable habitats for mesopredators and leopard (Balme *et al*. 2010) – for the future conservation of not only the endangered species like the mountain zebra and Cape leopard but all animals that form part of biodiversity.

Livestock management plays an important role in local biodiversity conservation. Unsustainable levels of predator culling can lead to catastrophic environmental degradation with herbivores overgrazing the natural habitat. However, the conservation of indigenous caracal and black-backed jackal is a long-term struggle as long as farmers lose livestock to them. The main notion is that most livestock losses are due to predators; which can be debated. Farmers tend to remove depredating mammals, which is a short-term solution. The problem is that a home-range vacancy then becomes available, causing neighbouring or floating males to compete for the territory and ultimately resulting in an increase in the mesopredator population (Odden *et al*. 2002). One of the main issues is that domestic livestock show weak responses to predators and are often kept in enclosures with no chance of escape, thus predators tend to prefer livestock over vigilant free-ranging wildlife (Laporte *et al*. 2010).

Results from this study can benefit both farmers and conservationists and be used (1) to provide a brief overview of the whereabouts and diet of the caracal and black-backed jackal; (2) to inform local farmers about the activity of mesopredators predating on their livestock; (3) to give an indication of the biodiversity present on their farm; and (4) to provide guidance on how to make their farms predator-proof in a way that will be beneficial to livestock and the mesopredators.

The challenge for mesopredator conservation will be to build farmer tolerance towards the benefits of keeping the existent mesopredators at bay without harm. Livestock farmers must understand that mesopredators are opportunistic feeders and would not choose to predate on livestock as they tend to have a much more variable diet within conservation areas and mainly prefer to eat indigenous rodents. This study provides a baseline for future studies on alleviating human-wildlife conflict. We must learn how to protect predators or face the consequences if we neglect to do so.

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Appendix 1: Frequency of occurrence and biomass tables

Table 4.1: Prey items recorded in caracal scat (n=11) collected on farmland in Gamkaberg in the Little Karoo, Western Cape, South Africa.

Prey species	Prey mass (kg)	Number of occurrences (tot=35)	Frequency of occurrence (%)	Corrected frequency of occurrence (%)	Total biomass of all prey items (%)	Corrected prey biomass (%)
Vlei Rat (*Otomys spp.*)	0.131	6	17.14	16.16	0.35	8.41
Striped Mouse (*Rhabdomys pumilio*)	0.040	2	5.71	4.57	0.04	2.37
Namaqua Rock Mouse (*Aethomys namaquensis*)	0.048	1	2.86	3.01	0.02	1.57
Common Molerat (*Cryptomus hottentotus*)	0.070	1	2.86	2.28	0.03	1.19
Duiker (*Sylvicapra grimmia*)	17.4	1	2.86	2.28	7.73	6.09
Goat (*Capra aegagrus hircus*)	40	5	14.29	26.58	88.82	70.90
Insecta	0.004	1	2.86	2.28	0.00	0.26
Beetles (Coleoptera)	0.004	4	11.43	9.41	0.01	1.06
Scorpiones	0.004	4	11.43	10.87	0.01	1.23
Reptilia	1	3	8.57	7.58	1.33	3.08
Tortoise (*Chersina angulata*)	1.25	3	8.57	7.85	1.67	3.20
Vegetation	0.004	4	11.43	7.12	0.01	0.64

Table 4.2: Prey items recorded in caracal scats (n=48) collected on conservation land in Gamkaberg in the Little Karoo, Western Cape, South Africa.

Prey species	Prey mass (kg)	Number of occurrences (tot = 127)	Frequency of occurrence (%)	Corrected frequency of occurrence (%)	Total biomass of all prey items (%)	Corrected prey biomass (%)
Elephant Shrew (*Elephantulus spp.*)	0.058	2	1.57	1.70	0.11	1.80
Round-eared Sengi (*Macroscelidus probiscensis*)	0.038	2	1.57	1.19	0.07	1.26
Vlei Rat (*Otomys spp.*)	0.131	25	19.69	22.88	3.06	24.22
Brants' Whistling Rat (*Parotomys brantsii*)	0.126	2	1.57	1.35	0.23	1.43
Hairy-footed Gerbil (*Gerbillurus paeba*)	0.025	4	3.15	2.89	0.09	3.06
Striped Mouse (*Rhabdomys pumilio*)	0.040	21	16.54	17.07	0.79	18.07
Namaqua Rock Mouse (*Aethomys namaquensis*)	0.048	2	1.57	3.07	0.09	3.25

Hare (*Lepus spp.*)	2.72	8	6.30	8.00	20.32	18.42
Aardvark (*Orycteropus afer)*	43.25	1	0.79	1.02	40.38	5.56
Mongoose (*Galarella pulverulenta*)	0.727	4	3.15	2.78	2.72	2.95
Small-spotted Genet (*Genetta genetta*)	1.9	1	0.79	1.02	1.77	1.08
Grysbok (*Raphicerus melanotis*)	10.25	1	0.79	0.51	9.57	2.78
Klipspringer (*Oreotragus oreotragus*)	11.9	1	0.79	0.68	11.11	3.67
Insecta	0.004	3	2.36	1.86	0.01	0.43
Beetles (Coleoptera)	0.004	9	7.09	6.26	0.03	1.44
Millipedes (Myriapoda)	0.004	3	2.36	1.43	0.01	0.33
Scorpiones	0.004	5	3.94	3.40	0.02	0.78
Birds (Aves)	0.9	3	2.36	1.86	2.52	3.00
Reptilia	1	5	3.94	3.13	4.67	2.59
Tortoise (*Chersina angulata*)	1.25	2	1.57	0.92	2.33	0.76
Vegetation	0.004	23	18.11	16.97	0.09	3.12

Table 4.3: Prey items recorded in black-backed jackal scats (n=32) collected on farmland in Gamkaberg in the Little Karoo, Western Cape, South Africa.

Prey species	**Prey mass (kg)**	**Number of occurrences (total=79)**	**Frequency of occurrence (%)**	**Corrected frequency of occurrence (%)**	**Total biomass of all prey items (%)**	**Corrected prey biomass (%)**
Elephant Shrew (*Elephantulus spp.*)	0.06	2.00	2.53	1.79	0.06	1.55
Vlei Rat (*Otomys spp.*)	0.13	19.00	24.05	25.50	1.35	22.08
Brants' Whistling Rat (*Parotomys brantsii*)	0.13	1.00	1.27	2.71	0.07	2.35
Hairy-footed Gerbil (*Gerbillurus paeba*)	0.03	1.00	1.27	0.54	0.01	0.47
Striped Mouse (*Rhabdomys pumilio*)	0.04	6.00	7.59	7.43	0.13	6.43
Namaqua Rock Mouse (*Aethomys namaquensis*)	0.05	1.00	1.27	14.91	0.03	12.90
Rodentia	0.069	1.00	1.27	2.71	0.04	2.35
Hare (*Lepus spp.*)	2.72	3.00	3.80	4.15	4.42	7.80
Klipspringer (*Oreotragus oreotragus*)	11.90	1.00	1.27	1.36	6.46	6.02
Duiker (*Sylvicapra grimmia*)	17.40	2.00	2.53	2.71	18.89	12.04
Springbok (*Antidorcas marsupialus*)	34.50	1.00	1.27	1.36	18.73	6.02
Goat (*Capra aegagrus hircus*)	40.00	2.00	2.53	2.25	43.43	9.99

Egg	1.42	2.00	2.53	1.22	1.54	0.23
Insecta	0.00	2.00	2.53	1.90	0.00	0.36
Beetles (Coleoptera)	0.00	7.00	8.86	5.58	0.02	1.05
Millipedes (Myriapoda)	0.00	1.00	1.27	0.54	0.00	0.10
Scorpiones	0.00	3.00	3.80	2.11	0.01	0.40
Birds (Aves)	0.90	2.00	2.53	1.44	0.98	1.89
Reptilia	1.00	7.00	8.86	5.69	3.80	3.86
Vegetation	0.00	15.00	18.99	14.12	0.03	2.13

Table 4.4: Prey items recorded in black-backed jackal scats (n=52) collected on conservation land in Gamkaberg in the Little Karoo, Western Cape, South Africa.

Prey species	Prey mass (kg)	Number of occurrences (total=131)	Frequency of occurrence (%)	Corrected frequency of occurrence (%)	Total biomass of all prey items (%)	Corrected prey biomass (%)
Elephant Shrew (*Elephantulus spp.*)	0.059	4	3.05	3.68	0.04	3.32
Vlei Rat (*Otomys spp.*)	0.131	25	19.08	22.81	0.62	20.56
Brants' Whistling Rat (*Parotomys brantsii*)	0.126	1	0.76	0.96	0.02	0.87
Hairy-footed Gerbil (*Gerbillurus paeba*)	0.025	2	1.53	1.27	0.01	1.15
Striped Mouse (*Rhabdomys pumilio*)	0.040	12	9.16	10.41	0.09	9.38
Namaqua Rock Mouse (*Aethomys namaquensis*)	0.048	3	2.29	2.89	0.03	2.61
Common Molerat (*Cryptomus hottentotus*)	0.0702	1	0.76	0.64	0.01	0.57
Rodentia	0.683	1	0.76	0.48	0.01	0.43
Hare (*Lepus spp.*)	2.715	5	3.82	4.65	2.56	9.10
Bush Pig (*Potamochoerus larvatus*)	70.6	1	0.76	0.96	13.31	4.46
Cape Grey Mongoose (*Galerella pulverulenta*)	0.727	2	1.53	2.31	0.27	2.09
Grysbok (*Raphicerus melanotis*)	10.25	5	3.82	3.68	9.66	17.03
Steenbok (*Raphicerus campestris*)	11.1	1	0.76	0.39	2.09	1.78
Duiker (*Sylvicapra grimmia*)	17.4	3	2.29	1.83	9.84	8.47
Goat (*Capra aegagrus hircus*)	40	1	0.76	0.39	7.54	1.78
Donkey (*Equus africanus asinus*)	175	1	0.76	0.96	33.00	4.46
Insecta	0.004	2	1.53	1.60	0.00	0.31
Termites (Isoptera)	0.004	1	0.76	0.64	0.00	0.12

Beetles (Coleoptera)	0.004	11	8.40	6.59	0.01	1.29
Scorpiones	0.004	7	5.34	4.13	0.01	0.81
Birds (Aves)	0.9	3	2.29	1.45	0.51	1.98
Ostrich (*Struthio camelus*)	100	1	0.76	0.48	18.86	0.66
Reptilia	1	3	2.29	1.93	0.57	1.36
Tortoise (*Chersina angulata*)	1.25	3	2.29	1.75	0.71	1.24
Lizard (Squamata)	1	1	0.76	0.96	0.19	0.68
Vegetation	0.004	31	23.66	22.15	0.02	3.47

Appendix 2: Species accumulation curves

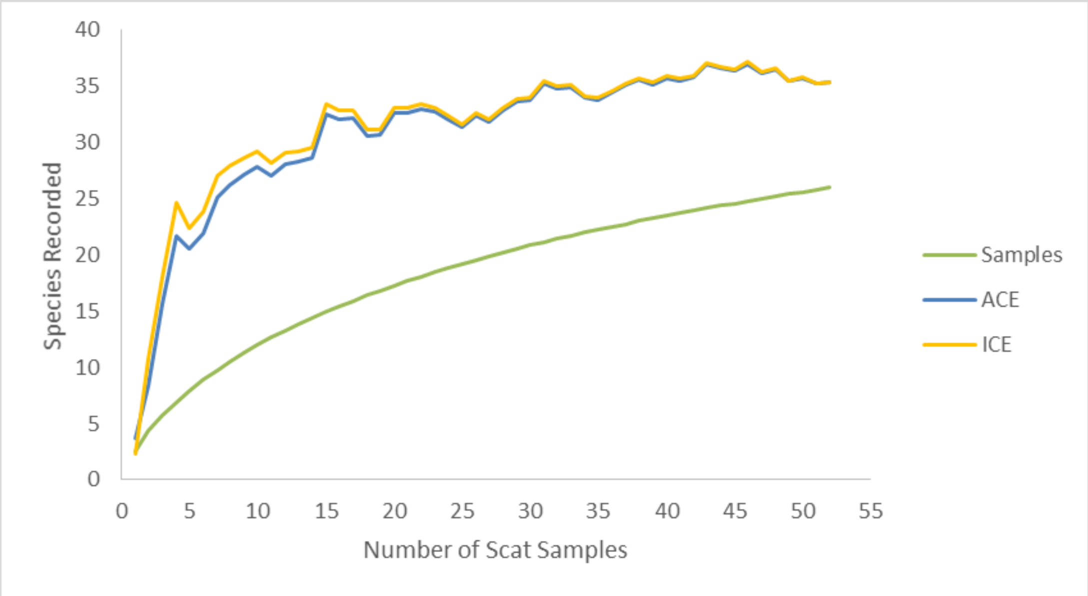

Figure 4.1: Sample-based Incidence Data Accumulation Curve (100 randomised repetitions; ACE mean 35.39, ICE mean 35.42) for 26 prey types recorded in 52 black-backed jackal scat samples collected in conservation areas in the Little Karoo.

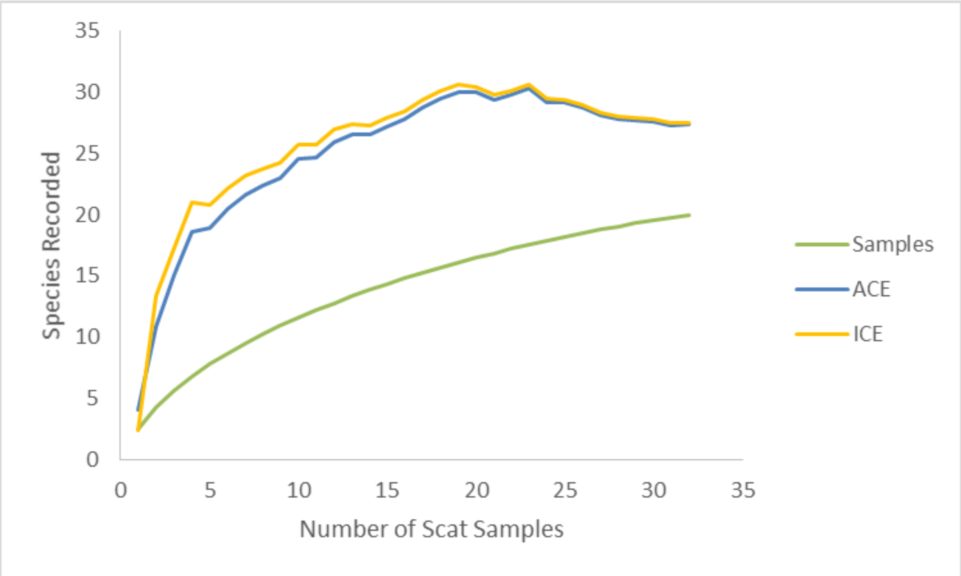

Figure 4.2: Sample-based Incidence Data Accumulation Curve (100 randomised repetitions; ACE mean 27.34, ICE mean 27.49) for 20 prey types recorded in 32 black-backed jackal scat samples collected in farmland areas in the Little Karoo.

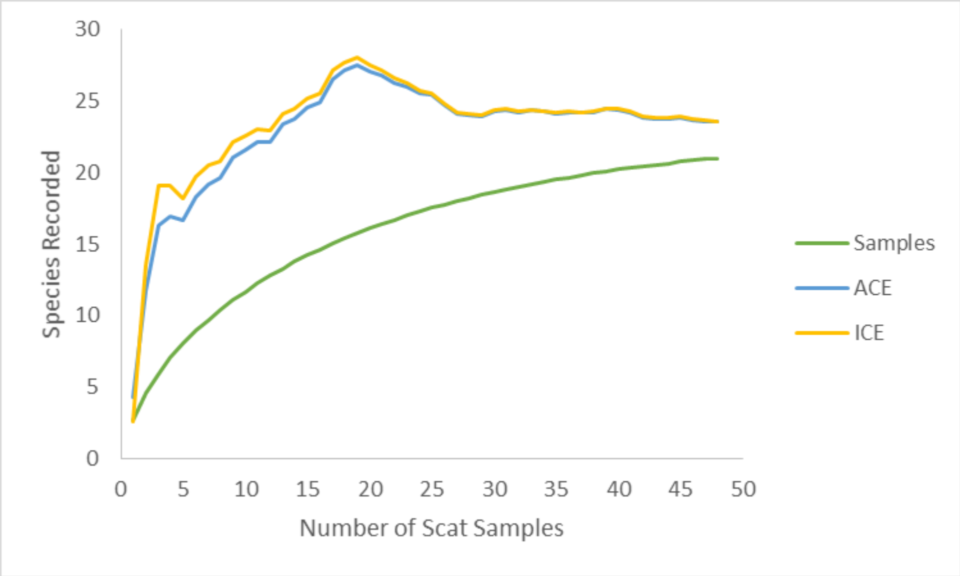

Figure 4.3: Sample-based Incidence Data Accumulation Curve (100 randomised repetitions; ACE mean 23.56, ICE mean 23.6) for 21 prey types recorded in 48 caracal scat samples collected in conservation areas in the Little Karoo.

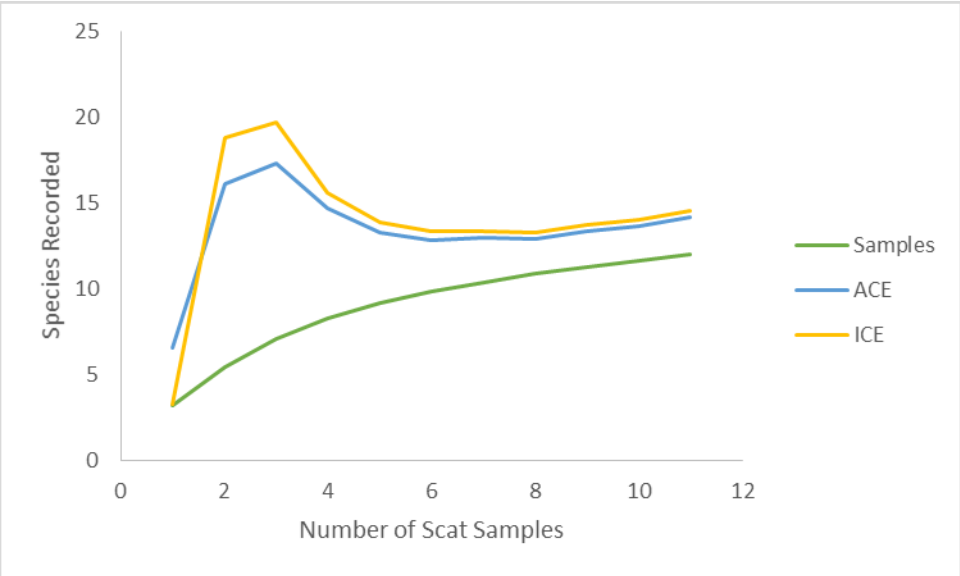

Figure 4.4: Sample-based Incidence Data Accumulation Curve (100 randomised repetitions; ACE mean 14.17, ICE mean 14.53) for 12 prey types recorded in 11 caracal scat samples collected in farmland areas in the Little Karoo.

Appendix 3: Relative Abundance Indices (RAIs)

Table 5.1: Summary of the Relative Abundance Indices (RAIs) of prey species for black-backed jackal in farmland areas in the Little Karoo. Jacobs' Indices were calculated for each species based on the corrected frequency of occurrence (CFO) of species in 32 scats collected in the area.

Species	Photos	RAI	Scat CFO	Jacobs' Index
Aardvark	43	1.78	0.00	-1.00
Aardwolf	3	0.12	0.00	-1.00
Baboon	18	0.75	0.00	-1.00
Bird	79	3.28	1.44	-0.40
Brants' Whistling Rat	0	0.00	2.71	1.00
Bush Pig	3	0.12	0.00	-1.00
Caracal	3	0.12	0.00	-1.00
Cattle	66	2.74	0.00	-1.00
Coleoptera	0	0.00	5.58	1.00
Domestic Dog	35	1.45	0.00	-1.00
Dorper Sheep	61	2.53	0.00	-1.00
Duiker	42	1.74	2.71	0.22
Egg	0	0.00	1.22	1.00
Elephant Shrew	0	0.00	1.79	1.00
Goat	511	21.19	2.25	-0.84
Grysbok	4	0.17	0.00	-1.00
Hairy-footed Gerbil	0	0.00	0.54	1.00
Hare	119	4.94	4.15	-0.09
Honey Badger	5	0.21	0.00	-1.00
Insects	0	0.00	1.90	1.00
Jackal	47	1.95	0.00	-1.00
Klipspringer	0	0.00	1.36	1.00
Large Ungulate	8	0.33	0.00	-1.00
Meerkat	13	0.54	0.00	-1.00
Millipedes	0	0.00	0.54	1.00
Mongoose	6	0.25	0.00	-1.00
Namaqua Rock Mouse	0	0.00	14.91	1.00
Ostrich	1110	46.04	0.00	-1.00

Polecat	2	0.08	0.00	-1.00
Porcupine	95	3.94	0.00	-1.00
Reptile	0	0.00	5.69	1.00
Rodent	0	0.00	2.71	1.00
Scorpions	0	0.00	2.11	1.00
Springbok	0	0.00	1.36	1.00
Steenbok	113	4.69	0.00	-1.00
Striped Mouse	0	0.00	7.43	1.00
Vegetation	0	0.00	14.12	1.00
Vlei Rat	0	0.00	25.50	1.00
Wild Cat	25	1.04	0.00	-1.00

Table 5.2: Summary of the Relative Abundance Indices (RAIs) of prey species for black-backed jackal in conservation areas in the Little Karoo. Jacobs' Indices were calculated for each species based on the corrected frequency of occurrence (CFO) of species in 52 scats collected in the area.

Species	**Photos**	**RAI**	**Scat CFO**	**Jacobs' Index**
Aardvark	28.00	2.91	0.00	-1.00
Aardwolf	5.00	0.52	0.00	-1.00
Baboon	277.00	28.76	0.00	-1.00
Bird	12.00	1.25	1.45	0.08
Brants' Whistling Rat	0.00	0.00	0.96	1.00
Bush Pig	4.00	0.42	0.96	0.40
Cape Mountain Zebra	2.00	0.21	0.00	-1.00
Caracal	25.00	2.60	0.00	-1.00
Cattle	35.00	3.63	0.00	-1.00
Coleoptera	0.00	0.00	6.59	1.00
Common Mole Rat	0.00	0.00	0.64	1.00
Domestic Dog	10.00	1.04	0.00	-1.00
Donkey	32.00	3.32	0.96	-0.56
Duiker	81.00	8.41	1.83	-0.66
Elephant Shrew	0.00	0.00	3.68	1.00
Genet	1.00	0.10	0.00	-1.00
Goat	0.00	0.00	0.39	1.00

Grysbok	7.00	0.73	3.68	0.68
Hairy-footed Gerbil	0.00	0.00	1.27	1.00
Hare	77.00	8.00	4.65	-0.28
Honey Badger	13.00	1.35	0.00	-1.00
Insects	0.00	0.00	1.60	1.00
Jackal	68.00	7.06	0.00	-1.00
Large Ungulate	43.00	4.47	0.00	-1.00
Lizard	0.00	0.00	0.96	1.00
Mongoose	5.00	0.52	2.31	0.64
Namaqua Rock Mouse	0.00	0.00	2.89	1.00
Ostrich	39.00	4.05	0.48	-0.79
Polecat	1.00	0.10	0.00	-1.00
Porcupine	99.00	10.28	0.00	-1.00
Reptile	0.00	0.00	1.93	1.00
Rodent	0.00	0.00	0.48	1.00
Scorpions	0.00	0.00	4.13	1.00
Steenbok	70.00	7.27	0.39	-0.91
Striped Mouse	0.00	0.00	10.41	1.00
Termites	0.00	0.00	0.64	1.00
Tortoise	0.00	0.00	1.75	1.00
Vegetation	0.00	0.00	22.15	1.00
Vlei Rat	0.00	0.00	22.81	1.00
Wild Cat	29.00	3.01	0.00	-1.00

Table 5.3: Summary of the Relative Abundance Indices (RAIs) of prey species for caracal in farmland areas in the Little Karoo. Jacobs' Indices were calculated for each species based on the corrected frequency of occurrence (CFO) of species in 11 scats collected in the area.

Species	Photos	RAI	Scat CFO	Jacobs' Index
Aardvark	43	1.78	0.00	-1.00
Aardwolf	3	0.12	0.00	-1.00
Baboon	18	0.75	0.00	-1.00
Beetles	0	0.00	9.41	1.00
Bird	79	3.28	0.00	-1.00

Bush Pig	3	0.12	0.00	-1.00
Caracal	3	0.12	0.00	-1.00
Cattle	66	2.74	0.00	-1.00
Common Mole Rat	0	0.00	2.28	1.00
Domestic Dog	35	1.45	0.00	-1.00
Dorper Sheep	61	2.53	0.00	-1
Duiker	42	1.74	2.28	0.13
Goat	511	21.19	26.58	0.15
Grysbok	4	0.17	0.00	-1.00
Hare	119	4.94	0.00	-1.00
Honey Badger	5	0.21	0.00	-1.00
Insects	0	0.00	2.28	1.00
Jackal	47	1.95	0.00	-1.00
Large Ungulate	8	0.33	0.00	-1.00
Meerkat	13	0.54	0.00	-1.00
Millipedes	0	0.00	0.00	
Mongoose	6	0.25	0.00	-1.00
Namaqua Rock Mouse	0	0.00	3.01	1.00
Ostrich	1110	46.04	0.00	-1.00
Polecat	2	0.08	0.00	-1.00
Porcupine	95	3.94	0.00	-1.00
Reptiles	0	0.00	7.58	1.00
Scorpions	0	0.00	10.87	1.00
Steenbok	113	4.69	0.00	-1.00
Striped Mouse	0	0.00	4.57	1.00
Tortoise	0	0.00	7.85	1.00
Vegetation	0	0.00	7.12	1.00
Vlei Rat	0	0.00	16.16	1.00
Wild Cat	25	1.04	0.00	-1.00

Table 5.4: Summary of the Relative Abundance Indices (RAIs) of prey species for caracal in conservation areas in the Little Karoo. Jacobs' Indices were calculated for each species based on the corrected frequency of occurrence (CFO) of species in 48 scats collected in the area.

Species	Photos	RAI	Scat CFO	Jacobs' Index
Aardvark	28	2.91	1.02	-0.49
Aardwolf	5	0.52	0	-1
Baboon	277	28.76	0	-1
Beetles	0	0.00	6.26	1
Bird	12	1.25	1.86	0.2
Brants' Whistling Rat	0	0.00	1.35	1
Bush Pig	4	0.42	0	-1
Cape Mountain Zebra	2	0.21	0	-1
Caracal	25	2.60	0	-1
Cattle	35	3.63	0	-1
Domestic Dog	10	1.04	0	-1
Donkey	32	3.32	0	-1
Duiker	81	8.41	0	-1
Elephant Shrew	0	0.00	1.7	1
Genet	1	0.10	1.02	0.81
Grysbok	7	0.73	0.51	-0.17
Hairy-footed Gerbil	0	0.00	2.89	1
Hare	77	8.00	8	0.0005
Honey Badger	13	1.35	0	-1
Insects	0	0.00	1.86	1
Jackal	68	7.06	0	-1
Klipspringer	0.00	0.00	0.68	1
Large Ungulate	43	4.47	0	-1
Millipedes	0	0.00	1.43	1
Mongoose	5	0.52	2.78	0.69
Namaqua Rock Mouse	0	0.00	3.07	1
Ostrich	39	4.05	0	-1
Polecat	1	0.10	0	-1
Porcupine	99	10.28	0	-1

Reptiles	0	0.00	3.13	1
Round-eared Sengi	0	0.00	1.19	1
Scorpions	0	0.00	3.4	1
Steenbok	70	7.27	0	-1
Striped Mouse	0	0.00	17.07	1
Tortoise	0	0.00	0.92	1
Vegetation	0	0.00	16.97	1
Vlei Rat	0	0.00	22.88	1
Wild Cat	29	3.01	0	-1

Appendix 4: Black-backed jackal individual stomach content records

Unique ID	Date dissected	Location	Sex	Weight (kg)	Condition	Head-tail (cm)	Tail length (cm)	Chest girth (cm)	Head length (cm)	Shoulder height (cm)	Neck girth (cm)	Head circumference (cm)	Estimated age (years)	Paw toe to pad (cm)	Paw toe to toe (cm)	Paw pad to pad (cm)
S01	04/07/2014	S33 46 22.4 E21 56 34.8	F	-	Car accident	106	28	53	21	41	36	32	3.5	5	4	3
S02	20/11/2014	-	M	7	Shot	114	39	51	25	51	25	31	8	6	4	3
S03	20/11/2014	Lategansvlei	F	6.45	Shot	92	35	48	20	48	27	30	10	5.5	4	3
S04	13/01/2015	Safari Ostrich Farm	F	6.7	Shot	94	35	46	17	45	28	34	7.5	5.5	4	3
S05	13/01/2015	Safari Ostrich Farm	M	5.4	Shot	86	36	40	17	45	26	34	4.5 months	5	4	2.5
S06	13/01/2015	Safari Ostrich Farm	M	5	Shot	82	31	42	17	43	28	30	4.5 months	5	4	2.5
S07	13/01/2015	Safari Ostrich Farm	F	5	Shot	83	35	42	16	38	26	32	4.5 months	4	3.8	2.5
S08	13/01/2015	Safari Ostrich Farm	M	5.9	Shot	88	36	48	16	44	26	32	4.5 months	4	4	3
S09	13/01/2015	Safari Ostrich Farm	F	5	Shot	86	36	48	17	40	28	34	4.5 months	4	4	3
S10	13/04/2015	Klokkie Farm	M	5.5	Shot	88	38	38	19	39	26	30	9 months	5.3	3.1	2.9
S11	13/04/2015	Klokkie Farm	F	6	Shot	79	33	42	20	43	20	26	9 months	6	4	2.5

Appendix 5: Camera data (extract)

File Name	Date	Time	Latitude	Longitude	Wildlife Species	Quantity	Folder	Sample Number
CDY_0113.JPG	13-Nov-14	11:53 PM	33.657417	21.273250	Aardvark	1	BC3	2
CDY_0158.JPG	29-Nov-14	4:22 AM	33.657417	21.273250	Aardvark	1	BC3	2
CDY_0009.JPG	5-Jul-14	12:13 AM	33.789454	21.644760	Aardvark	1	Britz	1
CDY_0010 (2).JPG	5-Jul-14	12:10 AM	33.789454	21.644760	Aardvark	1	Britz	1
Cdy00030.JPG	7-Jun-14	7:58 PM	33.634833	21.254389	Aardvark	1	Bruce	1
Cdy00031.JPG	7-Jun-14	8:27 PM	33.634833	21.254389	Aardvark	1	Bruce	1
Cdy00034 (2).JPG	7-Jun-14	7:58 PM	33.634833	21.254389	Aardvark	1	Bruce	1
Cdy00035 (2).JPG	7-Jun-14	8:26 PM	33.634833	21.254389	Aardvark	1	Bruce	1
Cdy00035.JPG	30-Jun-14	8:37 PM	33.634833	21.254389	Aardvark	1	Bruce	1
Cdy00039 (2).JPG	30-Jun-14	8:35 PM	33.634833	21.254389	Aardvark	1	Bruce	1
Cdy00055.JPG	19-Jul-14	7:58 PM	33.634833	21.254389	Aardvark	1	Bruce	1
Cdy00162.JPG	31-Jul-14	3:17 AM	33.761556	21.980472	Aardvark	1	Ellis	1
Cdy00168.JPG	2-Aug-14	2:34 AM	33.761556	21.980472	Aardvark	1	Ellis	1
Cdy00169.JPG	2-Aug-14	2:42 AM	33.761556	21.980472	Aardvark	1	Ellis	1
CDY_0107.JPG	31-Jul-14	3:21 AM	33.761556	21.980472	Aardvark	1	Ellis	1
CDY_0111.JPG	2-Aug-14	2:39 AM	33.761556	21.980472	Aardvark	1	Ellis	1
CDY_0112.JPG	2-Aug-14	2:46 AM	33.761556	21.980472	Aardvark	1	Ellis	1
CDY_0011 (2).JPG	30-Dec-14	10:54 PM	33.775361	21.659278	Aardvark	1	AA1	2
CDY_0036 (2).JPG	26-Jan-15	1:40 AM	33.775361	21.659278	Aardvark	1	AA1	2
CDY_0006.JPG	23-Jan-15	4:17 AM	33.811583	21.656694	Aardvark	1	AA3	2
Cdy00010.JPG	20-Dec-14	3:40 AM	33.798028	21.685972	Aardvark	1	AC2	2
Cdy00211.JPG	23-Jan-15	3:14 AM	33.798028	21.685972	Aardvark	1	AC2	2
Cdy00212.JPG	31-Jan-15	12:10 AM	33.798028	21.685972	Aardvark	1	AC2	2
Cdy00218.JPG	12-Feb-15	1:59 AM	33.798028	21.685972	Aardvark	1	AC2	2
CDY_0013.JPG	20-Dec-14	3:41 AM	33.798028	21.685972	Aardvark	1	AC2	2
CDY_0210.JPG	23-Jan-15	3:13 AM	33.798028	21.685972	Aardvark	1	AC2	2
CDY_0211.JPG	23-Jan-15	3:14 AM	33.798028	21.685972	Aardvark	1	AC2	2
CDY_0212.JPG	31-Jan-15	12:10 AM	33.798028	21.685972	Aardvark	1	AC2	2
CDY_0218.JPG	12-Feb-15	1:59 AM	33.798028	21.685972	Aardvark	1	AC2	2
CDY_0175.JPG	31-Dec-14	12:54 AM	33.717167	21.684611	Aardvark	1	AC3	2
CDY_0132 (3).JPG	14-Nov-14	2:59 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
CDY_0132.JPG	14-Nov-14	2:59 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
CDY_0133 (2).JPG	14-Nov-14	3:05 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
CDY_0133 (4).JPG	14-Nov-14	3:05 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
CDY_0139 (3).JPG	20-Nov-14	4:16 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
CDY_0139.JPG	20-Nov-14	4:16 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
CDY_0156.JPG	29-Nov-14	12:24 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
CDY_0158.JPG	2-Dec-14	12:06 AM	33.629028	21.239139	Aardvark	1	BA1 ja	2
Cdy00107.JPG	21-Nov-14	9:59 PM	33.642944	21.248611	Aardvark	1	BA2 ja	2
Cdy00111.JPG	9-Dec-14	1:24 AM	33.642944	21.248611	Aardvark	1	BA2 ja	2
CDY_0011.JPG	21-Oct-14	1:38 AM	33.633500	21.256333	Aardvark	1	BB1 ja	2
CDY_0082.JPG	9-Sep-14	1:59 AM	33.645333	21.259139	Aardvark	1	BB2	2
CDY_0010.JPG	24-Nov-14	11:49 PM	33.654806	21.257250	Aardvark	1	BB3	2

Appendix 6: Maps

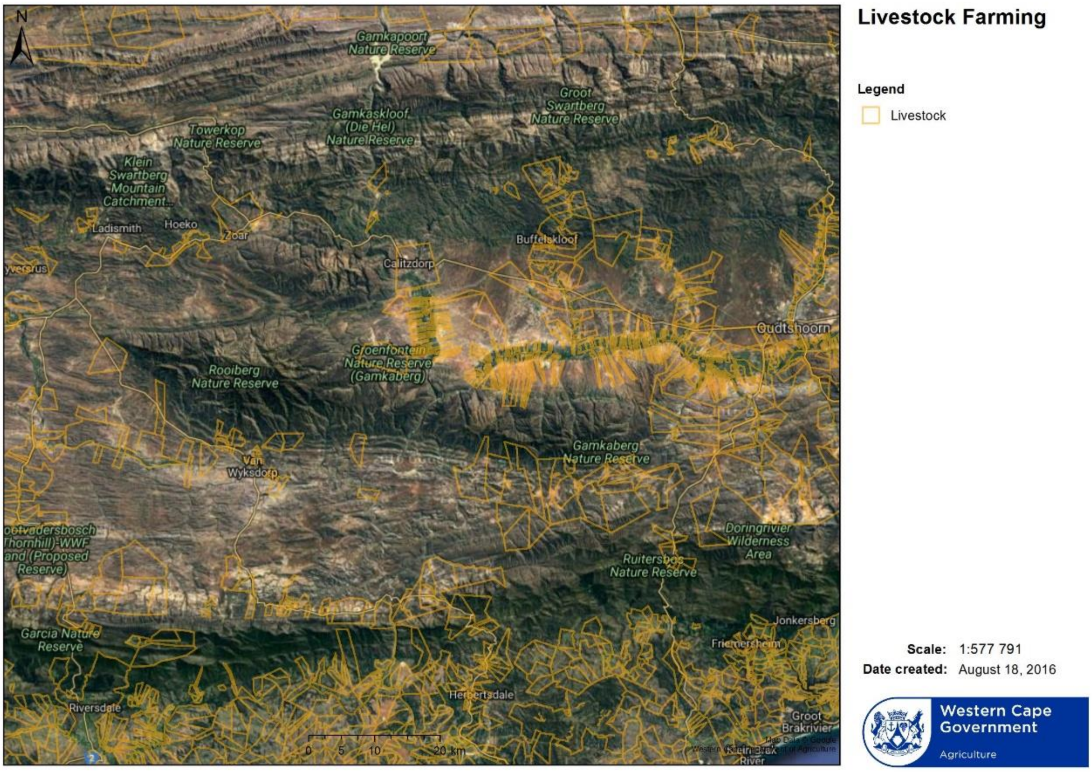

Figure 5.1: Livestock farms in the study area.

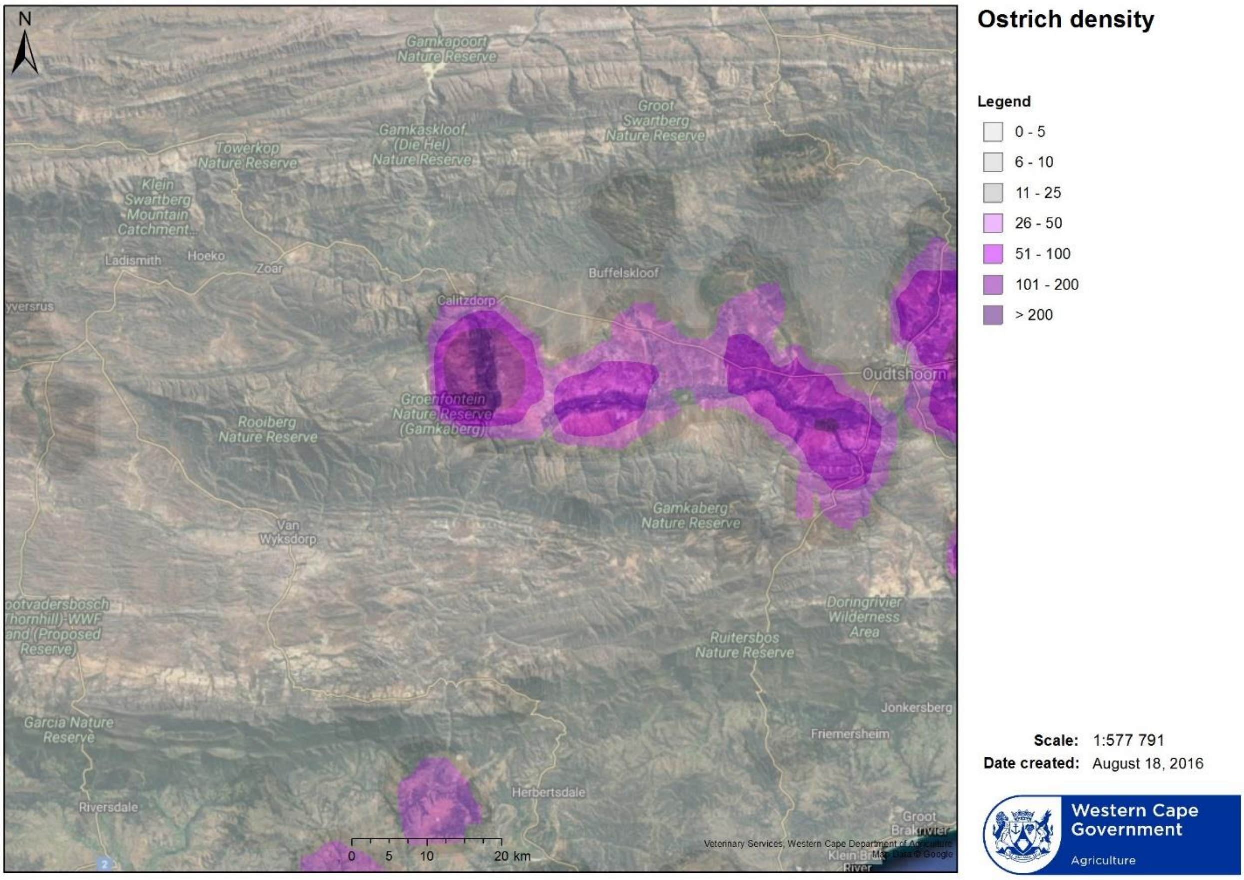

Figure 5.2: The density of ostrich farming in the study area.