ASSESSING THE DIET OF THE CAPE LEOPARD (*PANTHERA PARDUS*) IN THE CEDERBERG AND GAMKA MOUNTAINS, SOUTH AFRICA

By

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ABSTRACT

As limited prey availability and persecution by humans in response to livestock predation are key conservation concerns for the Cape leopard (Martins & Martins 2006), the present study aimed to provide more information regarding their feeding habits. The first objective was to determine whether the Cape leopard was subject to a change in their prey base and how they responded to the change. This was established by comparison of their current diet in the Cederberg and Gamka Mountains, determined by using scat analysis techniques, with a previous dietary assessment (Norton *et al.* 1986). The second aim was to provide a preliminary assessment of the prey preference of the Cape leopard and examine the utility of camera trap surveys to determine leopard prey preference.

Leopard diet in the Cederberg and Gamka Mountains consisted largely of small- (1-10 kg) and medium-sized (10-40 kg) mammals; rock hyraxes (*Procavia capensis*) and klipspringers (*Oreotragus oreotragus*) were key prey items. In terms of regional variation in leopard diet, there was a significant difference in the average weight of prey utilized in the Cederberg and Gamka Mountains. Despite the importance of prey availability of suitable size, their flexibility in terms of prey size utilization reflected their ability to switch to smaller prey to fulfil their dietary requirements, when prey is limited.

The study suggested a dietary shift, with significant variation in prey species utilization in both regions. The shift did not appear to be in response to prey scarcity, but rather a reduction in key prey species, particularly the rock hyrax. The shift involved an increase in the number of species utilized, and only a very small increase in livestock predation in both areas. There was however no significant variation in prey size category utilization. This demonstrated their dietary flexibility, as well as the importance of suitable prey sizes rather than the presence of specific prey species to fulfil their dietary requirements.

The camera trap survey revealed a strong correlation between the number of camera trap days and the number of photographs taken of identifiable species. Variation of this correlation between different habitats supported the notion that individual images are a better unit to determine sampling efficiency than trap days. The camera trap survey also showed that small rodent availability was underestimated by camera trap surveillance, which resulted in poor prey preference estimation. It was therefore suggested that camera trap surveys be restricted to the surveillance of larger prey species (> 1 kg). By excluding small rodents from the analysis, prey preference could be estimated for other species and prey size categories. Small- and medium-sized mammals were significantly preferred, whereas large mammals were significantly avoided by the Cape leopard.

Key words: *Cape leopard, Panthera pardus, feeding habits, diet, prey preference, prey availability, dietary shift, camera trap surveys, Cederberg Mountains, Gamka Mountains*

CHAPTER 1
INTRODUCTION

The leopard (*Panthera pardus*) (Schlegel 1857) is considered relatively successful, as indicated by broad distribution and conservation studies. Their tolerance and adaptability in terms of variation in environmental conditions and anthropogenic impacts are challenged by few other large carnivores (Turnbull-Kemp 1967; Marker & Dickman 2005). Their range includes the greater part of Africa, southern Asia and Malaysia, across which 27 distinct (based on distribution and morphology) populations occur and 9 subspecies have been identified (Turnbull-Kemp 1967; Miththapala *et al.* 1996; Uphyrkina *et al.* 2001; IUCN 2009). However, their numbers are declining and the leopard is currently considered “near threatened” by the IUCN red list of threatened species (IUCN 2009). The situation in South Africa is no exception; with leopards thought to be “threatened with extinction” (CITES 2009).

Despite the leopard’s broad dietary niche breadth and catholic prey preferences loss of prey remains to be a key conservation concern for numerous leopard populations in southern Africa (Turnbull-Kemp 1967; Martins & Martins 2006; Hayward & Kerley 2008; IUCN 2009). The persistence of large predator populations is highly dependent on sufficient prey availability, in terms of both preferred prey species and prey of suitable size (Karanth & Sunquist 1995; Karanth *et al.* 2004; Marker & Dickman 2005; Hayward *et al.* 2007). It is therefore important that we hold a thorough understanding of their feeding habits and knowledge of prey availability for effective management and conservation of the leopard.

The present study focused on the feeding habits of the Cape leopard (*Panthera pardus melanotica*) (Gunther 1885) in South Africa. The first aim was to provide a current record of leopard diet in the Cederberg and Gamka Mountains and explore their flexibility to regional and temporal variation in prey availability. The second aim was to provide a preliminary assessment of the prey preference of the Cape leopard and determine the utility of camera trap surveys to do so.

1.1 Diet

When prey is abundant vertebrate predators show preference towards certain species, whereas when prey is limited they utilize all prey that they encounter, thus their diet tends to reflect prey availability (Griffiths 1975; Karanth & Sunquist 1995). Leopard diet is known to be extremely flexible and thus ultimately depends upon local and temporal prey availability (Norton *et al.* 1986; Johnson *et al.* 1993; Ramakrishnan *et al.* 1999; Ott *et al.* 2007).

Variation in prey availability can occur for various reasons e.g. cyclic and random prey population fluctuations (Howell 1923; Willan & Bigalke 1982; Kerley & Erasmus 1992; Lima *et al.* 1999; Erb *et al.* 2001), as well as anthropogenic impacts (Marker & Dickman 2005; Martins & Martins 2006). When these changes involve loss or reduction of prey, leopards may respond in a number of ways. Firstly, it has been linked to larger range sizes (Marker & Dickman 2005), which may also result in increased conflict with neighboring landowners (Woodroffe & Ginsberg 1998). Secondly, it may cause reduced leopard population sizes and densities, thus compromising the genetic integrity of the populations (Karanth & Sunquist 1995; Hayward *et al.* 2007). Finally, it may cause changes in their feeding habits (Griffiths 1975; Karanth & Sunquist 1995; Mizutani 1999; Ramakrishnan *et al.* 1999; Marker & Dickman 2005; Henschel *et al.* 2005; Martins & Martins 2006; Ott *et al.* 2007).

Dietary shifts in the case of leopards may involve one or more of the following alterations. 1) Increased predation on livestock, which in turn may lead to increased conflict with neighboring landowners (Stuart & Heinecken 1977; Mizutani 1999; Marker & Dickman 2005; Martins & Martins 2006). 2) A shift towards smaller prey (Karanth & Sunquist 1995; Ramakrishnan *et al.* 1999; Henschel *et al.* 2005; Ott *et al.* 2007), which could result in competition for resources by initiating or increasing dietary overlap with other predators in the area. The smaller size of available prey has also been linked to a reduction in predator body size e.g. the suggested link between prey size of pumas (*Panthera concolor*) and puma body size in America (Iriarte *et al.* 1990). 3) The inclusion of more prey species as opportunistic feeding increases (Griffiths 1975; Karanth & Sunquist 1995), which may also lead to competition for resources with other predators.

The importance of adequate prey availability for effective conservation and management of leopard populations is thus clear. The difficulty in predicting their response to prey limitations and the potential of dietary shifts to exacerbate existing conservation threats suggest the need to monitor prey availability and leopard diet. This may enable identification of prey shortages and bring to light their response to said changes, which may further improve our understanding of their feeding habits.

1.2 Prey preference

The preference of predators towards certain prey species is dependent on several prey, predator and environmental characteristics (Turnbull-Kemp 1967; Griffiths 1975; Sunquist & Sunquist 1989; Karanth & Sunquist 1995; Hayward *et al.* 2006a). Predator prey preference is however first and foremost aimed at achieving maximal energy consumption, they are thus referred to as “energy maximizers” (Griffiths 1975). Carbone *et al.* (1999) later refined this model for mammalian, terrestrial carnivores, by showing that energy requirements vary with carnivore body size i.e. carnivores of 21.5 kg and more, generally select prey that weighs 45% or more of their own body mass, and visa verse. The lion (*Panthera leo*) for example prefers prey that weighs between 190 and 550 kg (Hayward & Kerley 2005). Their preference to such large prey is thought to be facilitated by their group hunting strategy (Hayward & Kerley 2005). This is because the risk of injury associated with prey capture is another key factor in determining predator prey preference and is particularly important for solitary hunters (Sunquist &

Sunquist 1989; Hayward *et al.* 2006a). Cheetahs (*Acinonyx jubatus*) and leopards for example prefer much smaller prey, i.e. 23 to 56kg and 10 to 40kg respectively, as solitary hunters tend to be more vulnerable when an injury is obtained during an attack (Hayward *et al.* 2005; Hayward *et al.* 2006a; Hayward *et al* 2006b).

As predator density is linked to sufficient prey availability in terms of both preferred species and suitable size categories (Karanth & Sunquist 1995; Hayward *et al.* 2006a; Hayward *et al.* 2007), it is important that we identify and understand predator prey preferences such as these. If the densities of preferred prey species are known, prey preference data can be used to determine predator carrying capacity of an area (Hayward *et al.* 2007). This may enable the identification of predator overpopulations and prey limitations, and when a shortage in prey is detected, attention and cost can then be focused on the reintroduction of prey most suitable for their sustenance (Hayward *et al.* 2006a; Hayward *et al.* 2007).

1.3 Camera trap surveys

As mentioned above, prey preference provides a measure of prey suitability for a species and can be determined by using prey usage and availability data (Jacobs 1974). To determine the availability of prey extensive data on the composition and abundance of potential prey species are required.

Though fish, birds, reptiles and insects are sometimes utilized, leopard diet consists mostly of mammals (Turnbull-Kemp 1967; Hayward *et al.* 2006a) for which availability can be determined using various methods e.g. track surveys, line-transects or camera trap surveys (Silveira *et al.* 2003). Owing to the advantages (Silveira *et al.* 2003; Sanderson 2004; Yasuda 2004; Rovero *et al.* 2005) and multitude of applications (Carbone *et al*. 2001; Fonseca *et al.* 2003; Trolle 2003; Yasuda 2004; Azlan & Lading 2006; Chetana & Ganesh 2007; Martins *et al*. 2007) associated with camera trap surveys, it has become a popular approach to monitoring wildlife. The former includes accurate identification of species during day and night time surveys, with limited impact on the environment (Silveira *et al.* 2003). Furthermore, surveys can be conducted in a variety of habitats (Trolle 2003), do not require many field staff or much experience and are relatively independent of environmental conditions (Silveira *et al.* 2003). In terms of its application, several prey estimates can be determined such as species richness, abundance, density, diversity, mammalian biomass, population size, activity patterns, species inventories and spatial and temporal variation in populations (Carbone *et al*. 2001; Fonseca *et al.* 2003; Goldman & Winther-Hansen 2003; Trolle 2003; Yasuda 2004; Rovero *et al.* 2005; Giman *et al.* 2007; Chetana & Ganesh 2007; Martins *et al*. 2007).

Though the use of camera trap surveys has been focused largely on the surveillance of a few target species, their utility to capture information regarding non-target species has also been recognized (Martins *et al.* 2007; Kelly & Holub 2008). However non-random sampling as a result of variation in prey body size and behaviour has been identified as one of the constraints in using camera traps (Giman *et al.* 2007; Tobler *et al.* 2008). Leopards predominantly utilize medium-sized mammals (10-40 kg) (Hayward *et al.* 2006), which are within the range of species successfully detected by camera traps i.e. medium- to large-sized mammals (Trolle 2003; Goldman & Winther-Hanson 2003; Yasuda 2004; Sanderson 2004; Martins *et al*. 2007; Tobler *et al.* 2008). Camera traps are thus expected to be successful in the surveillance of most leopard prey; however they are also known to utilize smaller mammals (Norton *et al.* 1986; Johnson *et al.* 1993; Ramakrishnan *et al.* 1999; Maheshwari 2006; Ott *et al.* 2007). Though small mammals such as rats, shrews and gerbils have been photo-trapped (Azlan & Lading 2006; Giman *et al.* 2007; Chetana & Ganesh 2007), camera trap surveys are likely to underestimate the abundance of small mammals (Tobler *et al.* 2008). Furthermore, as diet and prey availability data are used to determine prey preference one would also expect preference towards small mammals to be poorly estimated. More information is thus needed regarding the viability of using camera traps to survey the diverse mammal prey base of leopards and using the data to determine leopard prey preference.

1.4 Rational

The Cape leopard (Figure 1.1) is a morphologically distinct leopard population within the African subspecies (*Panthera pardus pardus*) (Stuart 1981; Miththapala *et al.* 1996; Martins & Martins 2006). They are largely restricted to the Cape Fold Belt Mountains at the southern tip of Africa, in areas unsuitable for farming (Stuart & Heinecken 1977; Stuart 1981; Boshoff & Kerley 2001). As with any species their conservation is heavily dependent on the identification of conservation threats, as well as knowledge and understanding of their biology and ecology (Caughley 1994). Key conservation concerns for the Cape leopard include a reduction in prey availability and persecution by humans to protect livestock (Norton & Lawson 1985; Martins & Martins 2006). However, information regarding their diet and feeding habits to aid conservation efforts are lacking (Martins & Martins 2006).

An extensive fecal analysis study (Norton *et al.* 1986) to determine the diet of leopards in the Cederberg, Stellenbosch, Jonkershoek and Gamka Mountains provided valuable insight in terms of the diet and feeding habits of the Cape leopard. Though Norton *et al.* (1986) did not perceive leopard diet in these areas to reflect prey limitations, current knowledge of leopard diet in the Cederberg and Gamka Mountains is lacking. Moreover, loss of prey remains to be a conservation concern for the Cape leopard (Martins & Martins 2006).

A meta-analysis of the prey preference of leopards was recently carried out (Hayward *et al.* 2006a). However intra-specific variation of leopard morphology may result in variation of prey preference between populations (Hayward *et al.* 2006a). This suggests the need for more focused studies of prey preference, particularly for populations that are known to be morphologically distinct. Exclusion of the Cape leopard from the meta-analysis of leopard diet by Hayward *et al.* (2006a), owing to lack of data, emphasizes the need to determine their prey preference.

Figure 1.1 Photograph of Johan, a male leopard caught on one of the camera traps in the Cederberg Mountains (Quinton Martins, Cape Leopard Trust).

1.5 Objectives

The first part of the study aimed to provide a current record of leopard diet in the Cederberg and Gamka Mountains, which may serve as a basis for future research and management. To identify prey limitations and explore their dietary flexibility, particularly in response to the predicted prey limitations, regional and temporal variation in their diet was also determined.

The second component of the study aimed to provide a preliminary assessment on the prey preference of the Cape leopard using data from the Cederberg. It also provided the opportunity to examine the utility of camera trap surveys to determine leopard prey preference, particularly regarding the bias associated with variable detection probability of different prey sizes, which is currently under much debate. This may be useful in the planning of future studies.

The key research questions of this project were the following:

1) What is the diet of the Cape leopard in the Cederberg and Gamka Mountains?
2) How does their diet vary regionally?
3) Has their diet changed since the previous assessment in 1986 and does the change reflect lack of prey?
4) What is the prey preference of the Cape leopard?
5) What is the utility of camera trap surveys to determine leopard prey preference?

The research approach was to describe the diet of leopards in the Cederberg and Gamka Mountains, using scat analysis techniques, compare these findings to a previous study (Norton *et al.* 1986) and relate prey consumption to camera trap data for the Cederberg. These findings are synthesized in the final chapter, which also includes recommendations for future research.

CHAPTER 2
STUDY AREA AND FOCAL SPECIES

2.1 Study area

Leopard scat samples were collected in the Cederberg [E 18º50’ to 19º30’ and S 32º00’ to 32º45’] and Gamka Mountains [E 21º15’ to 22º05’ and S 33º30’ to 33º50’], South Africa (Figure 2.1). In the former, camera trap stations were also set up and data were collected from three locations i.e. farmlands (S 32º31’ to

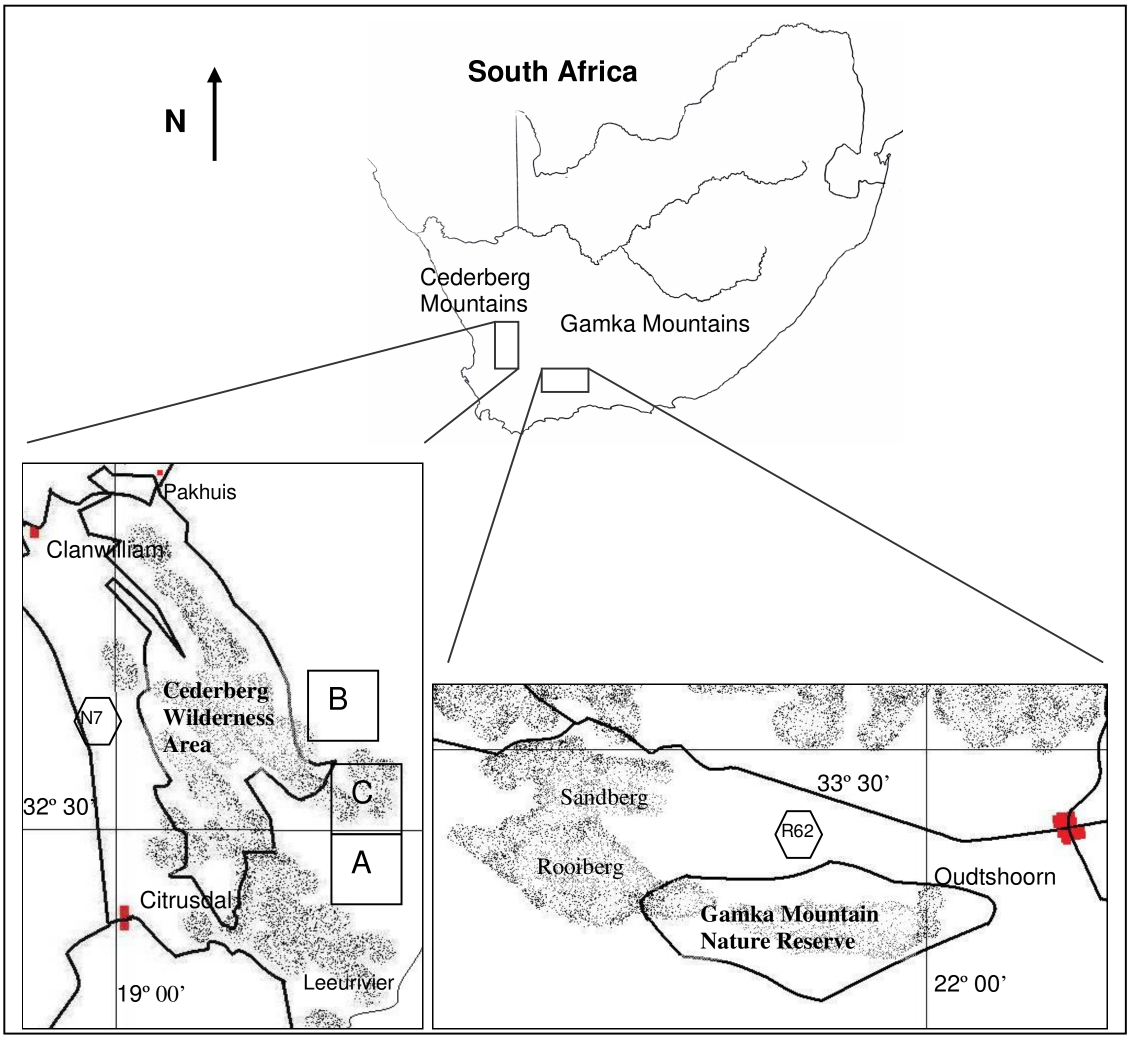

Figure 2.1 Map showing the location of the two study areas; the Cederberg and Gamka Mountains. The demarcated areas A, B and C indicate the three camera trap survey locations i.e. farmland, game farm and conservation areas respectively.

32º37’ and E19º19’ to 19º26), game farm areas (S 32º19’ to 32º25’ and E 19º17’ to 19º23’) and a conservation area (S 32º27’ to 32º31’ and E 19º20’ to 19º28’) (Figure 2.1).

2.1.1 The Cederberg Mountains

The Cederberg Mountains stretch from Pakhuis, northeast of Clanwilliam to the Leeurivier, southeast of Citrusdal (Walton *et al.* 1984) (Figure 2.1). It covers an area of about 200 000 hectares, which includes the Matjiesrivier Nature Reserve (Martins & Martins 2006), the Cederberg Wilderness Area (64 400 hectares), Forest reserve (67 000 hectares) and privately owned land (59 000 hectares) (Manders 1985; Taylor 1996).

The Cederberg form part of the Cape Fold Belt Mountains, which originated from the uplift of sedimentary rocks (Taylor 1996). It has a rugged topography and increase drastically in altitude over a short distance, with a maximum altitude of 2027 m a.s.l. (Taylor 1996). The rock strata consist predominantly of the Table Mountain Group, with the Malmesbury and Bokkeveld Groups also present (Taylor 1996; Cowling *et al.* 1997). The soil is acidic (pH of 4.5 to 6.5), sandy and nutrient poor (Taylor 1996).

The Cederberg has harsh climate conditions (Manders 1985). Summer temperatures (recorded in January), range between 22.6ºC and 25ºC, however it may reach up to 40ºC (Walton *et al.* 1984; Taylor 1996). Winter temperatures (recorded in July) range between 10ºC and 15ºC (Walton *et al.* 1984), with brief periods of snowfall in the upper regions (Taylor 1996). The Cederberg is situated in a winter rainfall region, and receives 300 to 1 400 mm of rainfall per annum (Taylor 1996). There is however local variation in rainfall e.g. it increases moving westwards and decreases to the north (Taylor 1996). Rainfall is also dependent on altitude, with an increase in altitude associated with higher rainfall (Taylor 1996).

The Cederberg is in the fynbos biome which is a global biodiversity hotspot (Cowling *et al.* 2003). The vegetation consists predominantly of mountain/sandstone fynbos in well-drained and poorly drained areas, with thickets in areas sheltered from fires e.g. kloofs and sand (Figure 2.2) (Taylor 1996; Mucina & Rutherford 2006). On the outer reaches, specifically to the east, Karoo vegetation dominates (Manders 1985; Mucina & Rutherford 2006).

Figure 2.2 Photograph of the study area in the Cederberg Mountains, showing the vegetation and rugged topography.

A total of 64 mammal species that may be potential prey for the Cape leopard occur in the Cederberg (Table 2.1). Data from three camera trap sites in the Cederberg were available at the launch of the study (Appendix A), which served as an additional source of species distribution information (see Chapter 4). The major land use activity on the farmlands (Figure 2.1) appeared to be livestock farming i.e. Boer goats and cattle were often recorded during the camera trap survey. A few donkeys were also recorded. Most of the species recorded on the game farm (Figure 2.1) also occurred in the conservation area and farmland. However the Cape mountain zebra, aardvark, Cape fox, springbuck and ostrich were recorded exclusively on the game farm. The conservation area (Figure 2.1) was for the most part situated in the Matjiesrivier Nature reserve and was thus the only one of the three study areas where management practices were strictly focused on conservation.

Fire is known to play a key role in the ecology of flora and fauna in fynbos habitats and is thus important for biodiversity conservation of areas such as the Cederberg (Willan & Bigalke 1982; Manders 1985; Taylor 1996; Cowling *et al.* 1997). Examples include the composition and age structure of vegetation, as well as the richness and population sizes of small mammals (Willan & Bigalke 1982; Cowling *et al.* 1997).

Humans have impacted the natural state of the Cederberg Mountains in numerous ways. These include changes in the fire frequency, livestock farming e.g. sheep and goats, introduction of alien vegetation and exploitation of resources e.g. buchu (*Agathosma betulina*), bush tea (*Aspalathus linearis*), tan bark (from *Protea nitida*) and the Clanwilliam cedars (*Widdringtonia cedarbergensis*) for wood (Manders 1985; Taylor 1996). However, economic and environmental incentives for the conservation of the Cederberg were later recognized, such as tourism, its scientific value and utilization as water catchments (Manders 1985; Taylor 1996). In 1973 the Cederberg Wilderness Area was established and later (1976) the Cederberg Mountains were declared a Mountain Catchment Area (MCA) (Manders 1985; Taylor 1996). Currently, conservation of the Cederberg region is focused on the establishment of the Greater Cederberg Biodiversity Corridor (see also www.cederbergcorridor.org.za). However, farmlands with free-ranging stock surround the conservation areas, thus conflict between neighboring landowners and predators still exists (Stuart & Heinecken 1977; Stuart 1981; Manders 1985;

Stuart *et al.* 1985; Martins & Martins 2006). Furthermore, legislation allows the use of unselective techniques for removal of caracal and black-backed jackals, with leopards inadvertently also targeted (Martins & Martins 2006).

2.1.2 The Gamka Mountains

For the purpose of this study the Gamka Mountains refer to the Sandberg, Rooiberg and Gamkaberg mountains. These are three isolated mountains adjacent to one another in the Klein Karoo region (Walton *et al.* 1984) (Figure 2.1). The Gamka Mountains are separated from the Swartberg Mountains by the R62 in the Karoo basin between Oudtshoorn and Ladismith, and to the south it is separated from the coast by the Langeberg and Outeniekwaberge (Walton *et al.* 1984) (Figure 2.1).

The geology of the Gamka Mountains is similar to that of the Cederberg as it also form part of the Cape Fold Belt Mountains (Taylor 1996). It has a rugged topography, with a maximum altitude of 1 470 m a.s.l. (Walton *et al.* 1984). The rock strata consist predominantly of the Bokkeveld Group and the Table Mountain Group (Cowling *et al.* 1997). Similar to the Cederberg, the soil is nutrient poor and sandy (Cowling *et al.* 1997).

Summer temperatures (recorded in January) range between 20.1 ºC and 22.5 ºC on average, and winter temperatures (recorded in July) range between 7.5 ºC and 12.5 ºC (Walton *et al.* 1984). The average annual rainfall ranges between 150 and 400 mm, which is distributed throughout the year (Cupido 2005). Rainfall is therefore unpredictable and the area is subject to random periods of drought (Cupido 2005).

Dominant vegetation in the Gamkaberg, Rooiberg and Sandberg region is mountain fynbos (Cowling *et al.* 1997; Mucina & Rutherford 2006). Fire regimes therefore play an important role in the ecology of fauna and flora in this area (Cowling *et al.* 1997). Thicket vegetation occurs to the east and Karoo vegetation to the west of the Gamka Mountains (Mucina & Rutherford 2006). A total of 57 mammals that are potential prey species for the Cape leopard occur in the Gamka Mountains (Table 2.1).

The Gamkaberg, Rooiberg and Sandberg Mountains are surrounded by farmlands (Cupido 2005). To the east agriculture is focused largely on sheep; however Boer goat and ostrich farms are also present (Cupido 2005). To the west ostrich farming and agriculture crops, predominantly Lucerne (*Medicago sativa*), are the main land use activities (Cupido 2005). The establishment of the Gamka Mountain Nature Reserve (9428 ha) (Watson *et al.* 2004) which includes almost the entire Gamkaberg and extends into the Rooiberg mountain is important for the conservation of the area. However, livestock are often free-ranging (Cupido 2005), therefore, similar to the situation in the Cederberg, the potential exists for conflict between neighboring landowners and predators in the surrounding mountainous areas such as leopards and caracals (Stuart & Heinecken 1977). Other land use activities in the area include game farming and tourism (Cupido 2005).

Table 2.1 The presence (indicated with a correct or incorrect symbol) and average weight (kg) of potential mammal prey species in the Cederberg and Gamka Mountains.

Order	Genus	Common name	Size (kg)	Cederberg Mountains	Gamka Mountains
Afrosoricida					
	Amblysomus corriae	Fynbos golden mole	0.052	✗	✓
	Chrysochloris asiatica	Cape golden mole	0.035	✓	✓
	Eremitalpa granti	Grant's golden mole	0.01	✓	✗
Macroscelidea					
	Elephantulus edwardii	Cape rock elephant shrew	0.05	✓	✓
	Macroscelides proboscideus	Round-eared elephant shrew	0.038	✓	✓
Eulipotyphla					
	Crocidura cyanea	Reddish grey musk shrew	0.009	✓	✓
	Crocidura flavescens	Greater red musk shrew	0.028	✗	✓
	Myosorex longicaudatus	Long-tailed forest shrew	0.013	✗	✓
	Myosorex varius	Forest shrew	0.0132	✓	✓
	Suncus varilla	Lesser dwarf shrew	0.007	✓	✗
Rodentia					
Porcupines	*Hystrix africaeaustralis*	Cape porcupine	12.15	✓	✓
Mole-rats	*Bathyergus suillus*	Cape dune mole-rat	0.783	✓	✗
	Cryptomys hottentotus	African mole-rat	0.078	✓	✓
	Georychus capensis	Cape mole-rat	0.181	✓	✗
Gerbils	*Desmodillus auricularis*	Cape short-tailed gerbil	0.052	✓	✓
	Gerbillurus paeba	Hairy-footed gerbil	0.027	✓	✓
	Tatera afra	Cape gerbil	0.097	✓	✗
Dormice	*Graphiurus murinus*	Woodland dormouse	0.028	✗	✓
	Graphiurus ocularis	Spectacled dormouse	0.083	✓	✓
Rats, mice	*Acomys subspinosus*	Cape spiny mouse	0.02	✓	✓
	Dasymys incomtus	African marsh rat	0.107	✗	✓
	Dendromus melanotis	Grey climbing mouse	0.01	✓	✓
	Dendromus mesomelas	Brants' climbing mouse	0.056	✓	✓
	Malacothrix typica	Gerbil mouse	0.015	✓	✓
	Micaelamys namaquensis	Namaqua rock mouse	0.047	✓	✓
	Micaelamys granti	Grant's rock mouse	-	✓	✗
	Mus minutoides	Pygmy mouse	0.006	✓	✓
	Mus musculus	House mouse	0.019	✓	✗
	Myomyscus verreauxi	Verreaux's mouse	0.041	✓	✓
	Mystromys albicaudatus	White-tailed mouse	0.087	✓	✗
	Otomys saundersiae	Saunders' vlei rat	0.118	✓	✗
	Otomys irroratus	Vlei rat	0.15	✓	✓
	Otomys unisulcatus	Bush vlei rat	0.125	✓	✓
	Parotomys brantsii	Brants' whistling rat	0.121	✓	✓

	Rattus rattus	House rat	0.167	✓	✗
	Rhabdomys pumilio	Four-striped grass mouse	0.044	✓	✓
	Saccostomus campestris	Pouched mouse	0.05	✗	✓
	Steatomys krebsii	Krebs' fat mouse	0.019	✓	✓
Lagomorpha					
	Lepus capensis	Cape hare	2.04	✓	✓
	Lepus saxatilis	Scrub hare	3.6	✓	✓
	Pronolagus rupestris	Smith's red rock rabbit	1.62	✓	✓
Hyracoidea					
	Procavia capensis	Rock hyrax	3.66	✓	✓
Primates					
	Papio ursinus	Chacma baboon	22.9	✓	✓
Tubulidentata					
	Orycteropus afer	Aardvark	43.3	✓	✓
Carnivora					
	Aonyx capensis	African clawless otter	14.00	✓	✗
	Atilax paludinosus	Marsh mongoose	2.76	✓	✗
	Canis mesomelas	Black-backed jackal	7.8	✓	✓
	Caracal caracal	Caracal	11.4	✓	✓
	Cynictis penicillata	Yellow mongoose	0.93	✓	✓
	Felis silvestris	African wild cat	4.3	✓	✓
	Galerella pulverulenta	Cape grey mongoose	0.77	✓	✓
	Genetta genetta	Small-spotted genet	1.85	✓	✓
	Genetta tigrina	Large-spotted genet	1.75	✗	✓
	Ictonyx striatus	Striped polecat	0.7	✓	✗
	Mellivora capensis	Honey badger	9.7	✗	✓
	Otocyon megalotis	Bat-eared fox	3.2	✓	✗
	Poecilogale albinucha	African striped weasel	0.357	✗	✓
	Proteles cristatus	Aardwolf	9.15	✓	✗
	Suricata suricatta	Suricate	0.7	✓	✗
	Vulpes chama	Cape fox	2.7	✓	✓
Perissodactyla					
	Equus zebra zebra	Cape mountain zebra	234.3	✓	✓
Suiformes					
	Potamochoerus larvatus	Bushpig	70.1	✗	✓
Ruminantia					
	Antidorcas marsupialis	Springbok	31.50	✓	✗
	Oreotragus oreotragus	Klipspringer	11.90	✓	✓
	Oryx gazella	Gemsbok	225.00	✓	✓
	Pelea capreolus	Grey rhebuck	20.00	✓	✓
	Raphicerus campestris	Steenbok	11.10	✓	✓
	Raphicerus melanotis	Cape grysbok	10.25	✓	✓
	Sylvicapra grimmia	Common duiker	16.10	✓	✓

	Tragelaphus oryx	Eland	348.5	✓	✓
Domestic stock					
	Bos taurus	Cattle	360	✓	✓
	Capra hircus	Goat	40	✓	✓
	Equus asinus	Donkey	250	✓	✓
	Struthio camelus	Ostrich	88.3	✓	✓

1. The distribution and weight of rodents were based on published distribution maps and data (De Graaff 1981; Skinner & Chimimba 2005).
2. The distribution and weight of other terrestrial mammals were based on distribution maps and previous dietary studies (Stuart 1981; Keogh 1983; 1985; Buys & Keogh 1984; Norton *et al.* 1986; Skinner & Chimimba 2005).
3. Data from three camera trap sites in the Cederberg served as an additional source of species distribution information (see Chapter 4).
4. The weight of domestic animals was taken from Burke (2004) and Williams *et al.* (1993).
5. The weight of potential prey refers to the average weight of adult males and females, for which the data were available. The mass of Grant's rock mouse was not available.

2.2 Focal species

2.2.1 The Cape leopard

The Cape leopard (Figure 1.1) is the southern-most population of leopards in Africa (Miththapala *et al.* 1996) and has been identified as a distinct population based on the following characteristics. Firstly, males have an average body weight of 30.1 kg and females of 21.2 kg, which is considerably smaller than leopard populations elsewhere in Africa (Stuart 1981; Skinner & Chimimba 2005; Martins & Martins 2006). Secondly, they occupy massive home ranges (235-600 km^2) and occur at low densities, about 6-9 individuals per 100 km^2 (Stuart 1981; Norton & Lawson 1985; Norton & Henley 1987; Martins & Martins 2006). Thirdly, a study is currently underway focusing on the genetic relation of leopard populations within South Africa to each other, and will thus provide clarity about the genetic status of the Cape leopard (personal communication, Quinton Martins 2008; see also www.capeleopardtrust.org).

2.2.2 Ecology

Once widespread in southwestern Africa, the Cape leopard population has declined and their range has been reduced largely to mountain regions, in areas unsuitable for farming (Stuart & Heinecken 1977; Stuart 1981; Boshoff & Kerley 2001). They are solitary predators, which form groups only when females have dependent young and when males and females temporarily pair off to breed (Stuart 1981). They communicate for the most part by means of scent marking such as urine, feces and tree-scratching (Stuart 1981). In the Cederberg and Gamka Mountains their diet consist largely of antelope and rock hyraxes (Norton *et al.* 1986), with leopards showing diurnal activity patterns in the Cederberg (Norton & Henley 1987). As the apex predator in the Western Cape region (Stuart 1981), the leopard is expected to experience little direct and indirect competition from other predators. This is because the larger size of the leopard increases the potential prey available to it, thus alleviating indirect competition for prey resources (Radloff & Du Toit 2004). In terms of direct competition, the black-backed jackal and caracal are the only relatively large carnivores in both areas that may be considered competition (Skinner & Chimimba 2005). However, their smaller body size in comparison to the Cape leopard reduces their direct competitiveness (Palomares & Caro 1999). Furthermore, a study in the Stellenbosch area suggested that leopards tend to occupy higher altitudes (> 600 m a.s.l.) in mountain fynbos vegetation, whereas caracals reside in transitional habitat at lower altitudes (< 600 m a.s.l.) (Norton & Lawson 1985).

Conservation concerns for the Cape leopard include reduction in prey species, loss of habitat, persecution by neighbouring landowners and non-selective management methods to protect livestock from other predators such as caracals (Martins & Martins 2006). Though the extent of their vulnerability to extinction is not certain, the Cape leopard has a number of characteristics associated with species at the risk of extinction (Purvis *et al.* 2000) i.e. they have low reproductive rates, are at a high trophic level and occur in a small area at low densities (Turnbull-Kemp 1967; Norton & Lawson 1985; Norton & Henley 1987; Martins & Martins 2006). In addition they have extremely large home ranges (Norton & Lawson 1985; Martins & Martins 2006), which suggest more frequent contact with neighboring landowners (Woodroffe & Ginsberg 1998).

CHAPTER 3

DIET OF THE CAPE LEOPARD (*PANTHERA PARDUS*) IN THE CEDERBERG AND GAMKA MOUNTAINS, SOUTH AFRICA

3.1 Introduction

The persistence of leopard populations is highly dependent on sufficient prey availability in terms of both preferred species and suitable size categories (Karanth & Sunquist 1995; Hayward *et al.* 2006a; Hayward *et al.* 2007). However, the availability of preferred prey may become restricted by cyclic and random prey population fluctuations (Howell 1923; Willan & Bigalke 1982; Kerley & Erasmus 1992; Small *et al.* 1993; Lima *et al.* 1999; Erb *et al.* 2001) and anthropogenic impacts (Marker & Dickman 2005; Martins & Martins 2006). As leopard diet is extremely flexible, their broad dietary niche breadth may enable predation on alternative prey (Griffiths 1975; Karanth & Sunquist 1995; Mizutani 1999; Ramakrishnan *et al.* 1999; Marker & Dickman 2005; Henschel *et al.* 2005; Hayward *et al.* 2006a; Martins & Martins 2006; Ott *et al.* 2007).

Though dietary flexibility may be beneficial to their immediate survival, it also has the potential to intensify existing conservation threats (Marker & Dickman 2005), by causing one or more of the following changes in their feeding habits. The first is increased predation on livestock, which may lead to increased conflict with neighboring landowners (Stuart & Heinecken 1977; Mizutani 1999; Marker & Dickman 2005; Martins & Martins 2006). The second may be a shift to smaller prey (Ramakrishnan *et al.* 1999; Henschel *et al.* 2005; Ott *et al.* 2007), which may result in competition for resources, as it may initiate or increase the overlap of leopard diet with the diet of other predators in the area. The third involves the inclusion of more prey species and reduced preference towards species, as opportunistic feeding increases (Griffiths 1975; Karanth & Sunquist 1995). This may also result in competition for resources with other predators in the area. The importance of adequate prey availability for the effective conservation and management of leopards is thus clear. By monitoring prey availability and leopard diet, prey shortages can be identified and their response to such changes in prey availability can be studied to provide a better understanding of their feeding habits.

The southernmost population of leopards in Africa, colloquially known as the Cape leopard, is thought to be subject to reductions in prey availability in parts of its range (Norton & Lawson 1985; Martins & Martins 2006). An extensive fecal analysis study (Norton *et al.* 1986) to determine the diet of leopards in the Cederberg, Stellenbosch, Jonkershoek and Gamka Mountains revealed that their diet consisted predominantly of rock hyraxes and small-sized antelope. Though Norton *et al.* (1986) did not perceive leopard diet in these areas to reflect prey limitations current knowledge of leopard diet in the Cederberg and Gamka Mountains is lacking and loss of prey remains to be a conservation concern for the Cape leopard (Martins & Martins 2006).

The first objective of the study was to provide a current record of leopard diet in the Cederberg and Gamka Mountains, which may aid in the management of the Cape leopard and serve as a basis for future research. The second objective was to determine regional variation of their diet in exploration of their dietary flexibility. The final and main objective was to determine whether leopards in the Cederberg and Gamka Mountains were subject to changes in prey availability, particularly concerning prey shortages.

3.2 Material and methods

3.2.1 Study area and focal species

This study focused on the diet of the Cape leopard in the Cederberg and Gamka Mountains. See Chapter 2 for description of the study areas and focal species.

3.2.2 Scat analysis

As the present study was largely comparative, leopard diet was determined by means of scat analysis (methods following Norton *et al.* 1986).

Field work was undertaken by the Cape Leopard Trust and scats were collected regardless of freshness. To reduce disturbance to the intra-specific communication system of the leopards (e.g. territorial marking - Stuart 1981), only half of each scat was collected. Each scat was placed in a container and labeled with the sample number, date, GPS coordinates and altitude. A total of 131 scats were collected from the Cederberg Mountains (2003 to 2007) and 138 from the Gamka Mountains (2008).

Scat identification was based on size and appearance i.e. presence of segments (Norton *et al.* 1986; Chame 2003). The former was used to distinguish between caracal scats and that of small or juvenile leopards, with analyses restricted to scats larger than 2 cm in diameter (Norton *et al.* 1986; Farhadinia *et al.* 2007; Ott *et al.* 2007). As leopards tend to ingest their own hair while grooming, smaller samples were only included if the origin could be confirmed by the presence of leopard hair (Norton *et al.* 1986).

Prey identification was primarily based on cuticular hair scale patterns, which have been used in several studies (Johnson *et al.* 1993; Bothma & Le Riche 1994; Mizutani 1999; Ramakrishnan *et al.* 1999; Kuanda & Skinner 2003; Ott *et al.* 2007). The hair scale patterns of 5 hairs per scat were compared to that of all the species found in the Cederberg and Gamka Mountains (Table 2.1). The hair reference collection consisted of published photographs and keys (Keogh 1983, 1985; Buys & Keogh 1984; Perrin & Campbell 1980), as well as photographs from an existing reference collection at the Centre for African Conservation Ecology (ACE) of the Nelson Mandela Metropolitan University (Ott *et al.* 2007). The Amathola Museum in King William's Town provided hair for the species not represented in the reference collection, for which slides were prepared as described below. Photographs of the scale patterns were taken and added to the reference collection. The limitations associated with the method include overlap in hair scale patterns between species, variation in scale pattern along the shaft of each hair and between hair types of an individual (Brunner & Coman 1974). The analysis was therefore supported and supplemented by macroscopic features of the hair e.g. hair type, size and pigmentation, as well as other remains found in the scat e.g. hooves, bones, teeth, feathers, scales and nails (Perrin & Campbell 1980; Norton *et al.* 1986; Johnson *et al.* 1993; Bothma & Le Riche 1994; Mizutani 1999; Kuanda & Skinner 2003).

Preparation of hair for analysis started by placing each scat in 4% formalin for a minimum of 24 hours to soften the scat (Norton *et al.* 1986; Kuanda & Skinner 2003), and kill potential parasites. The scats were rinsed over a sieve (1.5 mm) while separating the non-identifiable parts from the identifiable remains and hair (Norton *et al.* 1986; Ramakrishnan *et al.* 1999; Kuanda & Skinner 2003). These were then dried at 60ºC (Kuanda & Skinner 2003). Hair from each scat was evenly spread across a grid divided into 25 cm^2 squares and an assortment of 5 hairs were selected from random blocks, in an attempt to identify all the species present in each scat by random selection. These were then cleaned in an absolute alcohol and sulphuric ether mixture of equal amounts, after which it was washed in distilled water and left to dry (following Perrin & Campbell 1980; Keogh 1983; 1985; Kuanda & Skinner 2003). Slides were labeled and hair scale imprints were made using clear nail varnish (Mizutani 1999). A standard light microscope was used to study the scale patterns for species identification.

Mammals were identified down to species level and the presence of bird, insect and reptile remains were also noted. Identification of klipspringers, baboons and porcupines were supported by distinct macroscopic hair characteristics and spines (Norton *et al.* 1986; Skinner & Chimimba 2005). Springbuck, grysbok, steenbok, grey duiker, grey rhebuck, genet and mongoose identification was largely based on hair scale patterns, macroscopic hair characteristics and other remains such as hooves and nails (Perrin & Campbell 1980; Keogh 1983, 1985; Skinner & Chimimba 2005). Rock hyrax identification was supported by the presence of the unique humerus bone and footpads (Norton *et al.* 1986). Identification of rock hyraxes in the infant stage was based on the presence of extremely small humerus bones, compared to other hyrax humerus bones found in the scats. In many of the scats in which rodents were found, teeth were still intact and were used in support of identification (De Graaff 1981). Species identification to genus level was problematic within certain groups, such as Lagomorpha (scrub hare, Cape hare and red rock rabbit), gerbils (short-tailed gerbil, white-tailed gerbil, hairy-footed gerbil) and *Otomys* species (Saunders vlei rat and vlei rat); these species clusters were therefore grouped for the frequency of occurrence and sampling efficiency analyses. The results section therefore refers to prey types and not prey species, as prey types include species and groups of species.

3.2.3 Data analysis

Species accumulation curves were produced, using EstimateS (Version 7.5), to determine whether the scat sample sizes for the Cederberg and Gamka Mountains were large enough for a comprehensive description of leopard diet (Moreno & Halffter 2001; Willot 2001; Colwell 2005). The curve was produced using 50 randomized iterations and if it reached an asymptote, sample size was assumed to be sufficient (Colwell 2005). If not, the incidence-based Coverage Estimator (ICE Mean) was used to provide an estimate of how many species were not included in the analysis (Colwell 2005).

Diet was quantified as frequency of occurrence i.e. the number of observations of a specific prey species divided by the total number of prey items (Norton *et al.* 1986; Ott *et al.* 2007), and expressed in percentages for convenience of descriptive comparison. This was determined for the present and previous (Norton *et al.* 1986) records of leopard diet in the Cederberg and Gamka Mountains. For each data set the frequency of occurrence was also determined for different prey size categories, which was based on data from previous studies (see Chapter 2). The division of categories was as follows; “SM (< 1 kg)” refers to small mammals that weigh less than 1 kg, “SM” to mammals that weigh between 1 kg and 10 kg, “MM” to mammals that weight between 10 kg to 40 kg and “Other” refers to insects, birds and reptiles. For comparison with the previous dietary assessment the occurrence of plant material in the scats was excluded from the analyses. It is unlikely that no vegetation was found in the 237 scats analyzed by Norton *et al.* (1986), as felids tend to eat grass to assist in the removal of hair (Chame 2003). We therefore assume that they found plant material, but did not report it.

Column bar graphs were drawn to depict regional variation in the utilization of different prey size categories. This was also done to depict temporal variation of their diet in both areas. Two-way log-linear analyses using Statistica (Version 8) were used to determine the significance of regional and temporal variation in prey species composition and prey category utilization (Quinn & Keough 2002).

Further examination of regional variation in leopard diet is described in the following section, however this was not possible for temporal variation as original data from the assessment by Norton *et al.* (1986) were not available. Multidimensional scaling by means of Primer (Version 6) was used to depict variation between leopard diet in the Cederberg and Gamka Mountains, for which data was converted to a Bray-Curtis similarity matrix (Primer, Version 6; Quinn & Keough 2002). If data had a normal distribution and homogeneity of variance ANOVA was used (Statistica, Version 8) to determine the significance of variation in the number of species identified from each scat and the average weight of species utilized between the two locations. If the data were not in accordance with these assumptions, non-parametric statistics were used (Statistica, Version 8). Plant material, birds, reptiles and insects were left out of these analyses. Similarity percentage (SIMPER) analysis (Primer, Version 6) was used to determine the contribution (%) of the different variables to the similarity between and within the leopard diet in the Cederberg and Gamka Mountains. Data transformation and standardization was not necessary, as presence/absence data were used and the sample sizes were similar (Primer, Version 6; Quinn & Keough 2002).

3.3. Results

3.3.1 Sampling effort

Of the 131 scat samples collected from the Cederberg area, 98 were positively identified as leopard scats and had suitable remains for species identification. A total of 22 prey types were identified of which 17 could be identified to species level. However, as described in the methods section, gerbils, *Otomys* species, birds, lagomorphs and insects were grouped. It thus accounted for the other five prey types. The species accumulation curve produced from the scat analysis results in the Cederberg approached an asymptote (Figure 3.1), but did not reach it. The ICE analysis indicated that 2.8 species were not sampled.

In the Gamka Mountains 138 scat samples were collected of which 77 were positively identified as leopard scats and could be used for species identification. A total of 22 prey types were identified, of which 16 were identified to species level. Lagomorphs, gerbils, *Otomys* spp., birds, reptiles and insects were grouped and accounted for the other six prey types. The species accumulation curve did not reach an asymptote, with 2.8 species not sampled (Figure 3.2).

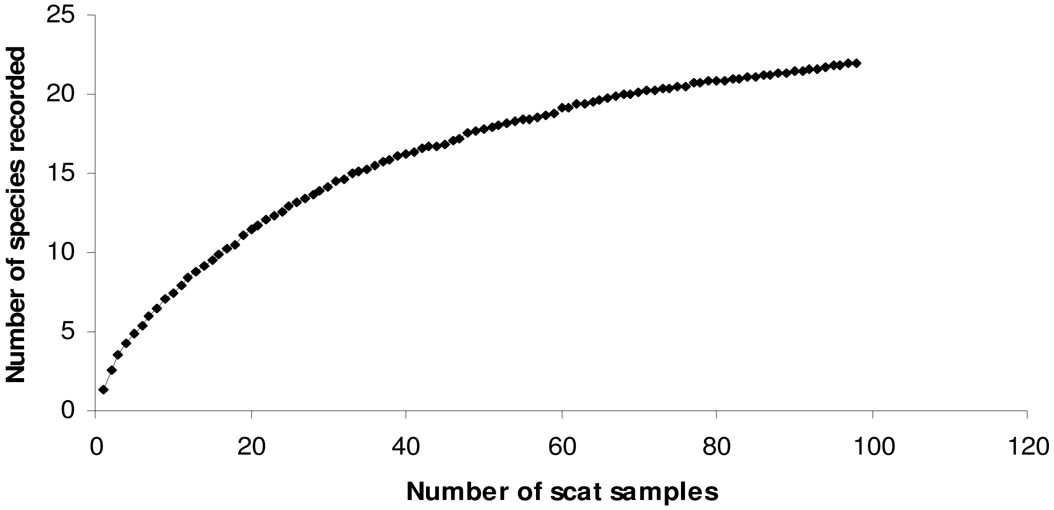

Figure 3.1 Species accumulation curve (50 randomized iterations; ICE mean 24.8) for the 22 prey types recorded from the 98 leopard scat samples collected in the Cederberg Mountains.

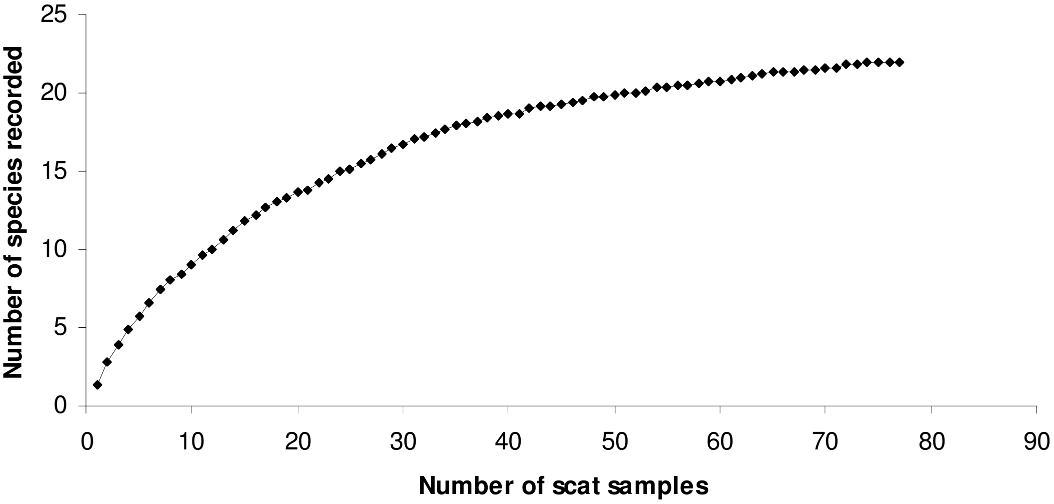

Figure 3.2 Species accumulation curve (50 randomized iteration; ICE mean 24.8) for the 22 prey types recorded in the 77 scat samples collected in the Gamka Mountains.

3.3.2 Prey species utilization

Appendix B and C provide data on scat size, species identification and the GPS coordinates where samples were collected for the Cederberg and Gamka Mountains respectively.

Table 3.1 The current and previously recorded (Norton *et al.* 1986) frequency of occurrence (%) of species found in scats collected in the Cederberg and Gamka Mountains. Prey mass (kg) and size category are also provided. See Table 2.1 for scientific names.

	Frequency of occurrence (%)					
	Cederberg		Gamka			
Species/Group	1986	2008	1986	2008	Category	Weight
Cape grey mongoose	0.0	2.9	0.0	4.1	SM (< 1 kg)	0.77
Cape rock elephant shrew	0.0	0.0	0.0	0.8	SM (< 1 kg)	0.05
Cape spiny mouse	0.0	0.0	0.0	0.8	SM (< 1 kg)	0.02
Gerbil	0.0	3.6	0.0	1.6	SM (< 1 kg)	0.06
House rat	0.0	0.7	0.0	4.9	SM (< 1 kg)	0.17
Namaqua rock mouse	1.3	1.4	0.0	3.3	SM (< 1 kg)	0.05
Otomys spp.	2.5	1.4	0.0	8.1	SM (< 1 kg)	0.13
Pygmy mouse	1.3	0.0	0.0	0.0	SM (< 1 kg)	0.01
Striped mouse	0.0	1.4	0.0	4.9	SM (< 1 kg)	0.04
Verreaux's mouse	0.0	0.7	0.0	0.0	SM (< 1 kg)	0.04
Yellow mongoose	0.0	0.7	0.0	0.0	SM (< 1 kg)	0.93
Aardwolf	0.0	2.1	0.0	0.0	SM	9.15
Lagomorpha	2.5	7.9	0.0	2.4	SM	2.42
Large spotted genet	0.0	0.0	0.0	0.8	SM	1.75
Rock hyrax	64.6	25.0	51.3	27.6	SM	3.7
Water mongoose	0.0	0.7	0.0	0.0	SM	2.8
Cape porcupine	0.0	1.4	0.0	3.3	MM	12.15
Chacma baboon	1.9	2.9	1.3	2.4	MM	22.9
Cape grysbok	0.6	2.1	19.2	3.3	MM	10.25
Grey duiker	0.0	2.1	1.3	3.3	MM	16.10
Grey rhebuck	10.1	5.0	7.7	4.1	MM	20.00
Klipspringer	12.7	29.3	15.4	16.3	MM	11.90
Springbok	0.0	0.7	0.0	0.0	MM	31.50
Steenbok	0.0	0.0	3.8	0.8	MM	11.10
Goat	1.3	2.1	0.0	0.8	Domestic	40
Insect	0.6	1.4	0.0	1.6	Other	-
Bird	0.6	4.3	0.0	2.4	Other	-
Reptile	0.0	0.0	0.0	2.4	Other	-
Total items	158	140	78	123		
Sample size	129	98	59	77		
Prey species	12	22	7	22		
Average weight (kg)	7.1	8.8	8.2	6.6		

In the previous assessment of leopard diet in the Cederberg a total of 158 prey items, including 12 prey types, were identified from 129 scats (Table 3.1). The average weight of prey was 7.1 kg. Rock hyrax (64.6%), klipspringer (12.7%) and grey rhebuck (10.1%) were mostly preyed upon (Table 3.1).

Their current diet in the Cederberg included 22 prey types, which were identified from 140 prey items, and 98 scats (Table 3.1). The average weight of prey was 8.8 kg. Klipspringer (29.3%), rock hyrax (25.0%) and Lagomorpha (7.9%) accounted for the largest part of their diet (Table 3.1).

In the previous evaluation of leopard diet in the Gamka Mountains 78 prey items, including 7 prey types, were identified from 59 scats (Table 3.1). The average weight of prey was 8.2 kg. Rock hyrax (51.3%), Cape grysbok (19.2%) and klipspringer (15.4%) were preyed upon most often (Table 3.1).

Their current diet in the Gamka Mountains included 123 prey items, with 22 prey types identified from 77 scats (Table 3.1). The average weight of prey was 6.6 kg. Their diet consisted mainly of rock hyrax (27.6%), klipspringer (16.3%) and *Otomys* spp. (8.1%) (Table 3.1). A total of 4 rock hyrax infants were identified.

3.3.3 Regional variation in leopard diet

K-factor analysis suggested no significant difference (Pearson $\chi^2 = 33.59$, d.f. = 26, P = 0.15) in species composition or prey category utilization (Pearson $\chi^2 = 2.66$, d.f. = 4, P = 0.62) between the two areas. Non-parametric statistics were used to determine the difference in the number of species identified from each scat between the two locations, as the Cochran C, Hartley, Bartlett test revealed that the data had insufficient homogeneity of variance (d.f. = 1; P = 0.02). The Kolmogorov-Smirnov two-sample test suggested no significant difference (P > 0.1) in the number of prey types identified per scat i.e. a mean (and standard deviation) of 1.4 ± 0.7 was identified in the Cederberg, whereas a mean of 1.6 ± 0.9 was identified in the Gamka Mountains.

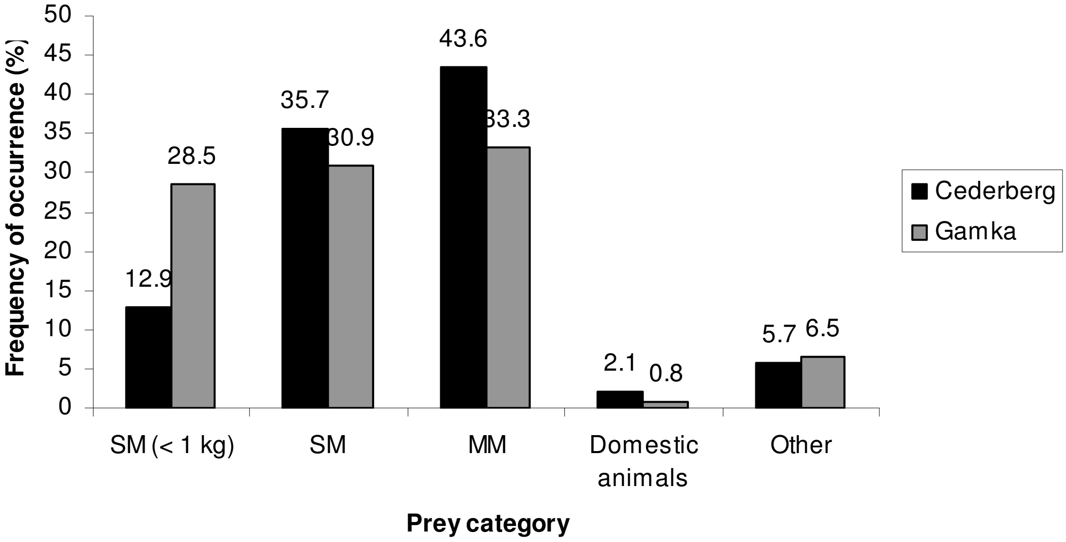

Figure 3.3 Comparison of prey categories found in leopard diet for the Cederberg and Gamka Mountains. See Table 3.1 for category division of species.

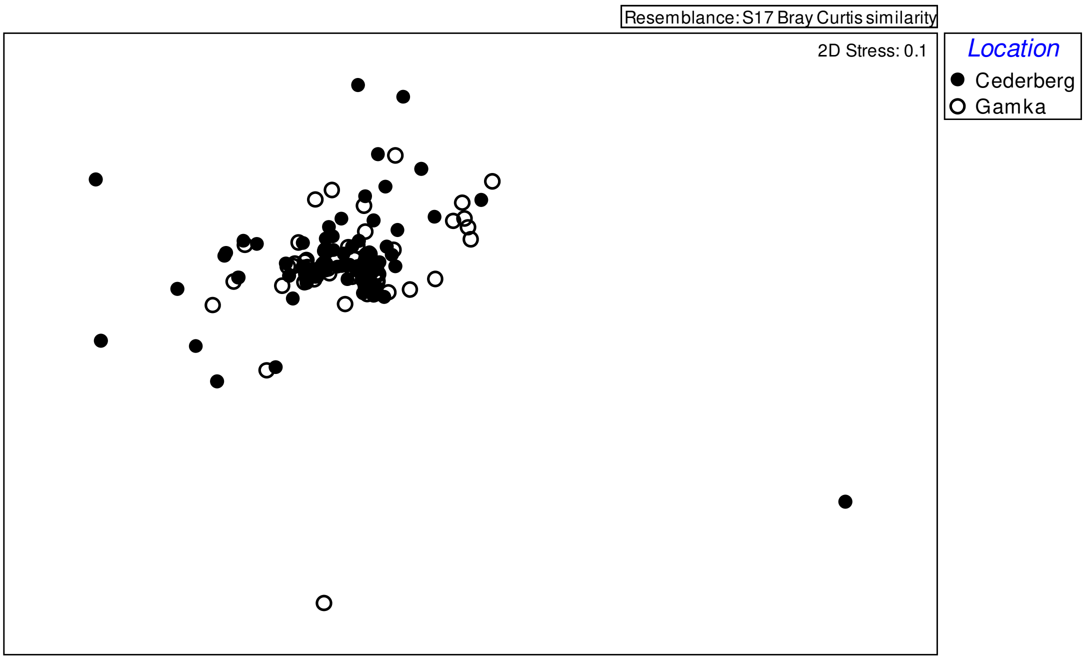

Figure 3.4 Multidimensional depiction (Stress = 0.1; 1 000 permutations) of leopard diet in the Cederberg and Gamka Mountains.

Variation between the diet of leopards in the Cederberg and Gamka Mountains was however noticeable (Figure 3.3; Figure 3.4). Leopards in the Cederberg consumed 12.9% small mammals (< 1 kg), 35.7% small mammals and 43.6% medium-sized mammals. In the Gamka Mountains small mammals (< 1 kg) made up 28.5% of leopard diet, small-sized mammals 30.9% and medium-sized mammals 33.3% of leopard diet (Figure 3.3). Livestock were seldom utilized in both the Cederberg (2.1%) and Gamka Mountains (0.8%). As the data were normally distributed and the Cochran C, Hartley, Bartlett test revealed sufficient homogeneity of variance (d.f. = 1; P = 0.18), ANOVA was used to determine variation in leopard diet between the two regions. There was a significant difference in the average weight of prey consumed in the Cederberg (8.8 ± 8.0 kg) and Gamka Mountains (6.6 ± 7.1 kg) ($R^2 = 0.02$; d.f. = 1; F = 5.43; P = 0.02).

Table 3.2 The average abundance of prey species in leopard diet in the Cederberg and Gamka Mountains. The average dissimilarity with standard deviation of prey species consumption between the two regions. The contribution of each species to the dissimilarity in the diet between the Cederberg and Gamka Mountains.

	Cederberg	Gamka		
Species	Average abundance	Average abundance	Average dissimilarity ± SD	Contribution (%)
Rock hyrax	0.36	0.44	17.98 ± 0.88	22.56
Klipspringer	0.42	0.26	17.08 ± 0.85	21.44
Grey rhebuck	0.07	0.06	4.61 ± 0.36	5.78
Lagomorpha	0.11	0.04	3.77 ± 0.39	4.74
Otomys spp.	0.02	0.13	3.66 ± 0.40	4.59
Cape grey mongoose	0.04	0.06	3.43 ± 0.31	4.3
Grey duiker	0.03	0.05	3.13 ± 0.28	3.93
Baboon	0.04	0.04	2.99 ± 0.28	3.76
Grysbok	0.03	0.05	2.90 ± 0.28	3.64
Porcupine	0.02	0.05	2.75 ± 0.26	3.45
Bird	0.06	0.04	2.53 ± 0.32	3.17
Striped mouse	0.02	0.08	2.09 ± 0.31	2.62
House rat	0.01	0.08	1.90 ± 0.30	2.39
Nam rock mouse	0.02	0.05	1.76 ± 0.27	2.21
Gerbil	0.05	0.03	1.69 ± 0.27	2.12

Similarity percentage analyses revealed that klipspringers and rock hyraxes were responsible for most of the dissimilarity observed between the two regions (21.44%; 22.56% contribution to the dissimilarity respectively) (Table 3.2). In terms of variation of leopard diet within each area, there appeared to be more variation of leopard diet in the Cederberg Mountains (Figure 3.4). Similarity percentage analyses revealed that klipspringers and rock hyraxes were responsible for most of the similarity within the samples of the Cederberg (56.61%; 36.65% contribution to the similarity respectively) and Gamka Mountains (22.53%; 67.54% contribution to the similarity respectively).

3.3.4 Temporal variation in leopard diet

In 1986 5.1% small mammals (< 1 kg), 67.1% small mammals and 25.3% medium-sized mammals were recorded from the dietary analysis for leopards in the Cederberg. In their current diet, small mammals (< 1 kg) made up 12.9%, small-sized mammals 35.7% and medium-sized mammals 43.6%. Domestic animals and other prey made up a small proportion of leopard diet in both cases (Figure 3.5). Though temporal variation in prey size category utilization was apparent (Figure 3.5), K-factor analysis suggested no significant difference (Pearson χ^2 = 2,04, d.f. 4, P = 0.73). There was however a significant difference (Pearson χ^2 = 67.52, d.f. 21, P < 0.001) in species composition.

In 1986 leopards in the Gamka Mountains consumed no small mammals (< 1 kg), 51.3% small mammals and 48.7% medium-sized mammals. In their current diet, small mammals (< 1 kg) made up 28.5%, small-sized mammals 30.9% and medium-sized mammals 33.3% (Figure 3.6). Domestic animals and other prey made up a small proportion of their diet in both cases (Figure 3.6). Similar to the Cederberg, K-factor analysis suggested no significant variation (Pearson χ^2 = 2.89, d.f. 4, P = 0.58) in prey category usage between 1986 and 2008 in the Gamka Mountains. Even so, temporal variation in the prey size category usage was apparent (Figure 3.6) and there was a significant difference (Pearson χ^2 = 42.80, d.f. 21, P = 0.001) in species composition.

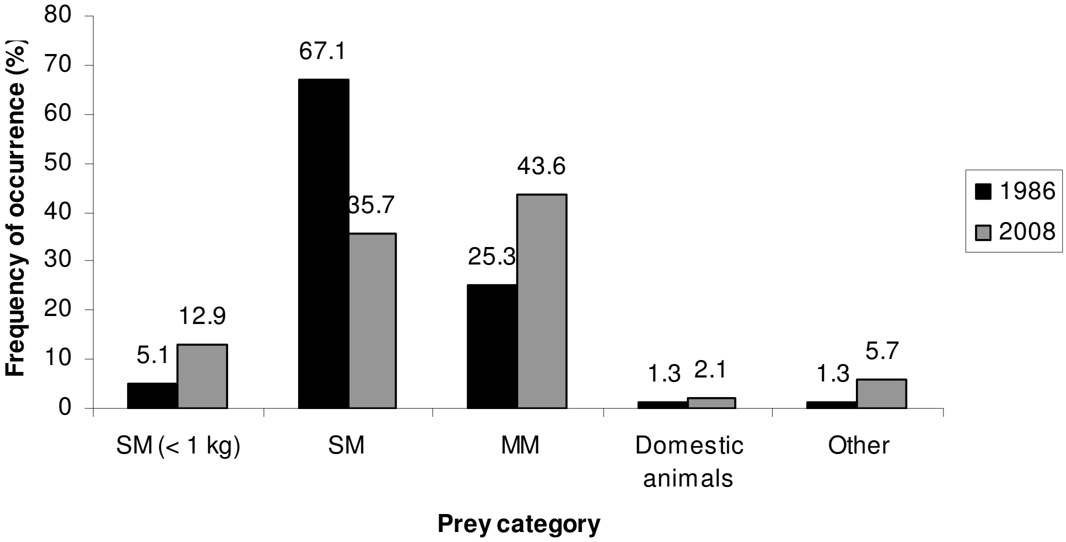

Figure 3.5 Comparison of previously recorded (Norton *et al.* 1986) and current prey categories of leopard diet in the Cederberg. See Table 3.2 for category division of species.

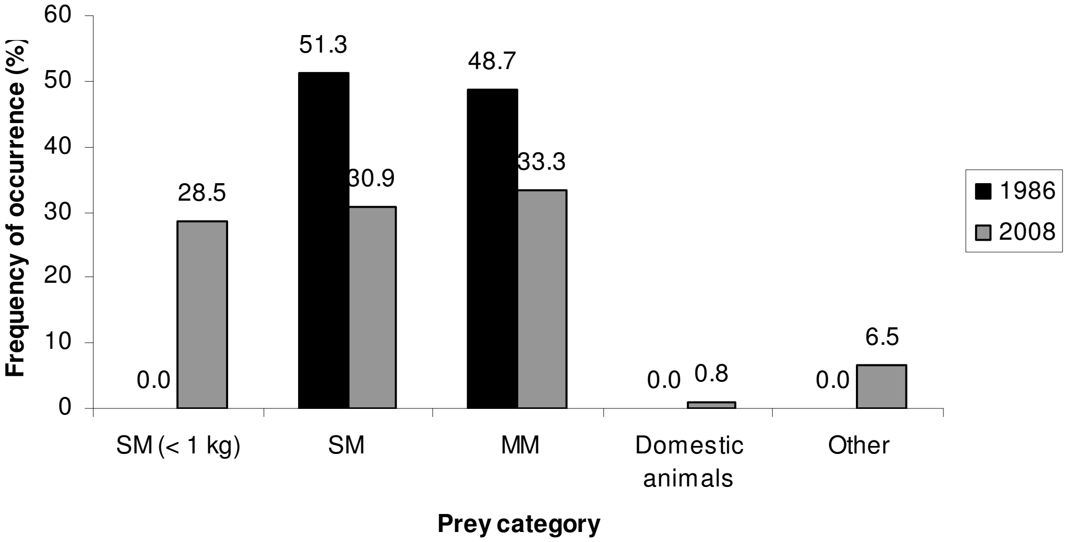

Figure 3.6 Comparison of previously recorded (Norton *et al.* 1986) and current prey categories (2008) utilized by the Cape leopard in the Gamka Mountains. See Table 3.2 for category division of species.

3.4 Discussion

3.4.1 Sampling efficiency

Scat analysis is a widely used (Norton *et al.* 1986; Johnson *et al.* 1993; Bothma & Le Riche 1994; Mizutani 1999; Ramakrishnan *et al.* 1999; Kuanda & Skinner 2003; Ott *et al.* 2007), non-invasive approach to determine predator diet and is particularly useful in the study of elusive predators (Chame 2003), such as the leopard. However, comprehensive assessment of carnivore diet requires an extremely large number of scat samples (Ott *et al.* 2009). Though this may vary between different populations, depending on the number of species utilized, the present study reaffirms the need for large sample sizes i.e. sampling effort was insufficient despite the large sample sizes for the Cederberg (98 samples) and Gamka Mountains (78 samples). Nonetheless, only 2.8 species were not sampled in both areas, thus the data are considered sufficient for the purpose of this study.

Misidentification of scat samples is another limitation of scat analysis. As the present study is largely comparative, the bias created in this regard is expected to be reduced. However, for management purposes and future monitoring it should be noted that a few caracal and/or black-backed jackal scats may have been included in the analysis. This is expected to be less in the Cederberg as leopards and caracals have the tendency to occupy different habitats and altitudes (Norton & Lawson 1985). In the Gamka Mountains on the other hand, apparent overlap in scat size and lack of spatial segregation in sites where leopard and caracal scats occur may have led to scat misidentification (personal communication, Leigh Potter 2008). This suggests the need for further investigation and possibly an alternative or additional method to improve confidence in scat identification, such as collecting scats while tracking leopards or using dogs for scat identification (Kerley & Salkina 2006; Marucco *et al.* 2008).

Further biases associated with scat analysis may include a bias towards small mammals (Floyd *et al.* 1978; O'Gara 1986; Karanth & Sunquist 1995), the potential for non-independence of data (Marucco *et al.* 2008) and seasonality in the decomposition of scats (Stein & Tjiteere 2006). However, the consumption of smaller prey by the Cape leopard in the Cederberg and Gamka Mountains (present study; Norton *et al.* 1986) is expected to reduce the effect of non-independence of data (Marucco *et al.* 2008). As scats were collected throughout the year, seasonality in scat decomposition should not affect the results for the present study. Furthermore, as the majority of results from this chapter are comparative these biases should be minimal; however it should be noted for future reference.

Finally, the possibility of cannibalism in the diet analysis was disregarded, though it is known to occur (Steyn & Funston 2006) and has been detected for leopards in the Cederberg (personal communication, Quinton Martins 2008). This is because cannibalistic behavior and quantification cannot be determined by scat analysis as leopard hairs in scats generally occur because of grooming. The presence of predominantly leopard hair in a scat may suggest cannibalism, however in none of the scats were all 5 hairs leopard hair, thus we assume these were from grooming.

3.4.2 Regional variation in leopard diet

There was considerable overlap in the diet of the Cape leopard between the Cederberg and Gamka Mountains in terms of prey species utilization and the use of species within particular prey size categories. Similar to leopard diet in the Baviaanskloof region the present study revealed that their diet consisted largely of small- to medium-sized mammals (Ott *et al.* 2007). Key prey species in the Cederberg and Gamka Mountains were rock hyraxes and klipspringers, of which the former was also a relatively important part (12.5%) of leopard diet in the Baviaanskloof region (Ott *et al.* 2007).

Variation in prey species utilization was however apparent and resulted in a significant difference in the average weight of prey consumed in the Cederberg

(8.8 kg) and Gamka Mountains (6.6 kg). The difference was owing to more utilization of small mammals (< 1kg) (15.6% more) and less use of prey weighing 1-10kg (4.8% less) and 10-40kg (10.3% less) in the Gamka region compared to the Cederberg. Their flexibility in terms of prey size utilization reflects their ability to acclimatize to local availability of different prey sizes and ability to switch to smaller prey to fulfil their dietary requirements when prey is limited. We assume that it is not an artifact of scat misidentification as it does not seem to be reflected in the previous assessment of their diet i.e. no small prey such as small rodents were consumed in the Gamka Mountains (Norton *et al.* 1986). However, the possibility that a few more caracal and/or black-backed jackal scats may have resulted in the detection of more small prey in leopard diet should be noted (Carbone *et al.* 1999; Kuanda & Skinner 2003; Skinner & Chimimba 2005).

An interesting observation was the high predation of hyrax infants in the Gamka Mountains. This may be linked to the high rainfall received in the Gamka Mountains in 2006 (Hartley *et al.* 2008), as hyrax fecundity is thought to be linked to variation in rainfall regimes (Barry & Mundy 1998).

Livestock predation, often involving surplus killing, is known to occur and is associated with economic loss to farmers (Stuart & Heinecken 1977; Stuart 1981; Stuart *et al.* 1985; Mizutani 1999; Butler 2000). Recent dietary studies provide limited support for livestock predation by the Cape leopard (Norton *et al.* 1986; Ott *et al.* 2007). However, similar to leopards in the Baviaanskloof region (Ott *et al.* 2007) livestock made up a small proportion of their diet in both the Cederberg (2.1%) and Gamka Mountains (0.8%).

3.4.3 Temporal variation in leopard diet

In 1986 the Cape leopard in the Cederberg and Gamka Mountains appeared to have had a selective diet (Norton *et al.* 1986); key prey species included rock hyrax (64.6%; 51.3% respectively), grysbok (0.6%; 19.2% respectively), klipspringer (12.7%; 15.4% respectively) and grey rhebuck (10.1; 7.7%

respectively). Leopards in both regions appeared to have undergone a dietary shift involving a considerable increase in diversity, probably owing to temporal variation in prey availability (Sunquist & Sunquist 1989). Temporal dietary shifts are known to occur in leopards (Johnson *et al.*1993) and in this case it appears to be typical of when reduced prey availability induces increased opportunistic feeding (Karanth & Sunquist 1995; Bothma & Walker 1999) i.e. "energy maximizers" that become "number maximizers" (Karanth & Sunquist 1995). The yellow mongoose for example was not previously found in their diet in the Cederberg and they have not been recorded where the scat was collected (S 32º34'28.9; E 19º20'12.6; 645 m a.s.l.) (Stuart 1981; Skinner & Chimimba 2005). This may therefore either be a case of incorrect identification or predation may have occurred elsewhere. The latter would suggest extensive movement to lowland habitats, which was previously not recorded (Norton & Lawson 1985).

In the Cederberg hyrax utilization decreased considerably, whereas klipspringer, Lagomorpha and rodent consumption increased. Rock hyraxes appeared to be a key prey species in 1986 and the large reduction confirms the perception of reduced prey availability by Martins & Martins (2006) in this regard. It is not clear what the cause for the apparent hyrax decline was, however disease, drought and predation pressure have been suggested in the fluctuation of rock hyrax populations (Barry & Mundy 1998). The increase in klipspringer utilization in the Cederberg may be in response to the apparent reduction in the rock hyrax population (Angelstam *et al.* 1984) or owing to an increase in klipspringer population; however we are not aware of any evidence for the latter. The increased predation on Lagomorpha is not clear, however it may be attributed to apparent high levels of Lagomorpha availability in the Cederberg (personal communication Quiton Martins, 2008) or it may be in response to the limited rock hyrax availability.

In the Gamka Mountains the dietary shift involved a reduction in hyrax and grysbok utilization, together with a large increase in rodent consumption. The higher levels of rodent predation suggested increased dependence on opportunistic feeding when rodents were encountered. This may be in response to limited availability of alternative prey (Johnson *et al.* 1993; Karanth & Sunquist 1995; Henschel *et al.* 2005; Ott *et al.* 2007), or these leopards may have taken advantage of an increase in rodent availability (Johnson *et al.* 1993; Bothma & Le Riche 1994). Both factors may have played a role, the latter because above average rainfall in 2006 in the Gamka Mountains (Hartley *et al.* 2008) may have brought about an increase in rodent numbers (Kerley & Erasmus 1992; Lima 1999) and the former because the observed decrease in hyrax utilization may have increased the leopards' dependence on alternative prey (Karanth & Sunquist 1995). As leopards in the Gamka Mountains appeared to utilize smaller mammals rather than livestock to compensate for the prey reductions (Ott *et al.* 2007), the study also supports the notion that livestock i.e. goats and sheep may exceed the prey size preference of leopards (Hayward *et al.* 2006; Ott *et al.* 2007).

In both regions the shift appeared to reflect a reduction in the availability of key prey species rather than a general prey scarcity. This is supported by the sustained low livestock predation in both regions as prey scarcity is often thought to induce increased livestock predation (Mizutani 1999; Butler 2000; Martins & Martins 2006). In addition, lack of prey is often also associated with a shift toward smaller prey (Ramakrishnan *et al.* 1999; Henschel *et al.* 2005; Ott *et al.* 2007), which was not reflected by leopard diet in the Cederberg. Instead there was an increase in the average weight of prey, owing to the reduction in hyrax usage and increased klipspringer and other small antelope predation. Finally, the insignificant change in the utilization of prey size categories suggests that alternative prey of similar size was available for utilization. This also shows their flexibility in response to temporal change in prey availability (Ramakrishnan *et al.* 1999) and stresses the importance of size appropriate prey availability (Karanth & Sunquist 1995), rather than the availability of specific prey species for the sustenance of predator populations. It also revealed a limitation of defining trends in leopard diet by analyzing category use rather than the use of specific prey.

CHAPTER 4

PREY PREFERENCE OF THE CAPE LEOPARD (*PANTHERA PARDUS*) IN THE CEDERBERG MOUNTAINS USING CAMERA TRAP SURVEYS

4.1 Introduction

The maintenance of large predator populations depends largely upon the availability of suitable prey in terms of both species and size (Karanth *et al.* 2004; Marker & Dickman 2005). Prey preference provides a measure of prey suitability for a species and can be determined by using prey usage and availability data (Jacobs 1974). To determine the availability of prey extensive data on the composition and abundance of potential prey species are required.

Typically, assessments of prey availability have been based on direct counts, spoor counts and more recently using remote sensing technology such as camera trapping (Silveira *et al.* 2003). Owing to the advantages (Silveira *et al.* 2003; Sanderson 2004; Yasuda 2004; Rovero *et al.* 2005) and multitude of applications (Carbone *et al*. 2001; Fonseca *et al.* 2003; Trolle 2003; Yasuda 2004; Azlan & Lading 2006; Chetana & Ganesh 2007; Martins *et al*. 2007) camera trap surveys have become a popular approach to monitoring wildlife. Though the use of camera trap surveys has been focused largely on the surveillance of a few target species, their utility to capture information regarding non-target species has also been recognized (Martins *et al.* 2007; Kelly & Holub 2008). However non-random sampling, as a result of variation in prey body size and behaviour, has been identified as one of the constraints in using camera traps (Giman *et al.* 2007; Tobler *et al.* 2008). Leopards prey for the most part on medium-sized mammals, with a body mass of 10-40 kg (Hayward *et al.* 2006), which is within the range of species successfully detected by camera traps i.e. medium- to large-sized mammals (Trolle 2003; Goldman & Winther- Hanson 2003; Yasuda 2004; Sanderson 2004; Martins *et al.* 2007). Camera traps are thus expected to be successful in the surveillance of most leopard prey; however leopards are also known to utilize smaller mammals (Norton *et al.* 1986; Johnson *et al.* 1993; Ramakrishnan *et al.* 1999; Maheshwari 2006; Ott *et al.* 2007). Though small mammals such as rats, shrews and gerbils have been photo-trapped (Azlan & Lading 2006; Giman *et al.* 2007; Chetana & Ganesh 2007), their abundances are likely to be underestimated by camera trap surveys (Tobler *et al.* 2008).

A meta-analysis on the prey preference of leopards has been conducted (Hayward *et al.* 2006a), however owing to lack of data, the Cape leopard was not included in the analyses. There is thus a need to determine the prey preference of the Cape leopard, particularly as it is expected to differ from other leopard populations as a result of their smaller body sizes (Carbone *et al.* 1999; Skinner & Chimimba 2005; Hayward *et al.* 2006a). Furthermore, though the bias regarding variable detection probability of different prey sizes have been identified (Giman *et al.* 2007; Tobler *et al.* 2008), more information is needed regarding the viability of using camera traps to survey the diverse mammal prey base of leopards and using the data to determine leopard prey preference.

The aim of the present study was to provide preliminary information regarding the prey preference of the Cape leopard using data from the Cederberg Mountains and to assess the utility of camera trap surveys to do so.

4.2 Material and Methods

4.2.1 Study area and focal species

This study focused on the prey preference of the Cape leopard in the Cederberg Mountains. See Chapter 2 for the description of the Cape leopard and the Cederberg Mountains.

4.2.2 Scat analysis

Scat analysis was used to determine the diet of the Cape leopard. See Chapter 3 for description of the dietary analysis.

4.2.3 Camera trap surveys

Data from camera trap surveys were collected by Quinton Martins in association with the Cape Leopard Trust. Under their survey protocol, camera trap stations were set up in three different locations consecutively; a conservation area, livestock farm and game farm (see Chapter 2). This was undertaken in the summer of 2004/2005 and in the winter of 2005 (for more detailed information regarding the time and location of the surveys, see Appendix D). Each survey included 20 camera trap stations and lasted approximately 40 days (Yasuda 2004). Camera trap stations were placed in a grid to ensure uniform coverage of the sample area (Sanderson 2004; Fonseca *et al.* 2003). To aid in the identification of leopards by their markings, individuals were photographed on both sides by setting up two cameras at each station (Sanderson 2004). This was also expected to increase the capture probability of small prey (Tobler *et al.* 2008). Site selection and camera trap set up were aimed at the surveillance of leopards, the focal species for the study. Camera trap stations were set up 40 cm above ground, and were placed 2 to 3 m from the chosen trails (Trolle 2003) and they recorded activity 24 hours per day. Deercam® passive camera traps were used, which are triggered by movement and heat. Camera traps were placed at least 3 km apart, therefore each survey area was about 28 km^2.

Species identification was also undertaken by Quinton Martins (Cape leopard Trust). For the analyses birds and reptiles were not identified down to species level. Mammals were for the most part identified down to species level; however species identification to genus level was problematic for species within certain groups. For the analysis of sampling efficiency only lagomorphs were grouped into hares and rabbits, as it was difficult to distinguish between scrub hares and Cape hares on the camera trap photographs. For all the other analyses Lagomorpha (scrub hare, Cape hare and red rock rabbit), mongooses (Cape grey mongoose, large grey mongoose and water mongoose) and genets (small spotted genet and large spotted genet) were grouped. The results section therefore refers to prey types and not prey species. Grouping of these species also meant the grouping of dietary data in the same groups as the prey availability data for this chapter. Images of leopards were left out of the analyses, however leopard counts for the three different survey areas are provided.

4.2.4 Data analysis

See Chapter 3 for the sampling efficiency and dietary analyses of the Cape leopard in the Cederberg.

EstimateS (Version 7.5) was used to determine whether the sample size for prey availability was large enough to identify all potential dietary species (Moreno & Halffter 2001; Willot 2001; Colwell 2005). Sampling efficiency was determined using the number of individuals observed (Moreno & Halffter 2001; Willot 2001). A sampling efficiency curve was produced using 50 randomized iterations. The Incidence-based Coverage Estimator (ICE Mean) was used to provide an estimate of how many species were not included in the sample set (Colwell 2005).

A Pearson (linear) correlation coefficient was used to determine the correlation between the number of camera trap days and the number of photographs taken of identifiable species. For comparison of correlation coefficients between the three survey areas, these were also determined (Quinn & Keough 2002).

Prey usage, relative abundance and prey preference were determined for each prey species present and/or utilized by the Cape leopard in the Cederberg Mountains. Prey usage data from the dietary assessment was used (see Chapter 3). To determine the relative abundance of each species the data were filtered, based on the assumption that only one individual of a species could be photographed per day (Sanderson 2004; Martins *et al.* 2007), unless individuals could be distinguished based on their sex or the presence of more than one individual on a photograph (Sanderson 2004; Martins *et al.* 2007). The relative abundance (%) of each species was then determined by dividing the number of individuals photographed per species by the total number of individuals recorded (Sanderson 2004). Jacobs' Index was used to determine the preference or avoidance of the various species in leopard diet and was determined by the following equation (Jacobs 1974):

$$D = (r - p)/(r + p - 2rp)$$

Utilization is represented by "r" and availability by "p". Jacobs' Index gives a range between +1 and -1. The latter is maximum avoidance and +1 is maximum preference (Jacobs 1974). The preference of the Cape leopard for different prey size categories was also determined, with the inclusion of all species. This was repeated with the exclusion of small rodent and insect utilization and availability (none were recorded) from the analysis. Confidence intervals for the dietary data were used to determine significant preference and avoidance of prey for both data sets (Gardner & Altman 1986; Quinn & Keough 2002).

4.3 Results

4.3.1 Sampling effort for prey usage

See Chapter 3 for the sampling efficiency results of scat analysis for leopards in the Cederberg Mountains.

4.3.2 Sampling effort for prey availability

In 4 597 camera trap days, 1805 photographs were taken of species that could be identified to species level. Of the 30 prey types identified, 28 were mammal species and the other two were birds and reptiles. The species accumulation curve clearly approached an asymptote, with 0.48 species not sampled (ICE mean of 31.48) (Figure 4.1), although scrub and Cape hares were grouped. A total of 1 265 individuals were counted after the photographs were filtered and for further analyses mongooses, genets and all lagomorphs (scrub hares, Cape hares and red rock rabbits) were grouped, thus the richness of possible prey items recorded declined to 26.

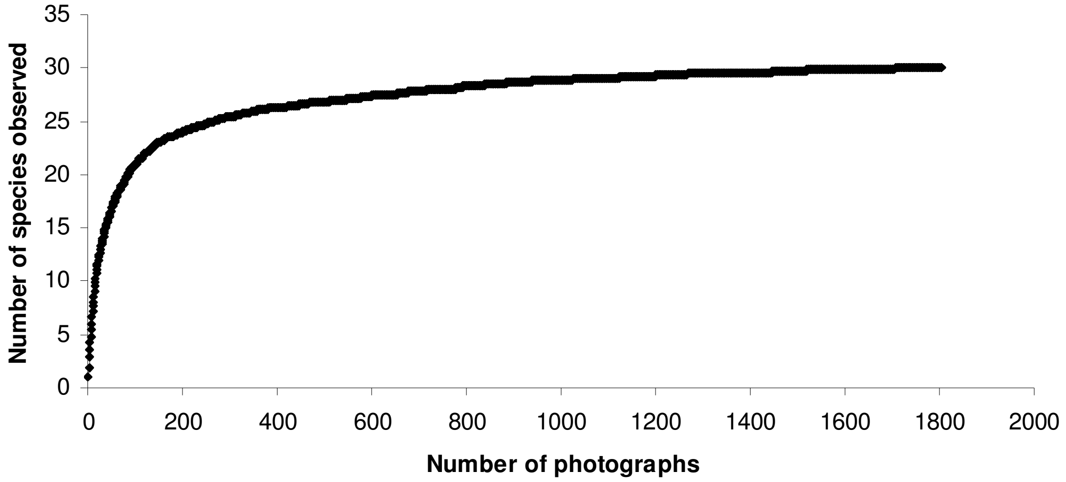

Figure 4.1 Species accumulation curve (50 randomized iterations; ICE mean 30.48) of the 30 potential prey types recorded in the 1805 photographs taken from which species could be identified.

A strong correlation ($R^2 = 0.98$; $Y = 0.3x + 264.2$) was found between trap days and usable images for the pooled trapping data (i.e. across the 3 habitats). Similarly the Pearson correlation coefficient for the three different locations also indicated a strong correlation between the number of photo-trap days and the number of photographs from which potential prey could be identified. There was little variation between the three locations. The strongest correlation was observed in the game farm ($R^2 = 0.99$; $Y = 0.3x + 282.3$), followed by the conservation area ($R^2 = 0.97$; $Y = 0.3x + 269.7$), whereas weakest correlation was observed in the farmland camera trap survey ($R^2 = 0.89$; $Y = 0.5x + 127.4$).

4.3.3 Prey usage, availability and preference

Dietary data for all species included in the diet of Cape leopards in the Cederberg are provided (Table 4.1), as well as data for which small rodents and insects were not included. A description of prey usage is provided in Chapter 3.

Prey availability data for all species included in the diet of leopards in the Cederberg are also presented (Table 4.1), as well as data for which small rodents and insects were not included. In terms of availability, the baboon (10.3%), rock hyrax (8.8%), cattle (8.7%), Lagomorpha (8.3%), klipspringer (8.1%), porcupine (6.8%) and gemsbok (6.8%) were recorded most often (Table 4.1). Birds (6.3%), aardwolves (4.8%), mongooses (4.3%) and the Cape grysbok (3.8%) were also recorded. No small rodents, grey duikers and insects were photographed. Appendix D also gives the counts for prey availability in the three areas surveyed separately, as well as during the summer and winter. The camera trap survey produced 15 photographs of leopards on the farmlands, 11 on the game farm and 36 in the conservation area.

Prey preference data for all species included in the diet of the Cape leopard in the Cederberg are also provided, as well as data for which small rodents and insects were not included (Table 4.1). The latter indicated preference towards the grey duiker (Jacobs' Index = 1.0), klipspringer (Jacobs' Index = 0.7), rock hyrax (Jacobs' Index = 0.6), grey rhebuck (Jacobs' Index = 0.5) and mongooses (Jacobs' Index = 0.1). Baboons (Jacobs' Index = -0.6), porcupines (Jacobs' Index = -0.6), aardwolves (Jacobs' Index = -0.3), springbuck (Jacobs' Index = -0.4), Cape grysbok (Jacobs' Index = -0.2) and birds (Jacobs' Index = -0.1) were avoided. Lagomorpha (Jacobs' Index = 0.0) and Boer goats (Jacobs' Index = 0.0) were taken in accordance with their abundance. Other available prey was not recorded in the scats (Table 4.1).

Table 4.1 Prey usage, availability and preference for all species with and *without small rodents (< 1 kg) and insects. See text for prey category division.

		Usage (%)		Availability (%)	Preference (Jacobs' Index)	
Common name	Prey category	All	Sorted*	All	All	Sorted*
Small rodents	SM (< 1 kg)	9.3	-	0.0	1.0	-
Striped polecat	SM (< 1 kg)	0.0	0.0	0.2	-1.0	-1.0
Aardwolf	SM	2.1	2.4	4.8	-0.4	-0.3
African wild cat	SM	0.0	0.0	2.7	-1.0	-1.0
Black-backed jackal	SM	0.0	0.0	0.4	-1.0	-1.0
Cape fox	SM	0.0	0.0	0.2	-1.0	-1.0
Genet	SM	0.0	0.0	2.1	-1.0	-1.0
Honey badger	SM	0.0	0.0	1.0	-1.0	-1.0
Lagomorpha	SM	7.9	8.8	8.3	0.0	0.0
Mongoose	SM	4.3	4.8	4.3	0.0	0.1
Rock hyrax	SM	25.0	28.0	8.8	0.6	0.6
Boer goat	MM	2.1	2.4	2.6	-0.1	0.0
Caracal	MM	0.0	0.0	3.6	-1.0	-1.0
Cape grysbok	MM	2.1	2.4	3.8	-0.3	-0.2
Cape porcupine	MM	1.4	1.6	6.8	-0.7	-0.6
Chacma baboon	MM	2.9	3.2	10.3	-0.6	-0.6
Grey duiker	MM	2.1	2.4	0.0	1.0	1.0
Grey rhebuck	MM	5.0	5.6	2.1	0.4	0.5
Klipspringer	MM	29.3	32.8	8.1	0.6	0.7
Springbok	MM	0.7	0.8	1.8	-0.4	-0.4
Steenbok	MM	0.0	0.0	0.3	-1.0	-1.0
Aardvark	LM	0.0	0.0	2.0	-1.0	-1.0
Cape mountain zebra	LM	0.0	0.0	2.8	-1.0	-1.0
Cattle	LM	0.0	0.0	8.7	-1.0	-1.0
Donkey	LM	0.0	0.0	1.0	-1.0	-1.0
Gemsbok	LM	0.0	0.0	6.8	-1.0	-1.0
Birds*	Other	4.3	4.8	6.3	-0.2	-0.1
Insect	Other	1.4	-	0.0	1.0	-
Reptile	Other	0.0	0.0	0.2	-1.0	-1.0

* The relative abundance of ostriches were 0.05%, however they were grouped with the other smaller birds.

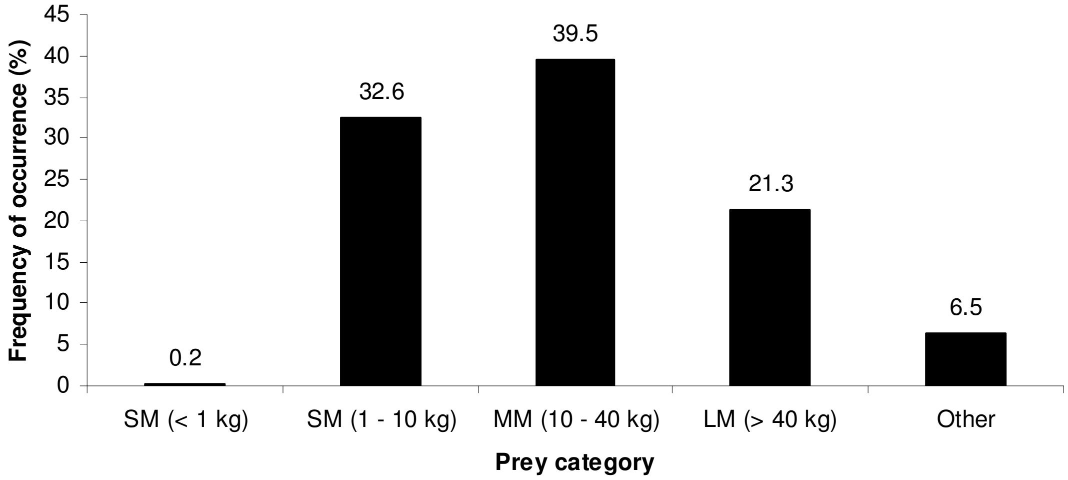

Figure 4.2 Prey availability for leopards in the Cederberg Mountains; expressed as the frequency of occurrence (%) of prey categories.

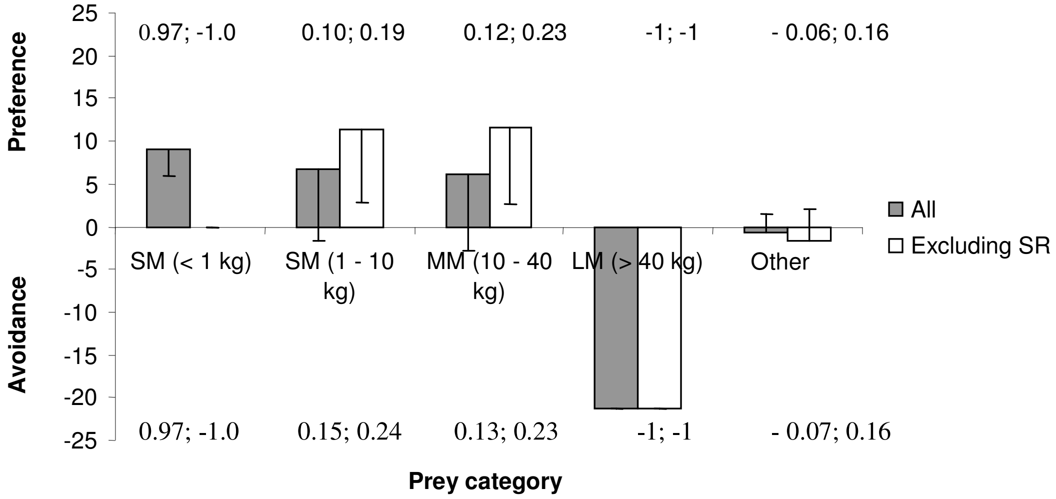

Figure 4.3 The difference in the frequency of usage (%) and availability (%) data for the various prey categories. The grey bars are prey category preference and avoidance for all data, whereas the white bars represent the data from which small rodents and insects were excluded. Confidence intervals and prey preference data (Jacobs' selectivity index values) are also provided.

4.3.4 Availability of prey categories

Small (1-10 kg), medium (10-40 kg) and large (> 40 kg) mammals were most frequently recorded by the camera trap surveys (Figure 4.2). Small (< 1 kg) mammals and other prey i.e. birds and reptiles were also recorded (Figure 4.2).

4.3.5 Preference towards prey categories

When all data were included in the analysis, small mammals (< 1 kg) were significantly preferred. Small- (1-10 kg) and medium-sized mammals, as well as other prey were also preferred; however the confidence intervals indicate that this was not significant. The large mammals were significantly avoided. When small rodents and insects were excluded from the analysis, small mammals (< 1 kg) were avoided. Small- (1 – 10 kg) and medium-sized mammals were significantly preferred. Large mammals were significantly avoided and other prey species were avoided when small rodents and insects were excluded.

4.4 Discussion

4.4.1 Sampling efficiency

Sampling effort for the camera trap surveys was assumed to reflect the entire prey selection that camera traps were able to detect as only 0.48 species were not included in the analysis. The data suggest that more than 80% of the potentially identifiable species (n = 27 out of 31) could be identified after about 400 photographs.

There was a strong correlation between the number of camera trap days and the number of photographs taken of identifiable prey. Though the correlations for the three different study areas were also strong, variation was detected. The results suggest that the same amount of camera trap days would produce more identifiable photographs on the game farm, followed by the conservation area and the least amount of identifiable photographs in the farmland. Therefore, in support of Willot (2001), we stress the importance of using the number of images taken of identifiable individuals in determining trapping effort rather than camera trap days.

Variation in the correlation between the three areas may be the result of numerous factors, such as variation in species richness or in trapping success (Willot 2001), which may be related to habitat type and prey size, in the case of camera trap surveys. Variation in species richness and prey size may have played a role in the present study, as a result of different management practices in the three locations. For example game farms are expected to house more animals, with specific focus on larger animals. This would result in more photographs taken per day. It is not clear why the farmlands produced the least photographs per day.

4.4.2 The utility of camera trap surveys

As expected (Yasuda 2004), medium- and large-sized mammals appeared to be surveyed with reasonable success. Though camera trap success has been shown to decrease with prey body size (Tobler *et al.* 2008), in the present study the surveillance of small mammals (1-10 kg) also appeared to be successful. Examples include rock hyraxes and lagomorphs for which the relative abundances were 8.8% and 8.3% respectively.

We were not able to make an accurate assessment on the utility of camera trap surveys to determine prey availability for all the prey categories and species, as prey availability assessments in the area using other techniques were not available. However, from the prey usage data we were able to identify the inability of camera traps to determine the availability of small mammals (< 1kg), particularly small rodents. Although small rodents have been photo-trapped in previous studies (Goldman & Winther-Hansen 2003; Giman *et al.* 2007) and 9.3% of leopard diet in the present study consisted of small rodents none were successfully recorded. A single possible exception was one photograph taken of a small mammal, thought to be a molerat, but this could not be established with certainty, thus it was left out of the analyses. Clearly camera traps tend to underestimate the abundance of small rodents, and in the present study cameras were unable to effectively photo-trap any.

The inability of camera trap surveillance to determine the availability of small mammals (< 1 kg) resulted in an overestimated preference towards small mammals (< 1 kg). Variation in preference was also found in the other prey categories, in response to the exclusion of small rodents and insects from the analysis. Preference towards small- (1-10 kg) and medium-sized (10-40 kg) mammals for example was not significant when all the data were included, however when small rodents and insects were excluded significant preference of these categories were found. The use of scat analysis and its expression in the form of frequency of occurrence may have resulted in the overestimation of the extent of small prey usage (Henschel *et al.* 2005), such as small rodents in leopard diet. However, small prey are regularly taken by leopards (Norton *et al.* 1986; Johnson *et al.* 1993; Ramakrishnan *et al.* 1999; Ott *et al.* 2007; Chapter 3) and recognition of the potential bias of using camera trap surveys to determine leopard prey preference is therefore important. Furthermore, the Cape leopard included smaller prey in their diet than leopards elsewhere (Hayward *et al.* 2006a), thus the potential bias of using camera trap surveillance to determine their prey preference is particularly important.

In general leopards prefer prey that is larger (i.e. 10-40 kg) than the minimum prey size (> 1 kg) that appeared to be effectively photo-trapped by the camera trap surveys (Hayward *et al.* 2006a). However their analysis did not include any data of leopard predation on smaller mammals such as small rodents. Therefore, though camera trap surveys will probably be sufficient to determine prey preference and availability for the majority of leopard populations, we suggest that the bias of underestimating small mammal (< 1 kg) abundance should be considered during data analyses of future studies. We also recommend that Hayward *et al.*'s (2006a) analysis of leopard prey preference be interpreted with caution as it is possible that the role of rodents may also have been underestimated at other localities.

4.4.4 Prey preference of the Cape leopard

The preference of leopards towards small mammals (< 1 kg) and insects could not be assessed and were thus excluded from the analysis. However preference towards larger prey, domestic animals, birds and reptiles were determined. The Cape leopard showed preference towards certain prey species and prey size categories, which supports the results in Chapter 3 that the change in the prey base for leopards in the Cederberg did not involve a general prey scarcity (Karanth & Sunquist 1995).

Mammals weighing between 1 and 10 kg were significantly preferred by the Cape leopard. The Cape leopard showed strong preference towards rock hyraxes (Jacobs' Index = 0.6), which is in agreement with the general outcome of studies in terms of the leopards' tendency to utilize rock hyraxes (Bothma & Le Riche 1994; Hayward *et al*. 2006a). Lagomorphs were taken approximately in accordance with their abundance, which was relatively high (8.3%). Mongooses were also opportunistically preyed upon, whereas other carnivores in this size category were avoided.

Medium-sized mammals made up the largest part of their diet and similar to leopards elsewhere (Hayward *et al.* 2006a), leopards in the Cederberg preferred prey that weigh between 10 and 40 kg. In terms of species preferences, they preferred the utilization of grey duikers (Jacobs' Index = 1.0), klipspringers (Jacobs' Index = 0.7) and grey rhebuck (Jacobs' Index = 0.5). Their strong preference towards grey duikers was an artefact as they were not recorded during the camera trap survey. The reason for this is not clear as they are known to occur in the area (personal communication, Quinton Martins 2008). Klipspringers are thought to be significantly avoided by leopards elsewhere (Hayward *et al.* 2006a) and in the Baviaanskloof region klipspringers also made up only a small proportion (2.5%) of leopard diet (Ott *et al.* 2007). However, considering the overlap in habitat use between leopards and klipspringers (Norton & Lawson 1985; Druce 2005) the strong preference of leopards towards klipspringers in the Cederberg was not surprising. However, klipspringer usage increased since the previous leopard dietary assessment in the Cederberg Mountains (Norton *et al.* 1986; see Chapter 3). Therefore, it may partly be owing to increased dependence on klipspringer predation in response to the apparent reduction in rock hyrax numbers. Baboons were avoided, thus the general belief that leopards prefer baboons and regulate baboon population numbers (Wright 1960) was therefore once again refuted (Hayward *et al.* 2006a) by the low incidence of baboon predation, specifically for the Cape leopard (Norton *et al.* 1986; Ott *et al.* 2007). Similar to the outcome of Hayward *et al.* (2006a), steenbok (Jacobs' Index = -1.0), caracal (Jacobs' Index = -1.0), honey badgers (Jacobs' Index = -1.0), springbuck (Jacobs' Index = -0.4), grysbok (Jacobs' Index = -0.2) and porcupine (Jacobs' Index = -0.6) were avoided. Springbuck have been found to be avoided by leopards elsewhere, and was suggested to be a result of their utilization of more open habits, which are not preferred hunting conditions for leopards (Hayward *et al.* 2006a). Porcupines were also taken, and are known to be included in leopard diet (Johnson *et al.* 1993; Bothma & Le Riche 1994; Ramakrishnan *et al.* 1999); however they were avoided probably because of the risk of injury associated with their predation (Skinner & Chimimba 2005).

Large mammals were avoided by leopards in the Cederberg (Jacobs' Index = -1.0), with zebra, gemsbok and aardvark not recorded in leopard diet. This category also included most of the domestic animals. Livestock predation is known to occur (Stuart & Heinecken 1977; Stuart 1981; Stuart *et al.* 1985; Mizutani 1999; Butler 2000), however recent dietary studies provide limited support for livestock predation by the Cape leopard (see Chapter 3; Norton *et al.* 1986; Ott *et al.* 2007). Despite the abundance of livestock, i.e. cattle (8.7%) and donkeys (1.0%), recorded by camera traps and the presence of leopards on the farmlands (15 photographs taken), no predation on these were reflected in the scat analysis. The only livestock that were included in the leopard diet were goats, and they were only taken opportunistically (Jacobs' Index = 0.0). This is thought to be related to livestock exceeding the prey size preference of leopards (Hayward *et al.* 2006a; Ott *et al.* 2007).

Though there was considerable overlap in the prey preference of the Cape leopard and that of leopards elsewhere, the Cape leopard appeared to focus on smaller prey than most other leopard populations, despite the availability of larger prey. The average weight of prey consumed by the Cape leopard in the Cederberg (8.8 kg; see Chapter 3) is less than half the average weight of prey utilized by leopards in general (23 kg) (Hayward *et al.* 2006a). In addition to the dietary data of the present and previous studies (Norton *et al.* 1986; Ott *et al.* 2007), preference data also provided support for the notion that the smaller size of the Cape leopard may be linked to the sustainability of and preference (as shown by the present study) towards what appears to be a diet of smaller prey size, when compared to other leopard populations (Iriarte *et al.* 1990; Carbone *et al.* 1999; Hayward *et al.* 2006a).

CHAPTER 5
CONCLUDING DISCUSSION

The conservation and management of a species is heavily dependent on the identification of conservation threats, as well as knowledge and understanding of their biology and ecology (Caughley 1994). Prey availability, which is central to the survival of large felids (Karanth *et al.* 2004), is considered one of the threats facing the Cape leopard (Norton *et al.* 1986; Martins & Martins 2006). The aim of the present study was therefore to determine whether the Cape leopard in the Cederberg and Gamka Mountains was subject to changes in their prey base. This was done using scat analysis techniques, and comparing their current diet to a previous dietary study (Norton *et al.* 1986). The second major objective was to provide a preliminary assessment of prey preference of the Cape leopard and determine the utility of camera traps to do so. This was achieved by relating prey consumption to camera trap data recorded in the Cederberg Mountains.

5.1 Variation in leopard diet

5.1.1 Regional variation in the diet of the Cape leopard

The diet of the Cape leopard appears to consist largely of small- to medium-sized mammals (see Chapter 3; Norton *et al.* 1986; Ott *et al.* 2007). Key prey species in the present study were rock hyraxes and klipspringers. Though the size and composition of species consumed between the two regions were similar, variation was apparent and resulted in significant variation of the average weight of prey consumed. This reflected their dietary flexibility and ability to utilize locally available prey.

5.1.2 Temporal variation in the diet of the Cape leopard

The Cape leopard underwent a dietary shift in both the Cederberg and Gamka Mountains, with significant variation in prey species composition. Both areas appeared to be subject to a reduction in the availability of key prey species, particularly the rock hyrax, rather than a general prey scarcity. The study was also useful in the identification of other conservation concerns, which can be used towards the conservation of the Cape leopard in the Cederberg and Gamka Mountains.

1. The study provided an up to date record of the diet of the Cape leopard, which may serve as a reference point for future monitoring. This will enable the identification of future dietary shifts in response to natural and anthropogenic impacts on their prey base.
2. The dietary assessment was also important to determine the role of leopards in livestock predation. Results indicated that leopards are seldom implicated in livestock predation i.e. 2.1% in the Cederberg and 0.8% in the Gamka Mountains. Caracals and black-backed jackals can be removed without permits; however the methods used to do so are non-selective, therefore leopards are inadvertently also targeted (Martins & Martins 2006). We suggest a more species specific method to remove the responsible animals or another approach such as protecting livestock rather than persecution of problem animals (Shelton 2004).
3. The study also provided an indication of the dietary flexibility of the Cape leopard. Furthermore, in support of previous work on leopards (Karanth & Sunquist 1995; Hayward *et al.* 2006a), the study suggested that the maintenance of leopard populations in terms of their diet depend largely upon the availability of suitable prey size categories, rather than specific prey species.

The plasticity of the Cape leopard in terms of the utilization of different prey species is associated with a number of advantages, as well as constrains and disadvantages for their management.

Advantages of the dietary flexibility of the Cape leopard include the following examples:

1) In the event of prey limitations, the Cape leopard would be able to undergo a dietary shift and be less dependent on prey reintroductions.
2) Similarly, when a leopard population is declining, as a result of anthropogenic pressure for example, their reintroduction is not dependent on the availability of specific prey species, but rather the availability of prey size categories. However, it is important to assess the size of such a prey base prior to the introduction of leopards. Carbone & Gittleman (2002) showed that on average a predator of 90 kg requires about 10 000 kg of prey biomass. This suggests that Cape leopards, with their small body sizes would each require in the region of 3 000 to 5 000 kg of prey biomass. More recently, Hayward *et al.* (2007) developed prediction models for the carrying capacity of large carnivores. Their model for leopards was based on a few preferred prey species. Based on our finding we suggest that this model is too conservative as it does not reflect the broader prey base for leopards.
3) The study also provided the opportunity to gain a better understanding of their biology. The broad and flexible diet of the Cape leopard may also explain how their populations have persisted in the face of persecution and habitat loss (Martins & Martins 2006). This resource breadth may sustain leopards from other threats as for example Hayward & Kerley (2008) showed that generalist predators with wide dietary niches are less vulnerable to extinction than more specialized species.

The nature of the dietary shift in response to variations in prey availability has the potential to introduce challenges to the management of the Cape leopard:

1. This includes increased dependence on smaller prey (Ramakrishnan *et al.* 1999; Henschel *et al.* 2005; Ott *et al.* 2007). This may mean increased dietary overlap with smaller carnivores such as caracals and black-backed jackals (Norton *et al.* 1986; Avenant & Nel 2002; Kuanda & Skinner 2003;

Ott *et al.* 2007; Farhadinia *et al.* 2007), thus increasing exploitative competition for resources.

2. Alternatively or in addition, the apparent reduced availability of important prey species may lead to increased predation on domestic stock (Mizutani 1999; Martins & Martins 2006), thus increasing the already existing conflict between leopards and neighboring landowners (Stuart & Heinecken 1977; Stuart 1981; Stuart *et al.* 1985; Mizutani 1999; Butler 2000).

5.2 Prey preference

This study also provided a preliminary assessment on the prey preference of the Cape leopard in the Cederberg Mountains. When a shortage of prey is detected and prey needs to be reintroduced, information regarding the prey preference of the Cape leopard may assist management to focus attention and costs on prey that is most suitable for their sustenance (Hayward *et al.* 2007).

Results indicated that the Cape leopard prefers small- (1-10 kg) and medium-sized mammals (10-40 kg), specifically klipspringer, rock hyrax and grey rhebuck. The assessment suggested that though the Cape leopard is free from larger competitors such as lions, wild dogs and cheetahs which are normally their main competitors (Hayward & Kerley 2008), their preference towards smaller prey may result in dietary overlap with smaller carnivores, thus introducing competition with smaller competitors such as caracals and black-backed jackals (Norton *et al.* 1986; Avenant & Nel 2002; Kuanda & Skinner 2003; Ott *et al.* 2007; Farhadinia *et al.* 2007). Knowledge about overlap in the diet of competitors and preference towards similar species may be useful in determining the extent of prey reintroductions needed to sustain leopard populations.

The present study also confirmed speculation by Hayward *et al.* (2006a) that their meta-analysis on the prey preference of leopards may have underestimated the importance of small mammals in leopard diet. It therefore suggests that data on smaller prey should be included in prey preference studies of leopards, to avoid biases in this regard. It also highlights the importance of intra-species variation in prey preference and suggests that prey preference for a particular leopard population should involve more focused studies, as leopard diet varies and the inclusion of smaller mammals may vary in space and time.

Predation is constrained by body size in terms of the size of prey (Carbone *et al.* 2001), therefore it is expected that the smaller body size of the Cape leopard will be reflected in a downward shift in preferred prey size. As mentioned in Chapter 4, the dietary data of the present study, previous studies (Norton *et al.* 1986; Ott *et al.* 2007), as well as preference data (of the present study) provide support for the notion that the smaller size of the Cape leopard may be linked to the sustainability of and preference towards what appears to be a diet of smaller prey size, when compared to other leopard populations (Iriarte *et al.* 1990; Carbone *et al.* 1999; Hayward *et al.* 2006a). This hypothesis needs to be tested however.

5.3 The utility of camera traps

The study also assessed the utility of using camera trap surveys to determine leopard prey availability and preference, which will be useful in the planning of future studies. Camera trap surveillance is thought to be the superior method in determining mammal availability (Silveira *et al.* 2003; Trolle 2003). However the present study demonstrated the inability of camera trap surveys to determine the availability of smaller prey species such as small rodents. Generally, leopards are thought to prefer prey that is larger i.e. 10-40 kg (Hayward *et al.* 2006a) than the minimum prey size that appeared to be successfully surveyed by camera traps. Therefore camera trap surveillance should be successful in studying prey preference for most leopard populations. However, Hayward *et al.*'s (2006a) analysis did not include studies in which leopards preyed upon small mammals (< 1 kg), therefore we suggest that the bias of underestimating small mammal (< 1 kg) abundance should be considered during the analysis of data, as small prey are regularly taken by leopards (Norton *et al.* 1986; Johnson *et al.* 1993; Ramakrishnan *et al.* 1999; Ott *et al.* 2007), as also shown by this study. The potential bias of using camera trap surveillance to determine the prey preference of the Cape leopard is expected to be particularly pronounced as they are inclined to include more small prey in their diet than leopards elsewhere (Carbone *et al.* 1999; Hayward *et al.* 2006a).

Camera trap surveys may however be efficient in determining prey preference of other large carnivores such as lions that prefer prey that weigh between 190 and 550 kg (Hayward & Kerley 2005) and hyenas (Stein & Tjiteere 2006), however the potential bias of camera trap surveys should be taken into account when determining the prey preference of smaller carnivores such as cheetahs that prefer that weigh between 23 and 56 kg (Marker *et al.* 2003; Hayward *et al.* 2006), caracals and black-backed jackals (Kuanda & Skinner 2003; Farhadinia *et al.* 2007). Using camera trap surveys to determine prey preference for carnivores weighing less than about 10 kg will probably not be a viable method.

5.4 Future research

The flexibility of the Cape leopard in terms of their diet in both the Cederberg and Gamka Mountains has enabled a dietary shift in both areas. Changes in the prey base of the Cape leopard was apparent from this study and is expected to be an ongoing phenomenon (Howell 1923; Willan & Bigalke 1982; Norton *et al.* 1986; Kerley & Erasmus 1992; Johnson *et al.* 1993; Lima *et al.* 1999; Erb *et al.* 2001; Marker & Dickman 2005; Martins & Martins 2006). Therefore we suggest continuous long-term monitoring of leopard diet to detect changes in prey availability. This may assist in identifying the need to reintroduce prey and may provide more information on the prey-predator interactions of the Cape leopard. Furthermore, possible dietary overlap between leopards and other carnivores need to be established to determine the extent of indirect competition, as well as the ability of alternative prey populations to endure increased predation by leopards.

As rock hyraxes are key prey items for the Cape leopard in the Cederberg and Gamka Mountains, the apparent population decline needs to be examined. The extent and reason for the decline in rock hyrax numbers is not certain. Furthermore, the sustainability of the dietary shift in both areas is also not known. We therefore suggest that the population dynamics of the rock hyrax populations in both areas should be monitored. There is also a need to monitor the leopard population level response to changes in hyrax population. Given their broad prey base however, it is not known whether the leopard/hyrax predator-prey system will show the cyclycity of snowshoe hares (*Lepus americanus*) in response to predation and resource availability (Krebs 1996), as generalist predators tend to stabilize prey cycles rather than sustain them (Hanski *et al.* 1991).

This study also provided valuable information on livestock predation on a regional scale; however more focused dietary studies and closer examination of problem areas with the potential for conflict between leopards and farmers need to be done. More detailed studies on stock losses in terms of the contribution of each predator species towards stock losses are also necessary. This may assist in the identification of the species responsible for most stock losses so that management of livestock predation can be focused on species responsible for most stock losses (Shelton 2004).

In terms of the utility of camera traps, this study identified one of the major limitations of using camera traps to determine leopard diet. The utility of camera traps to determine prey availability have been explored for other large predators such as tigers, however this was not related to dietary data (O'Brien *et al.* 2003). As camera surveys have many advantages and applications (Silveira *et al.* 2003; Trolle 2003), it would be useful to determine the utility of using camera traps in the surveillance of prey preference for other large carnivores as well. The efficiency of camera trap surveys have also not yet been established for smaller carnivores such as cheetahs and would also be useful in prey preference studies for these species. For the smaller carnivores, that often include small prey (< 1 kg) in their diet; the potential for using an alternative or additional method to determine leopard prey availability and preference is needed.

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Appendix A

Prey availability in percentage, as well as their counts during the summer and winter, and for the three areas that were surveyed. A total of 868 individuals were recorded.

Species	All (Counts)	All (%)	Summer	Winter	A	B	C
Aardvark	25	2.9	9	16	0	25	0
Aardwolf	61	7.0	33	28	3	54	4
African wild cat	34	3.9	11	23	8	23	3
Black-backed jackal	5	0.6	5	0	0	0	5
Boer goat	33	3.8	33	0	33	0	0
Cape fox	2	0.2	0	2	0	2	0
Cape grysbok	48	5.5	25	23	40	0	8
Chacma baboon	130	15.0	79	51	63	33	34
Caracal	46	5.3	20	26	1	31	14
Cattle	110	12.7	69	41	110	0	0
Donkey	13	1.5	13	0	12	0	1
Gemsbok	86	9.9	39	47	0	65	21
Genet	27	3.1	18	9	17	1	9
Grey duiker	0	0.0	0	0	0	0	0
Grey rhebuck	27	3.1	23	4	1	17	9
Honey badger	13	1.5	10	3	2	5	6
Insect	0	0.0	0	0	0	0	0
Klipspringer	103	11.9	63	40	28	28	47
Lagomorpha	105	12.1	36	69	19	67	19
Mongoose	54	6.2	24	30	26	7	21
Ostrich	6	0.7	0	6	0	6	0
Cape porcupine	86	9.9	75	11	51	18	17
Reptile	2	0.2	2	0	2	0	0
Rock hyrax	111	12.8	60	51	24	3	84
Small birds	73	8.4	34	38	32	24	17
Small rodents	0	0.0	0	0	0	0	0
Springbok	23	2.6	18	5	0	23	0
Steenbok	4	0.5	0	4	0	0	4
Striped polecat	2	0.2	0	2	0	1	1
Zebra	36	4.1	30	6	0	36	0
Total	868		486	382	337	351	180

Appendix B

Data for each scat sample collected in the Cederberg Mountains, including scat diameter (cm) and species identified in the scat. GPS coordinates and altitude was also included where available.

No.	Species	Dia. (cm)	Location (South)	Location (East)	Altitude (m a.s.l.)
1	Baboon	2.3	-	-	-
2	Baboon	2.5	-	-	-
3	Rock hyrax	2.5	-	-	-
4	Klipspringer	2.0	32º29'24.8	19º22'58.0	-
5	Baboon, Klipspringer	2.0	32º29'22.0	19º23'06.0	-
6	Klipspringer	2.4	32º34'51.3	19º19'54.9	-
7	Rock hyrax, Lagomorpha	2.2	32º34'57.4	19º19'50.3	-
8	Klipspringer	2.6	32º34'00.0	19º21'00.7	-
9	Rock hyrax	2.9	32º29'19.4	19º23'09.2	928
10	Grey rhebuck	2.8	32º34'01.5	19º20'31.6	-
11	Klipspringer	2.8	32º24'21.3	19º05'16.1	581
12	Klipspringer, Rock hyrax	2.1	-	-	-
13	Klipspringer, Rock hyrax	2.4	-	-	-
14	Klipspringer, Rock hyrax, Lagomorpha	3.2	-	-	-
15	Klipspringer	2.6	32º24'24.0	19º08'43.6	987
16	Klipspringer	3.0	32º24'34.9	19º05'07.9	786
17	Klipspringer	2.9	32º24'36.7	19º05'09.7	824
18	Klipspringer	2.4	32º24'32.2	19º05'07.5	780
19	Klipspringer	3.2	-	-	-
20	Klipspringer	2.6	32º07'71.0	19º07'09.6	-
21	Klipspringer	2.5	32º30'24.0	19º23'38.0	-
22	Klipspringer	2.4	32º38'58.3	19º12'46.1	740
23	Klipspringer	2.2	32º38'47.4	19º12'46.0	-
24	Rock hyrax	1.9	32º29'23.6	19º29'15.3	525
25	Klipspringer	3.0	32º29'29.7	19º27'16.4	503
26	Klipspringer	2.6	32º29'31.8	19º27'20.6	512
27	Klipspringer	3.1	32º29'23.6	19º29'15.3	525
28	Klipspringer, Grey rhebuck	3.0	32º21'47.4	19º20'21.9	747
29	Grey rhebuck	2.9	32º24'29.0	19º21'31.1	1063
30	Klipspringer, Rock hyrax	2.2	32º21'49.0	19º20'23.5	736
31	Klipspringer, Rock hyrax	2.1	32º32'11.8	19º26'28.4	482
32	Lagomorph, Bird	1.9	32º37'11.3	19º26'29.3	450
33	Klipspringer, *Otomys* spp., Gerbil, Insect	2.1	32º35'22.3	19º20'05.1	719
34	Grey rhebuck	2.5	32º32'34.0	19º20'32.0	654
35	Cape grysbok	3.0	32º34'58.2	19º19'50.0	687
36	Klipspringer	2.5	32º30'16.1	19º23'23.5	756
37	*Otomys* spp., Gerbil	2.3	32º30'24.5	19º16'58.3	896
38	Grey rhebuck	3.0	-	-	-
39	Boer goat	2.3	32º08'28.7	19º05'20.3	495
40	Grey duiker	2.6	32º08'27.6	19º05'20.5	466
41	Rock hyrax	2.0	32º24'04.4	19º12'33.9	1333
42	Cape grey mongoose	-	32º30'01.5	19º19'37.8	745
43	Grey rhebuck	2.4	32º33'41.1	19º19'17.9	648
44	Cape grey mongoose	2.2	32º33'41.1	19º19'17.9	648

45	Cape grysbok	2.7	32º33'39.2	19º13'11.3	660
46	Cape grysbok, Cape grey mongoose, Verreaux's mouse	2.5	32º33'48.3	19º20'03.4	627
47	Rock hyrax, Grey duiker	2.3	32º33'48.2	19º20'02.4	626
48	Klipspringer	2.3	32º34'36.7	19º20'05.1	599
49	Rock hyrax, Lagomorpha, Gerbil	1.8	32º35'07.4	19º19'49.0	565
50	Klipspringer	2.4	-	-	-
51	Klipspringer, Rock hyrax	2.6	32º30'32.0	19º23'42.4	635
52	Rock hyrax	-	32º'3015.9	19º23'23.6	672
53	Rock hyrax	2.2	-	-	-
54	Klipspringer	2.0	-	-	-
55	Rock hyrax	2.4	32º34'42.3	19º20'02.1	653
56	Klipspringer	3.3	32º33'41.9	19º24'24.6	534
57	Klipspringer	2.0	32º29'29.0	19º27'15.6	-
58	Klipspringer	2.2	32º29'63.2	19º26'66.6	-
59	Aardwolf	2.2	-	19º20'27.2	-
60	Grey rhebuck	2.8	32º22'24.4	19º21'03.2	952
61	Klipspringer	2.0	32º22'16.6	19º22'33.7	906
62	Klipspringer, Gerbil, Bird	2.0	-	-	-
63	Boer goat	2.3	32º'2939.0	19º27'09.6	523
64	Rock hyrax, Klipspringer	2.0	-	-	-
65	Rock hyrax, Klipspringer	2.0	32º29'39.3	19º27'09.2	537
66	Klipspringer, Yellow mongoose, Lagomorpha	2.1	32º34'28.9	19º20'12.6	645
67	Klipspringer, Rock hyrax	2.0	32º29'15.6	19º26'55.8	600
68	Cape grey mongoose	2.1	-	-	-
69	Rock hyrax, Gerbil	2.0	32º'27'43.5	19º22'44.5	1077
70	Baboon	2.6	32º18'52.4	19º02'00.3	881
71	Klipspringer	2.1	-	-	-
72	Namaqua rock mouse, Bird	2.0	32º40'13.2	19º23'04.0	1123
73	Klipspringer	2.3	32º52'40.1	19º39'97.3	670
74	Rock hyrax	2.2	32º43'09.5	19º24'34.2	1302
75	Rock hyrax	2.5	32º30'23.2	19º23'30.4	680
76	Rock hyrax	2.2	32º40'16.2	19º22'16.2	1221
77	Rock hyrax, Lagomorpha	2.6	32º56'76.3	19º34'17.8	630
78	Grey duiker	2.4	32º50'30.7	19º28'82.8	913
79	Klipspringer, Rock hyrax	2.6	-	-	-
80	Springbuck	2.7	-	-	-
81	Boer goat	3.4	32º61'98.2	19º45'13.6	464
82	Lagomorpha	2.4	32º57'05.2	19º41'17.4	513
83	Lagomorpha, Porcupine	2.0	32º50'72.7	19º39'23.5	629
84	House rat, Bird, Lagomorpha, Rock hyrax	1.9	-	-	-
85	Rock hyrax	2.5	32º57'95.3	19º33'29.3	654
86	Water mongoose	2.7	-	-	-
87	Aardwolf	2.2	32º50'41.5	19º38'96.8	764
88	Rock hyrax	2.3	32º57'63.6	19º33'43.2	647
89	Rock hyrax	2.3	-	-	
90	Rock hyrax	2.2	32º36'42.0	19º36'42.0	638
91	Rock hyrax	2.0	32º40'25.2	19º19'35.4	1429
92	Lagomorpha, Striped mouse, Insect	2.2	32º25'39.4	19º02'86.2	316
93	Rock hyrax, Bird	2.1	32º40'63.6	19º14'64.7	979

94	Porcupine, Rock hyrax, Lagomorpha	3.0	32º29'64.5	19º27'15.5
95	Namaqua rock mouse, Striped mouse, Bird	2.0	-	-
96	Rock hyrax	2.0	-	-
97	Rock hyrax	2.5	-	-
98	Aardwolf	2.5	-	-

Appendix C

Data for each scat sample collected in the Gamka Mountains, including scat diameter (cm) and species identified in the scat. GPS coordinates and altitude was also included where available.

No.	Species	Dia. (cm)	Location (South)	Location (East)	Alt. (m a.s.l.)	Location
1	Baboon, Klipspringer	2.6	33º41'24.4	21º35'58.5	930	Rooiberg
2	Rock hyrax	2.3	33º41'22.7	21º35'31.3	920	Rooiberg
3	Klipspringer, Grey duiker	2.1	33º41'00.9	21º38'42.5	792	Rooiberg
4	Rock hyrax, Bird	2.2	33º41'26.9	21º35'44.0	926	Rooiberg
5	Klipspringer	2.4	33º41'20.9	21º35'27.6	912	Rooiberg
6	Klipspringer	2.1	33º41'20.9	21º35'27.6	912	Rooiberg
7	Grey rhebuck	2.1	33º41'23.2	21º36'02.4	927	Rooiberg
8	Klipspringer	2.6	33º41'24.4	21º35'58.5	930	Rooiberg
9	Grey rhebuck, Cape grey mongoose	2.0	33º41'23.4	21º35'34.4	925	Rooiberg
10	Grey duiker	3.0	33º41'26.9	21º35'44.0	926	Rooiberg
11	Rock hyrax	2.3	33º41'25.3	21º35'53.4	938	Rooiberg
12	Rock hyrax, Klipspringer	2.1	33º41'22.7	21º35'31.3	921	Rooiberg
13	Rock hyrax	2.0	33º41'22.7	21º35'31.3	920	Rooiberg
14	Cape grey mongoose	2.1	33º41'23.7	21º35'35.5	922	Rooiberg
15	Rock hyrax	2.6	33º41'03.6	21º38'33.9	802	Rooiberg
16	Klipspringer	2.0	33º41'04.3	21º37'09.6	825	Rooiberg
17	Rock hyrax, Cape grey mongoose, Reptile, Klipspringer	2.1	33º43'23.6	21º38'43.8	322	Rooiberg
18	Cape grysbok	2.5	33º43'28.1	21º39'45.2	266	Rooiberg
19	Klipspringer	2.8	33º43'27.9	21º39'50.5	256	Gamkaberg
20	Klipspringer, Rock hyrax	2.2	33º43'15.4	21º33'39.2	471	Rooiberg
21	Grey duiker	2.4	33º43'10.8	21º33'36.6	483	Rooiberg
22	Rock hyrax, *Otomys* spp.	2.4	33º31'11.3	21º37'09.4	239	Sandberg
23	Cape grey mongoose	2.1	33º31'07.2	21º37'05.8	217	Sandberg
24	Rock hyrax	2.0	33º30'53.1	21º37'09.4	210	Sandberg
25	Klipspringer	2.1	33º31'04.4	21º37'06.5	228	Sandberg
26	Klipspringer, Rock hyrax	2.3	33º31'10.8	21º37'09.4	238	Sandberg
27	Rock hyrax	2.0	33º31'05.4	21º37'06.1	227	Sandberg
28	Rock hyrax	2.1	33º30'53.1	21º37'09.4	209	Sandberg
29	Rock hyrax	2.7	33º30'54.8	21º37'08.4	245	Sandberg
30	Rock hyrax	2.5	33º30'33.1	21º37'18.9	258	Sandberg
31	Porcupine	2.3	33º31'03.5	21º37'06.7	228	Sandberg
32	Rock hyrax	2.2	33º31'08.0	21º37'05.9	228	Sandberg
33	Rock hyrax	2.6	33º31'10.3	21º37'08.4	246	Sandberg
34	Rock hyrax	2.4	33º31'11.0	21º37'20.9	227	Sandberg
35	Rock hyrax	2.0	33º30'53.8	21º37'08.7	228	Sandberg
36	Rock hyrax (infant)	2.0	33º30'32.1	21º37'18.9	235	Sandberg
37	Rock hyrax	2.0	33º30'37.8	21º37'18.7	219	Sandberg
38	Klipspringer, Rock hyrax	2.3	33º35'52.9	21º27'34.0	746	Rooiberg
39	House rat, Rock hyrax (infant), *Otomys* spp.	2.2	33º'37'52.0	21º38'26.0	315	Rooiberg
40	Klipspringer	2.0	33º27'42.8	21º35'35.4	412	Swartberg
41	Baboon	2.3	33º37'42.7	21º35'35.6	445	Rooiberg
42	Grey duiker	2.1	33º38'44.4	21º38'57.5	337	Rooiberg

43	Rock hyrax	2.5	33º37'36.6	21º35'44.3	417	Rooiberg
44	Steenbok	2.0	33º38'28.7	21º38'11.6	321	Rooiberg
45	Rock hyrax	2.0	33º37'45.8	21º35'42.0	408	Rooiberg
46	Porcupine	2.5	33º37'37.7	21º35'28.2	434	Rooiberg
47	Porcupine	3.1	33º'37'37.7	21º35'28.2	434	Rooiberg
48	Cape grysbok, Rock hyrax	2.0	33º37'37.7	21º35'28.2	434	Rooiberg
49	Rock hyrax	2.3	33º37'37.7	21º35'28.2	434	Rooiberg
50	Porcupine	2.3	-	-	-	Rooiberg
51	Striped mouse, Insect, *Otomys* spp.	2.0	-	-	-	Gamkaberg
52	Cape spiny mouse, Cape rock elephant shrew, Namaqua rock mouse, Hair-footed gerbil	2.0	-	-	-	Gamkaberg
53	Klipspringer	2.1	33º37'31.6	21º37'32.8	385	Rooiberg
54	House rat, Striped mouse	2.0	33º37'58.5	21º38'44.0	296	Rooiberg
55	Vlei rat, Lagomorph	2.4	33º37'16.5	21º36'13.6	463	Rooiberg
56	House rat, *Otomys* spp, Lagomorpha	2.1	33º37'33.6	21º37'39.1	371	Rooiberg
57	Rock hyrax (infant), Large spotted genet, Short-tailed gerbil, Striped mouse	2.0	33º38'07.8	21º39'07.2	267	Rooiberg
58	Klipspringer	2.0	33º42'52.4	21º53'13.5	1005	Gamkaberg
59	Baboon	2.5	33º42'49.4	21º53'15.2	1004	Gamkaberg
60	Rock hyrax	2.0	33º43'21.8	21º28'20.5	542	Rooiberg
61	Klipspringer, rock hyrax	2.3	33º43'19.7	21º28'20.3	553	Rooiberg
62	Rock hyrax	2.3	33º43'40.0	21º28'36.8	414	Rooiberg
63	House rat, Snake, Bird	2.0	33º43'36.0	21º56'38.0	96	Rooiberg
64	Striped mouse, *Otomys* spp, Grey rhebuck	2.0	33º43'27.8	21º39'17.7	294	Rooiberg
65	Klipspringer	2.2	33º43'26.8	21º39'00.9	299	Rooiberg
66	Klipspringer	2.4	33º43'24.4	21º38'47.4	339	Rooiberg
67	Cape grey mongoose, *Otomys* spp., Lagomorpha	2.0	33º38'15.4	21º37'45.1	348	Rooiberg
68	Rock hyrax	2.0	33º37'48.4	21º36'24.8	386	Rooiberg
69	Rock hyrax, *Otomys* spp.	2.1	33º38'8.3	21º37'18.5	373	Rooiberg
70	Rock hyrax (infant), House rat, Striped mouse, Namaqua rock mouse	2.0	33º38'13.5	21º40'05.7	252	Rooiberg
71	Grysbok, Tortoise	2.0	33º38'12.9	21º40'21.4	249	Rooiberg
72	Boer goat, Bird	2.0	33º38'13.7	21º40'06.3	263	Rooiberg
73	Klipspringer, Namaqua rock mouse	2.3	33º41'06.9	21º48'50.6	370	Gamkaberg
74	Namaqua rock mouse, *Otomys* spp.*	2.2	33º37'51.9	21º38'23.7	307	Rooiberg
75	Cape grysbok	2.4	33º38'34.0	21º29'43.0	1409	Rooiberg
76	Grey rhebuck	2.3	-	-	-	Rooiberg
77	Grey rhebuck, Striped mouse, House rat, Bush vlei rat, Insect	2.0	33º38'31.5	21º38'54.6	298	Rooiberg

* Two different *Otomys* species; vlei rat and bush vlei rat

Appendix D

The survey number and area; A refers to farmland, B to game farm and C to a conservation area. The location and date each survey started and ended are also provided. The survey included 4 597 days of camera trap surveillance.

Survey	Survey Area	Date (Start)	Date (End)	Location (South)	Location (East)	Altitude (m asl)	Survey Time (days)
1	A	11/12/2004	12/22/2004	32º37'41.8	19º26'11.1	479	40
2	A	11/12/2004	12/22/2004	32º37'15.6	19º26'49.5	426	40
3	A	11/12/2004	12/19/2004	32º36'31.3	19º26'58.7	436	37
4	A	11/12/2004	12/22/2004	32º35'53.8	19º26'18.0	456	40
5	A	11/12/2004	12/22/2004	32º35'19.4	19º25'47.5	487	40
6	A	11/12/2004	12/22/2004	32º34'28.2	19º25'25.4	511	40
7	A	11/12/2004	12/22/2004	32º34'22.4	19º24'52.6	519	40
8	A	11/12/2004	12/22/2004	32º34'05.3	19º24'35.4	512	40
9	A	11/12/2004	12/22/2004	32º33'42.3	19º23'24,8	528	40
10	A	11/12/2004	12/22/2004	32º33'39.3	19º23'06.6	514	40
11	A	11/11/2004	12/21/2004	32º33'57.5	19º21'10.7	612	40
12	A	11/11/2004	12/21/2004	32º33'56.0	19º20'48.7	619	40
13	A	11/11/2004	12/21/2004	32º34'31.6	19º20'10.1	627	40
14	A	11/22/2004	12/21/2004	32º35'07.3	19º19'48.9	671	29
15	A	11/11/2004	12/21/2004	32º32'24.5	19º24'52.8	839	40
16	A	11/11/2004	12/21/2004	32º31'50.7	19º24'26.5	705	40
17	A	11/11/2004	12/21/2004	32º31'40.8	19º24'20.9	771	40
18	A	11/11/2004	12/21/2004	32º31'25.1	19º23'54.9	701	40
19	A	11/11/2004	12/21/2004	32º32'07.5	19º23'30.3	924	40
20	A	11/11/2004	12/21/2004	32º32'24.2	19º23'07.0	975	40
21	A	05/17/2005	06/26/2005	32º37'41.8	19º26'01.1	479	40
22	A	05/17/2005	06/26/2005	32º37'15.6	19º26'49.5	426	40
23	A	05/17/2005	06/26/2005	32º36'31.3	19º26'58.7	436	40
24	A	05/17/2005	06/26/2005	32º35'53.8	19º26'18.0	456	40
25	A	05/17/2005	06/26/2005	32º35'19.4	19º25'47.5	487	40
26	A	05/15/2005	06/24/2005	32º34'28.2	19º25'25.4	511	40
27	A	05/15/2005	06/24/2005	32º34'22.4	19º24'52.6	519	40
28	A	05/15/2005	06/24/2005	32º34'05.3	19º24'35.4	512	40
29	A	05/15/2005	06/24/2005	32º33'42.3	19º24'24.8	528	40
30	A	05/15/2005	06/23/2005	32º33'57.7	19º21'10.7	612	39
31	A	05/15/2005	06/24/2005	32º33'56.0	19º20'48.7	619	40
32	A	05/15/2005	06/24/2005	32º34'31.6	19º20'10.1	627	40
33	A	05/15/2005	06/24/2005	32º35'07.3	19º19'48.9	671	40
34	A	05/17/2005	06/26/2005	32º32'24.5	19º24'52.8	839	40
35	A	05/15/2005	06/24/2005	32º31'50.7	19º24'26.5	705	40
36	A	05/15/2005	06/24/2005	32º31'40.8	19º24'20.9	771	40
37	A	05/15/2005	06/24/2005	32º31'27.0	19º24'00.0	701	40
38	A	05/15/2005	06/18/2005	32º32'07.5	19º23'30.3	924	34
39	A	05/15/2005	06/24/2005	32º32'24.2	19º23'07.0	975	40
40	B	12/24/2004	02/03/2005	32º24'43.1	19º23'14.1	818	41
41	B	12/24/2004	02/03/2005	32º23'49.4	19º22'42.8	800	41
42	B	12/24/2004	02/03/2005	32º22'56.1	19º22'44.9	663	41
43	B	12/24/2004	02/03/2005	32º21'53.3	19º22'08.2	641	41

44	B	12/24/2004	02/03/2005	32º21'35.5	19º22'04.8	613	41
45	B	12/24/2004	02/03/2005	32º21'35.5	19º22.04.8	613	41
46	B	12/24/2004	02/03/2005	32º21'46.3	19º20'21.3	740	41
47	B	12/24/2004	02/03/2005	32º22'01.8	19º20'29.1	727	41
48	B	12/24/2004	02/03/2005	32º22'48.6	19º20'49.1	702	41
*49	B	12/24/2004	02/02/2005	32º24'11.9	19º21'05.7	1066	40
49	B	02/18/2005	02/27/2005	32º24'11.9	19º21'05.7	1066	9
50	B	12/24/2004	02/02/2005	32º25'07.7	19º20'22.9	1179	40
51	B	12/24/2004	02/03/2005	32º25'16.8	19º21'47.1	1142	41
52	B	12/26/2004	02/04/2005	32º20'52.3	19º18'31.7	875	40
53	B	12/26/2004	02/04/2005	32º21'04.7	19º19'16.9	937	40
54	B	12/26/2004	02/04/2005	32º20'20.7	19º18'43.5	973	40
55	B	12/26/2004	01/25/2005	32º19'44.5	19º20'47.6	739	30
56	B	12/26/2004	02/04/2005	32º19'33.0	19º19'40.6	819	40
57	B	12/26/2004	02/02/2005	32º19'33.0	19º19'40.6	819	38
58	B	12/26/2004	02/04/2005	32º19'25.1	19º17'51.9	1030	40
59	B	12/26/2004	02/04/2005	32º19'47.4	19º17'14.7	964	40
60	B	06/27/2005	08/07/2005	32º24'43.1	19º23'14.1	818	41
61	B	06/27/2005	07/25/2005	32º23'49.4	19º22'42.8	800	28
62	B	06/27/2005	08/07/2005	32º22'56.1	19º22'44.9	663	41
63	B	06/27/2005	08/07/2005	32º21'53.3	19º22'08.2	641	41
64	B	06/27/2005	08/07/2005	32º21'35.5	19º22'04.8	613	41
65	B	06/27/2005	08/02/2005	32º21'35.5	19º22'04.8	613	36
66	B	06/27/2005	08/07/2005	32º21'46.3	19º20'21.3	740	41
67	B	06/27/2005	08/07/2005	32º22'01.8	19º20'29.1	727	41
*68	B	06/27/2005	08/01/2005	32º22'48.6	19º20'49.1	702	35
68	B	08/05/2005	08/07/2005	32º22'48.6	19º20'49.1	702	2
69	B	06/27/2005	08/07/2005	32º24'11.9	19º21'05.7	1066	41
70	B	06/27/2005	08/07/2005	32º25’07.7	19º20'22.9	1179	41
71	B	06/27/2005	07/28/2005	32º25'16.8	19º21’47.1	1142	31
72	B	06/28/2005	08/07/2005	32º20'52.3	19º18'31.7	875	40
73	B	06/28/2005	08/07/2005	32º21'04.7	19º19'16.9	937	40
74	B	06/28/2005	08/07/2005	32º20'20.7	19º18'43.5	973	40
75	B	06/28/2005	08/07/2005	32º19'44.5	19º20'47.6	739	40
76	B	06/28/2005	08/01/2005	32º19'33.0	19º19'40.6	819	34
77	B	06/28/2005	08/07/2005	32º19'33.0	19º19'40.6	819	40
78	B	06/28/2005	08/05/2005	32º19'25.1	19º17'51.9	1030	38
79	B	06/28/2005	08/07/2005	32º19'47.4	19º17'14.7	964	40
80	C	02/04/2005	03/16/2005	32º29'18.1	19º27'09.0	556	40
81	C	02/04/2005	04/25/2005	32º29'32.1	19º27'20.3	514	80
82	C	02/04/2005	03/16/2005	32º29'30.9	19º28'49.0	522	40
83	C	02/04/2005	03/16/2005	32º29'09.7	19º28'39/1	554	40
84	C	02/04/2005	03/16/2005	32º28'40.0	19º28'28.2	575	40
85	C	02/04/2005	03/16/2005	32º28'12.6	19º28'18.7	586	40
86	C	02/04/2005	03/16/2005	32º27'48.8	19º28'01.6	585	40
87	C	02/04/2005	02/21/2005	32º29'01.0	19º25'59.6	971	17
88	C	02/04/2005	03/17/2005	32º29'50.2	19º25'35.1	906	13
89	C	02/16/2005	03/05/2005	32º28'41.1	19º22'42.6	934	17
90	C	02/05/2005	03/18/2005	32º29'45.2	19º21'58.3	861	41
91	C	02/05/2005	03/18/2005	32º30'30.8	19º26'14.7	621	41

92	C	02/05/2005	03/18/2005	32º30'32.7	19º23'42.2	666	41
93	C	02/05/2005	03/18/2005	32º30'00.3	19º23'19.7	702	41
94	C	02/05/2005	03/18/2005	32º29'36.8	19º23'14.0	741	41
95	C	02/05/2005	03/18/2005	32º29'28.2	19º22'50.5	784	41
96	C	02/05/2005	02/07/2005	32º29'34.7	19º21'07.6	839	2
97	C	02/03/2005	03/17/2005	32º31'02.7	19º21'13.4	728	42
98	C	02/03/2005	03/17/2005	32º31'43.1	19º20'39.6	829	42
99	C	08/09/2005	10/05/2005	32 29'18.1	19 27' 09.0	556	57
100	C	08/09/2005	10/06/2005	32 29'32.1	19 27' 20.3	514	58
101	C	09/03/2005	10/05/2005	32 29'30.9	19 28' 49.0	522	32
102	C	08/09/2005	09/19/2005	32 29'09.7	19 28' 39.1	554	41
103	C	08/09/2005	08/29/2005	32 28'40.0	19 28' 28.2	575	20
104	C	08/09/2005	10/07/2005	32 28'12.6	19 28' 18.7	586	59
105	C	08/09/2005	10/05/2005	32 27'48.8	19 28' 01.6	585	57
106	C	08/09/2005	09/13/2005	32 28'41.4	19 22' 42.6	934	35
107	C	08/09/2005	10/04/2005	32 29'45.2	19 21' 58.3	861	56
108	C	08/09/2005	09/22/2005	32 30'32.7	19 23' 42.2	666	44
109	C	08/09/2005	10/04/2005	32 30'00.3	19 23' 19.7	702	56
110	C	08/09/2005	10/04/2005	32 29'36.8	19 23' 14.0	741	56
111	C	08/09/2005	10/03/2005	32 29'28.2	19 22' 50.0	784	55
112	C	08/08/2005	09/29/2005	32 29'34.7	19 21' 07.6	839	52
113	C	08/08/2005	09/14/2005	32 31'02.7	19 21' 13.4	728	37
114	C	08/08/2005	09/06/2005	32 31'43.1	19 20' 39.6	829	29
115	C	08/08/2005	09/13/2005	-	-	-	36

* Indicated surveys that were divided into two sections.