The roles of black-backed jackals and caracals in issues of human-wildlife conflict in the Eastern Cape, South Africa.

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Abstract

Human-wildlife conflict is a widely observed phenomenon and encompasses a range of negative interactions between humans and wildlife. Depredation upon livestock and game species proves to be the prevalent form of this conflict and often results in the killing of carnivores. Within the South African context, despite intense lethal control, two sympatric mesopredators, the black-backed jackal (*Canis mesomelas*) and the caracal (*Caracal caracal*), remain common enough to be considered a major threat to human livelihoods through depredation. Wildlife ranches and livestock farms dominate the landscape in the Eastern Cape Province. Moreover, human-predator conflict within the region is extensive as both the black-backed jackal and caracal are seen to be inimical by landowners. Understanding this conflict is essential for mitigating any potential adverse environmental reactions (i.e. range collapses or extinctions) and requires knowledge of anthropogenic, ecological and environmental factors. I interviewed 73 land owners across five municipal boundaries in the Eastern Cape to quantify perceptions of predator control methods. A total of 4 529 head of livestock (3.4 % of total livestock owned) were reportedly lost due to depredation between March 2013 and July 2014. Futhermore, 732 black-backed jackal and 435 caracal were killed across the study area. The approach believed to be most effective at alleviating conflict with predators was lethal control, a method used by 73 % of respondents. However, no single method of predator control was able to halt conflict completely. The behavioural plasticity of both mesopredators probably allowed for adaptation to different control techniques. Surprisingly, stock loss (the number of animals lost to predators) was not a significant predictor of which predator control method was preferred by the respondents. However, the widespread use of both lethal and non-lethal predator control measures in the study area suggests that a hyperawareness of risk may exist amongst respondents. This risk may come in the form of the perceptions of livestock/game lost, the alleged potential for wildlife ranches to act as refuges for mesopredators, or even the mere presence of the predator. A dietary analysis conducted on culled black-backed jackals within the study area indicated a high relative frequency of occurrence of common duiker (*Sylvicapra grimmia*; 77 %), scrub hare (*Lepus saxatilis*; 75 %) and introduced nyala (*Tragelaphus angasii*; 63 %). The presence of large wild ungulates in the diet could indicate that black-backed jackals may pose a threat to the livelihoods

of wildlife ranchers who breed wild ungulates for profit. While no livestock remains were observed in the stomachs of the culled black-backed jackals, this could be due to the small (n = 30) sample size and should be interpreted with caution. The methods used to cull the black-backed jackals examined for this part of my study did not discriminate between sexes or age classes, indicating a lack of selectivity. Such blanket removal could have negative effects on the ecosystem (e.g. facilitating the increase in abundance of sympatric predators, such as caracal, thereby exacerbating the issue). My study has shown that the issue of human-mesopredator conflict in the Eastern Cape is more complex than simply livestock depredation. Without knowledge surrounding the ecological and social impacts of mesopredator control, long-term outcomes cannot be predicted. Future studies should be dedicated to assessing the ecological role played by both mesopredators within the Eastern Cape to aid future mitigation efforts.

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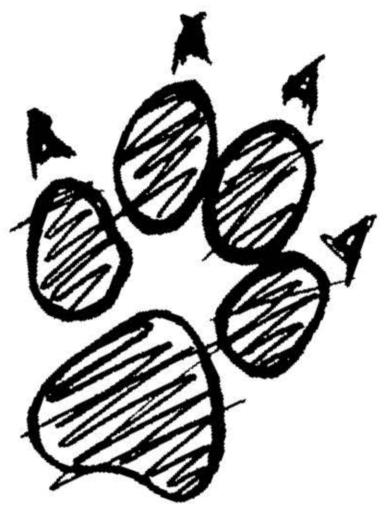

Chapter 1
General introduction

3.1 INTRODUCTION

An overview of human-wildlife conflict

Humans have interacted with wildlife for millennia, with both positive and negative outcomes (Thirgood *et al.* 2005). The term 'human-wildlife conflict' encompasses a plethora of negative interactions between humans and wildlife, including crop raiding by elephants (*Loxodonta africana*; Naughton-Treves 1999; Knickerbocker & Wiathaka 2005) and the subsequent persecution of the elephants (Osborn & Hill 2005). Through disease transmission (e.g. badgers, *Meles meles*, and bovine tuberculosis, *Mycobacterium bovis*; Tuyttens *et al*. 2000; Carter *et al*. 2007) and the removal of badgers in order to decrease this risk (Treves & Naughton-Treves 2005). Other issues include the killing/attacking of humans (Herrero 1985) by predators, such as bears (*Ursus* spp.), followed by the general persecution of these animals (Herrero 1985). However, the most common form of conflict, is that of livestock/game depredation by carnivores (Thirgood *et al*. 2005; Treves & Naughton-Treves 2005; Sillero-Zubiri *et al*. 2007; Muir 2010). Livestock depredation occurs due to a variety of factors involving the prey, the predator and the land owner (Thirgood *et al.* 2005; Treves & Naughton-Treves 2005). Domestic livestock have lost most of their anti-predator behaviour and are therefore an easy target for predators. In addition, competition between livestock and native prey species may cause a decrease in native prey abundance (Thirgood *et al*. 2005). Moreover, changes in livestock husbandry techniques (or the lack thereof) and the negative perceptions of predators by land owners increase the risk of depredation and retaliatory killing of predators (Treves & Karanth 2003; Inskip & Zimmermann 2009).

The factors driving human-predator conflict are complex and diverse, ranging from individual beliefs, socio-economic backgrounds, and the behaviour of the predator (Suryawanshi *et al*. 2014). On an individual basis, the perception of predators will vary and any form of negative experience with a predator may drive the land owner to react in a hostile manner towards the predator (Heberlein 2012). In addition, human-predator conflict often reflects an economic concern by land owners to protect their livestock/game (Graham *et al*. 2005; Gusset *et al*. 2009; Gervasi *et al*. 2014). Some land owners may respond to this threat using illegal methods (e.g. poison; Ogada 2014) in an attempt to defend their livelihoods (Gusset *et al*. 2009). Overall, the economic concerns of the land owner are the basis for their perceptions of predators (Delibes-Mateos *et al*. 2013). Landowners who raise livestock for sale generally exhibit a higher rate of retaliatory killing than those who keep livestock for personal use (Hazzah *et al*. 2009). However, the actual number of livestock killed by predation may be lower than perceived figures. In the Masai steppe, disease claimed more livestock than depredation (10 times greater for cattle, *Bos primigenius;* and five times greater for goats, *Capra hircus*.; Kissui 2008). These pastoralists believed that the numbers lost to predators were high enough to justify the killing of lions (*Panthera leo*), leopards (*Panthera pardus*) and spotted hyenas (*Crocuta crocuta*; Kissui 2008). In some instances even if compensation is offered it may not change an owner's willingness to accept predators (Gusset *et al*. 2009). The large home ranges required by predators and their subsequent dispersal across human-dominated land increases the risk of this form of conflict (Treves & Karanth 2003; Graham *et al*. 2005). Furthermore, the competition for space resources is exacerbated by the encroachment of humans on natural habitat (Michalski *et al*. 2006). This inevitably affects prey abundances through 'natural' game depletion and the high stocking densities of livestock (Graham *et al*. 2005).

What is often neglected by the land owner is that most animals live within species-rich and complex communities, while issues of conflict are often simplistically described as 1 predator : 1 prey (Graham *et al*. 2005). This perception has led to a crude view of trophic interactions (Graham *et al*. 2005; Woodroffe *et al.* 2005). Significantly, many 'problem animal' species are often also keystone species and their ensuing removal can affect the entire ecosystem (Woodroffe *et al.* 2005). Ecological cascades are defined as the interactions between trophic levels (e.g. predators and their prey), where changes at one level can impact upon the biomass, abundance and productivity of another trophic level (Pace *et al*. 1999). One of the best-known trophic cascades was demonstrated in Yellowstone National Park, USA. When wolves (*Canis lupus*) were reintroduced, they greatly impacted upon the abundance and diversity of the flora and fauna, as well as the ecological stability of the area (Berger *et al*. 2001; Ripple & Beschta

2003, 2004; Ripple *et al*. 2013). Following this reintroduction, the abundance of cervids (i.e. elk, *Cervus elaphus*; moose, *Alces alces*) decreased through predation. Furthermore, the presence of the wolves altered the behaviour of the ungulates by creating a landscape of fear, whereby the ungulates avoided certain areas in the park as they viewed them to be too hazardous (Ripple & Beschta 2003, 2004). Within these avoided areas, the trees (aspen, *Populus tremuloides*; cottonwoods, *P. angustifolia* and *P. balsamifera*; willow, *Salix* spp.) began to grow, which then allowed for an increase in certain bird species, bears (*Ursus arctos*) and beavers (*Castor canadensis*; Berger *et al*. 2001; Ripple & Beschta 2004). Since beavers are keystone species when it comes to river hydrology, they in turn impacted upon the diversity and ecological stability of the area by altering drainage patterns. The reintroduction of wolves also decreased the impact of coyote (*Canis latrans*) predation on the pronghorn (*Antilocapra americana*) population (Berger *et al*. 2008; Ripple *et al*. 2013). The Yellowstone example illustrates the inter-connected nature of terrestrial ecosystems and how, through 'top-down forcing', a predator can impact upon the functioning of an entire ecosystem (Berger *et al*. 2001; Ripple & Beschta 2003, 2004).

Historically, humans have attempted to decrease conflict with predators by killing them. Lethal predator control can be defined as the effort to reduce or eliminate predators in order to protect human lives or livelihoods (Treves & Naughton-Treves 2005). Examples of such control efforts exist as far back as 800 AD when Emperor Charlemagne tasked professional hunters with removing wolves from central Europe (Boitani 1995). Furthermore, both legal and illegal means have been used to kill predators over time (Woodroffe *et al.* 2005). However, the blanket removal of predators from a system can have negative consequences such as species extinctions (Woodroffe *et al.* 2005). For example, the Guadalupe Caracara (*Polyborus lutosus*) of Mexico went extinct in 1990 due to perceptions that this bird preyed on juvenile goats (Woodroffe *et al.* 2005). Similarly, the Falkland Island wolf (*Dusicyon australis*) was exterminated by sheep farmers from the Falkland Islands in 1876 (Woodroffe *et al.* 2005). Predator species which have limited geographical range, such as the now extinct thylacine (*Thylacinus cynocephalus*) in Tasmania, are especially at risk (McKinght 2008). Predators are particularly vulnerable to population declines due to their slow life histories, large home ranges, complex social structures and low population densities (Treves & Karanth 2003; Kissui 2008). Therefore, given their role in structuring ecosystems, the conservation of carnivores must be viewed as a global priority (Blaum *et al*. 2009). However, this objective is often at odds with the priorities of pastoralists whose livelihoods depend on the continued survival of their farmed animals (Treves & Naughton-Treves 2005; Graham *et al*. 2005). Consequently, it can be said that the conservation of many predators is ultimately dependent upon the attitudes and management activities of land owners (Treves & Karanth 2003; Lindsey *et al*. 2005; Stein *et al*. 2010). However, the lethal control of predators need not always cause negative consequences, as some methods, if correctly used, may allow for mitigation of unselective predator control (Treves & Naughton-Treves 2005). In the Swiss Alps, where the availability of wild prey was considered high, habitual stock-raiding lynx (*Lynx lynx*) were shot (Angst 2001). Most of the lynx preferentially preyed upon the native species (roe deer, *Capreolus capreolus*; and chamois, *Rupicapra rupicapra*), therefore infrequent removal of specific problem animals did not affect the population (Breitenmoser *et al.* 2005). By assessing the risks and benefits of individual situations, lethal control can play a legitimate role in wildlife management and even contribute towards the conservation of predators (Treves & Naughton-Treves 2005). However, the impact of site-effects must always be noted when assessing human-wildlife conflict. For example, on the French Jura, the removal of problem animals only temporarily reduced the issue of livestock depredation (Stahl *et al*. 2001). Over the long term (sometimes even weeks), livestock depredation events reappeared at specific sites, indicating that other methods (e.g. shepherding with guard dogs, *Canis familiaris*) need consideration (Stahl *et al*. 2001).

A brief history of pastoralism and lethal predator control in South Africa

While better known for its extensive shipping industry and mineral production, South Africa is a significant area for sheep (*Ovies aries*) and cattle farming (Beinart 2003). Throughout the 18th century, trekboers (nomadic pastoralists) initiated one of the first forms of an itinerant pastoral economy by following game and water sources while pushing out indigenous people (Beinart 2003). The trekboers farmed the indigenous Khoikhoi fat-tailed sheep, and when the British took over the Cape in 1806, the total population of these sheep approximated over one million (Beinart 2003). The sheep industry was then dominated by European settlers, both Boer and British (Beinart 2003).

Indigenous livestock species, such as types of fat-tailed sheep, were kept in areas of low rainfall while imported species such as merino sheep and angora goats were generally kept in the east, which had higher annual rainfall (Beinart 2003). However, the ever-present threat of carnivores allowed for the development of vermin eradication campaigns in South Africa from the 1880s (van Sittert 1998). As such, wild carnivores were exempt from the Game Protection Act of 1888 and were seen to be pests that had to be exterminated (van Sittert 1998; Beinart 2003). At this time, the threat of livestock depredation was minimal compared to the impact of environmental factors and disease (van Sittert 1998). However, land owners had a disproportionate perception of the impact of carnivores (van Sittert 1998) and several predator control methods were employed.

Initially, packs of hounds were used to hunt problem animals in the Cape Colony (Beinart 2003; Du Plessis 2013). However, with the advent of the Fencing Act (1883), it became difficult for the land owners to track the hounds across farmlands (Hey 1964; van Sittert 1998). Not only this, but the increase in the appeal of poison decreased the use of hunting dogs, as many of the hounds fell victim to the land owner's other predator control methods (Hey 1964; van Sittert 1998). Trapping using cage traps was commonly used to hunt felid species (e.g. leopards, caracals, *Caracal caracal*), but it was not very efficient and was also time consuming (Hey 1964; van Sittert 1998). Poison, again, was deemed to be the better method due to time constraints, cost effectiveness and the lethality of the method (Hey 1964; van Sittert 1998). With the advent of 'jackal-proof' (predator proof) fencing, the use of poison declined, as fencing was viewed as the new 'silver bullet' for preventing livestock depredation (van Sittert 1998).

The term 'jackal' encompassed not only the typical black-backed jackal (*Canis mesomelas*) but a variety of other species, such as aardwolf (*Protele cristatus*) or bat-eared fox (*Otocyon megalotis*; van Sittert 1998), all of which were believed to kill livestock. The official body count of predators removed from the Cape colony did not reflect the true number removed from the population, mostly because poisoned predator carcasses were difficult to locate (van Sittert 1998). It was evident that due to the eradication of jackals (identified as most canid species), there were subsequent negative environmental effects in the form of increasing populations of rodents/small mammals (e.g. rock hyraxes, *Procavia capensis*) and the impact of large numbers of livestock changing the landscape (van Sittert 1998; Eccard *et al*. 2000; Prugh *et al*. 2009). However, this did not decrease the negative perception held by land owners towards predators in South Africa (van Sittert 1998; Beinart 2003). A study assessing the impact of human-wildlife conflict was conducted in KwaZulu-Natal, South Africa for an 11 month period (July 1986 – June 1987). A total of 159 respondents were required to keep records of livestock predation events (Lawson 1989). Overall, black-backed jackals, domestic dogs and caracals were the most often implicated predators in livestock depredation events (Lawson 1989).

While the control of 'vermin' decimated some carnivore populations (e.g. African wild dogs, *Lycaon pictus*), black-backed jackal and caracal populations appeared to be unaffected in southern Africa (van Sittert 1998; Beinart 2003). Both the black-backed jackal and the caracal are inimical on farmland due to livestock depredation, to the extent that both have been classified as damage-causing animals in South Africa (Cape Problem Animal Control Ordinance, No. 26 of 1957). This classification has led to the widespread lethal control of both species (Beinart 2003; Inskip & Zimmermann 2009). Subsequently, over 2 000 caracal were killed between 1931 and 1952 in the Karoo (Marker & Dickman 2005). Furthermore, livestock farming is of great economic importance in the Eastern Cape and ultimately the South African economy (van Sittert 1998; Beinart 2003). Thus, the impact of livestock depredation by both black-backed jackals and caracals has the potential to put substantial pressure on the economic viability of the industry.

1.2. MOTIVATION FOR MY STUDY

While several studies have been conducted on the lethal control of both black-backed jackals and caracals (Hey 1964, 1967; Rowe-Rowe 1975; Rowe-Rowe & Green 1981; Palmer & Fairall 1988; Lawson 1989; Conradie 2012; Thorn *et al*. 2012, 2013), no research has been done on the impact and extent of lethal control on these two mesopredators (middle ranking predators). In addition, many conflict studies focus on the larger carnivores such as lions, leopards and African wild dogs, and there is a general lack of knowledge surrounding the smaller predator species (Inskip & Zimmermann 2009). Little is known about the extent and use of predator control methods and the role of black-backed jackals and caracals in livestock depredation. Significantly, both species can occur sympatrically and may represent the top predator in many ecosystems (Loveridge & Nel 2008).

The deliberate removal of wildlife can be a threat to certain species and it is therefore essential to record the effects of these efforts (Treves & Naughton-Treves 2005). If managed properly, lethal control may aid in reducing the illicit killing of carnivores (Treves & Naughton-Treves 2005). It may also provide benefits to conservation efforts (e.g. trophy hunting) and the selective removal of problem animals may cause conspecifics to avoid humans, thereby decreasing conflict (Treves & Naughton-Treves 2005; Woodroffe & Frank 2005). However, the complete elimination of both black-backed jackals and caracals will not be beneficial to the land owner because of the ecosystem services (e.g. controlling rodent populations) they provide (Thorn *et al*. 2012). My research therefore aimed to determine the extent of the use and perceived efficacy of lethal and non-lethal predator control methods for black-backed jackals and caracals within the Eastern Cape Province, South Africa. I also investigated the demography and mammalian diet of legally culled black-backed jackals on two land use types, both wildlife ranches and livestock farms, within the Eastern Cape. This second aspect was included in order to allow for the assessment of the impact of the two predator species on livestock (i.e. livestock consumption), the possible effect of land use type on diet and to describe the potential demographic consequences of lethal control on black-backed jackal populations.

Culled black-backed jackal left on a fence from the previous night's hunting

Chapter 2
Study species & study area

2.1. STUDY SPECIES

Black-backed jackal

The black-backed jackal (*Canis mesomelas*), first described in 1775 by Schreber, is a common and widespread species, occurring in two discrete regions of Africa. The northern territory extends from the Gulf of Aden to southern Tanzania, with the southern territory extending from south-west Angola to South Africa (Figure 2.1; Skinner & Chimimba 2005, Hoffman 2014). The only other mammals with similar distribution patterns are the bat-eared fox (*Otocyon megalotis*) and the aardwolf (*Proteles cristatus*; Hoffman 2014). In the eastern part of its range, this jackal co-exists with the golden jackal (*Canis aureus*; eastern range) and the side-striped jackal (*C. adustus*, eastern and southern range; Skinner & Chimimba 2005). The black-backed jackal has a wide habitat tolerance, demonstrated by its widespread abundance (Moehlman 1987).

Figure 2.1: The distribution of black-backed jackal *Canis mesomelas* (dark grey) extending from the Gulf of Aden to southern Tanzania, and the southern territory ending in South Africa (IUCN 2014).

The black-backed jackal is one of five canids found in southern Africa (Figure 2.2; Skinner & Chimimba 2005; Skead 2007). This jackal has the characteristic feature of a black-silver saddle extending from the nape of the neck to the base of the tail (Figure 2.2; Skinner & Chimimba 2005). These canids are monogamous and may hold a territory for life, with the breeding season occurring between August and November in the Eastern Cape, South Africa (Loveridge & Nel 2004; Skinner & Chimimba 2005). Litter sizes range from one to six, with three pups being the most common. Both sexes take part in the feeding and rearing of young (Loveridge & Nel 2004; Skinner & Chimimba 2005). Initially, food is regurgitated by both parents and after eight – nine weeks, solid food is carried back to the den for the pups (Loveridge & Nel 2004).

Figure 2.2: Black backed jackals (*Canis mesomelas*) have a characteristic black-silver saddle extending from the neck region to the base of the tail (Photo: Chad Wright).

Extremely difficult to trap, these canids are wary of humans, especially where anthropogenic disturbance is high (Skinner & Chimimba 2005). The black-backed jackal is listed as 'least concern' by the IUCN (International Union for the Conservation of Nature), with the major threats to the species being disease (e.g. rabies) and retaliatory killing due to livestock depredation (Hoffman 2014). Despite intense lethal control, mostly in South Africa, this canid remains common throughout its range due to behavioural plasticity and a catholic diet (Beinart 2003; Klare *et al.* 2010; Kamler *et al.* 2012; Van de Ven *et al.* 2013). The diet of the black-backed jackal is discussed in more detail in Chapter 4. However, the role of black-backed jackals as livestock predators is controversial (Rowe-Rowe 1975; Stuart 1981; Lawson 1989; Kamler *et al.* 2012). Furthermore, most of the data surrounding black-backed jackal livestock depredation may be biased towards perceived problem animals and poorly designed diet studies (Stuart 1981). Nevertheless, a study conducted on a small-livestock farm in Kimberley, South Africa, indicated that while sheep (*Ovies aries*) comprised as much as 48 % of black-backed jackal diet at certain times of year (Kamler *et al*. 2012), jackals may preferentially kill and eat wild ungulates over sheep.

Caracal

First described in 1776 by Von Schreber, the caracal (*Caracal caracal*) was originally grouped with the lynxes (*Lynx* spp.) due to morphological similarities (Skinner & Chimimba 2005). However, due to a lack of phylogenetic evidence (Werdelin 1981), this felid was later placed into the monophyletic genus *Caracal* (Wozencraft 1993). The caracal has a uniform coat, with colours ranging from pale-light red to brick red (Figure 2.3; Skinner & Chimimba 2005). Other characteristic features are the tufted ears and short tail (Figure 2.3; Skinner & Chimimba 2005). This felid is common and widespread throughout its distribution which stretches from Africa, through the Middle East and into India (Figure 2.4; Skinner & Chimimba 2005; Skead 2007; Breitenmoser *et al.* 2008). Despite the wide distribution, data on this felid are limited relative to other, larger felid species (e.g. leopards, *Panthera pardus*; lions, *P. leo*; Braczkowski *et al*. 2012). Litters have been reported throughout the year, however females generally have only one litter per annum (Bernard & Stuart 1987; Skinner & Chimimba 2005). It is speculated that breeding occurs during periods of high food availability (Bernard & Stuart 1987). The youngest age recorded for reproducing was 12.5 – 15 months for males and 14 – 16 months for females (Bernard & Stuart 1987). Caracals have been categorized as 'least concern' by the IUCN, with retaliatory killing and habitat destruction (in Asia) listed as the major threats to the persistence of the species (Breitenmoser *et al.* 2008).

Figure 2.3: The caracal *Caracal caracal* has a characteristic uniform coat, short tail and tufted ears (Photo: David Ryan).

Figure 2.4: The distribution of *Caracal caracal* (dark grey) extending from Africa through the Middle East and into India (IUCN 2014).

Similar to the black-backed jackal, the diet of the caracal is often influenced by the most abundant prey species available (Avenant & Nel 2002; Kok & Nel 2004; Braczkowski *et al*. 2012), as well as temporal differences (Stuart 1982; Stuart & Hickman 1991; Avenant & Nel 2002). For example, during low rodent density caracals were found to prey more upon springbok (*Antidorcus marsupialis*) which became more abundant on a wildlife ranch in South Africa (Avenant & Nel 2002).

Mammals make up the majority of the caracal's diet, however the importance of different mammalian species varies (Table 2.1; Stuart & Hickman 1991; Avenant & Nel 2002; Melville *et al*. 2004; Braczkowski *et al*. 2012). Rodents have been found to be the dominant mammalian prey for this felid (Table 2.1; Avenant & Nel 2002; Mukherjee *et al*. 2004; Braczkowski *et al*. 2012). The role of caracal as a livestock predator, not unlike that of the black-backed jackal, is controversial (Du Plessis 2013). It has been hypothesized that caracals select prey species based on their vulnerability (Stuart 1981; Melville *et al*. 2004), thereby making livestock a preferable target due to their lack of anti-predator behaviour (Thirgood *et al.* 2005). However, there is a paucity of studies concerning caracal livestock depredation. While Melville *et al.* (2004) did recover livestock from caracal scats in the Kgalagadi Transfrontier National Park (Table 2.1), remains were only observed in 6 scats. Nevertheless, the furthest distance from the park border that livestock was found in scat remains was 23.3 km, suggesting that these felids may travel long distances when foraging and that they do leave park borders in order to forage (Melville *et al*. 2004).

Table 2.1: Summary of the relative percent contribution (%) of mammalian prey groups from four caracal diet studies. All studies were based on scat analysis.

	Study area			
Prey species	SW & EC[1]	Kgalagadi[2]	West Coast NP[3]	Karoo NP[4]
Rodentia	50	60.9	57.4	30.2
Ruminantia (ex Artiodactyla)	10.9	1.3	4.2	21.7
Lagomorpha	5.2	4.9	1.3	14.7
Carnivora	2.9	10.7	1.2	1.6
Hyracoidea	9	na	1.2	17.1
Domestic stock	16.8	na	na	na
TOTAL	94.8	81.3	69.8	85.2
n	248	116	201	100

[1] Stuart &Hickman 1991, SW= South West, EC= Eastern Cape
[2] Melville *et al.* 2004
[3] Avenant & Nel 1997
[4] Palmer & Fairall 1988

2.2. STUDY AREA

My study covered areas of five municipalities within the Eastern Cape, South Africa (Figure 2.5). The Eastern Cape Province is one of nine provinces in South Africa and shares boundaries with four neighbouring provinces (Western Cape, Northern Cape, KwaZulu-Natal and Free State) and Lesotho. The Eastern Cape is the second largest province (169 580 km^2), representing over 13 % of South Africa (Eastern Cape State of the Environment Report 2004). The five municipalities were selected due to the large number of livestock and game farms within them (Knight & Cowling 2012). The municipalities selected were the Blue Crane Route (hereafter referred to as Cacadu), Makana, Nkonkobe (hereafter referred to as Fort Beaufort), Nxuba (hereafter referred to as Adelaide Bedford), Tsolwana (hereafter referred to as Tarkastad; Figure 2.5).

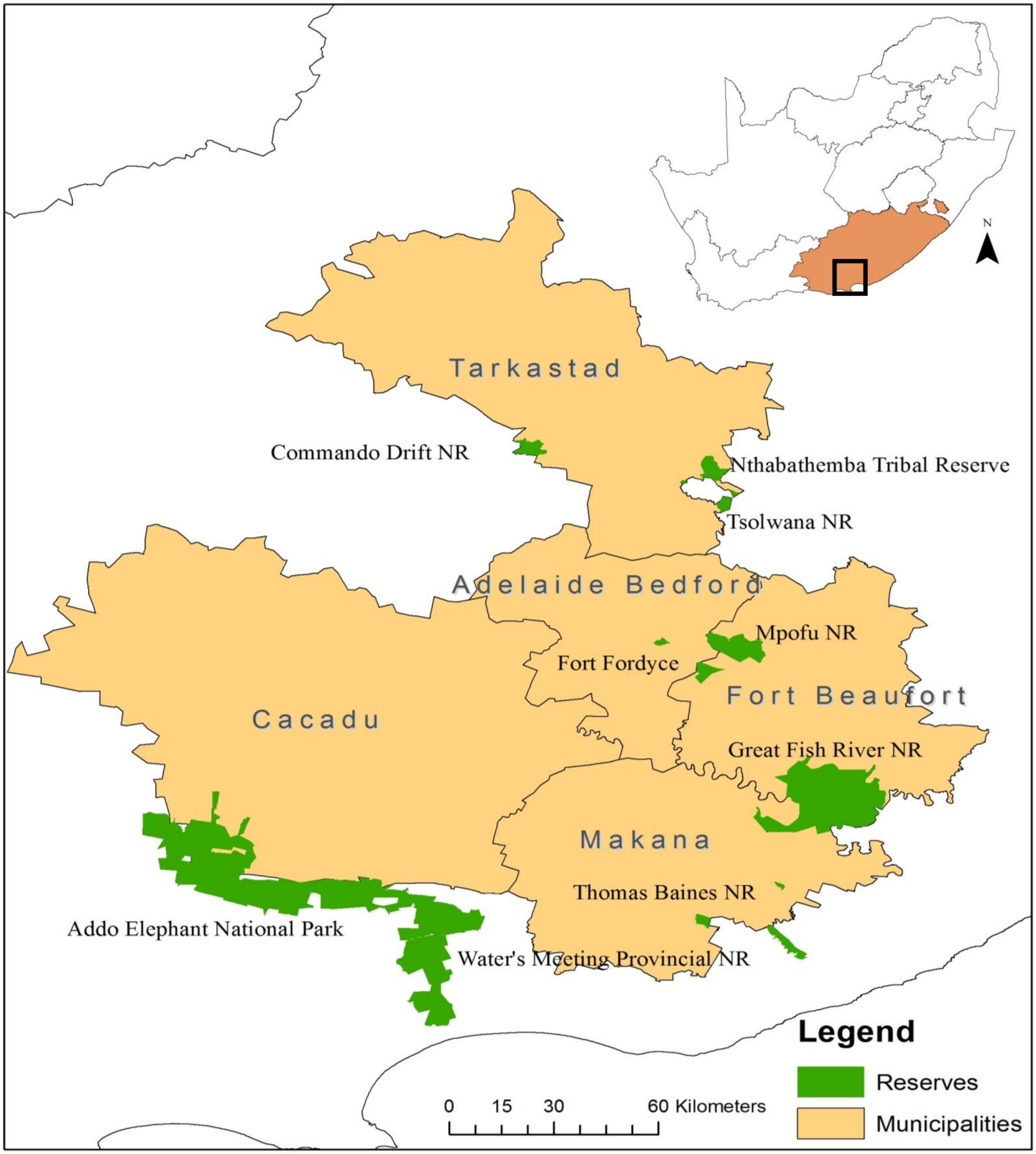

Figure 2.5: The location of the study area and the protected areas in the Eastern Cape, South Africa (NR = Nature reserve; ArcGIS 10.1; central meridian 27, map units: kilometres).

Climatic conditions

The study area (area south of the Sneeuberg – Winterberg – Amatole escarpment) is a region of complexity and of vast climatic, topographic and geological transition (Cowling 1983). The area is characterized by aseasonal rainfall mostly due to orographic precipitation (Cowling 1983). Varied climatic conditions occur within the study area, ranging from warm temperate and humid in the south-west to subtropical humid in the north-east (Cowling 1983). This is mostly due to the location of this region within a climatic transition zone, with the proximity to the Indian Ocean and its position between two provinces which receive different rainfall patterns (Kopke 1988, Stone *et al.* 1998). The Western Cape (temperate) receives winter rainfall, while KwaZulu-Natal (sub-tropical) receives summer rainfall, thereby allowing for the Eastern Cape to assimilate both climatic features (Eastern Cape State of the Environment Report 2004). Rainfall occurs throughout the year, but it is unreliable and droughts lasting several months are common (Figure 2.6; Hoare *et al.* 2006). In addition, variation in topography also leads to local variations in climatic conditions. For example, south-facing slopes generally experience cooler, moist conditions, whilst north-facing slopes experience warmer, drier conditions (Stone *et al.* 1998).

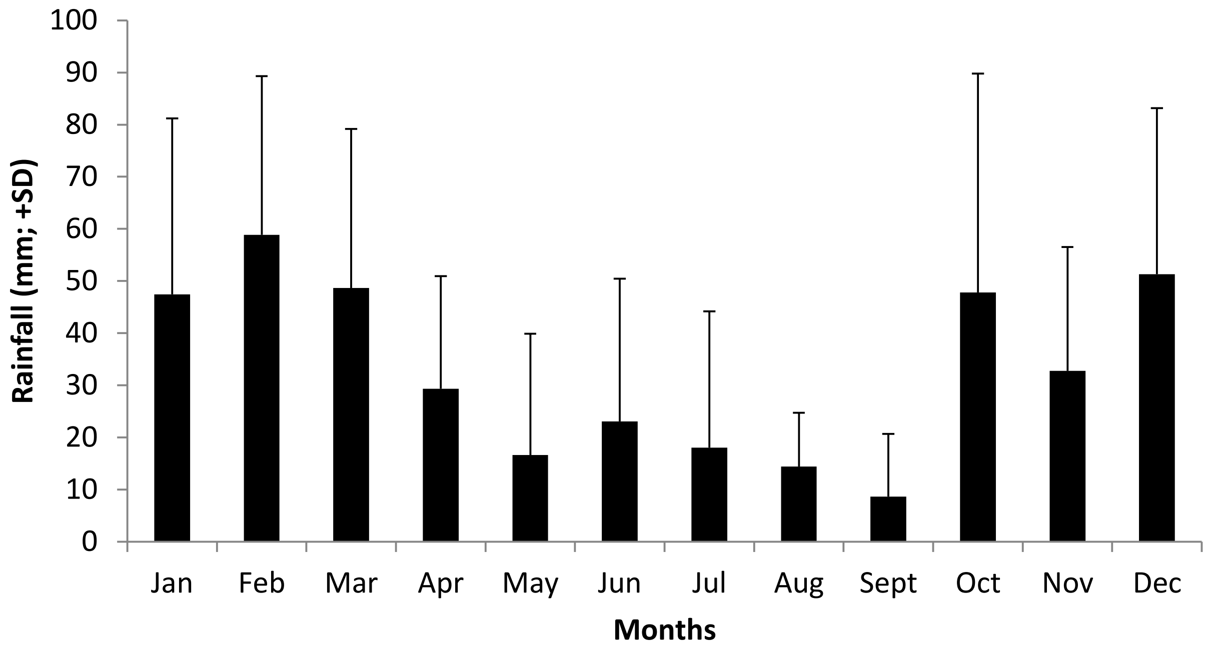

Figure 2.6: The mean monthly rainfall (mm) for eight years within the study area (Weather stations: Somerset East, Grahamstown, Fort Beaufort, Graaff-Reinet; January 2007 – December 2014; +SD, South African Weather Service).

The variable climatic conditions are produced by the alternating frontal systems (both cold and warm fronts) and the winds (e.g. effect of 'Berg' winds; Kopke 1988). During particularly hot days (> 40 °C), adiabatic ('Berg wind') wind conditions are experienced (Stone *et al.* 1998). This phenomenon encompasses a hot dry wind that is blown coastward. The Eastern Cape generally experiences warm summers and mild winters, with occasional frost (Figure 2.7; Kopke 1988).

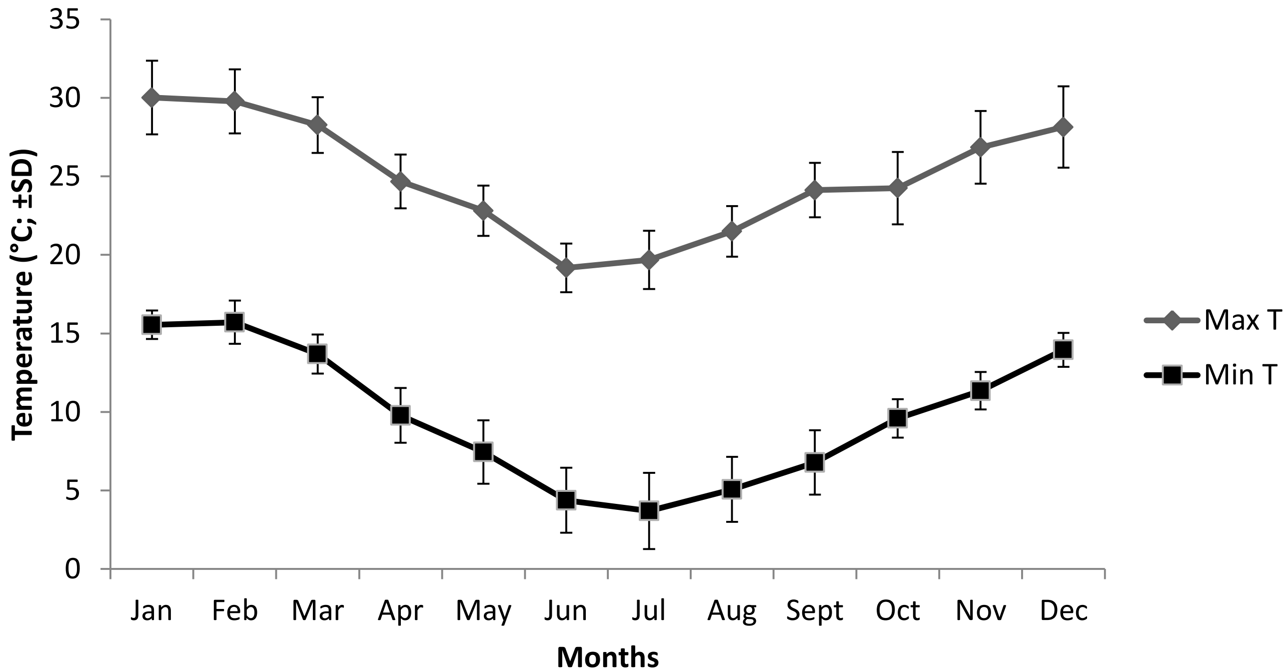

Figure 2.7: The mean monthly maximum and minimum temperature (° C) over the study area (Weather stations: Somerset East, Grahamstown, Fort Beaufort, Graaff-Reinet) for seven years (January 2007 – December 2014; ±SD; South African Weather Service).

Topography, geology & vegetation

The topography of the study area is made up of fairly level interior basins and wide, deep valleys with large river systems (e.g. Kei, Fish, Sundays; Cowling 1983). The valley system was caused by the dropping of sea levels which accelerated the erosion in the area (Mucina & Rutherford 2006). The overall geology represents the sandstones and quartzites of the Cape Supergroup (Cowling 1983). Furthermore, within the Supergroup rocks, Dwyka and Ecca Groups are also folded into the belt (Mucina & Rutherford 2006). However, the pattern in vegetation structure is largely due to the interaction of climate and soil type (Mucina & Rutherford 2006). The Eastern Cape is made up of diverse vegetation and has the highest number of biomes (Forest, Fynbos, Grassland, Nama-Karoo, Savanna, Succulent Karoo, Thicket) in South Africa (all but the Desert Biome; Low & Rebelo 1996; Mucina & Rutherford 2006). Within the study area, six biomes are represented (Figure 2.8; Mucina & Rutherford 2006).

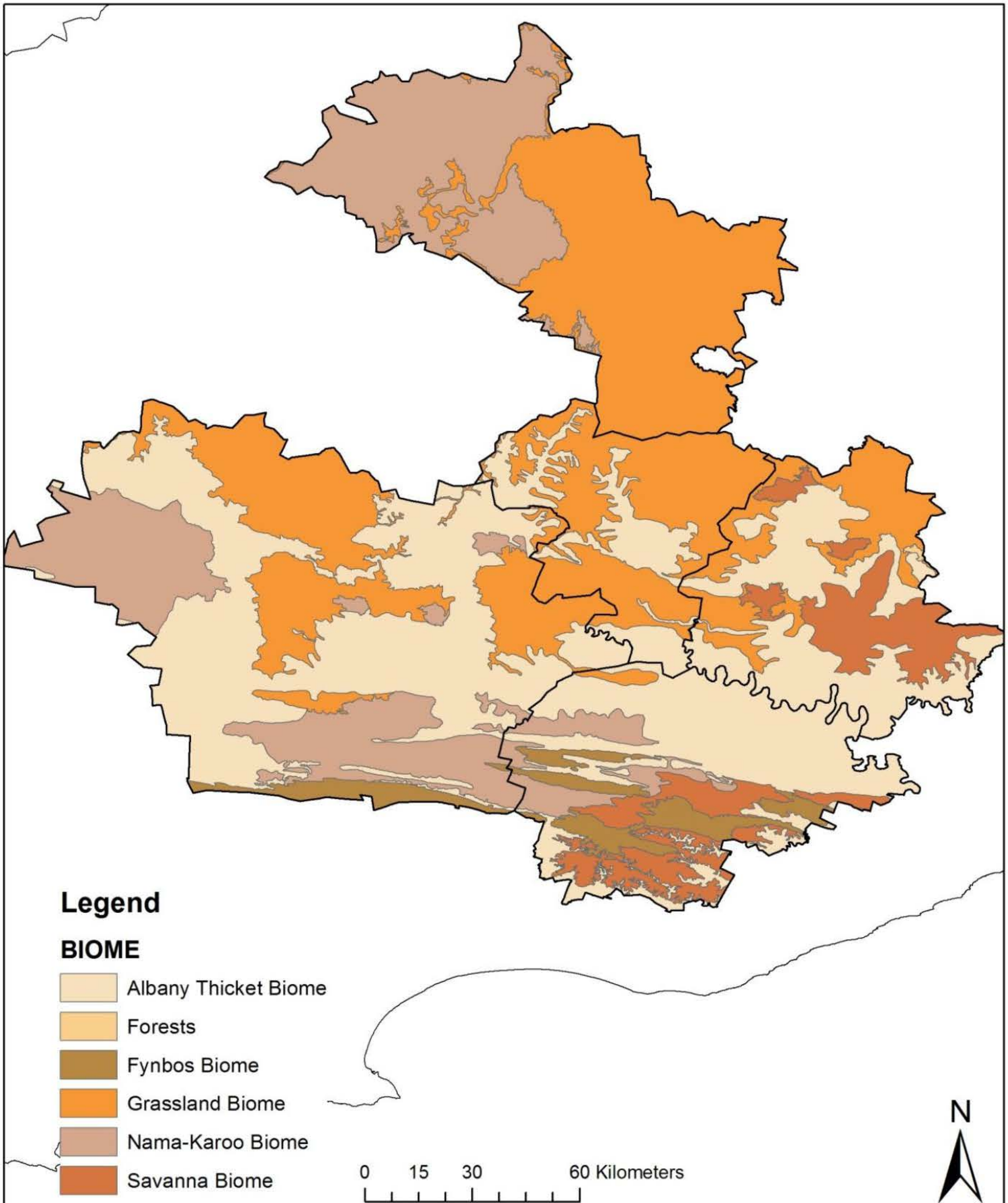

Figure 2.8: The six biomes within the study area in the Eastern Cape, South Africa (Mucina & Rutherford 2006; ArcGIS 10.1; map units: kilometres).

The Albany Thicket biome was originally classified as Valley Bushveld and is a dominant biome within the study area (Figure 2.8; Hoare *et al.* 2006). Recently, using the STEP (Subtropical Thicket Ecosystem Planning Project) analysis which assessed climatic uniqueness, vegetation structure and floristic diversity has justified the recognition of this vegetation type as a separate biome (Robertson & Palmer 2002). This biome is typically dense and is dominated by woody shrubs (Figure 2.9; Kerley & Landman 2006). It supports the highest number of endemic plant taxa in the Eastern Cape (e.g. for the families listed: Asclepiadacae, Crassulaceae, and Euphorbiaceae; Hoare *et al.* 2006; Kerley & Landman 2006).

Figure 2.9: The Albany Thicket vegetation with the typically dense vegetation and woody shrubs (Bissett 2004).

Looking at the Forest biome, the Eastern Cape is comprised of afromontane forest and coastal forests (Low & Rebelo 1996). The vegetation generally encompasses evergreen trees, herbaceous plants and epiphytes (Low & Rebelo 1996). Within the study area, the afromontane forest is present, wherein soils are generally well developed (Low & Rebelo 1996). There is a diversity of plant species within the Amatole Mountains of the Eastern Cape, such as Real Yellowwood (*Podocarpus latifolius*) and White Witchhazel (*Trichocladus ellipticus*; Low & Rebelo 1996). For the Fynbos biome, three vegetation types are present: grassy fynbos, mountain fynbos and coast Renosterveld (Low & Rebelo 1996). Fynbos species are extremely localized and as such most are threatened with extinction (Low & Rebelo 1996). Within the Grassland biome of the Eastern Cape, three vegetation types are present: the coastal grassland, the dry sandy and the moist cold highveld grasslands (Low & Rebelo 1996). This biome is dominated by single layer grasses and is generally devoid of trees due to frosts, fire and grazing (Low & Rebelo 1996). Overall, this biome is the backbone of livestock production (dairy, beef, wool) in South Africa (Low & Rebelo 1996). Three vegetation types are present in the Nama-Karoo biome (central-, Eastern- and great Nama-Karoo; Low & Rebelo 1996). While grasses tend to be more dominant, the effect of grazing increases the abundance of shrub species (Low & Rebelo 1996). The impacts of overgrazing are best observed in this biome, with the proliferation of indigenous species such as Threethorn (*Rhigozum trichotomum*) and Bitterbos (*Chrysocoma ciliata*), and a consequent decrease in palatable grasses (Low & Rebelo 1996). The Savanna biome is the largest biome in southern Africa, but is only partially observed in the study area (Figure 2.8; Low & Rebelo 1996). Within this biome four vegetation types are represented: the eastern- and sub-arid thorn bushveld, coast hinterland bushveld and coastal bushveld/grassland (Low & Rebelo 1996). Generally, these vegetation types are used for grazing by either livestock or game (Low & Rebelo 1996). Overall, the grassland is dominated by C_4 – type grasses and the dominant tree is the Sweet Thorn (*Acacia karroo*; Low & Rebelo 1996).

Brief history of land use

Before the 1880s, human populations were sparsely distributed within the study area, with general concentrations occurring along the Sundays River (Hoare *et al.* 2006). Before the advent of dipping and boreholes (i.e. a lack of available drinking water), and the prevalence of tick-borne diseases (e.g. heartwater caused by *Cowdria ruminantium*) livestock were restricted to certain areas in the Eastern Cape such as the Sundays River Valley (Hoare *et al.* 2006; Skead 2007). Once these pressures could be overcome (e.g. through dipping of cattle and the sinking of boreholes), livestock densities could increase and stock could access the thicket, thereby opening up large areas for grazing (Hoare *et al.* 2006).

After 1880, the occupation of the area by European settlers led to the extirpation of many wildlife species (e.g. the mega-herbivores; Kerley & Landman 2006; Skead 2007). With the removal of many herbivore species, livestock began to dominate the landscape. Goats (*Capra hircus*) were among the most successful species in the Albany Thicket owing to their use of high biomass browse species (Hoare *et al.* 2006). The impact of domestic livestock on the vegetation was noticeable and eventually led to ecosystem-level degradation (Stuart-Hill 1992; Moolman & Cowling 1994; Kerley & Landman 2006). Overall, a total of 7 500 km^2 of Albany Thicket is now considered degraded (e.g. transformed vegetation resulting in a decline in species diversity and ecological function; Lloyd *et al*. 2002). Possible reasons for the extent of this degradation could be that the dense thicket increased the risk of tick-borne diseases, such as heartwater (tick-borne disease affecting both wild and domestic ruminants) and land-owners intentionally over-stocked the land to reduce/degrade the thicket (Hoare *et al.* 2006). In addition, through this degradation, conservation, ecotourism and animal production values have been jeopardized (Knight & Cowling 2012). Farming ventures currently comprise the majority of land use through commercial pastoralism (sheep, goats) and the farming of game species (both for ecotourism and hunting), and the latter has expanded rapidly (Langholz & Kerley 2006; Knight & Cowling 2012). Overall, livestock farms occupy between 3 000 and 5 000 ha on average, while private wildlife ranches average around 22 000 ha (Knight & Cowling 2012). The increasing presence of wildlife ranches within the Eastern Cape fuels the view of livestock farmers that these areas are refugia for both black-backed jackal and caracal (Knight & Cowling 2012). However, on both land use types, mesopredators are viewed negatively due to livestock and game loss (Thorn *et al*. 2012). In an effort to reduce this, intense lethal control of the black-backed jackal and caracal ensued (van Sittert 1998; Beinart 2003).

Chapter 3
Assessing the use of predator control methods in the Eastern Cape, South Africa

3.1 INTRODUCTION

Through expanding human populations and the alteration of landscapes, humans have greatly modified environments to suit their own needs (Treves & Karanth 2003; Thirgood *et al.* 2005; Kansky *et al*. 2014; Jochum *et al*. 2014). As such, the incidence of human-predator conflict is increasing despite many carnivore species experiencing population and range reductions (Woodroffe & Ginsberg 1998). The most common incitement for this conflict is perceived livestock depredation by carnivores (Treves & Karanth 2003; Graham *et al*. 2005; Thirgood *et al*. 2005; Inskip & Zimmermann 2009; Stein *et al*. 2010; Thorn *et al*. 2013). Retaliatory killing of predators generally follows as livestock losses impact upon the food security and agricultural output of individual farmers (Treves & Karanth 2003; Graham *et al*. 2005; Thorn *et al*. 2013).

Financial loss is the most frequently cited reason for the retaliatory (often prophylactic) killing of carnivores worldwide (Butler 2000; Thorn *et al*. 2013; McManus *et al*. 2014). For example, hunters cite Peregrine Falcons (*Falco peregrinus*) and Hen Harriers (*Circus cyaneus*) as the reason for the decline in Red Grouse (*Lagopus lagopus*), thereby affecting the viability of commercial hunting in the United Kingdom (Thirgood & Redpath 2005). African wildlife ranchers may view the presence of predators as a threat to hunting bag limits (Delibes-Mateos *et al*. 2013). Actual livestock/game loss is often lower in reality, but if losses are perceived to be high, retaliatory killing of predators is likely to be high (Butler 2000; Graham *et al*. 2005; Baker *et al*. 2008; Thorn *et al*. 2012; McManus *et al*. 2014).

Livestock depredation can become an economic constraint (Holmern *et al*. 2007). In Tanzania, households lost 5.3 heads of stock (~USD 97.7) per annum to predation, which equates to two-thirds of the local average household income and, as such, local predator tolerance was generally low (Holmern *et al.* 2007). In South Africa, there is widespread debate over the actual number of livestock lost to predators annually, but a 2007 assessment estimated this financial loss to be around USD 22 million per annum (McManus *et al*. 2014).

Conflict due to livestock depredation is a worldwide concern, with wolves (*Canis lupus*), lynx (*Lynx lynx*), coyotes (*Canis latrans*), and bobcats (*Lynx rufus*) killing sheep (*Ovis aries*) in North America and Europe (Robinson 1961; McAdoo & Klebenow 1978; Till & Knowlton 1983; Breitenmoser 1998; Knowlton *et al*. 1999; Stahl *et al*. 2001; Blejwas *et al*. 2002; Odden *et al*. 2002; Pezzo *et al*. 2003; Berger 2006; Muhly & Musiani 2009). While cougars (*Puma concolor*) and jaguars (*Panthera onca*) kill cattle (*Bos primigenius*) in South America (Polisar *et al*. 2003; Zimmermann *et al*. 2005; Azevedo & Murray 2007; Cavalcanti 2008; Lucherini & Merino 2008; Zarco-González *et al*. 2013). In Asia, tigers (*Panthera. tigris*), wolves and leopards (*Panthera uncia*) prey upon livestock (Wang & Macdonald 2006; Suryawanshi *et al*. 2013; Harihar *et al*. 2014). While, almost all carnivores in Africa kill livestock (Woodroffe & Frank 2005; Schiess-Meier *et al*. 2007; Kissui 2008; Lagendijk & Gusset 2008; Blaum *et al*. 2009; Gusset *et al*. 2009; Hemson *et al*. 2009; Schumann *et al*. 2012). Due to their notoriety, conflict with black-backed jackals (*Canis mesomelas*) and caracals (*Caracal caracal*) has been widely documented (Rowe-Rowe 1975, 1976; Lawson 1989; Beinart 2003; Szabo *et al*. 2010; Kamler *et al*. 2012; Thorn *et al*. 2012, 2013, 2014).

While the conservation of large carnivores is a global priority (Musiani *et al*. 2003; Treves & Karanth 2003) and these species have been extensively studied, little attention in the form of conflict mitigation has been dedicated towards small- and medium-sized carnivores (Blaum *et al*. 2009). From what little research has been conducted, the rates of destruction for mesopredators (small to middle-ranked predators) can be as high as 14.7 black-backed jackals/100 km^2 and 0.55 caracals/100 km^2 per year in some parts of South Africa (Thorn *et al*. 2012), yet livestock and game depredation continues (Avenant & Du Plessis 2008). Worryingly, the estimation of mesopredator densities is notoriously difficult, so assessing the demographic effects of lethal control is extremely problematic (Thorn *et al*. 2012).

Both the black-backed jackal and the caracal are perceived to be common and are distributed throughout the Eastern Cape province, South Africa (Skinner & Chimimba 2005;

Skead 2007; Hayward *et al*. 2007). However, actual population numbers are unknown and neither mesopredator has an annual bag-limit during the 12 month hunting season (January – December; Breitenmoser-Wursten *et al.* 2008; Hunting Proclamation 2013). Both black-backed jackals and caracals are seen as inimical to livestock farms and are regularly killed in an attempt to reduce or prevent livestock losses (Rowe-Rowe 1975; Thorn *et al*. 2012). Despite the intense lethal control of both these mesopredators their numbers are still apparently large enough to remain an issue on farms, and livestock losses are believed to be increasing (Avenant & Du Plessis 2008; McManus *et al*. 2014).

The role of lethal control in attempting to relieve human-carnivore conflict is one of the oldest predator management tools (Treves & Naughton-Treves 2005; Berger 2006; Avenant & Du Plessis 2008; McManus *et al*. 2014). Lethal control has been defined as a method which is employed to deliberately remove or decrease wildlife numbers in order to protect human lives and/or livelihoods (Treves & Naughton-Treves 2005). Underlying this definition is the assumption that by decreasing the abundance of the problem animal/species, there will be a decrease in conflict. However, this is not always the case as eradication may have unpredictable ecological consequences (Treves & Naughton-Treves 2005; Berger 2006), and studies on mesopredators have indicated that there are very few long-term benefits of lethal control (Baker & Harris 2006). The potential consequences of removal include increased replacement (i.e. immigration and recruitment of conspecifics), compensatory demographic responses and an increase in local predator populations (termed the perturbation effect) which all serve to exacerbate conflict (Crooks & Soule 1999; Knowlton *et al*. 1999; Tuyttens *et al*. 2000; Carter *et al*. 2007; Avenant & Du Plessis 2008; Baker *et al*. 2008; Robinson *et al*. 2008; Prugh *et al*. 2009; McManus *et al*. 2014). Compensatory breeding is also a well-known concept (Baker & Harris 2006). However, very little work has been conducted on whether it manifests in South African mesopredators which are subject to lethal control (Conradie 2012). A further, unpredictable biological consequence of lethal control is mesopredator release (Crooks & Soule 1999). This phenomenon is characterized by an increase in the abundance of mesopredators due to the decline and/or change in the distribution of a larger predator (e.g. lions; *Panthera leo*, leopards; *P. pardus;* Soule *et al*. 1988; Prugh *et al*. 2009). The top predators affect the mesopredators (e.g. black-backed jackals) through population regulation and thereby reduce the effects which the mesopredators can have on prey species (Prugh *et al*. 2009; Ritchie *et al*. 2012; Greenville *et al*. 2014). For example, the suppression of two mesopredators (red foxes; *Vulpes vulpes*, and feral cats; *Felis catus*) by an apex predator (the dingo; *Canis dingo*) was observed in Australia during periods of low prey density (Greenville *et al*. 2014). Additionally, through intraguild interactions, apex predators can affect mesopredator abundance though direct removal or by altering behaviour (Ritchie & Johnson 2009). Several studies therefore suggest that the most effective means to control mesopredators is the presence of apex predators (Barton & Roth 2008; Prugh *et al*. 2009). However, this may not be feasible as both livestock farmers and wildlife ranchers would not want to add an additional threat to their livestock/game abundances.

Popular methods of lethal control include calling and shooting, which employs the use of animal calls, usually that of a female, a male or an injured animal, to lure other predators in the area toward the hunter (Beasom 1974). Cage traps are also used, as are packs of trained hunting dogs (Rowe-Rowe 1975). Gin traps or leg-holding devices are legal in South Africa and are employed to clamp the animal‟s limb (Beasom 1974). The use of poison (e.g. strychnine), while illegal, is also still practiced in South Africa (Ogada *et al*. 2012).

Selectivity of control methods is crucial if a particular animal or even an entire species is targeted (Beasom 1974). In addition, if the target species is able to avoid the control method, conflict will persist (Knowlton *et al*. 1999; Avenant & Du Plessis 2008; McManus *et al*. 2014). The overall selectivity of an eradication/culling technique depends on factors such as the recolonization of vacant territories by other predators and the risk of removal of non-target animals (Treves & Naughton-Treves 2005). Targeting a particular „problem animal" and not the entire population may prevent unpredictable consequences (e.g. mesopredator release) or the complete eradication of a species from an area (Treves & Naughton-Treves 2005). Moreover, most methods of lethal control are unselective towards a specific animal and can potentially kill non-target species (Beasom 1974; McManus *et al*. 2014). As such, the removal of non-culprit animals from ecosystems may have significant knock-on effects, and are unlikely to lead to the alleviation of conflict (Treves and Naughton-Treves 2005; Inskip and Zimmermann 2009).

An alternative to lethal control is the implementation of non-lethal techniques (McManus *et al*. 2014). Popular non-lethal methods include kraaling, which is the corralling of livestock during vulnerable periods such as lambing or at night (Schiess-Meier *et al*. 2007). In addition, livestock guarding animals are becoming increasingly popular and involve the use of other animals to protect livestock, with the most common being Livestock Guard Dogs (LGDs; *Canis lupus familiaris*), donkeys (*Equus africanus asinus*) and alapacas (*Vicugna pacos;* Conover 2001; Marker *et al*. 2005). "Jackal-proof" fencing has been used in South Africa since the 1890s (Beinart 2003; Breitenmoser *et al.* 2005). While the use of herdsmen was historically popular, in recent times this non-lethal practice is not commonly practiced mostly due to high labour costs (Shivik 2006). Further, there are many livestock protection collars available such as the "King collar" or "Dead-stop" collar. Relocation is also sometimes considered, but assumes that the relocated animal will be moved to an area where the issue of conflict can be avoided (Linnell *et al*. 1997). However, this method is not seen to be practical as few animals remain in the release area and may roam into other areas of potential conflict (Linnell *et al*. 1997).

Mesopredator behavioural plasticity and ecological flexibility have allowed certain species to endure persecution by humans (Boydston *et al*. 2003; Holmern *et al*. 2007). A study conducted *in situ* on black-backed jackals and the use of cyanide guns, indicated that this plasticity has allowed for the establishment of avoidance behaviour towards predator control methods (Brand & Nel 1997). Inherent and acquired behaviour allowed black-backed jackals to avoid cyanide guns, and even „naïve" partners of experienced jackals avoided this form of lethal control (Brand & Nel 1997). Regular use of a method may therefore decrease its efficacy, with target species eventually showing trap avoidance behaviour (Brand *et al*. 1995; Brand & Nel 1997).

When assessing the effectiveness of lethal and non-lethal approaches for mitigating perceived human-predator conflict, it is also important to consider the influence of the socio-demographics of the land owners (Anthony *et al*. 2010; Thorn *et al*. 2013; Suryawanshi *et al*. 2014). Such variables as age, gender and education can all influence land owner tolerance of predators (Bath & Buchanan 1989; Lindsey *et al*. 2005; Holmern *et al*. 2007; Nilsen *et al*. 2007; Anthony 2007; Schumann *et al*. 2012). For example, younger farmers may generally express more conservation-orientated attitudes, being more positive towards carnivores than their older counterparts (Lindsey *et al*. 2005). A study conducted around the Kruger National Park, South Africa, demonstrated that the neighbouring farmers expressed positive attitudes when predators appeared on their land and this was because of the high education levels of the respondents (Lagendijk & Gusset 2008). Greater education, fosters a conservation-based acceptance of predators (Lagendijk & Gusset 2008).

Baseline information concerning which control methods are used by land owners is key to understanding which methods are believed to manage mesopredators, especially in areas that have very little pre-existing information (Conradie 2012; Thorn *et al*. 2012, 2013; McManus *et al*. 2014). Information regarding respondents" social factors and the use of predator control methods has been identified as necessary in order to apply appropriate mitigation strategies (Thorn *et al*. 2014). Thus, the aim of this chapter was to assess the perceived efficacy of lethal and non-lethal control methods for black-backed jackals and caracals on wildlife ranches and livestock farms within the Eastern Cape, South Africa. Specifically, I asked:

- Which predator control method(s) are perceived to be more effective at reducing conflict?; and
- Which variables best predict landowner attitudes towards predator control methods?

Broad hypotheses:

- Lethal control will be perceived to be more effective at reducing conflict, and
- High levels of livestock/game depredation will elicit a negative response from land owners and who will then use more lethal predator control methods.

3.2 METHODS

3.2.1 Data collection

While the Eastern Cape is one of the top five stock- producing provinces in South Africa, the area is made up of both livestock farms and wildlife ranches (Bothma 2005; Bergman *et al*. 2013). Five municipalities were used in my study: 1) Tarkastad, 2) Adelaide Bedford, 3) Fort Beaufort, 4) Makana and 5) Cacadu, as farming associations occur within their borders (Figure 3.1). Because many farm boundaries cross the Cacadu and Makana municipality border, these two municipalities were combined for the data analysis. The income from wildlife ranching is derived from sport hunting for meat and trophies, and the sale of live game and ecotourism (Bothma 2005). Livestock farms with cattle and small stock (sheep, goats; *Capra hircus*, and pigs; *Sus scrofa*) deal with meat, dairy and wool sales (Department of Agriculture Forestry and Fisheries 2013). Several free-roaming (i.e. not confined by fences) carnivore species are found in the area, including caracals, black-backed jackals and leopards, with some transient species also occasionally present (e.g. brown hyaenas; *Hyaena brunnea*; Skead 2007).

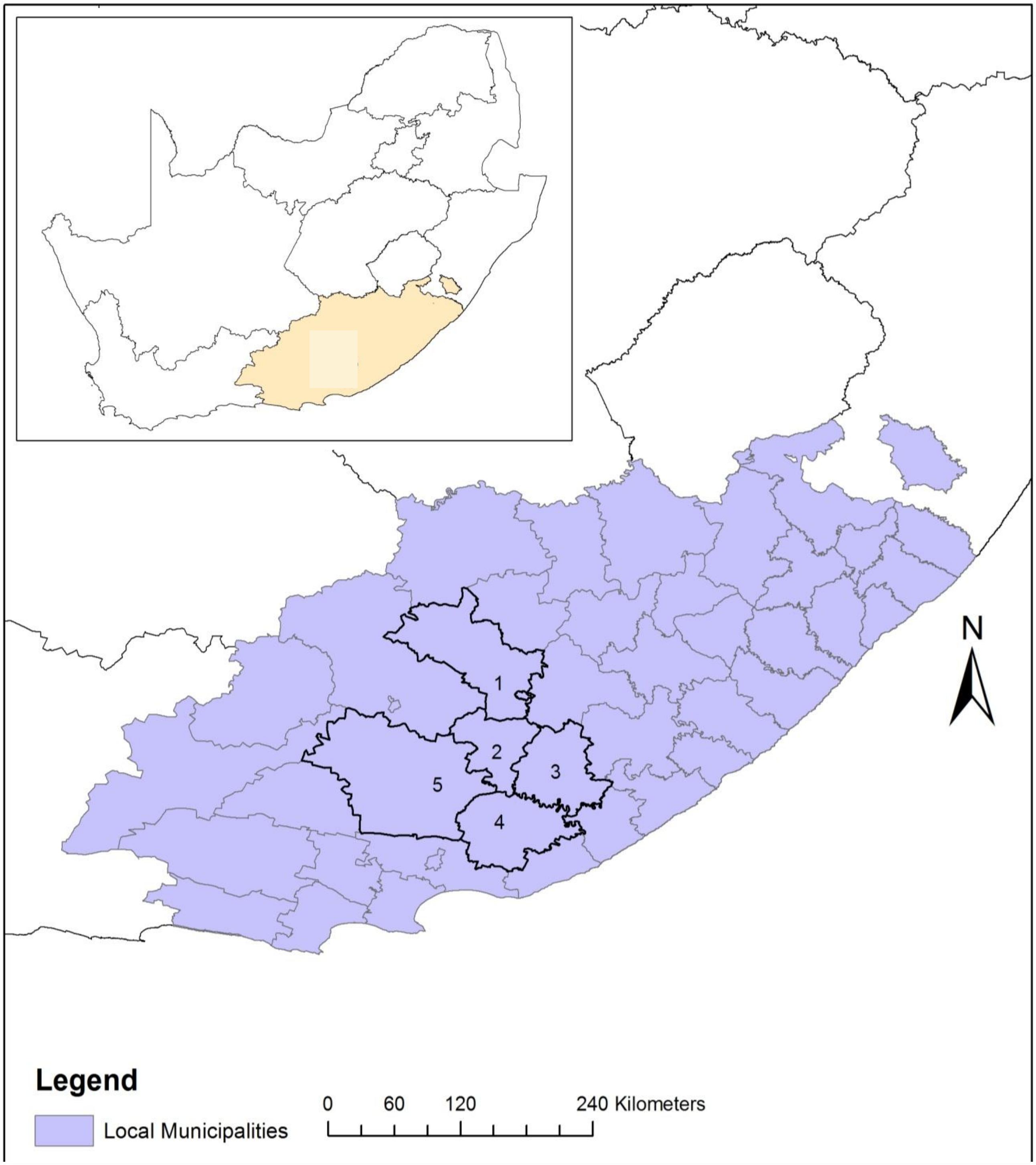

Figure 3.1: The five municpalities wherein the questionnaire interviews were conducted (1. Tarkastad, 2. Adelaide Bedford, 3. Fort Beaufort, 4. Makana and 5. Cacadu) in the Eastern Cape, South Africa (ArcGIS 10.1; map units: kilometres).

Questionnaires are used in ecological studies to obtain specific information from a target population, particularly in the realm of human-wildlife conflict issues (White *et al*. 2005; Lucherini & Merino 2008). The increase in interdisciplinary research has made this tool highly effective in collecting quantitative conservation and management data (Riley *et al*. 2002; O"Connor *et al*. 2003; Drechsler 2004; White *et al*. 2005).

A structured questionnaire (Appendix I) for determining the use and extent of predator control methods and conflict with mesopredators was used to interview respondents (n = 73) across the study area. The respondents were identified as either owners or managers of both wildlife ranches and livestock farms. The questionnaire contained four sections. The first consisted of general questions about the structural elements of the respondent"s farm, namely the land-use, number of stock/game, main economic problems faced and the size of the property. The second dealt with perceived conflict with predators. The third section was concerned with the use of predator control and its perceived efficacy. Specifically, land owners would rate each control method based on whether they believed it was effective at minimizing conflict with mesopredators on their land. This section gathered the data for constructing the attitude index (see below). The final section covered demographic information of the respondent (i.e. age, education level, gender and first language). The questionnaire was structured in this manner in order to allow respondents to become more relaxed as the interview progressed and only answer the more personal questions towards the end of the interview (McColl *et al*. 2001; Anthony 2007; Schüttler *et al*. 2011; Delibes-Mateos *et al*. 2013). Both closed-ended and open-ended questions were employed in the questionnaire, the latter allowing for the respondents to express their opinions (Anthony 2007).

The questionnaire was three pages in length and took approximately 10 minutes to complete (White *et al*. 2005). Data were collected from March 2013 to July 2014. All interviews were conducted in the home language of the respondent, which was either English (n = 55) or Afrikaans (n = 18). Land owners were initially contacted by telephone. The project was briefly described and they were asked whether they would be willing to participate. Only five of 78 potential participants phoned refused to take part, making a response rate of 93.5 %. Non-response bias was therefore assumed to be minimal (Thorn *et al*. 2013). The reasons given for not participating were either that they did not have time (n = 4) or that they were selling their land (n = 1). Before each interview was conducted, it was explained to the respondent that there would be complete anonymity and that the results would be used purely for academic purposes (White *et al*. 2005; Anthony 2007; Jones *et al*. 2008).

The attitude index

Attitude is defined as the favourable or unfavorable outlook toward an action or issue (Manfredo & Dayer 2004). An index was created in order to determine perceived attitude concerning predator control methods within the study area. In essence, the index reflected the extent of the control measures employed on each farm. The index was generated from a total of 14 statements (Appendix II). Likert scales are used to quantify respondent emotions towards particular statements, and are commonly used in questionnaires surrounding the issue of human-wildlife conflict (McIvor & Conover 1994; Zimmermann *et al*. 2005; Marshall *et al*. 2007; Nilsen *et al*. 2007; Anthony 2007; St John *et al*. 2012; Thorn *et al*. 2014). For 12 of the statements, a 5-point Likert scale was used, where 1 indicated that a method was believed to be ineffective and 5 indicated that a method was believed to be highly efficient at eliminating conflict on the property (McIvor & Conover 1994; White *et al*. 2005). All lethal methods (N = 6), were allocated a negative value (between -1 and -5). The more negative the score, the greater the use of lethal control employed on the farm. Conversely, non-lethal methods (N = 6) were allocated positive numbers (between +1 and +5). Therefore, the more positive the value the more the respondent used non-lethal measures on their farm.

In addition, two other questions were asked and rated accordingly. The questionnaire asked: “What is your preferred method of control on your farm?” A score of +1 was given if the respondent answered with a method of non-lethal control, 0 if the respondent used no method to control, -1 if both lethal and non-lethal methods were employed, and a score of -2 was given if the respondent answered with a method of lethal control. The final question was trichotomous (Lethal/Non-lethal/None), “Which method do you think is the most effective at reducing conflict on your farm?” and values were allocated according to a non-lethal (+1), none (+1) or lethal (-1) response (Appendix II; Anthony 2007). The value for the index was calculated as the sum of the scores for all 14 statements (Zimmermann *et al*. 2005). The maximum value that could be achieved for the index was +32 (indicating the respondent generally used non-lethal methods of control), while the lowest value possible was -33 (indicating that the respondent generally used lethal methods of control; Anthony 2007).

3.2.2 Data analysis

Descriptive analysis

To allow for quantitative comparisons, data were calculated as percentages, and graphs were constructed in order to display results (Anthony 2007; Schumann *et al*. 2012). Maps of the study site were created using ArcMap 10.1 (ESRI, Redlands, California) to display the data.

Quantitative analysis

Data from the attitude index were subject to a Cronbach α test in order to determine the internal consistency of the questionnaire data (Cronbach 1951; Peterson 1994). Cronbach α is superior to the Kuder and Richardson Formula 20 as it can be used with both continuous and non-dichotomous data (Cronbach 1951; Peterson 1994). It is also the most widely used test for scale reliability (Peterson 1994). Values between 0.6 and 0.7 are considered acceptable and indicate that the scale yields internal consistency, but higher values (closer to 1.00) indicate high levels of redundancy (Peterson 1994; Zimmermann *et al*. 2005). The value was calculated as follows (Cronbach 1951; Peterson *et al*. 2010):

$$\alpha = \left(\frac{k}{k-1}\right)(1 - \sum_{i=1}^{k} \sigma_i^2 / \sigma_s^2)$$

where k indicates the number of items on the scale, σ_i^2 is the variance of an item within the Likert scale, and σ_s^2 is the variance within the scale (Cronbach 1951).

The statistical significance was set at $p < 0.05$ and all data were analyzed using R 3.0.2 Software (Appendix III; R Foundation for Statistical Computing, 2013).

The effects of property and socio-demographic variables on the attitude index

To determine the relationship between eight predictor variables (four property and four socio-demographic) and the attitude index, a multiple regression analysis was performed (Archibald *et al*. 2005; Kolowski & Holekamp 2006; Berger 2006; Berger *et al*. 2008; Thorn *et al*. 2012; Holmern & Røskaft 2013; Page 2014). Four continuous variables (stock loss, number of mesopredators killed, age of respondent, and size of farm) and four categorical variables (land use, two levels – livestock farming or wildlife ranching; district, four levels – Adelaide Bedford, Cacadu Makana, Fort Beaufort, or Tarkastad; education, three levels – high school (Grade 9), matric or tertiary; and first language, two levels – English or Afrikaans) were used in the construction of the models. Prior to analysis, a Spearman‟s rank order correlation (r_s) was performed on the continuous variables to test for co-linearity (Kolowski & Holekamp 2006). The criterion for exclusion was set at Spearman‟s rho(r_s) > 0.7 (Kolowski & Holekamp 2006; Symonds & Moussalli 2011; Thorn *et al*. 2012, 2013). No variables were co-linear and all were included in the subsequent model building process. A Shapiro-Wilk test was conducted to determine for normality of the response variable residuals – attitude index ($W = 0.97$; $p > 0.05$).

The overall aim of conducting the model selection was to determine which variable/combination of variables best approximated the attitude index (Kolowski & Holekamp 2006; Peterson *et al*. 2010; Thorn *et al*. 2012, 2013, 2014; Beasley *et al*. 2013). The eight predictor variables were incorporated into a best subset multiple regression model selection using the Akaike Information Criterion (AIC; Burnham & Anderson 2002). Multiple models were constructed for each individual variable as well as any combination of variables, giving a total of 232 potential models to predict the attitude index (Burnham & Anderson 2002). AIC models enable one to compare multiple models and best approximate the biological phenomenon occurring (Symonds & Moussalli 2011). As the sample size was relatively small ($n = 73$ respondents), AIC values were adjusted into AICc which is the small sample adjustment

(Symonds & Moussalli 2011). The equation for calculating AICc is as follows (Burnham & Anderson 2002; Symonds & Moussalli 2011; Thorn *et al*. 2012, 2013, 2014):

$$AICc = AIC + \frac{2k(k+1)}{n-k-1}$$

The value *n* is the sample size and the value *k* indicates the number of parameters in the most complex model (Symonds & Moussalli 2011). AICc scores cannot be interpreted in their raw format and need to be converted into ΔAICc (Burnham & Anderson 2002; Symonds & Moussalli 2011). The models were ranked parsimoniously and selected according to the ΔAICc values (ΔAICc > 2.00; Burnham & Anderson 2002; Thorn *et al*. 2012; Holmern & Røskaft 2013). Impact factors were calculated by summing the AICc weight values (Wi) of all models containing that specific variable (Burnham & Anderson 2002; Holmern & Røskaft 2013). This equates to the influence that variable has on the response variable (attitude index) with a value of 0.80 considered favourable (Burnham & Anderson 2002; Rowe 2009; Thorn *et al*. 2012).

Generalised linear models were then run using the top two models which best approximated the attitude index (Burnham & Anderson 2002; Symonds & Moussalli 2011). These two models incorporated the following variables as the best predictors of the attitude index: land use, district and number of mesopredators killed. However, land use was non-normally distributed therefore a Kruskal Wallis one-way analysis of variance was performed (Holmern & Røskaft 2013).

3.4. RESULTS

Of the 73 respondents, the majority were male (97 %) and only 3 % were female (Table 3.1). There were two first languages, with 75 % of respondents speaking English and 25 % speaking Afrikaans as their home language (Table 3.1). Of the three education levels, 63 % of the respondents had some form of tertiary education, while 22 % had at least a grade 9 and 15 % had matriculated (Table 3.1). The average age was 47 (± 13.0) years (range: 24 – 79 years; Table 3.1).

Table 3.1: Summary of the demographics of the respondents surveyed concerning the perceived effectiveness of mesopredator control within the Eastern Cape (n = 73).

Demographics of respondent		N	%	Mean (±SD)
Gender:				
	Male	71	97.3	
	Female	2	2.7	
First language				
	English	55	75.3	
	Afrikaans	18	24.7	
Education				
	High school (Grd9)	16	21.9	
	Matric	11	15.1	
	Tertiary	46	63.0	
Age				46.8 (±13.0)

The majority of respondents came from the Fort Beaufort district (34 %), while 25 % came from both the Cacadu Makana and the Tarkastad districts (Table 3.2). Only 16 % came from the Adelaide Bedford region. The main land use type in the study area was livestock farming (78 %) and 22 % were wildlife ranchers (Table 3.2). The average farm size was 4069 (±8226) ha (range: 24 – 65 000 ha; Table 3.2).

Table 3.2: Summary of the property characteristics of the respondents surveyed concerning the perceived effectiveness of mesopredator control within the Eastern Cape.

Property characteristics		N	%	Mean (±SD)
District				
	Adelaide Bedford	12	16.4	
	Cacadu Makana	18	24.7	
	Fort Beaufort	25	34.2	
	Tarkastad	18	24.7	
Land use				
	Wildlife ranch	16	21.9	
	Livestock farm	57	78.1	
Size of farm				4068 (±8226.0)

The respondents were asked to describe their most pressing economic issue from a list of problems (Appendix I; Figure 3.2). Overall, the main problem faced by the respondents was the threat of predators (38 %) followed by the threat of stock theft/poaching (32 %; Figure 3.2). Disease to livestock/game was a problem for 18 % of the respondents, while an unreliable market and drought was an issue for 5 and 4 % of the respondents, respectively (Figure 3.2).

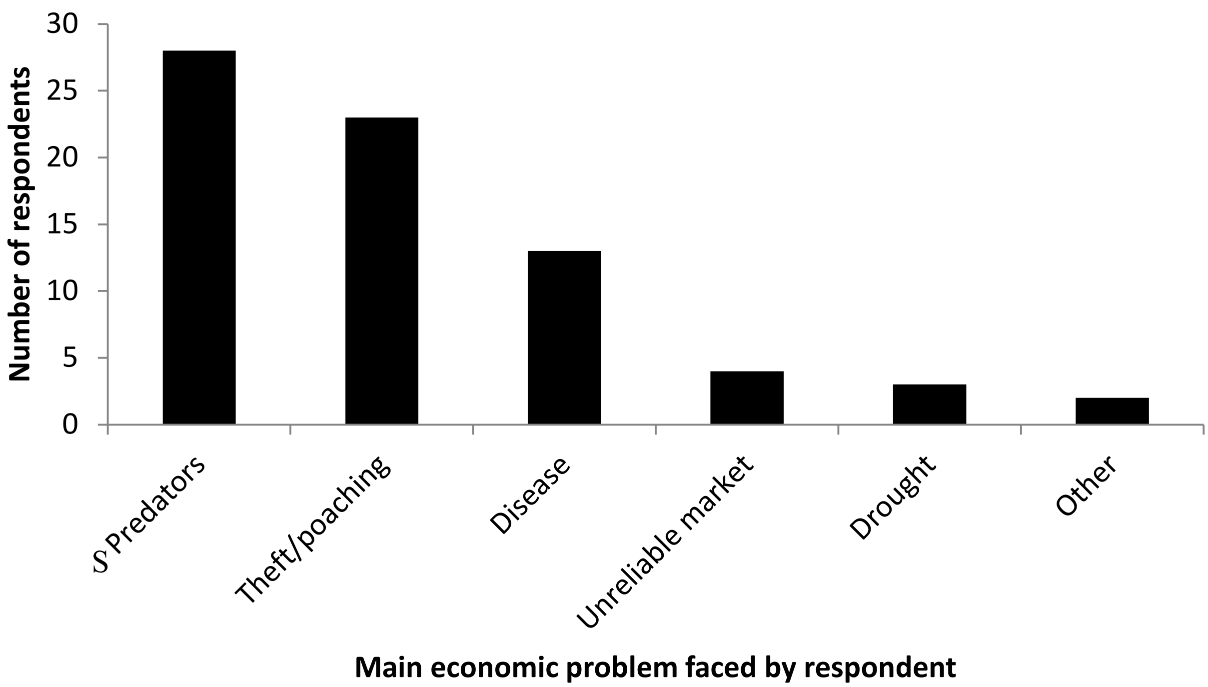

Figure 3.2: The rated scores of possible problems faced by respondents to their economic livelihoods within the Eastern Cape.

Conflict with predators and predator control methods

Sixty-seven percent of respondents believed that the conflict with predators was increasing on their farms, while 29 % believed that the issue of conflict had stabilized and only 4 % believed that conflict with predators was decreasing. Concerning the threat of mesopredators, 64 % of respondents believed that there was a greater issue of conflict with black-backed jackals compared to 61 % with caracals (Figure 3.3). Sixteen percent of respondents did not encounter conflict with caracals and 12 % had no conflict issues with black-backed jackals (Figure 3.3).

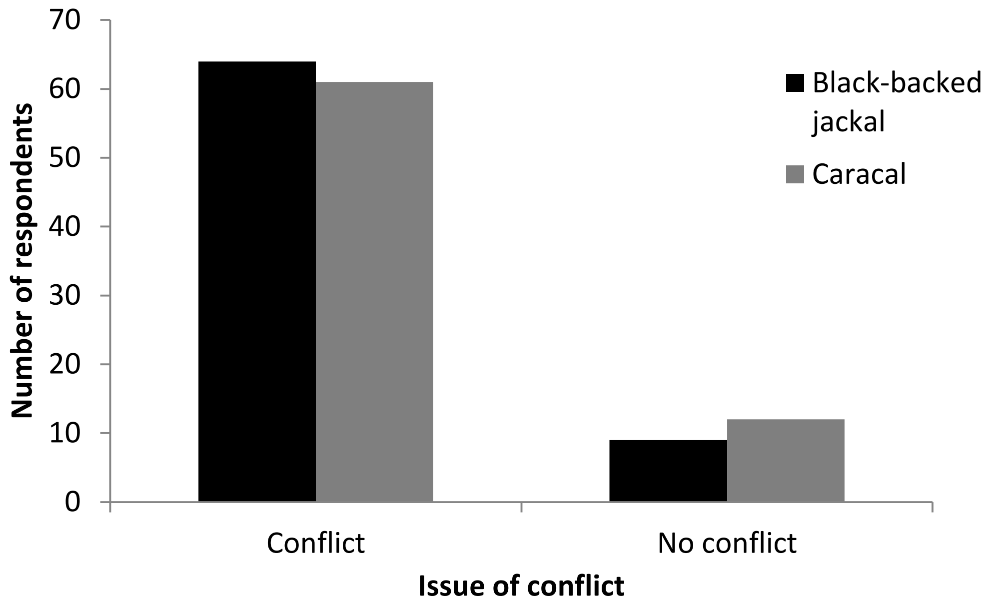

Figure 3.3: Total number of respondents experiencing conflict with mesopredators and the number of respondents who did not experience conflict with mesopredators.

Lethal control was the most popular method used on the farms to deal with predator conflict (73 %; Figure 3.4). Non-lethal predator control (12 %), using both lethal and non-lethal measures (8 %) and using no form of predator control at all (7 %) had very similar responses and were not the perceived to be the best method to reduce mesopredator conflict (Figure 3.4).

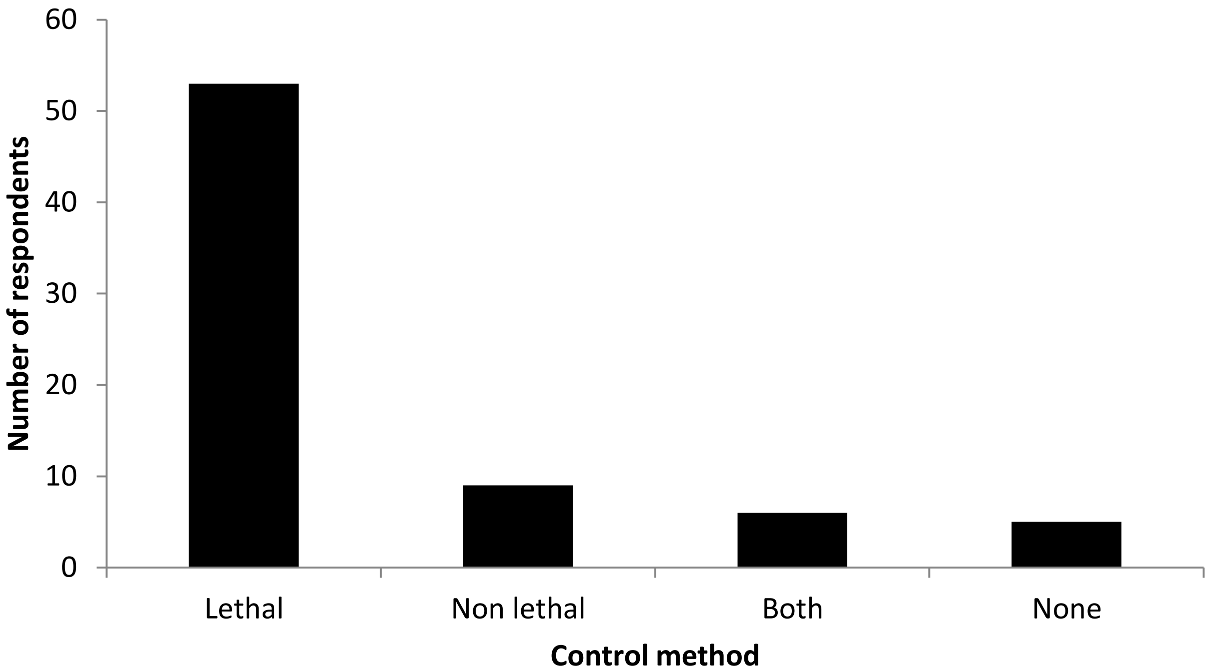

Figure 3.4: Number of respondents and predator control methods applied which were perceived to be the most effective at reducing human-mesopredator conflict within the Eastern Cape.

The lethal predator control method attributed to be most effective at reducing mesopredator conflict was calling and shooting (25 %), whereas 12 % of respondents felt that the most effective non-lethal predator control method was fencing (Figure 3.5). Other lethal methods believed to be effective were the use of dog packs (16 %), cage traps (11 %) and poison (5 %; Figure 3.5). Of the non-lethal control measures, popular methods included using no control (12 %), kraaling (4 %) and several species of livestock guarding animals such as donkeys or Anatolian guard dogs (3 %; Figure 3.5). The least popular lethal and non-lethal predator control methods were gin traps (3 %) and other (which included intensive lambing; 1 %; Figure 3.5).

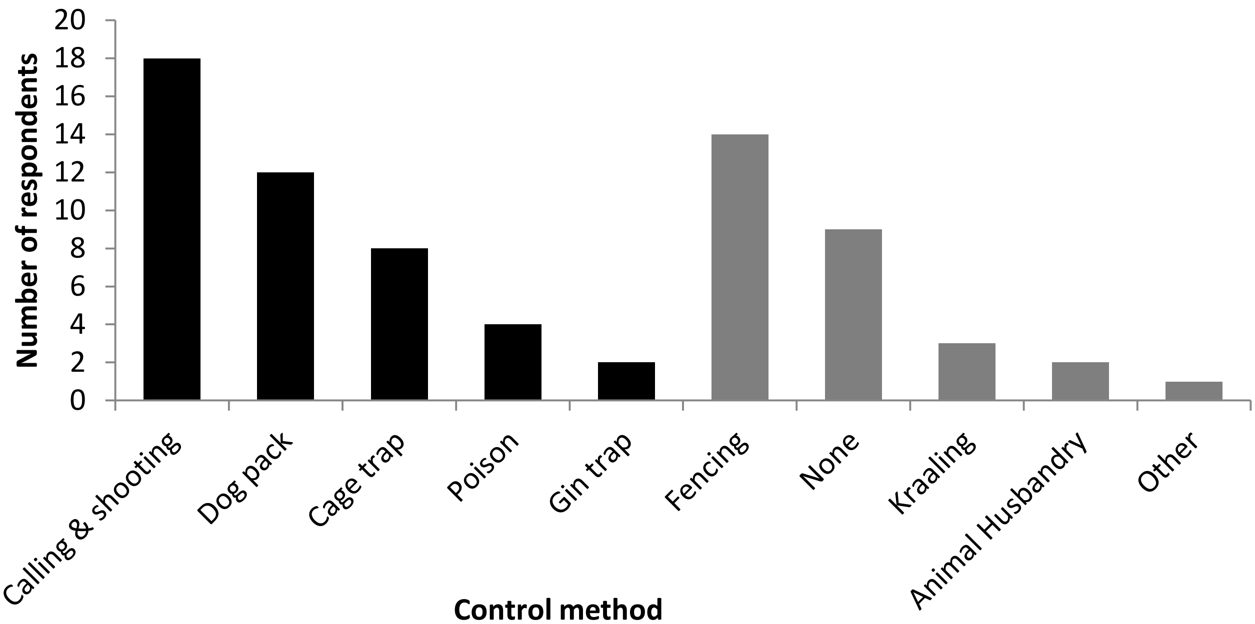

Figure 3.5: The top lethal and non-lethal predator control methods believed by the respondents to best decrease human-mesopredator conflict within the study area of the Eastern Cape.

A total of 732 black-backed jackals and 435 caracals were reported as eradicated from the farms in the study area over the study period (16 months; Figure 3.6). In addition, 115 domestic dogs (*Canis lupus familiaris*), 33 bush pigs (*Potamochoerus larvatus*), four eagles (Family: Accipitridae) and one leopard were eradicated from the study area (Figure 3.6).

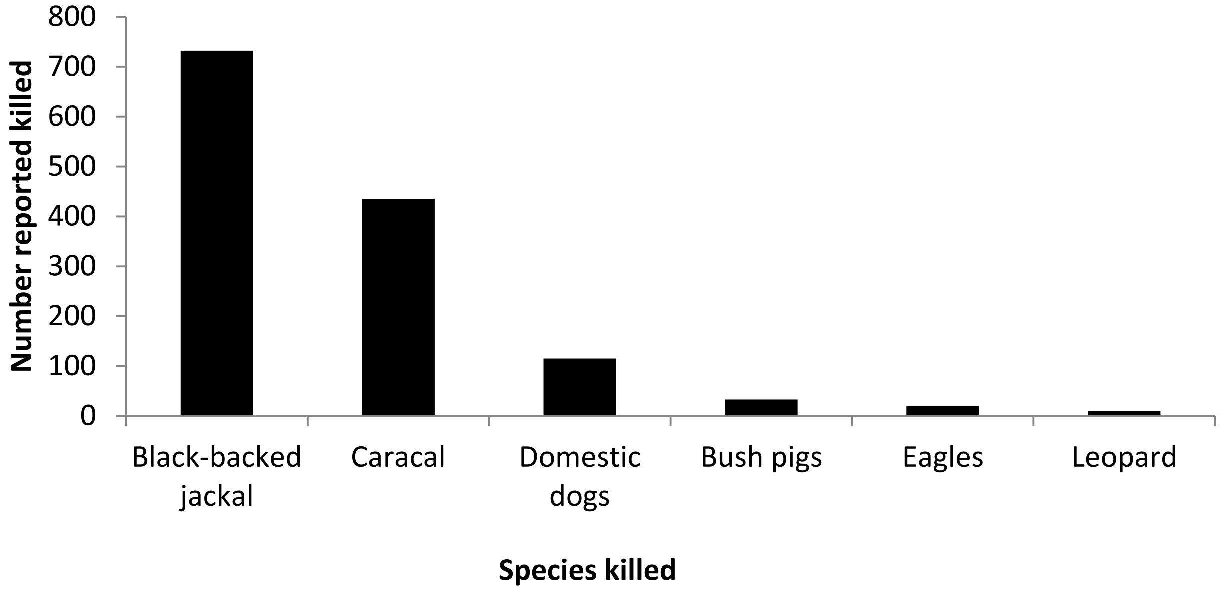

Figure 3.6: The total number of animals killed between March 2013 to July 2014 by respondents within the study area of the Eastern Cape.

The effects of property and demographic variables on the attitude index

The internal consistency of the attitude index as a tool to measure respondent attitudes towards predators was good (Cronbach"s α = 0.71), as was the consistency of each individual question used to construct the index (range α = 0.68 – 0.77; Bath & Buchanan 1989; Zimmermann *et al*. 2005; Jacobs *et al*. 2014; Thorn *et al*. 2014). Overall, 63 % of respondents believed lethal predator control reduced the threat of mesopredator conflict on their farms, as opposed to 25 % who believed that non-lethal control was more efficient. Twelve percent of respondents did not use any method of predator control (Table 3.3).

Table 3.3: The number of respondents and the responses given to the management section of the questionnaire concerning predator control methods.

	Lethal	Non-lethal	None	Both		
What is your preferred method of control?		See figure 4.5				
Which method do you believe works best on your farm?	46	18	9			
Please rate the following predator control methods from 1 to 5, where 1 = least effective and 5 = most effective at reducing mesopredator conflict:						
	0	**1**	**2**	**3**	**4**	**5**
Shooting	3	14	17	19	10	10
Calling & shooting	5	6	11	19	20	12
Cage trap	7	12	11	18	19	6
Gin trap	14	24	18	11	3	3
Poison	14	28	4	12	5	5
Dog pack	11	23	3	17	10	10
Herder	33	3	5	0	0	0
Kraaling	23	18	4	13	8	8
Animal husbandry	34	20	6	8	2	2
Fencing	2	10	9	19	21	12
King collar/Dead stop collar	29	20	10	8	3	3
Relocation of predator	33	29	6	1	4	0

Six models were selected, based on parsimony according to the ΔAICc values, to best predict the attitude index (ΔAICc > 2.00; Table 3.4; Burnham & Anderson 2002; Kolowski & Holekamp 2006; Berger 2006; Berger *et al*. 2008; Holmern & Røskaft 2013). Only six predictor variables were observed in the top six models, indicating that the other two variables (age and education) were not appropriate predictors of the attitude index.

Table 3.4: Generalised linear models that were less than two ΔAICc units of the global model with associated AICc, ΔAICc and Akaike model weight (W*i*) values.

Model	Variable 1	Variable 2	Variable 3	Variable 4	Variable 5	Variable 6	AICc	ΔAICc	W*i*
1	District	Land [a]	Mesop. [b]				485.5	0.00	0.115
2	District	Land [a]					485.8	0.29	0.100
3	District	Land [a]		Stock [c]			486.8	1.21	0.063
4	District	Land [a]			Language		487.1	1.57	0.053
5	District	Land [a]	Mesop. [b]		Language		487.5	1.92	0.044
6	District	Land [a]	Mesop. [b]			Size [d]	487.5	1.99	0.043

[a] Land use (Wildlife/Stock)
[b] Number of mesopredators killed
[c] Stock loss
[d] Size of farm (ha)
Most parsimonious model is at the top of the list

The summed W*i* values for each of the eight predictor variables were calculated to determine the impact each variable had on the attitude index (Impact factors; Table 3.5). Two of the three predictor variables in the global model ranked high in terms of relative impact (Impact factor > 0.80; Burnham & Anderson 2002; Rowe 2009; Thorn *et al*. 2012; Holmern & Røskaft 2013), with district having the highest impact factor of 0.95 thereby being the best individual predictor variable for the attitude index (Table 3.5). The effect of district was highly significant on the attitude index ($F_{(3,69)} = 4.84$; $p < 0.01$). Respondents from the Adelaide Bedford region generally used more non-lethal methods (Figure 3.7). Tarkastad had the most negative attitude index scores, indicating a propensity for lethal control. The difference in the attitude index between respondents from Adelaide Bedford and Tarkastad was highly significant (Tukey test, $p < 0.01$).

Table 3.5: The Impact factors (summed W*i*) for each of the predictor variables used in predicting the attitude index of the respondents within the Eastern Cape.

Variable	Impact factor
District	0.95
Land use	0.85
Mesopredators killed	0.51
Stock loss	0.29
Language	0.28
Age	0.25
Size of farm	0.24
Education	0.13

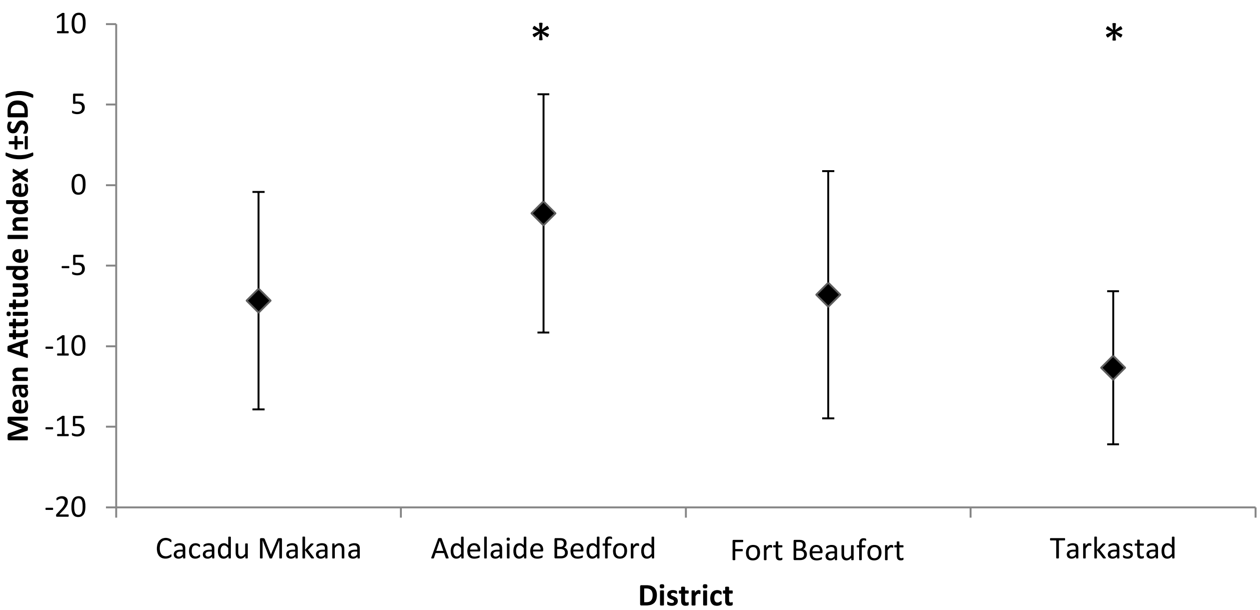

Figure 3.7: The variation in the attitude index in relation to district ($F_{(3,69)} = 4.84$; $p < 0.01$). Vertical bars denote standard deviation. *Denotes highly significant differences (Tukey test, $p < 0.01$).

Land use was the second best predictor of the attitude index (Impact factor score = 0.85; Table 3.6) and there was a significant effect of the land use on the attitude index ($\chi^2 = 7.60$, df = 1, $p < 0.05$). Wildlife ranchers had more negative attitude index scores, indicating that this land use type uses more lethal predator control methods than the livestock farmers (Figure 3.8).

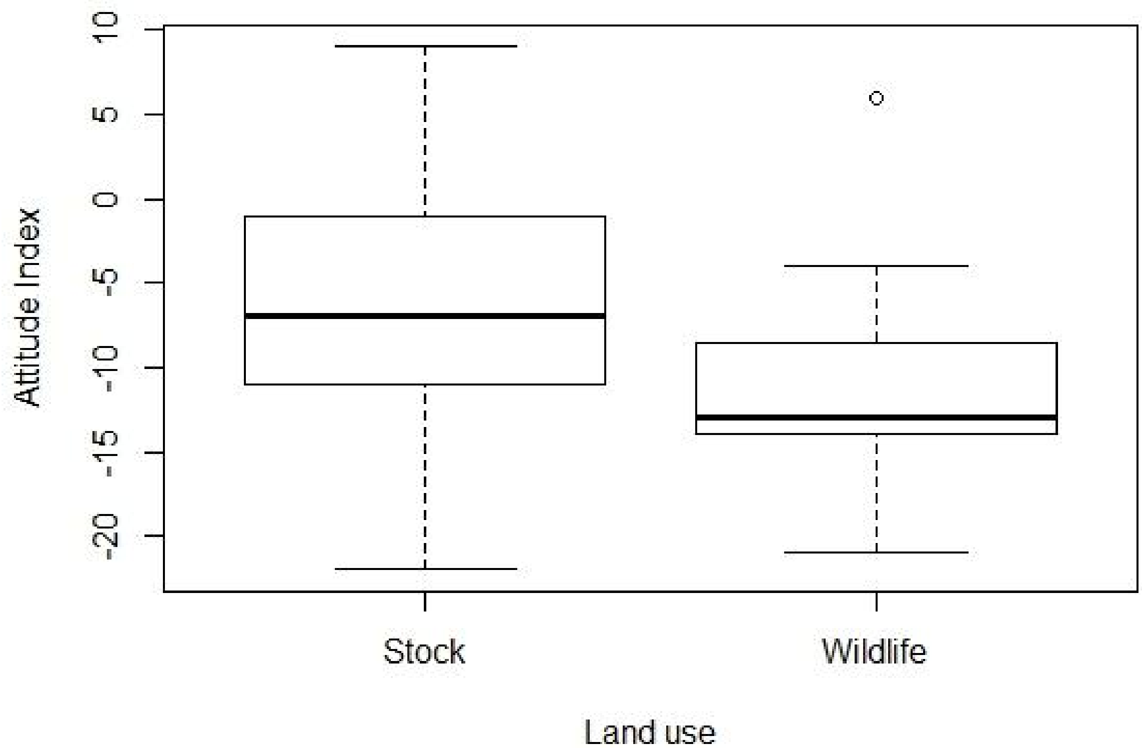

Figure 3.8: The difference between the land use (wildlife ranching or livestock farming) on the attitude index ($\chi^2 = 7.60$, df = 1, $p < 0.05$). The boxplot displays the median, 25 % and 75 % quartiles, maximum, minimum and outliers (°).

The number of mesopredators killed was observed in the global model but had a relatively low impact factor score (Impact factor = 0.51; Table 3.7). Nevertheless, there was a significant effect of the number of mesopredators killed on the attitude index ($R^2 = 0.07$, $F_{(1,71)} = 6.38$; $p < 0.01$), indicating that the more negative the index score, the greater the number of mesopredators killed on the farms (Figure 3.9).

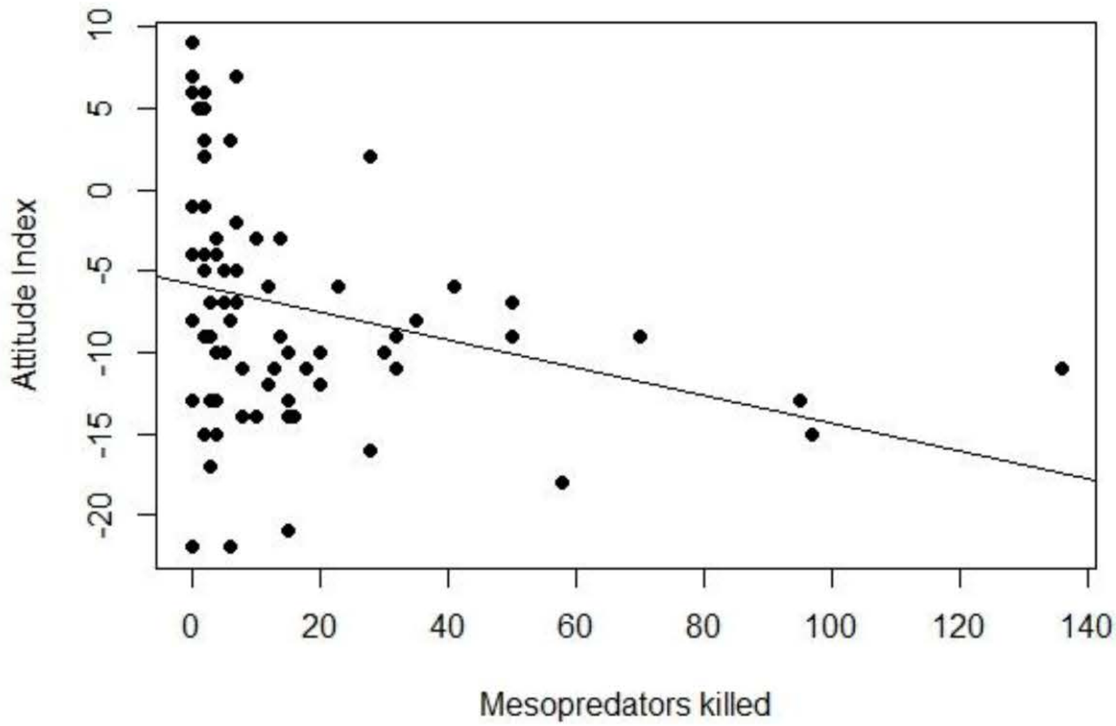

Figure 3.9: The effect of the number of mesopredators killed per property on the attitude index ($R^2 = 0.07$, $F_{(1,71)} = 6.38$; $p < 0.01$) within the study area of the Eastern Cape.

The other variables, stock loss, language, age, size of farm and education, all had very low impact factor scores, suggesting that these variables had little or no impact on the attitude index (Table 3.5). There was no effect of the number of stock lost due to mesopredator depredation on the attitude index ($R^2 = 0.002$, $F_{(1,71)} = 1.20$, $p > 0.05$). Nor was there an effect of the first language on the attitude index ($\chi^2 = 0.89$, df = 1, $p > 0.05$). Afrikaans speaking respondents had a slightly lower attitude index score than English speaking respondents. Again, there was no significant effect of age of the respondent on the attitude index ($R^2 = 0.002$, $F_{(1,71)} = 0.14$, $p > 0.05$). The effect of the size of the respondent's farm on the attitude index was not significant ($R^2 = 0.066$, $F_{(1,71)} = -0.01$, $p > 0.05$). The education variable revealed no significant effect of education on the attitude index ($\chi^2 = 0.29$, df = 2, $p > 0.05$). High school (Grade 9) and matric respondents had a slightly lower attitude index score than did the tertiary level respondents; however, there were no significant differences among the three education levels ($p > 0.05$).

Overall, a total of 4 533 head of stock (3.4 % of total stock) was lost due to mesopredator depredation over a period of 16 months and there was a significant effect of stock loss across the four districts ($\chi^2 = 19.60$, df = 3, $p < 0.01$; Figure 3.10) during the study period. Tarkastad had the highest amount of stock depredation across the study area, and was shown to be significantly different from the Fort Beaufort region (Multiple comparison test, $p < 0.05$).

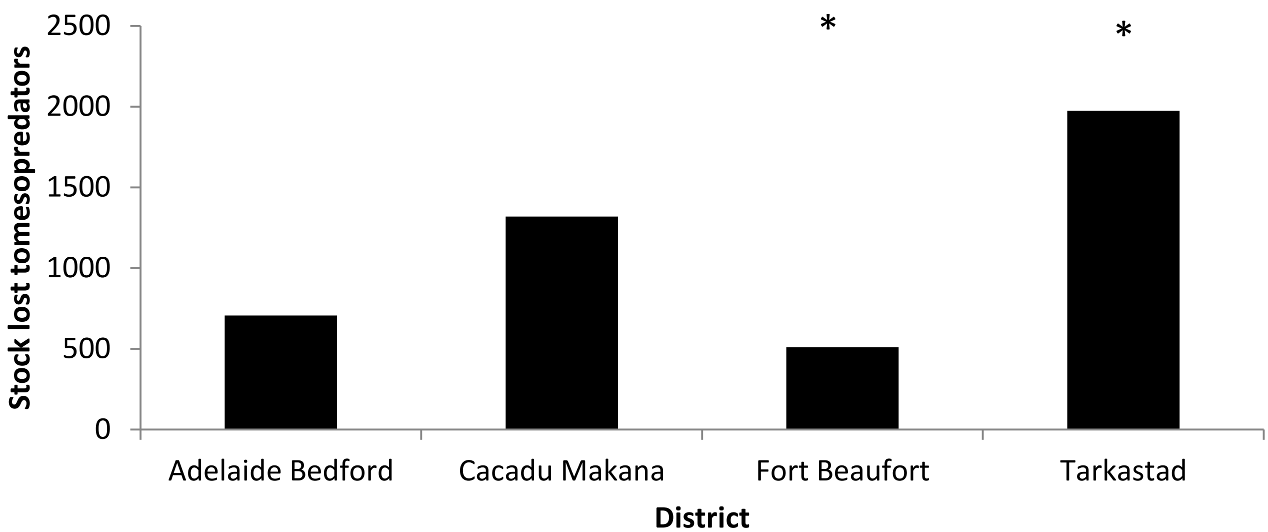

Figure 3.10: The number of head of stock lost due to mesopredator depredation across the four municipalities ($\chi 2 = 19.60$, df = 3, $p < 0.01$) during the study period. There was a significant difference between the number of stock lost in Tarkastad and in the Fort Beaufort region (Multiple comparison test, $p < 0.05$).

There was a significant effect of the number of mesopredators killed in total across the four municipalities ($\chi^2 = 10.32$, df = 3, $p < 0.05$; Figure 3.10). Across the four districts, Tarkastad killed the most mesopredators (both black-backed jackals and caracals; Figure 3.11). This was significantly different from Fort Beaufort (Multiple comparison test, $p < 0.05$), however there was no significant difference between the other two districts (Multiple comparison test, $p > 0.05$; Cacadu Makana and Adelaide Bedford; Figure 3.11).

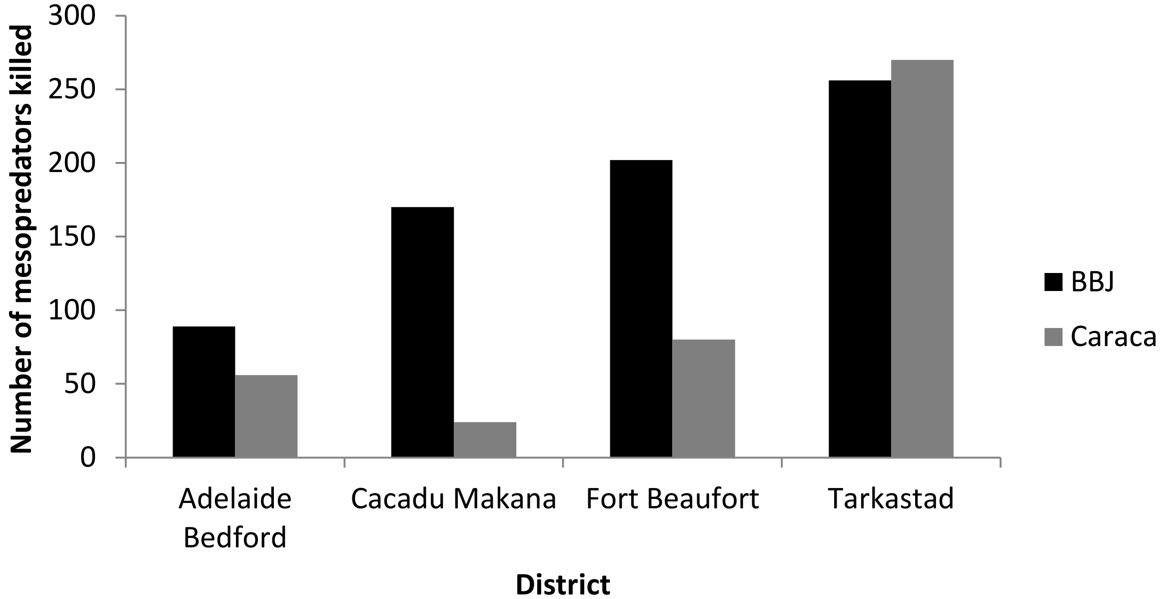

Figure 3.11: The number of mesopredators killed in each of the four municipalities sampled ($\chi 2 = 10.32$, df = 3, $p < 0.05$). There was a significant difference between the number of mesopredators persecuted in Tarkastad and in the Fort Beaufort region (Multiple comparison test, $p < 0.05$).

3.4. DISCUSSION

In my study, stock loss did not appear to determine which control method was used by the respondents, nor did it determine whether or not respondents used lethal control methods. Effectiveness at reducing conflict (seen in the form of a reduction in stock loss due to mesopredator depredation) did not appear to be the main driver in the choice of lethal or non-lethal control methods. My findings suggest that the type of land use and the region of origin of the respondent best determine which form of predator control is used. The most persecuted animal was the black-backed jackal, followed by the caracal. This was not surprising as the indiscriminate killing of both these mesopredators is widespread in southern Africa (Thorn *et al*. 2012). Overall, lethal predator control appeared to be the most popular method, and conflict with predators was believed to be increasing.

Lethal control was widely used throughout the study areas. This may be due to the wide availability of lethal control methods, as opposed to non-lethal alternatives and the perception that lethal methods are more effective (Conover 2001; Treves & Naughton-Treves 2005). The increased use of illegal predator control methods, namely poison, was noted. This was similar to a study conducted in Spain, and a possible reason may be that respondents believe legal methods to be ineffective at reducing conflict (Delibes-Mateos *et al*. 2013). The implications of this are that these illegal methods are mostly unselective and could affect a wide number of species (including those that are vulnerable to extinction). Thus, mitigation attempts need to include education surrounding the effects of non-selective control methods. In Africa, vulture (*Gyps* spp.) populations have declined dramatically due to the widespread use of poison (Ogada *et al*. 2012; Ogada 2014). The loss of scavenging birds has impacted upon the environment through issues of increased disease transmission (Ogada *et al*. 2012). Furthermore, there is little evidence suggesting that lethal control is more cost effective in reducing livestock depredation (Treves & Naughton-Treves 2005).

Perceptions surrounding the risk of having mesopredators on the respondents" land („hyper-awareness" of risk; Dickman 2010), elicited a response from the respondent to want to remove the predator: a finding similar to those of Schumann *et al.* (2012). For example, the calling of black-backed jackals on the farm provoked respondents to use lethal predator control methods. However, indiscriminate blanket control methods are unlikely to reduce depredation and can have negative biological consequences such as compensatory demographic responses (Woodroffe & Frank 2005; Inskip & Zimmermann 2009; Prugh *et al*. 2009; Thorn *et al*. 2012; McManus *et al*. 2014). The compensatory mortality hypothesis suggests that culling will trigger responses in demography (reproduction, survival, population growth all increasing; Cooley *et al*. 2009). For example, the removal of cougars on both public and private land in the United States resulted in increased immigration into the now unoccupied area and also an increase in recruitment of younger animals (Robinson *et al*. 2008).

The impact of social-demographic variables in human-wildlife conflict are increasingly important to identify, as they aid in developing an understanding of the underlying pattern of the drivers of such conflict (Dickman 2010). Some studies have indicated how social variables such as education (Kellert 1985; Anthony 2007; Lagendijk & Gusset 2008), age (Lindsey *et al*. 2005; Zimmermann *et al*. 2005), gender (Lindsey *et al*. 2005) and cultural group (e.g. in the form of the home language; Lindsey *et al*. 2005; Thorn *et al*. 2012) have influenced respondents‟ attitudes towards predators. In addition, other studies have pointed out the need to assess how the use of lethal control varies with social variables (Thorn *et al*. 2014). However, none of the social variables in my study proved to play any significant role in determining the use of lethal and non-lethal predator control.

The majority of the respondents were male and, as such, there was very little input from females, which may have affected the influence of gender on the attitude index. This occurred as males were generally the owners of the property and therefore had a greater input in the daily running of the farm (Schumann *et al*. 2012). Most of the respondents had a high level of education, and most literature suggests that high levels of education foster a good conservation ethic; however in my study this did not affect the use of predator control. Generally, higher levels of education are associated with increased levels of tolerance towards predators (Kellert 1985; Anthony 2007; Lagendijk & Gusset 2008; Schumann *et al*. 2012). This is not always the case, as a study conducted in Wyoming, USA, revealed that two highly educated groups were on either end of the attitude scale with respect to recolonizing wolves (Bath & Buchanan 1989).

Similarly, in my study, respondents who had a tertiary education were found to be using both lethal and non-lethal predator control methods. A higher level of education is also apparently associated with being more environmentally conscious, especially nurturing human-carnivore relationships (Lagendijk & Gusset 2008). However, respondents with a tertiary level education were still using non-selective lethal measures such as poison and dog packs. This may be due to peer group norms affecting the use of control method (Treves & Bruskotter 2014), and as such the respondent may react towards a predator in a way similar to that of the community as a whole.

It was expected that younger respondents would be more accepting of predators and therefore less likely to employ lethal control measures, while different cultural groups would have differing levels of tolerance affecting their choice of control method (Lindsey *et al*. 2005; Thorn *et al*. 2012). In my study, neither age nor home language (cultural group) impacted upon the method of predator control. This may be due to cultural tradition defying age (e.g. sons hunting with fathers), or older farmers recognizing the need to become more environmentally conscious with respect to farm management. However, the perceived risk of economic loss may also be driving the respondents to react to a potential situation regardless of the potentially negative environmental impacts (Thorn *et al*. 2012).

District (the municipality where the respondent resided) can be viewed as both an environmental variable and a social variable as the respondents came from farming associations that typically have similar perceptions and values. District also highlighted the importance of scale within human-wildlife conflict, because while stock loss did not appear to affect the attitude index, it did affect the tolerance of respondents from the Tarkastad District. Not only did the Tarkastad respondents have the highest livestock depredation, but they also removed the greatest number of predators. The beliefs and values of humans determine the course of conflict resolution, so at social gatherings within farming communities, individuals may discuss their own perceptions and the perceived advantages/disadvantages of different predator control methods which can then impact what methods other individuals use (Allen & Sparkes 2001; Manfredo & Dayer 2004). Experience drives behaviour therefore respondents who had or knew of negative experiences with carnivores, this experience may alter their own behaviour (e.g.

persecution) toward them (Heberlein 2012). This was also seen in the rating of problems. For example, respondents from the Fort Beaufort district indicated that their most pressing issue was that of theft/poaching, while Tarkastad respondents had the greatest issue with predators.

It was expected that lethal control would be employed more regularly on livestock farms than on wildlife ranches because predation of intensively managed stock is easier to observe and the impact of livestock depredation may have an increased financial impact (Bothma 2005; Thorn *et al*. 2012). However, wildlife ranchers had significantly lower attitude index scores than livestock farmers and generally employed a higher degree of lethal predator control. Very few non-lethal alternatives are feasible on wildlife ranches (*pers. obs.*), and this may explain their greater use of lethal control (Thorn *et al*. 2014). Again, this alludes to the compensatory mortality hypothesis (altered demographic responses) manifesting, in which areas of increased lethal control could result in predator population sinks (Robinson *et al*. 2008; Cooley *et al*. 2009) and create refugia for mesopredators. This is certainly the general perception of stock farmers in the Eastern Cape (*pers. obs.*). Further, the high extent of land use change currently being experienced in the Eastern Cape has seen an increase in wildlife ranches (Langholz & Kerley 2006). In this respect, many of the previous livestock farmers may react with the same traditional prejudice towards predators on their new wildlife ranches (Delibes-Mateos *et al*. 2013). Similar to livestock farmers, predators may represent an economic risk by decreasing hunting bags creating a „hyper-awareness" of risk (Dickman 2010; Delibes-Mateos *et al*. 2013). Thus the high use of lethal control on wildlife ranches could be attributed to this predation risk, in that they may incur decreased hunting bags due to predation, thereby affecting their livelihood (Graham *et al*. 2005; Lindsey *et al*. 2005; Dickman 2010; Delibes-Mateos *et al*. 2013).

The perception of economic loss through livestock depredation is common and is observed globally (Baker & Macdonald 2000; Marker *et al*. 2003; Muhly & Musiani 2009). This direct wildlife damage is often cited as the main driver of human-wildlife conflict, but it may not always be the case (Dickman 2010; Thorn *et al*. 2012; Schumann *et al*. 2012) as tolerance to predators may be influenced by a range of socio-economic variables (Delibes-Mateos *et al*. 2013). These perceptions are then generally based on cultural norms, values and attitudes (Dickman 2010). Recent studies in southern Africa have shown stock losses amounting to 2.2 %

of total stock in Botswana (Schiess-Meier *et al*. 2007), 1.4 % in Namibia (Marker *et al*. 2003) and 2.77 % in South Africa (Thorn *et al*. 2012). Within my study, the perceived depredation rate was 3.4 % of the total stock owned. I expected that increased livestock depredation would result in increased use of lethal control (Thorn *et al*. 2012). However, stock loss was not the best predictor of the attitude index. This suggests that respondents were acting towards a perceived risk of livestock loss rather than reacting to the actual threat of livestock depredation (Treves & Naughton-Treves 2005).

Generally, predators are seen as a nuisance by farmers and little attention is paid to their ecological role (Kellert 1985; Schumann *et al*. 2012). While the lack of depredation behaviour is not always associated with a positive attitude towards predators as human emotions and beliefs may come into play (Kellert 1985; Schumann *et al*. 2012), it is highly plausible that the respondents may use control methods (lethal or non-lethal) even if there is no actual risk of livestock depredation. It is worrying that there is a high use of generally unselective control methods. The widespread removal of these predators may lead to ecological cascades in the form of mesopredator release or other unknown environmental consequences in the Eastern Cape (Prugh *et al*. 2009; Beasley *et al*. 2013; Ripple *et al*. 2013; Greenville *et al*. 2014).

Determining the levels of conflict and the effects they may have on the control measures employed may be achieved through questionnaires (Thorn *et al*. 2012, 2013). However, questionnaires may be subject to bias as respondents may provide incorrect information or give answers they think the researcher is seeking (White *et al*. 2005). The numbers of livestock killed by predators may also be subject to inflation if the respondent poorly monitors stock abundance, if individuals wish to elicit a response from the interviewer or if the perception of loss is believed to be great (Oli *et al*. 1994; Rasmussen 1999; Schumann *et al*. 2012; Thorn *et al*. 2013). However, by informing the respondents prior to the questionnaire of anonymity and that there would be no risk of negative consequences, this allowed the respondents to answer without bias. In fact, some respondents were so comfortable that they even admitted to using illegal methods of control (e.g. poison).

In total, 4 529 head of livestock were reportedly lost to mesopredator depredation, and in response, 732 black-backed jackals and 435 caracals were killed across the study area during the 16 months of my study. Many studies have shown that the blanket removal of problem species only leads towards a short term reduction in livestock depredation (Stahl *et al*. 2001; Blejwas *et al*. 2002; Graham *et al*. 2005). While the use of lethal control is criticized, selective control rather than blanket removal may mitigate conflict without the risk of extinction or negative ecological consequences (Treves & Naughton-Treves 2005). Furthermore, due to the multi-species predator community of black-backed jackals and caracals, a single method of predator control will not be effective in decreasing the issue of conflict (Graham *et al*. 2005). As such, there does not appear to be a panacea for decreasing the conflict between the respondents in my study area and mesopredators. The „hyper-awareness" of risk, be it the perception of livestock loss, the source-sink dynamic of wildlife ranches, or the mere presence of the predator, may be the driving factors in the killing of mesopredators.

Chapter 4

Mammalian diet and population demographics of culled black-backed jackals within the Eastern Cape

4.1 INTRODUCTION

Human populations have interacted with wildlife for millennia with both positive and negative effects (Thirgood *et al*. 2005). The high intensity of this conflict can be attributed to several factors, such as the loss of anti-predator behaviour in livestock, the decrease in abundance of natural prey due to land use change and poor livestock husbandry practices (Thirgood *et al*. 2005). For generations, land owners have been controlling predator populations in an effort to decrease livestock depredation (Breitenmoser 1998; Treves *et al*. 2004; Treves & Naughton-Treves 2005; Berger 2006).

Examples of predator control have been observed globally, with dingoes (*Canis lupus dingo*) in Australia (Allen & Sparkes 2001; Wallach *et al*. 2009; Allen & Leung 2014), wolves (*Canis lupus*), cougars (*Puma concolor*) and bobcats (*Lynx rufus*) in North America (Chamberlain & Leopold 2002; Robinson *et al*. 2008; Muhly & Musiani 2009; Teichman *et al*. 2013; Jacobs *et al*. 2014), wolves and lynx (*Lynx lynx*) in Europe (Boitani 1995; Stahl *et al*. 2001, 2002) large felids in Asia (Suryawanshi *et al*. 2013) and most carnivore species in Africa (Woodroffe & Frank 2005; Schiess-Meier *et al*. 2007; Kissui 2008; Lagendijk & Gusset 2008; Thorn *et al*. 2012, 2013, 2014; Bergman *et al*. 2013). However, the eradication of one predator species may facilitate the increase in abundance of another (known as mesopredator release: Prugh *et al*. 2009) or cause a trophic cascade (Ripple & Beschta 2004; Berger *et al*. 2008; Ripple *et al*. 2013). Furthermore, despite predator removal, issues of conflict may still persist, indicating that human-predator conflict is a multifaceted problem (Treves & Naughton-Treves 2005). A study conducted in the French Alps indicated that the selective removal of lynx did not decrease the number of livestock depredated (Stahl *et al*. 2001). However, another study conducted on coyotes (*Canis latrans*), in California USA, suggested that by targeting only the breeding pair, there was a decrease in livestock depredation (Blejwas *et al*. 2002). Nevertheless, the removal of animals may also cause compensatory demographic responses (Crooks & Soule 1999) or cause ‘site effects’ (i.e. interactions within the characteristics of a particular site) thereby increasing the risk of livestock depredation events (Stahl *et al*. 2001). For example, age bias in predator control methods has shown that younger (non-breeding) individuals having a higher risk of capture than older individuals (Sacks *et al*. 1999). However, in areas that have not previously been exposed to lethal control, there is no effect of age (Windberg & Knowlton 1990). Sex differences among lethally controlled coyotes have also been observed, with males being more likely to be shot than females. By contrast, females are generally more likely to be caught in snare-traps (Sacks *et al*. 1999). Possible reasons can be attributed to females being smaller and making use of holes rather than jumping over fence lines, while males tend to be more territorial and therefore more likely to be killed using the method of calling and shooting (using the calls of animals to lure the predator in; Beasom 1974; Sacks *et al*. 1999).

The success, often observed as decreased stock loss, of predator removal programmes depends on the avoidance behaviour of the target species toward the predator control method (Treves & Naughton-Treves 2005). Avoidance behaviour towards certain control methods has been shown in black-backed jackals (*Canis mesomelas*) and coyotes (Brand *et al*. 1995; Brand & Nel 1997; Sacks *et al*. 1999) and can either be learnt or acquired avoidance behaviour (Brand *et al*. 1995; Brand & Nel 1997). Social learning by predators allows for decreases in capture rates and can partially explain why these predators still persist in areas with high control effort (Sacks *et al*. 1999).

When assessing the diet of predators in the context of human-predator conflict, it is necessary to address the theory of optimal foraging. The theory states that as the availability of a resource (i.e. prey) increases, so the utilization of that particular resource increases (MacArthur & Pianka 1966). Thus, a decrease in natural prey numbers may increase livestock depredation. For example, in the Pantanal, Brazil, prey availability and climatic conditions impacted upon the diet of jaguars (*Panthera onca*; Cavalcanti 2008). Not only were cattle (*Bos primigenius*) more vulnerable to predation (because of a lack of anti-predator behaviour) but they also represented the largest available ungulate biomass (Cavalcanti 2008). However, during the wet season, an increase in peccary (*Pecari tajacu* and *Tayassu pecari*) density was observed and this resulted in a decrease in cattle depredation (Cavalcanti 2008). Prey switching was also observed in caracals

(*Caracal caracal*) in South Africa (Avenant & Nel 2002). During periods of low rodent densities, caracals targeted springbok (*Antidorcas marsupialis*; on wildlife ranches) and small stock (on livestock farms; Avenant & Nel 2002) instead of rodents. Furthermore, this pattern of prey switching was demonstrated in Norway as the density of wild ungulates (e.g. roe deer, *Capreolus capreolus*) impacted upon livestock depredation rates (Gervasi *et al*. 2014). Essentially, the more abundant the one species (roe deer), the less the lynx would prey upon the other species (sheep, *Ovis aries*; Gervasi *et al*. 2014).

The black-backed jackal is endemic to Africa and is distributed between two disjunct areas separated by 900 km (Skinner & Chimimba 2005; Hoffman 2014). One of the main reasons for their persistence across a varied habitat is their diverse diet (Stuart 1976; Bernard & Stuart 1992; Kaunda & Skinner 2003; Brassine 2011; Forbes 2011; Van de Ven *et al*. 2013). Prey items include vertebrates, invertebrates, plant material, inorganic substances (e.g. rocks) and even anthropogenic items (e.g. plastic; Rowe-Rowe 1983, 1975; Hall-Martin & Botha 1980; Hiscocks & Perrin 1988; Atkinson *et al*. 2002; Kaunda & Skinner 2003; Do Linh San *et al*. 2009; Klare *et al*. 2010; Brassine 2011; Forbes 2011; Kamler *et al*. 2012). With regard to the vertebrates, the diet is reported to be predominately small mammals and birds (Kaunda & Skinner 2003; Skinner & Chimimba 2005). However, recent studies have shown a greater reliance on large ungulate species by black-backed jackals (Klare *et al*. 2010; Van de Ven *et al*. 2013).

The diet of a generalist species is mostly dependent on the availability of the prey species (*sensu* the optimal foraging theory; MacArthur & Pianka 1966; Kaunda & Skinner 2003). As such, studies have indicated temporal variation in the diet of the black-backed jackal and this may reflect the breeding patterns of certain prey species (Rowe-Rowe 1975; Lawson 1989; Klare *et al*. 2010; Kamler *et al*. 2012). Studies conducted in South Africa have demonstrated that the consumption of sheep is twice as high during the birthing seasons (spring and winter) than the rest of the year (Rowe-Rowe 1975; Lawson 1989; Kamler *et al*. 2012). These temporal patterns can be attributed to either the ecology of the predator itself (increased livestock depredation during birthing season due to higher energy demands; Harrison & Harrison 1984; Klare *et al*. 2010), or the increase in prey abundance during lambing/calving season (Rowe-Rowe 1975;

Lawson 1989). Alternatively, the decrease in native prey species availability during winter seasons could drive such dietary shifts (Avenant & Du Plessis 2008).

Mesopredator release has been demonstrated when African wild cats (*Felis lybica*), caracals and black-backed jackals have been removed from arid systems (Blaum *et al*. 2009). The control of these predators allowed for an increase in the abundance of small-spotted genets (*Genetta genetta*), Cape foxes (*Vulpes chama*) and bat-eared foxes (*Otocyon megalotis*) in the Kgalagadi (Blaum *et al*. 2009). Such changes in abundances can then impact upon the overall structure and function of the ecosystem. For example, the control of coyotes in North America led to an increase in raccoon (*Procyon lotor*) numbers which negatively affected nest success of Song Sparrows (*Melospiza melodia*; Rogers & Caro 1998). Cascading effects such as this can only negatively affect ecosystem functionality (Blaum *et al*. 2009). The interactions among members of a food web are complex, with both linear and triangular structural categories (Prugh *et al*. 2009). With linear interactions, a decline in the apex predator is likely to result in an increase in the mesopredator and a decrease in the prey species (Prugh *et al*. 2009). By contrast, the triangular interaction allows for shared predation (between apex and mesopredators). For example, in a controlled experiment in Texas, USA, the removal of apex predators (coyotes, bobcats, *Lynx rufus;* gray foxes, *Urocyon cinereoargenteus*; and badgers, *Taxidea taxus*) and the increase in mesopredators did not facilitate a decrease in prey (rodent) populations (Henke & Bryant 1999). Furthermore, one species of rodent (Ord's kangaroo rat, *Dipodomys ordii*) began to outcompete other rodent species, leading to additional destabilization of the ecosystem functionality (Henke & Bryant 1999; Prugh *et al*. 2009).

Few studies have simultaneously assessed the diet and demography of culled black-backed jackals in southern Africa (Kalahari, Bothma 1966; Eastern Cape, Hall-Martin & Botha 1980; Botswana, Kaunda 1998). The restriction to black-backed jackals in this study was based upon a low sample size of available caracal stomachs. Significantly, gaining insight into the role of black-backed jackals as livestock predators is essential for the management of this important human wildlife-conflict issue (Adams *et al*. 2010). Therefore, only mammalian diet was determined in this study. The aims of this chapter were therefore to assess the mammalian component of the diet and the demography of culled black-backed jackals in the Eastern Cape, South Africa. Specifically, I asked:

- Are there differences in the diets of black-backed jackal on two different land use types (wildlife ranches and livestock farms), between age classes and/or between sexes?,
- Do black-backed jackals prey on livestock? and
- Which black-backed jackal individuals, in terms of age and sex, are removed from the population by lethal predator control methods?

Broad hypotheses:

- The diet of culled black-backed jackal will be broader (i.e. more species taken) on wildlife ranches than on livestock farms. In addition, male black-backed jackals will be expected to have larger-sized prey species than females, and similarly with age classes: as age increases so does prey size.
- A higher frequency of occurrence of livestock will be observed in the stomachs of black-backed jackals culled on livestock farms than on wildlife ranches, and;
- A higher number of young male black-backed jackals will be culled than older females.

4.2 MATERIALS & METHODS

4.2.1 Data collection

Mammalian diet composition and black-backed jackal population demographics were determined from 32 black-backed jackals which were legally culled between April 2013 and June 2014 in the Eastern Cape, South Africa. This was done by private landowners, chosen based upon willingness to participate in the study, using three lethal predator control methods (calling & shooting, dog packs and shooting) on five properties (three wildlife ranches and two livestock farms; Figure 4.1). All predator carcasses were recovered from the private individuals and no animals were killed specifically for this study.

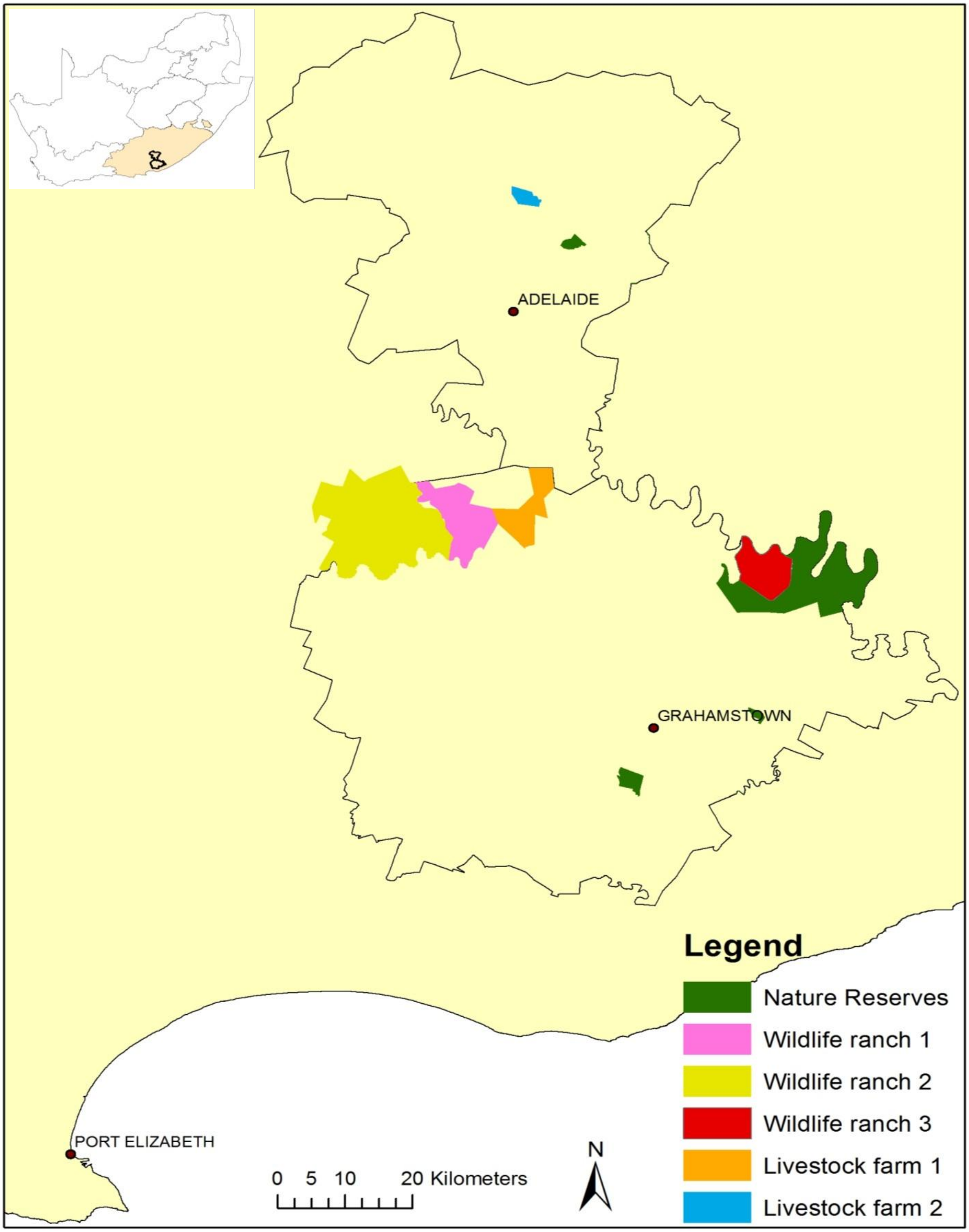

Figure 4.1: The five properties (three wildlife ranches, two livestock farms) from which stomachs from culled black-backed jackal were collected. Neighbouring nature reserves are also indicated (ArcGIS 10.1; map units: kilometres).

Knowledge of diet habits is crucial to broaden our understanding of an animal's behaviour and ecology. Various methods have been developed to examine the diet of carnivores, including scat analysis (Kaunda & Skinner 2003; Do Linh San *et al*. 2009; Klare *et al*. 2010; Braczkowski *et al*. 2012), direct observations (Bissett 2004), stable isotope analysis (Adams *et al*. 2010), and stomach content analysis (Cavallini & Volpi 1995; Pezzo *et al*. 2003; Azevedo *et al*. 2006). The choice of method is related to the study area and the welfare concerns of the study species as each method has its own advantages and disadvantages. As an indirect method, scat analysis is frequently used (Mills 1996; Trites & Joy 2005; Tambling *et al*. 2012). However, the majority of dietary research on predators which has been conducted in South Africa has made use of stomach content analysis to determine diet (Bothma 1966; Stuart 1976; Trites & Joy 2005). Stomach samples have advantages in that it is possible to identify partially digested remains (Witt 1980), thereby decreasing the risk of prey misidentification (Pezzo *et al*. 2003). The main disadvantage concerns the culling of the animal, which not only raises ethical concerns but also decreases the number of available samples (Norbury & Sanson 1992; Mills 1996).

A study by Pezzo *et al.* (2003) indicated that diet composition of wolves was similar when comparing stomach and intestinal contents. Thus only stomach contents were assessed in my study. Carcasses were acquired during routine predator control operations by landowners and were unevenly distributed throughout the year. Mammalian prey items within the stomach were identified using a standard hair analysis method (Perrin & Campbell 1980; Keogh 1985; Goldenberg *et al*. 2010). Black-backed jackals were examined post-mortem. The stomachs were removed and stored in a 1 L screw-top bottle and filled with 70 % ethanol prior to laboratory analysis (Kaunda 1998).

For analysis, the stomachs were opened and the contents sieved through a 44 µm sieve and placed on a white dissecting tray (Bissett 2004). Dietary components were then separated into petri dishes based on physical appearance (Bissett 2004). Mammalian hair was identified to species level using negative cuticle scale imprints and transverse sections (Keogh 1983). Mammalian hair is widely used for identification because different mammal species hairs have characteristic features, varying in length, shape, colour and scale patterns (Keogh 1983). An advantage of using hair to identify prey items is that hair is largely indigestible (Keogh 1983;

Reynolds & Aebischer 1991). However, due to the variation between hair types within a species, such as guard hairs and under hairs, samples were compared to dorsal, ventral and guard hair references of each species (Brassine 2011).

Hair analysis

To prepare negative cuticle impressions of the hair, a method similar to that of Keogh (1983) was employed. Hairs were cleaned using absolute alcohol, washed with water and left to air-dry (Bissett 2004). Standard light microscope slides were coated with a 5 % gelatin solution (Royal) to obtain cuticle impressions. Ten randomly chosen hairs from each stomach sample were placed on the gelatin-covered slides using fine forceps and allowed to cool to room temperature for approximately 24 hours before the removal of the hairs (Kaunda 1998; Bissett 2004; Brassine 2011; Forbes 2011). Two slides (five hairs per slide) were made for each stomach (Bissett 2004). As cuticle imprints alone are not sufficient to accurately identify a species, this was done in combination with the transverse sections (Douglas 1989). Transverse sections were created by placing cleaned hairs (~10 – 20 hairs; Bissett 2004) into labeled plastic pipettes, and molten Paraplast© Plus wax was sucked in (Douglas 1989). These pipettes were then placed in iced water to rapidly cool the wax and then cut into 1 mm sections with a sharp scalpel and glued onto standard microscope slides using wax (Douglas 1989). The sections and the negative cuticle impressions were examined under a Carl Zeiss PrimoStar Upright Microscope (10 x) and compared to the Rhodes University hair reference collection, plus the following published data: the microstructure of the hair of southern African bovids (Keogh 1983) and the key to the mammals of the Andries Vosloo Kudu Reserve (Perrin & Campbell 1979). The reference collections contained both cross sections and cuticle imprints of all hair types (e.g. guard, dorsal; Keogh 1983, 1985; Bissett 2004; Brassine 2011; Forbes 2011). Photographs were taken of each imprint and cross section using a Canon Power Shot A640 digital camera (10.0 megapixel) attached to the microscope by a 52 mm adaptor tube. When I had identified the hairs, the results were checked by another observer (Charlene Bissett), experienced in hair analysis, to increase accuracy (Brassine 2011).

Population demographics

To determine the population demographics of the culled jackals, the specimens were sexed and aged. The animals were aged by assessing their dentition and measuring their body length (cm), and were divided into three broad categories: juvenile, sub-adult and mature adult (Figure 4.2; Bingham & Purchase 2003; Skinner & Chimimba 2005). The ridges observed on the incisors are extremely noticeable in juvenile and sub-adults, but are worn down and cannot be seen in mature adults (*pers. obs.*). The age classes identified from the carcasses were checked by the land owner at each site to increase accuracy. The sexes of the animals were noted by examining external genitalia.

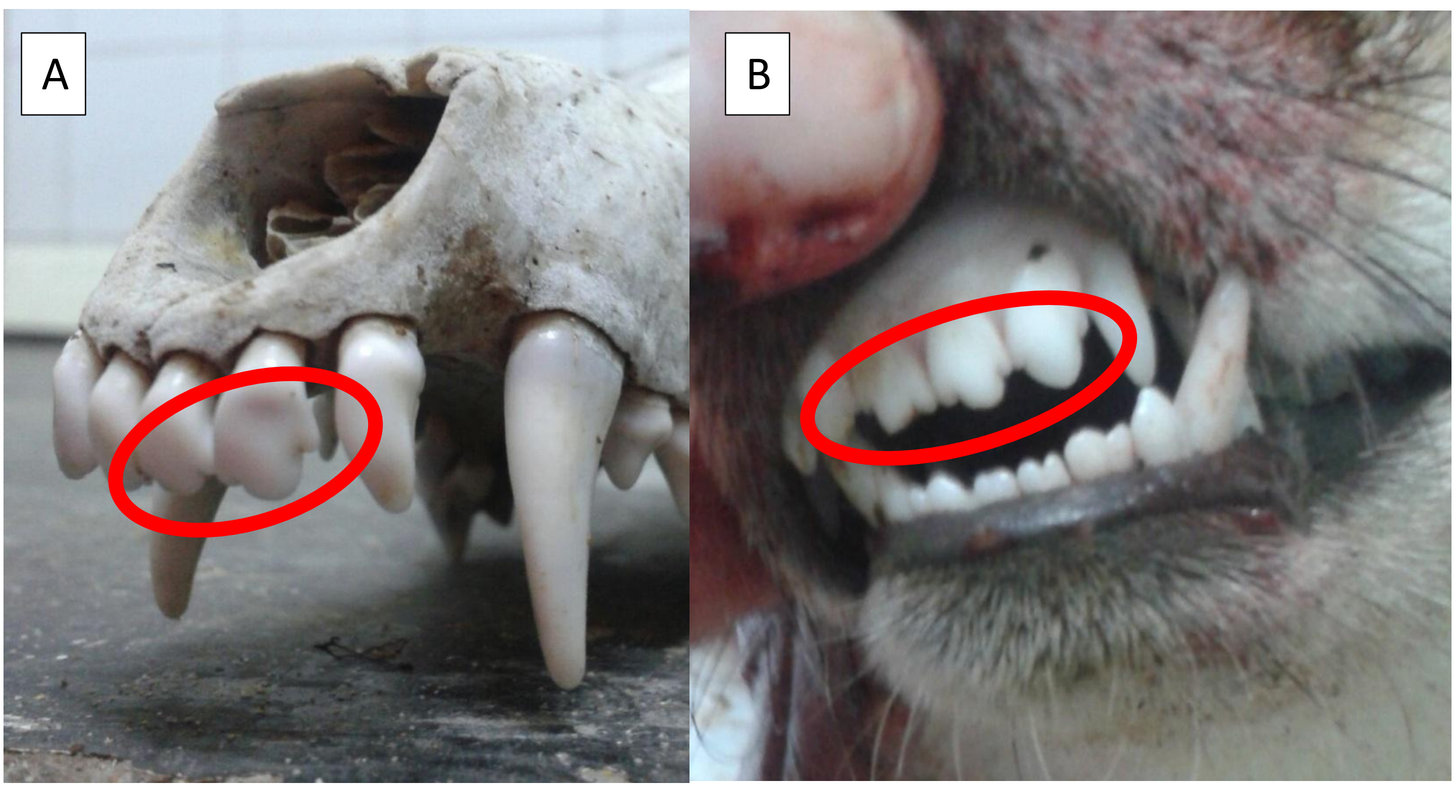

Figure 4.2: The method of age determination by assessing the dentition of the black-backed jackal. Red oval indicates the teeth used to assess age. A = Mature adult (note the wear of ridges on incisors), and B = Sub-adult (note ridges still seen on incisors).

4.2.2. Data analysis

Quantitative analysis

Two common methods used to express dietary composition are frequency occurrence (FO) and relative frequency occurrence (RFO) (Loveridge & Macdonald 2003; Breuer 2005; van der Merwe *et al*. 2009; Giannatos *et al*. 2010; Klare *et al*. 2011b; Balestrieri *et al*. 2011, 2013). FO and RFO are calculated as follows:

$$Frequency\ of\ Occurrence = \frac{n_a}{n} \times 100$$

$$Relative\ Frequency\ of\ Occurrence = \frac{PC_a}{PC_b + PC_c + PC_d} \times 100$$

where n_a is the number of stomachs containing species prey item $_a$, n is the total number of stomachs, PC_a is the number of observations of prey category *a* within a stomach and $PC_{b\text{-}d}$ are the other prey species category observations found in that particular stomach.

The FO indicates how often that species/dietary category appears in the diet (Loveridge & Macdonald 2003; Breuer 2005; van der Merwe *et al*. 2009; Klare *et al*. 2011b). However, this method overestimates the contribution of infrequently consumed prey species (Balestrieri *et al*. 2011, 2013). By contrast, the RFO represents the relative occurrence of each prey species in the diet and indicates dietary breadth by showing how often a particular prey species is encountered relative to other prey items (Loveridge & Macdonald 2003; van der Merwe *et al*. 2009; Klare *et al*. 2011b). Most dietary studies use FO, however a limitation to my study is that biomass of prey consumed could not be calculated. Biomass calculations give the best approximation of the true diet of a carnivore (Klare *et al*. 2011b). While most studies use FO, Klare *et al.* (2011) claim this to be the least accurate method. However, due to widespread use, it allows for easy comparisons to be made across studies (Mills 1996). Overall, the best approach to examining the true diet of a carnivore is to use both methods concurrently (Klare *et al*. 2011b). While not applying a biomass quantification may be a limitation, it does not deviate from the aim of the study, which was to determine and describe the mammalian dietary composition of the diet of culled black-backed jackals.

Sample-based rarefaction curves were produced to illustrate the number of observed species as a function of sampling effort (Colwell 2009). The curves were produced using presence/absence data from stomach analyses of the culled black-backed jackals. The curves produced used the analytically calculated S(obs) (Mao Tau; the number of species expected), the incidence-based coverage estimator (ICE) and the Chao 2 in Estimate S V 9 (Figure 4.3; Chazdon *et al*. 1998; Chao *et al*. 2004; Colwell 2009). ICE and the abundance-based coverage estimator (ACE) are the same when using a presence/absence matrix, therefore only ICE was used as both ICE and Chao 2 are incidence based (Chao *et al*. 2004; Colwell 2009). All curves appear to be nearing an asymptote (Figure 4.3). This suggests that the sample size was sufficient to demonstrate the variability within the animals' diet.

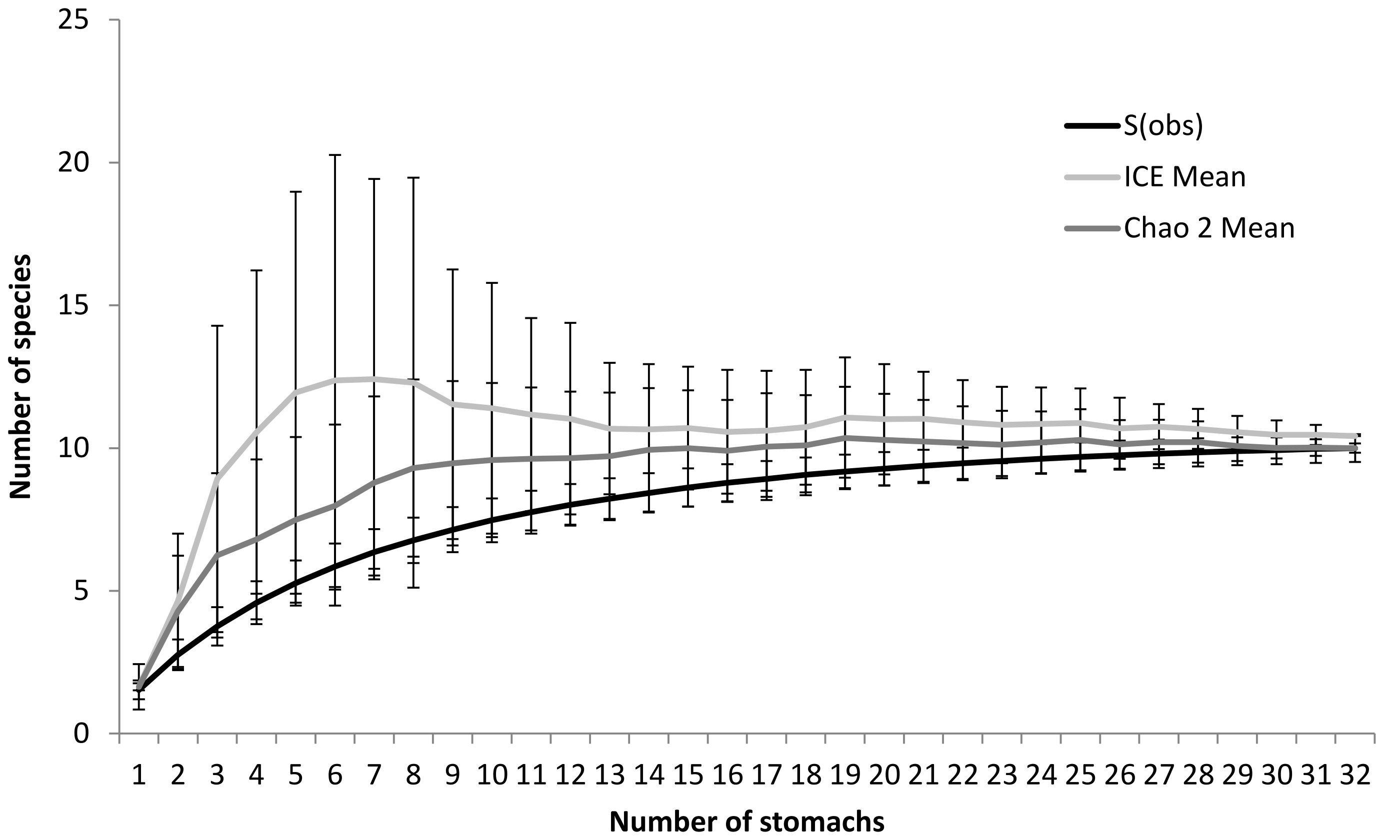

Figure 4.3: Sample rarefaction curves showing the results of a s(obs) (Mao Tau), incidence-based coverage estimator (ICE) and Chao 2 produced in Estimate S V 9 (±SD; Colwell 2009) indicating all curves to be reaching an asymptote.

Seasonal comparisons could not be made due to an unequal distribution of samples over the year. All data were non-normally distributed ($p < 0.05$), therefore non-parametric statistics were used. The statistical significance was set at $p < 0.05$ and all data were analyzed using PRIMER V 5.0 (Clarke 1993) and R 3.0.2 Software (Appendix D; R Foundation for Statistical Computing, 2013). For comparative purposes, the data were converted in a presence/absence matrix (binary data; Rees *et al*. 2004). A similarity matrix was calculated using a Bray-Curtis coefficient (Clarke 1993; Rees *et al*. 2004). Multidimensional scaling (MDS) was used to display the similarity data along two dimensions to visualize group differences/similarities (Rees *et al*. 2004). ANOSIM (Analysis of Similarities) tests were then performed in PRIMER to examine any statistically significant similarity between groups (Clarke 1993; Rees *et al*. 2004). Following this, a SIMPER analysis was conducted to calculate the average dissimilarity between groups

(Clarke 1993; Rees *et al*. 2004). Chi-square tests of independence were calculated in R 3.0.2 to test the demographic variables and the control methods (Appendix IV). Due to low expected frequencies, the results of the chi-square test were compared to those of the Fisher Exact test to gain the correct p-value approximation (Campbell 2007).

4.3 RESULTS

Thirty two stomachs were retrieved, of which 20 were from wildlife ranches and 12 from livestock farms (Table 4.1). More males were retrieved (19) than females (13; Table 4.1). By assessing age classes, it was apparent that most of the animals were juveniles (12), followed by mature adults (11) and nine sub-adults (Table 4.1). The most popular method of controlling was calling and shooting (66 % of those culled), while eight were culled using a dog pack, and three were culled by shooting (Table 4.1).

Table 4.1: Summary data of the black-backed jackals (n = 32) collected from problem animal control in the Eastern Cape.

Variable		Number	%
Land use			
	Wildlife ranch	20	62.5
	Livestock farm	12	37.5
Sex			
	Male	19	59
	Female	13	41
Age			
	Juvenile	12	37.5
	Sub-adult	9	28
	Mature adult	11	34.5
Control method			
	Calling & shooting	21	66
	Shooting	3	9
	Dog pack	8	25

Stomach data from culled black-backed jackals

Two stomachs were empty and were thus excluded from the stomach data analysis (N = 30). By assessing the FO, warthog (37 %) and kudu (25 %) were found to be the dominant diet species (Figure 4.4). Of the large (> 50 kg) Ruminantia, red hartebeest (16 %), gemsbok (9 %) and nyala (6 %) were also observed in the diet (Figure 4.4). For the small (< 50 kg) Ruminantia, impala (6 %) and common duiker (17 %) remains were found in the stomachs (Figure 4.4). Other mammals in the stomachs included porcupine (3 %) and scrub hare (17 %; Figure 4.4). No livestock remains were found in any of the stomachs.

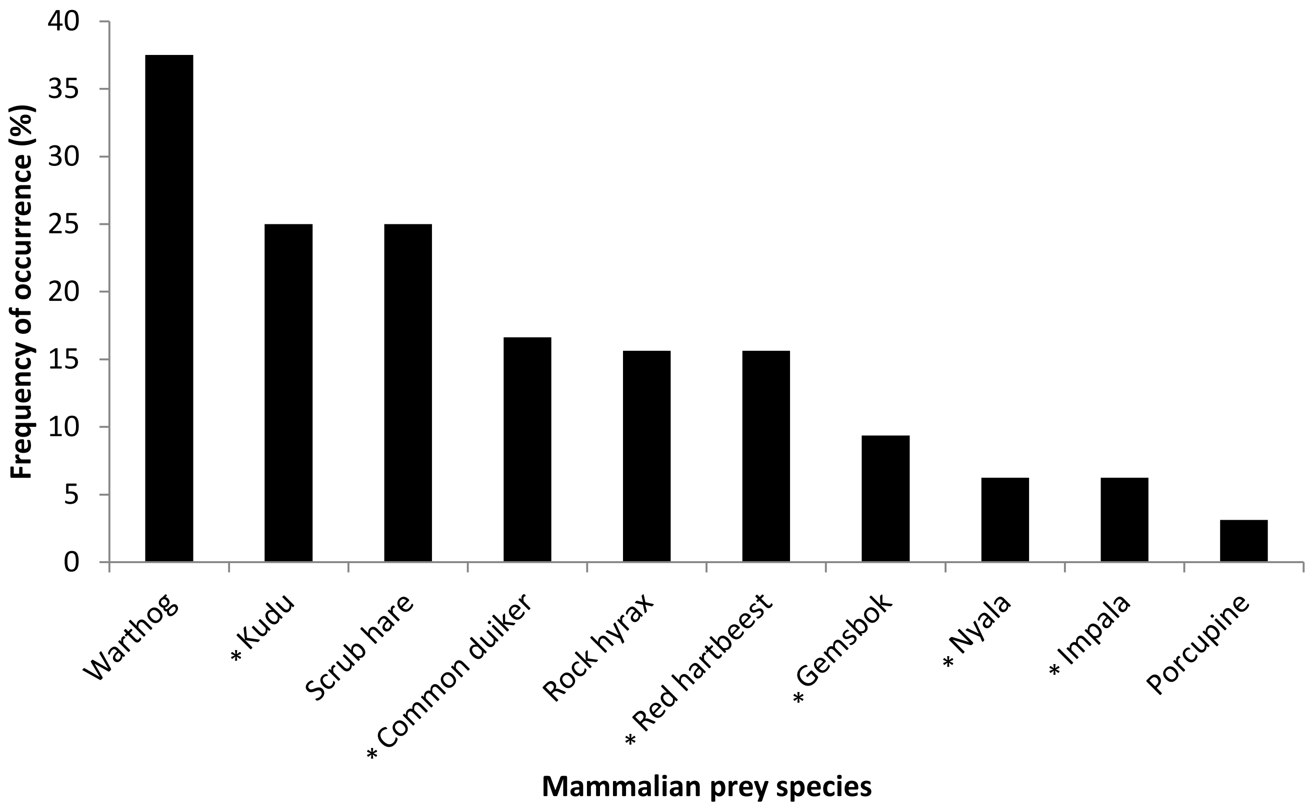

Figure 4.4: The frequency of occurrence (%) of mammalian prey species observed in the stomachs of culled black-backed jackals (n = 30) in the Eastern Cape.

***Indicates species that are ranched**

In terms of the RFO, the two dominant mammalian prey species were found to be the common duiker (77 %) and the scrub hare (75 %; Figure 4.5). Of the large Ruminantia, nyala (63 %) followed by gemsbok (50 %) were the dominant diet species, while kudu (43 %) and red hartebeest (42 %) were also observed (Figure 4.5). Impala (61 %) and rock hyrax (57 %) also appeared to form a substantial component of the diet (Figure 4.5). Porcupine remains were observed in only one stomach (Figure 4.5).

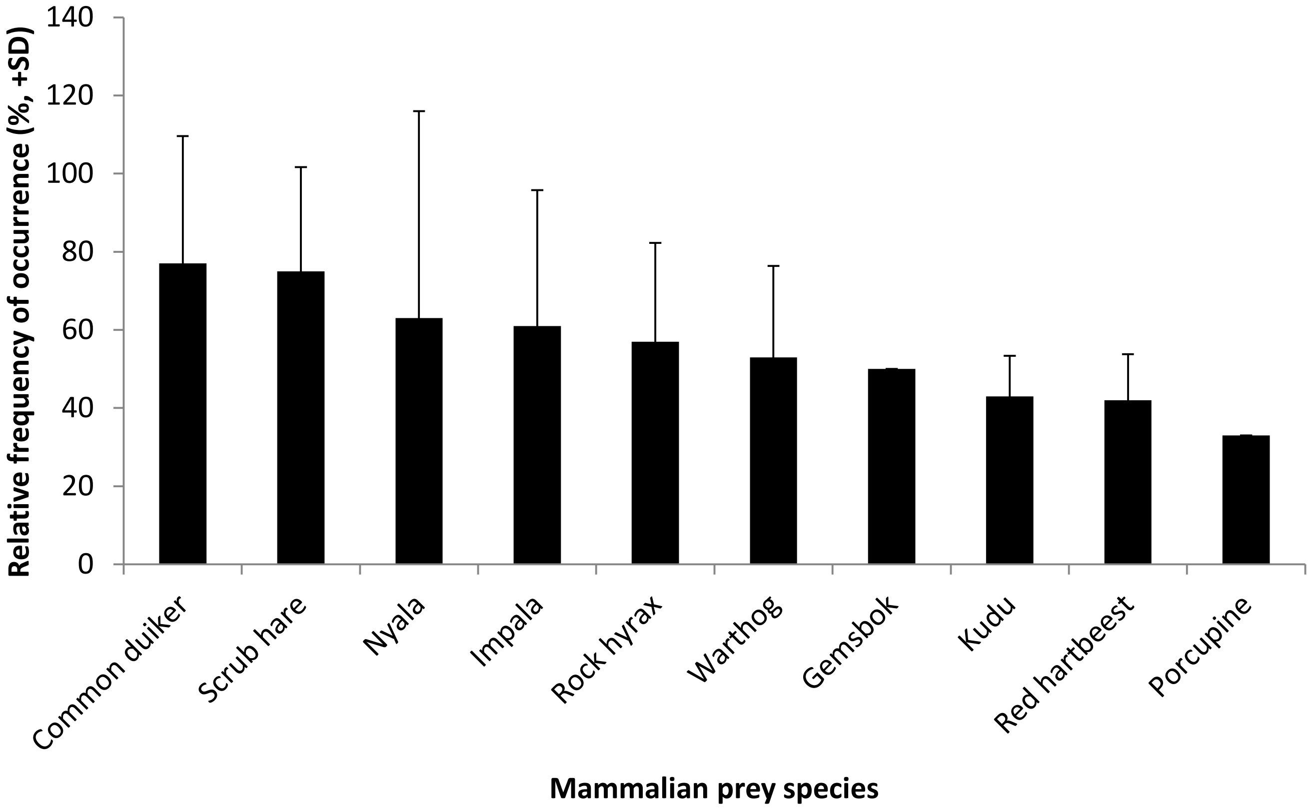

Figure 4.5: Relative frequency of occurrence (%; +SD) of mammalian prey species observed in the diet of black-backed jackals culled (n = 30) in problem animal control efforts in the Eastern Cape.

Multidimensional scaling (MDS) indicated that there was some overlap in the diet of black-backed jackals on the two land use types (wildlife ranches and livestock farms; Figure 4.6). However, an ANOSIM indicated a significant difference between the diets on the two land use types (Sample statistic/Global R = 0.102, significance of sample statistic = 3.3 %, $p < 0.05$). The strength of the relationship was considered ideal (Kruskal stress = 0.02; Figure 4.6).

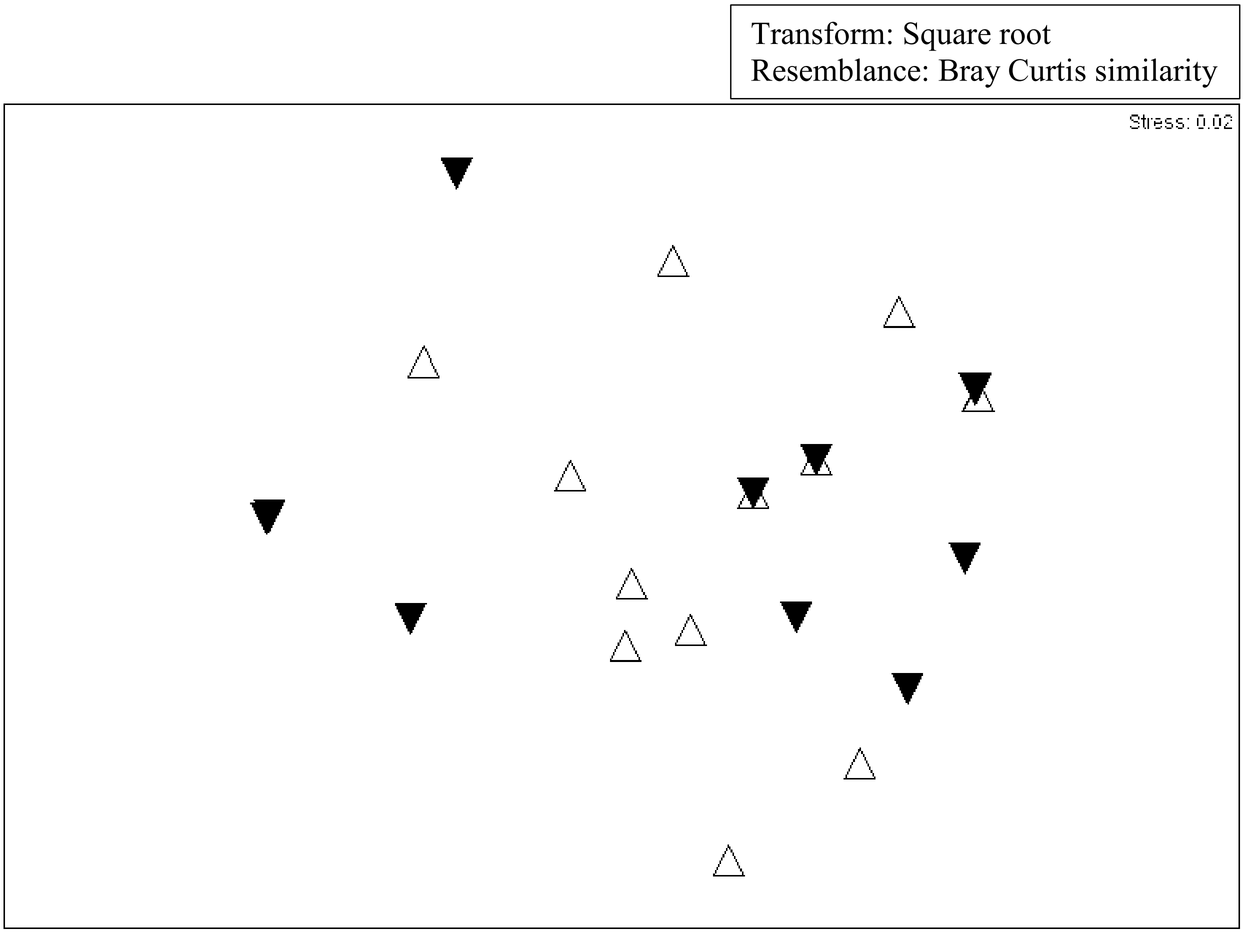

Figure 4.6: MDS ordination for the diet composition of black-backed jackals culled on two land use types, namely wildlife ranches (white) and livestock farms (black) from April 2013 to June 2014.

As the MDS did not display the dissimilarity observed with the ANOSIM, a cluster analysis was performed in PRIMER (Figure 4.7). The cluster analysis indicated a greater dissimilarity between the two land use types (Figure 4.7).

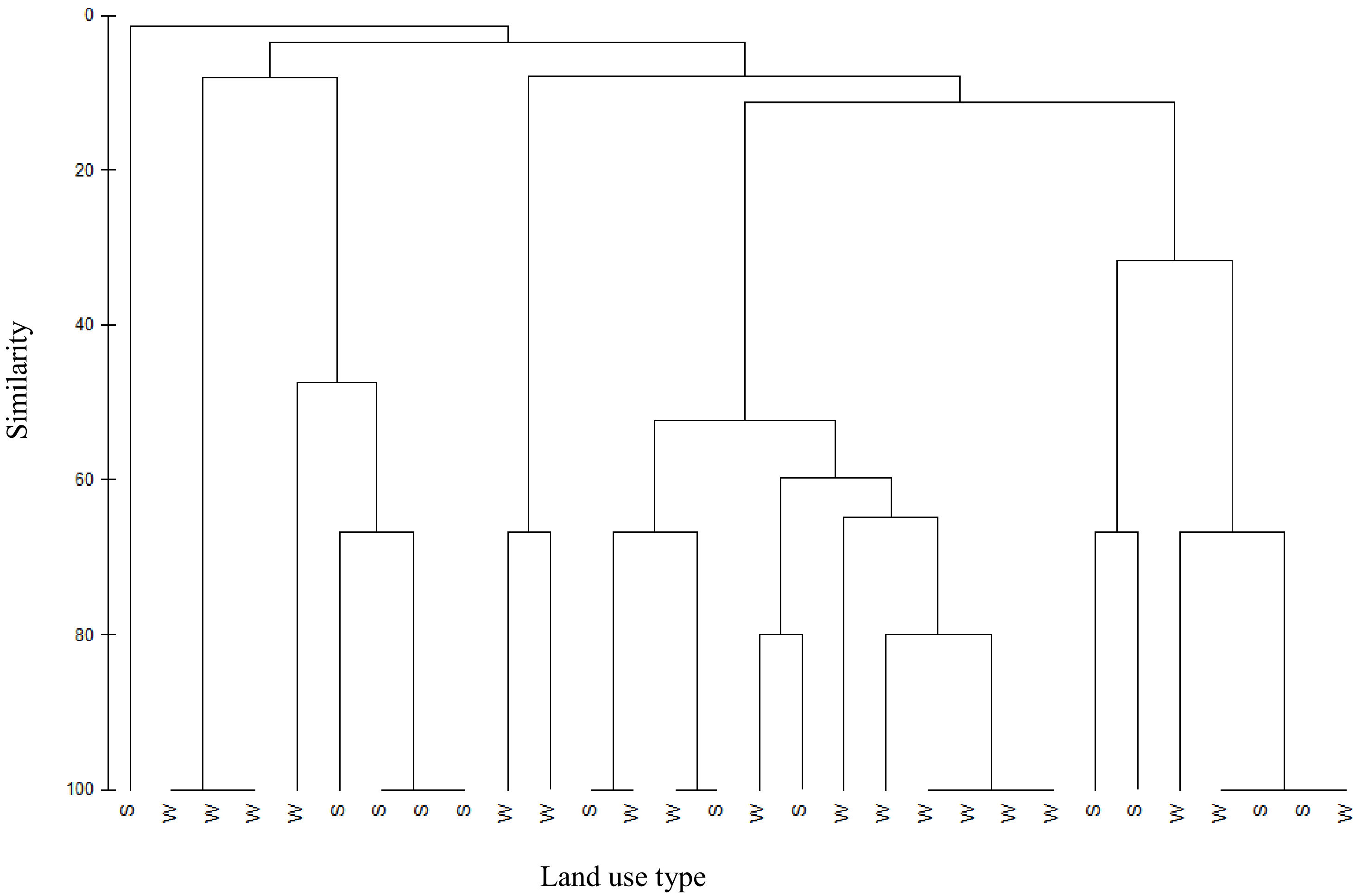

Figure 4.7: Cluster analysis for the diet composition of black-backed jackal culled on two land use types (Wildlife ranches = W, livestock farms = S) from April 2013 to June 2014 indicating a greater dissimilarity.

A SIMPER analysis indicated that the black-backed jackals culled on wildlife ranches included a slightly greater variety of prey species in their diet (5 species, 3 unique species) than those culled on livestock farms (4 species, 2 unique species; Table 4.2). The within -group similarity of black-backed jackals culled on wildlife ranches was 95 %, while on livestock farms the within-group similarity was 100 % and was attributed to four prey species (Table 4.2). Overall, the average dissimilarity was 84.23 %. Warthog and scrub hare were found in the stomachs of culled black-backed jackals from both land use types (Table 4.2). Notably, many smaller mammals, the largest being warthog (~ 50 kg), were observed in the diet of black-backed jackals culled on livestock farms (Table 4.2). On wildlife ranches, the most common contributor to the diet was warthog (43 %), while on stock farms the dominant prey species was common duiker (39 %; Table 4.2).

Table 4.2: Average Bray-Curtis similarity between the mammalian species composition found in black-backed jackal stomachs from two land use types (Wildlife ranches n = 20, Livestock farms n = 12).

Wildlife ranches			
Prey species	**Common name**	**% Contribution**	**Cumulative %**
Phacochoerus africanus	Warthog	43.1	43.1
Tragelaphus strepsiceros	Kudu	22.3	65.4
Lepus saxatilis	Scrub hare	11.0	76.4
Alcelaphus buselaphus	Red hartebeest	10.5	86.9
Oryx gazella	Gemsbok	7.9	94.8
Livestock farms			
Prey species	**Common name**	**% Contribution**	**Cumulative %**
Sylvicapra grimmia	Duiker	39.0	39.0
Lepus saxatilis	Scrub hare	32.3	71.4
Phacochoerus africanus	Warthog	14.3	85.7
Procavia capensis	Rock hyrax	14.3	100.0

The diet composition indicated that there was no resource partitioning between the sexes of culled black-backed jackals (Figure 4.8). In addition, a MDS showed that there was a high degree of overlap between the two sexes of culled black-backed jackals (Figure 4.8). Furthermore, an ANOSIM indicated no significant difference between the diets of males and females (Sample statistic/Global R = 0.009, significance of sample statistic = 36.3 %, $p > 0.05$). Again, the strength of the relationship was considered ideal (Kruskal stress = 0.02; Figure 4.8).

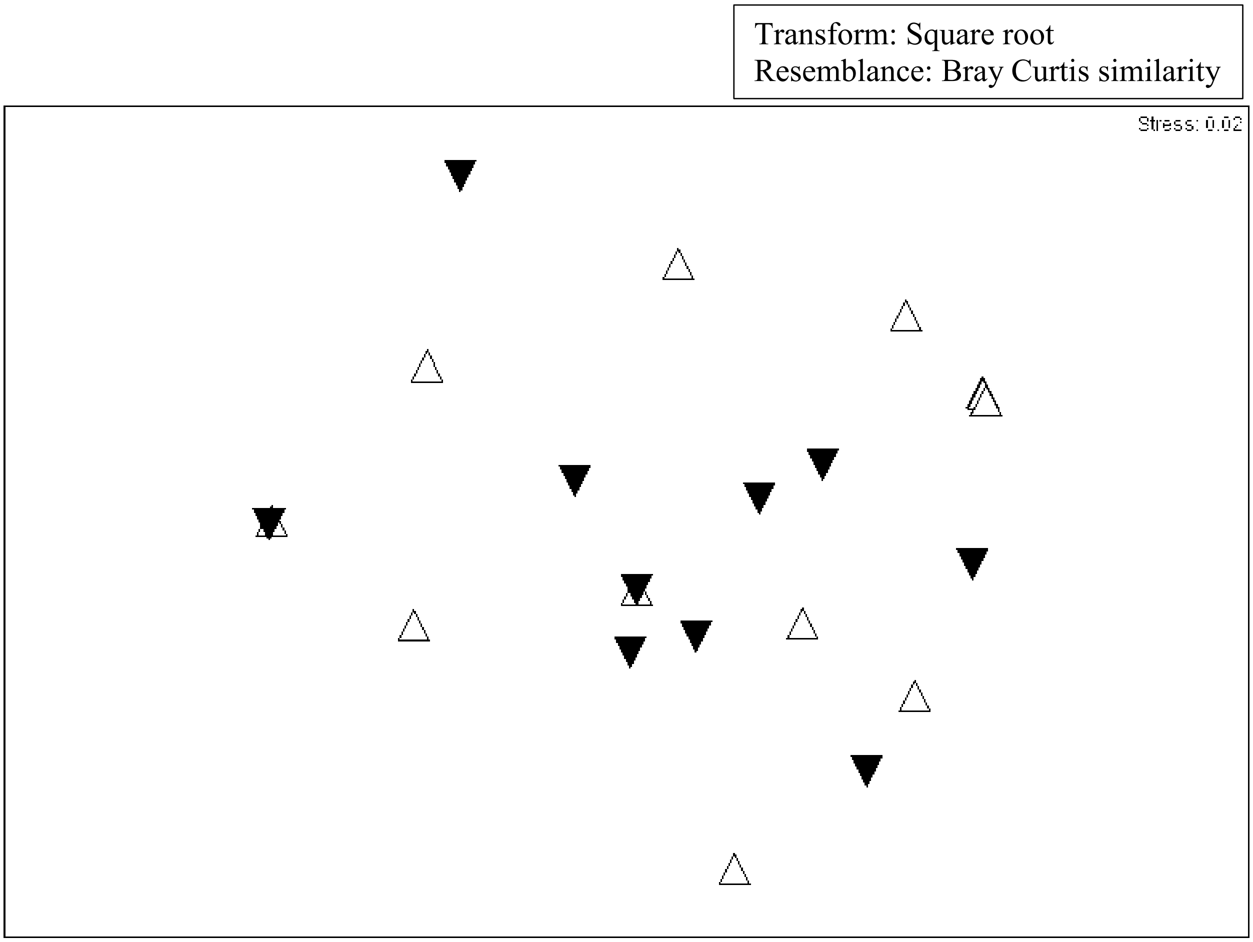

Figure 4.8: MDS ordination for the diet composition of male (white) and female (black) black-backed jackals culled in the Eastern Cape between April 2013 and June 2014.

While the ANOSIM indicated no resource partitioning between males and females, a SIMPER analysis indicated that males included a wider variety of prey species in their diet than females (Table 4.3). While the diets of both sexes incorporated large Ruminantia, only kudu were observed in female stomachs and kudu, gemsbok and red hartebeest were found in the stomachs of males (Table 4.3). The within-group similarity of males (97 %) comprised six species, compared to the within-group similarity of females, which was 96 % of four species (Table 4.3). The most common prey species for males was scrub hare (35 %), while warthog had a 71 % contribution to the diet of females (Table 4.3). Common duiker was not observed in the diet of females (Table 4.3).

Table 4.3: Average Bray-Curtis similarity between the diets of culled male and female black-backed jackals (Male n = 19, female n = 13).

	Male		
Prey species	**Common name**	**% Contribution**	**Cumulative %**
Lepus saxatilis	Scrub hare	35.0	35.0
Sylvicapra grimmia	Duiker	15.1	50.8
Phacochoerus africanus	Warthog	12.1	62.2
Oryx gazella	Gemsbok	12.1	74.3
Tragelaphus strepsiceros	Kudu	12.1	86.4
Alcelaphus buselaphus	Red hartebeest	11.0	97.3
	Female		
Prey species	**Common name**	**% Contribution**	**Cumulative %**
Phacochoerus africanus	Warthog	70.7	70.7
Tragelaphus strepsiceros	Kudu	10.6	81.3
Lepus saxatilis	Scrub hare	7.8	89.1
Procavia capensis	Rock hyrax	6.8	95.8

A MDS of age class indicated a high degree of overlap among the different ages of black-backed jackals, showing little resource partitioning (Figure 4.9). Furthermore, the results of an ANOSIM indicated that there was no statistically significant similarity surrounding the dietary composition of the three different age classes of culled specimens (Global $R = -0.009$, significance of sample statistic = 53.9 %; $p > 0.05$). The stress level for the test was again ideal (Kruskal stress = 0.02; Figure 4.9).

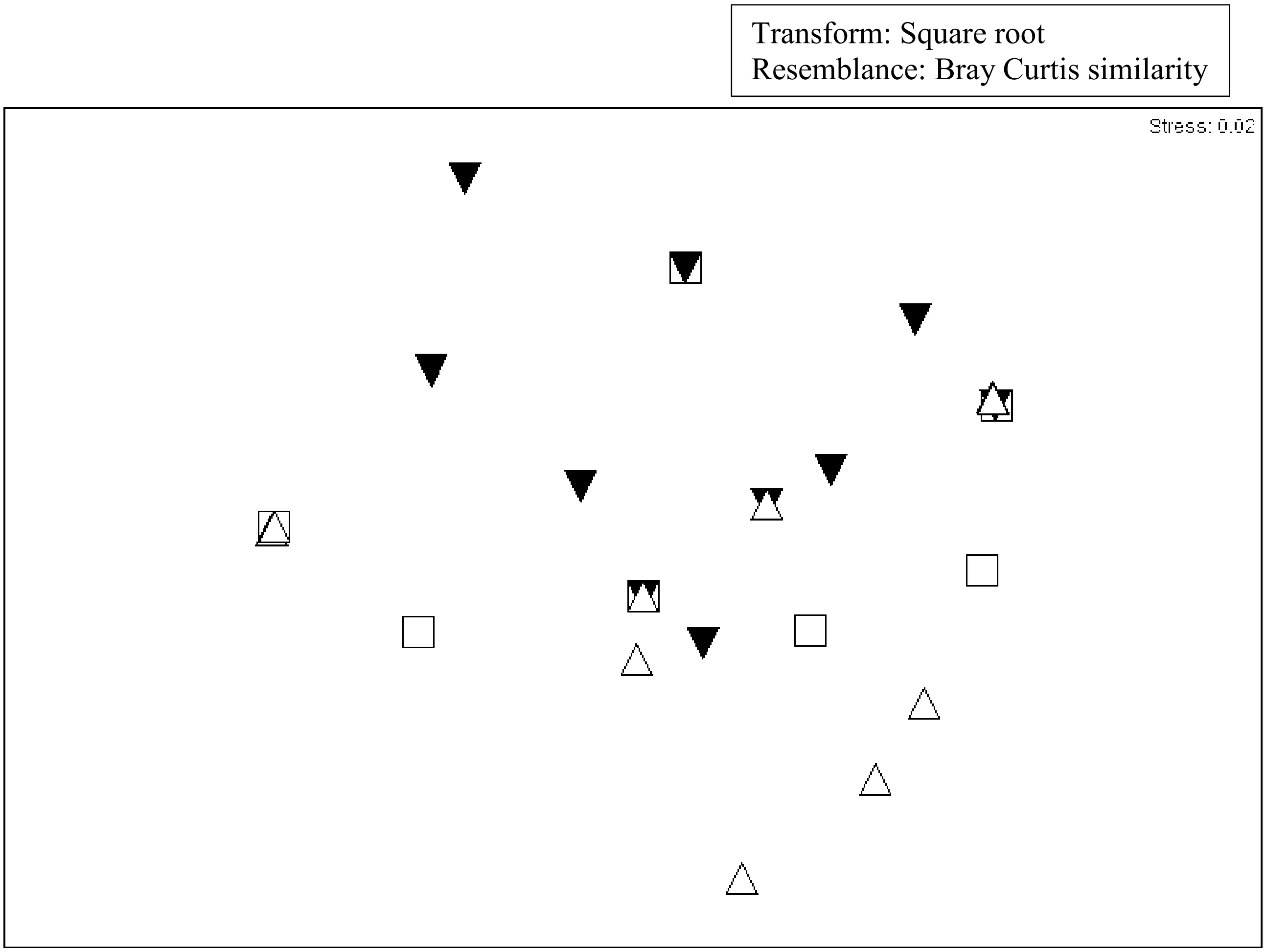

Figure 4.9: MDS ordination for the diet composition of three age classes (juvenile = black triangle, sub-adult = white square, mature adult = white triangle) for culled black-backed jackals from April 2013 to June 2014.

The SIMPER analysis did not reveal any differences among the age classes of culled specimens (Table 4.4). The within-group similarity of juveniles consisted of four species (93 %), while for sub-adults it was six species (91 %) and five species for mature adults (95 %; Table 4.4). For all age classes, warthog was the dominant prey species (52 %, 26 % and 25 %, respectively; Table 4.4). However, the other dominant prey species for mature adults was impala (25 %; Table 4.4). Kudu was only observed in the diet of juveniles and sub-adults, while rock hyrax was only observed in the diet of sub-adult and mature jackals (Table 4.4).

Table 4.4: Average Bray-Curtis similarity between the diets of three age classes of culled black-backed jackals (Juvenile n = 12, sub-adult n = 9, mature adult n = 11).

Prey species	Common name	% Contribution	Cumulative %
Juvenile			
Prey species	**Common name**	**% Contribution**	**Cumulative %**
Phacochoerus africanus	Warthog	51.7	51.7
Lepus saxatilis	Scrub hare	26.3	78.0
Tragelaphus strepsiceros	Kudu	7.7	85.6
Alcelaphus buselaphus	Red hartebeest	7.7	93.3
Sub-adult			
Prey species	**Common name**	**% Contribution**	**Cumulative %**
Phacochoerus africanus	Warthog	25.7	25.7
Tragelaphus strepsiceros	Kudu	25.7	51.4
Lepus saxatilis	Scrub hare	11.4	62.9
Sylvicapra grimmia	Duiker	11.4	74.3
Alcelaphus buselaphus	Red hartebeest	8.6	82.9
Procavia capensis	Rock hyrax	8.6	91.4
Mature adult			
Prey species	**Common name**	**% Contribution**	**Cumulative %**
Aepyceros melampus	Impala	25.3	25.3
Phacochoerus africanus	Warthog	25.3	50.5
Lepus saxatilis	Scrub hare	16.1	66.7
Sylvicapra grimmia	Duiker	16.1	82.8
Procavia capensis	Rock hyrax	10.8	93.6

Demographic data from culled black-backed jackals

All three methods of predator control killed both males and females (Figure 4.10). Overall, more males were culled than females, particularly with shooting and calling & shooting (Figure 4.10). However, there was no significant effect of the type of control method on the sex of the culled black-backed jackals ($\chi^2 = 0.41$, df = 2, $p > 0.05$; Figure 4.10).

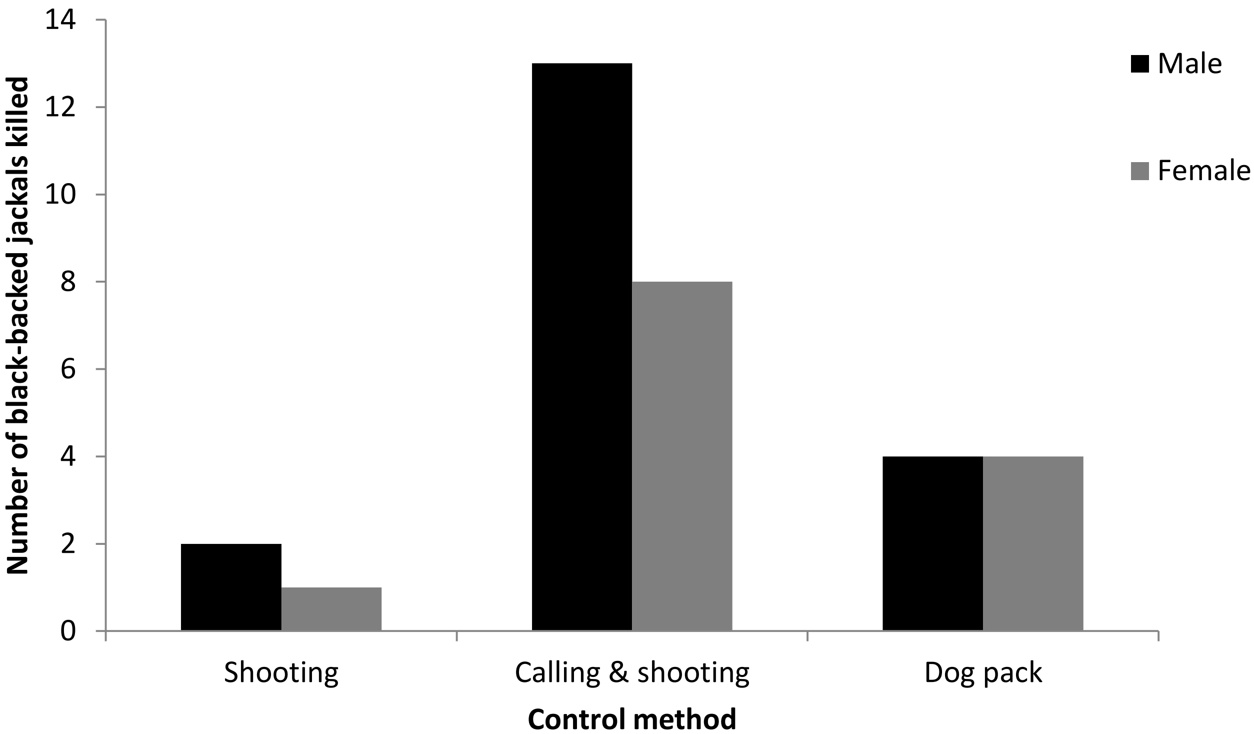

Figure 4.10: The number of male and female black-backed jackals culled using three different control methods (shooting, calling & shooting, dog pack) in the Eastern Cape(χ^2 = 0.41, df = 2, p > 0.05; N = 32).

Both calling & shooting and dog packs culled black-backed jackals from all three age groups; shooting killed only juvenile black-backed jackals (Figure 4.11). More sub-adult black-backed jackals were culled using dog packs than the other two methods (Figure 4.11). However, there was no significant effect of the control method on the number of black-backed jackals culled per age class (χ^2 = 7.16, df = 4, p > 0.05; Figure 4.11).

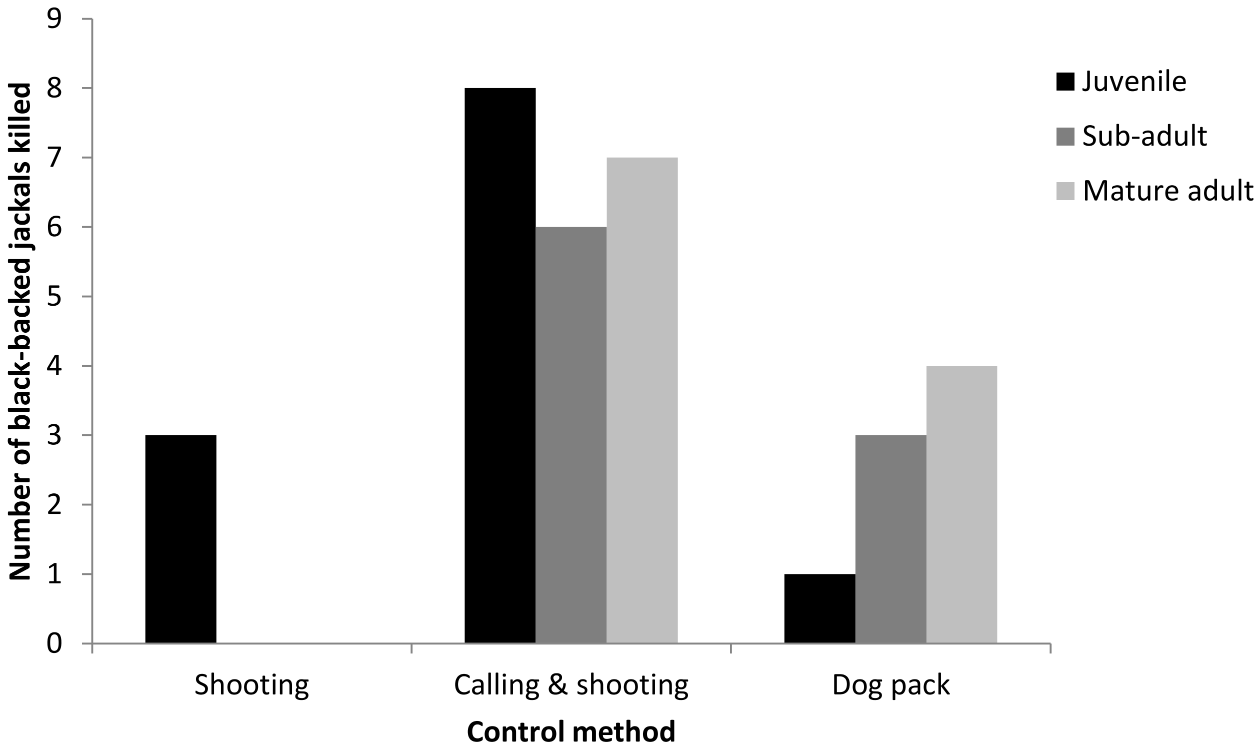

Figure 4.11: The number of black-backed jackals culled using three different control methods (shooting, calling & shooting, dog pack) according to three broad age classes ($\chi^2 = 7.16$, df = 4, $p > 0.05$).

4.4 DISCUSSION

Black-backed jackals are commonly implicated in issues of livestock/game depredation and are culled in large numbers in an attempt to prevent this (Kaunda 2000; Beinart 2003; Szabo *et al*. 2010; Thorn *et al*. 2013). It is therefore necessary to gain an understanding of the mammalian contribution of the diet of these mesopredators. Mammals generally contribute the majority of the diet of black-backed jackals (Bernard & Stuart 1992; Kaunda & Skinner 2003; Do Linh San *et al*. 2009; Goldenberg *et al*. 2010; Klare *et al*. 2011a; Kamler *et al*. 2012). The use of stomach content analysis for dietary analysis in the present study allowed for a direct comparison of perceived versus actual threat of livestock depredation (Mills 1996).

As with other studies, the overall mammalian component of the diet of black-backed jackals in my study highlighted the importance of ungulates (Klare *et al*. 2010; Kamler *et al*. 2012; Van de Ven *et al*. 2013). Interestingly, the majority of the ungulates observed in the diet were considered large (> 80 kg), while the black-backed jackal itself weighs around 7 kg (Skinner & Chimimba 2005). While I cannot determine whether the mammals recorded were actively hunted or scavenged (Mills 1996), there are records indicating that these canids are able to kill prey much larger than themselves (Kamler *et al*. 2009). This is done by running the ungulate to exhaustion (Kamler *et al*. 2009), and highlights the plasticity of black-backed jackal foraging behaviour (Boydston *et al*. 2003; Holmern *et al*. 2007). As regards the behaviour of the prey species, three ungulates (gemsbok, red hartebeest and nyala) are considered hider species. Hider species conceal their young in dense vegetation while out foraging (Estes 2012). Again, no distinction can be made across the age classes for the prey species when using stomach content analysis (Mills 1996), however other studies in South Africa have demonstrated the prevalence of hider ungulates in the diet of black-backed jackals (Klare *et al*. 2010; Kamler *et al*. 2012). The presence of such species may indicate that black-backed jackals are actively hunting younger ungulates rather than scavenging off larger individuals.

The overall prevalence of ungulates in the diet of an opportunistic mesopredator will vary according to the presence of apex predators or on the life history patterns of the ungulates (Berger & Conner 2008; Berger *et al*. 2008; Van de Ven *et al*. 2013). For example, in the presence of an apex predator, scavenging among mesopredators is likely to occur more and, due to the more stable diet of the apex predator (Pereira *et al*. 2014), the diet of the mesopredator will also appear more stable across seasons. By comparison, in areas lacking an apex predator, the diet of the opportunistic predator will vary across seasons with ungulate consumption, peaking with the ungulate birthing season (Metz *et al*. 2012). Due to low apex predator population numbers within South Africa (Thorn *et al*. 2013), mesopredators (e.g. black-backed jackal and caracal) are often the top predator in the system (Ritchie *et al*. 2012). It is therefore extremely important to determine the role of black-backed jackals as top predators, as this can have far reaching consequences (Ritchie *et al*. 2012). None of the properties from which I obtained black-backed jackal samples had apex predators present, except for Wildlife ranch 1, where tracks of a transient leopard (*Panthera pardus*) had been seen. On a reserve with an apex predator (cheetah, *Acinonyx jubatus*), the diet of the black-backed jackal was shown to be fairly stable across seasons (Van de Ven *et al*. 2013), supporting the hypothesis above. However, the results of another study done in the Eastern Cape, South Africa, did not show any difference in black-backed jackal diet between sites with and without apex predators (Brassine & Parker 2011). Thus I would expect that black-backed jackal diet would vary seasonally at my sites and that the jackals actively hunt young ungulates. I cannot verify this as my stomach samples were unevenly distributed across the seasons and were limited to one year.

Many studies, including this one, have shown variation in the diet of black-backed jackals across different land use types (Rowe-Rowe 1975, 1976; Forbes 2011; Kamler *et al*. 2012). On the wildlife ranches, more ungulates were observed in the jackals' diet than in those culled on livestock farms. The stomach contents of the latter group contained the remains of common duiker, scrub hare, rock hyrax and warthog. Invoking the theory of optimal foraging (MacArthur & Pianka 1966), a high abundance of these species (particularly common duiker, scrub hare and rock hyrax) in the diet of the black-backed jackal may indicate a high abundance of these smaller mammals in the study area. Furthermore, ungulate densities on the wildlife ranches were apparently high (see Chapter 3) and generalist predators, such as the black-backed jackal, probably use the most abundant prey species (Van de Ven *et al*. 2013). The difference in ungulates observed in the diet may be due to the removal of these animals from livestock farms, as they are often seen as competition for livestock (Beinart 2003). Furthermore, the lack of apex predators (and consequent scarcity of ungulate carcasses) within the study area may further decrease the proportion of ungulates in the diet of the black-backed jackal (Do Linh San *et al*. 2009).

Notably, no livestock was observed in the stomachs of the culled black-backed jackals. However, the selective consumption of wild prey species over sheep has been demonstrated with other predators (e.g. Eurasian lynx; Odden *et al*. 2006) and may be evident in this study area. Within the Eastern Cape, not only is there an abundance of wildlife ranches, but these ranches tend to cover large areas (~ 22 00 ha average; Knight & Cowling 2012). The rate of encounter with wild prey species may thus be higher, decreasing the potential risk of livestock depredation (Stahl *et al*. 2002). This wide variety of prey illustrates the opportunistic trophic ecology of the black-backed jackal as a dietary generalist (Rowe-Rowe 1983; Kaunda & Skinner 2003; Do Linh San *et al*. 2009; Klare *et al*. 2010; Kamler *et al*. 2012; Van de Ven *et al*. 2013).

In many areas, mesopredators are the *de facto* apical carnivores in the ecosystem due to the absence of higher predators (Prugh *et al*. 2009; Ritchie *et al*. 2012). As such, mesopredators are able to have far-reaching consequences within an ecosystem (e.g. mesopredator release; Prugh *et al*. 2009). As many abundant species were observed in the diet, the removal of the black-backed jackal will therefore affect the abundance of these prey species (Prugh *et al*. 2009), in particular the warthog. The warthog itself is seen by most as a problem animal in the Eastern Cape (Somers 1997; *pers. obs.*), and has few natural predators due to the lack of apex predators. It could therefore be assumed that the presence of black-backed jackals in the Eastern Cape may allow for some form of population control for common species such as scrub hare or warthog.

For social predators (e.g. wolves), both sexes are generally involved in livestock depredation, but livestock depredation by solitary predators (e.g. cougars, leopards; Linnell *et al*. 1999) is often committed by the males. Possible reasons for a male bias may be the between sex differences in foraging behaviour, the larger home ranges and wider ranging movements of males, potentially increasing the encounter rate with livestock (Sukumar 1991; Wilson *et al*. 1994). Age may also play a role in livestock depredation as younger animals tend to be poorer hunters and may therefore target prey that is easier to catch and kill (i.e. livestock; Holecamp *et* *al*. 1997). As noted earlier, no livestock was encountered in the stomachs of the culled black-backed jackals in my study. Further, no significant resource partitioning was observed in my study as the diets of both sexes and three age classes appeared to overlap. There is no sexual dimorphism between black-backed jackals (Skinner & Chimimba 2005), which enables both sexes to capture similar prey items. Furthermore, both sexes aid in the rearing and feeding of the young, thus allowing for a similar dietary composition (Skinner & Chimimba 2005). The dietary overlap between the age classes may be due to the dominant pair (mature adults) and subordinate (sub-adults) helpers bringing food back to the den for the juveniles, as juveniles may remain near the natal den for up to six months (Skinner & Chimimba 2005). However, caution should be exercised when interpreting these results as my sample sizes were low and treatments were pooled.

The removal of older, territorial animals can create voids in which younger transients or neighbouring individuals can take over (Lindzey *et al*. 1992; Laing & Lindzey 1993; Stahl *et al*. 2001). For example, the removal of resident female cougars allowed their daughters to fill the vacated range, while transient males filled the vacated range of resident culled males (Laing & Lindzey 1993). It is thus imperative to record the age and sex of animals culled during problem animal control procedures as this may have far-reaching consequences for the population, such as increased rate of replacement. For example, in populations of hunted animals (e.g. cougars), removal of females indicated that recovery of the population relied on immigration and will therefore be much slower due to harvesting of neighbouring cougars (Laing & Lindzey 1993). In southern Utah, USA, the removal of cougars (> 1 year old) demonstrated that the effect of harvesting is dependent on the level (intensity) of removal (Lindzey *et al*. 1992). Population recovery was limited when adult females were removed (Lindzey *et al*. 1992). Within my study, there was no effect of age or sex on the three different control methods, but this may be due to the low sample size. Nevertheless, the long-term impacts of blanket control may not be immediately noticeable (Treves & Naughton-Treves 2005). The continued threat of mesopredators may be due to 'site effects' or the continuous filling of unoccupied territories left vacant by culling procedures, therefore respite may only be noticeable in the short term. For example, the consumption of ungulate species by black-backed jackals may impact upon the hunting industry which relies on these ungulates and will cull this canid to reduce ungulate losses (Treves & Karanth 2003; Klare *et al*. 2010; Thorn *et al*. 2012).

Interactions with sympatric mesopredators and prey species aid in ecosystem functionality (Glen & Dickman 2006; Blaum *et al*. 2009). Changes in carnivore community structure (e.g. culling), this will affect intraguild predation (Berger & Gese 2007). For example in North America it was noted that wolves lowered the density of coyotes, which in turn limited the distribution of grey foxes (*Urocyon cinereoargenteus*; Fedriani *et al*. 2000; Berger & Gese 2007). As sympatric mesopredators, the black-backed jackal and caracal may affect the abundance of one another through competitive interactions. The culling of one may thus affect the abundance of the other due to increased resources (competitive exclusion; Hardin 1960; Avenant & Du Plessis 2008; Blaum *et al*. 2009). This will then affect the functioning of the system through altered prey abundance and diversity (Blaum *et al*. 2009).

Overall, no livestock remains were observed in the stomach contents of the culled black-backed jackals, indicating that these animals were apparently no threat on the livestock farms at that particular time. However, the presence of large ungulates indicates the threat this mesopredator may pose on wildlife ranches as the loss of these ungulates may impact upon the livelihoods of land owners (Treves & Karanth 2003). Additionally, the presence of other problem animals (warthog) within the diet demonstrates the beneficial role that this canid can have within the system (Prugh *et al*. 2009; Brook *et al*. 2012). The difference in land use type suggests that natural game should be present on livestock farms in order to act as a 'buffer' to reduce livestock depredation (Thirgood *et al*. 2005). Furthermore, no resource partitioning was observed between the sexes or between the age classes of culled black-backed jackal, therefore control operations to reduce livestock/game loss need to be aimed at all black-backed jackals. No control method used (all lethal control) was believed to fully alleviate the threat of black-backed jackals on either land use type (Chapter 3). The implications of understanding the diet of this mesopredator is to better understand their role in the system as a top predator in the absence of apex predators, and for livestock farmers and wildlife ranchers to assess the actual impact on their livestock/game animals. Assessing the population demographics of culled animals allows us to determine whether land owners are indirectly selecting towards a certain age group or sex.

This may have further implications for a population that is being culled, and while this was not evident in the present study (no resource partitioning), possibly due to limited sample size, this may have broader implications for the population of a sympatric mesopredator (the caracal).

Chapter 5
Synthesis & conclusions

Carnivores play an integral role in ecosystems through their influence on biological communities (Treves & Karanth 2003). This is achieved by predation, and subsequent population regulation (i.e. limiting the numbers of prey species), but also intra- and interspecific competition with other carnivores (Berger *et al*. 2001; Treves & Karanth 2003; Glen & Dickman 2006). Given these factors, the potential impact of human-carnivore conflict is considerably larger as regards ecosystem functioning. There are many manifestations of human-carnivore conflict, but the most notorious form is that of livestock depredation (Treves & Karanth 2003; Graham *et al*. 2005; Inskip & Zimmermann 2009; Muir 2010; Thorn *et al*. 2012; Suryawanshi *et al*. 2013; Kansky *et al*. 2014). Furthermore, controversy surrounding the effectiveness of both lethal and non-lethal predator control indicates that no single method may provide the 'silver bullet' to decrease human-carnivore conflict (Treves & Naughton-Treves 2005).

The Eastern Cape is the second largest province in South Africa and the majority of the landscape comprises farming ventures, both livestock (livestock farms) and game species (wildlife ranches; Knight & Cowling 2012). While a potential threat to livestock farms, the presence of black-backed jackals (*Canis mesomelas*) and caracals (*Caracal caracal*) on wildlife ranches also proves to be inimical due to financial losses through ungulate depredation (Kaunda 2000; Treves & Karanth 2003; Sillero-Zubiri *et al*. 2007; Szabo *et al*. 2010; Thorn *et al*. 2013). Moreover, in systems in which apex predators (e.g. lions, *Panthera leo*) have been extirpated (Skead 2007), both of these mesopredators may represent the top predator (Bergman *et al*. 2013) and have large impacts upon the structure and function of the system (Treves & Karanth 2003; Blaum *et al*. 2009). The aims of this study were to assess the perceived impact of the black-backed jackal and caracal within the Eastern Cape, and to determine the perceived effectiveness of predator control methods. My findings support the notion of 'hyper-awareness' of risk (Dickman 2010) for both mesopredators, and while lethal predator control was perceived to be the most effective, no single method of predator control appeared to be effective (in that there was no perception of risk by land owners over livestock/game losses to depredation events) over all land-use types or area. Additionally, the diet and the population demographics of culled black-backed jackals were assessed in order to determine the impact this mesopredator had on prey species (specifically livestock), and whether different methods of lethal control were selecting certain sexes or age classes. The findings supported other studies in that ungulates are important in the diet of black-backed jackal (Klare *et al*. 2010; Kamler *et al*. 2012; Van de Ven *et al*. 2013). There was no evidence of resource partitioning between the sexes and age classes, and while no livestock was observed in the diet of (culled) black-backed jackals, it cannot be assumed that these canids did not ever feed upon livestock. However, the caveat of a small sample size must be noted.

The role of social capital, especially within farming communities, should not be overlooked when assessing issues of human-carnivore conflict (Knight & Cowling 2012). Social capital includes social networking, trust and a sense of belonging (Grootaert & van Bastelaer 2001; Pretty & Ward 2001). This has been identified as a key factor when assessing broader issues of conservation (e.g. the development of the Fish-Kowie corridor; Knight & Cowling 2012). Within the study area, traditional social institutions (e.g. sporting clubs, farmer group meetings) which aid in sustaining a strong social capital, have either declined or have been abandoned due to increased urbanization and land claims (*pers. obs.;* Knight & Cowling 2012). This has the effect of leaving land owners feeling alone and isolated. However, the collective hunting of 'problem animals', may have facilitated a similar social institution for the land owners. Discussions among land owners will typically deviate towards the control of 'their' problem animals (*pers. obs.*) thereby fulfilling the need for social capital. This example indicates how the control of predators may have less to do with the actual predator or predation, but more to do with the community and the need for increased sociality.

The driving forces of human-carnivore conflict vary across the globe and vary between the human component (e.g. altering land use, increasing human populations) and the carnivore component (e.g. large home ranges, dietary requirements; Treves & Karanth 2003; Inskip & Zimmermann 2009). The most pressing driver of conflict is the economic concern of perceived or actual livestock/game losses due to carnivores (Butler 2000; Holmern *et al*. 2007; McManus *et al*. 2014). However, Sillero-Zubiri *et al.* (2007) believe that the antipathy felt towards predators is the root of conflict. Thus, what are the drivers of human-wildlife conflict in the Eastern Cape? Indeed, the need for social capital may play a role in fostering the issue of conflict but there are other possibilities. The 'hyper-awareness' of the risk of predation prompts land owners to react to a perceived threat (Dickman 2010). However, livestock depredation did not determine if predator control methods were employed on a farm. The use of predator control methods, used during times of no stock loss, indicated that these land owners may be reacting to the mere presence of a predator.

Management implications & future research

My data show that the method perceived to most effectively decrease human-carnivore conflict was lethal predator control. Generally, current methods of predator control are unselective and focus on the elimination of a species (Avenant & Du Plessis 2008). Furthermore, non-lethal methods are mostly novel, untested or understudied and are believed to be less effective and more expensive than lethal predator control (Conover 2001; Musiani *et al*. 2003; Sillero-Zubiri *et al*. 2007; Delibes-Mateos *et al*. 2013). However, some studies have advocated the success of livestock-guard dogs (LGDs) in reducing livestock losses (Marker et al. 2005; McManus et al. 2014). The indiscriminate use of lethal control has many adverse consequences, such as bycatch (killing of non-target species) and may ultimately lead to the demise of non-target species (Beasom 1974; Treves & Naughton-Treves 2005). High numbers of bycatch using lethal control have been shown in studies conducted in North America (Beasom 1974), but little research has focused on the impacts of lethal predator control on non-target South African wildlife (but see Ogada *et al*. 2012; Ogada 2014). Bycatch can have serious implications to population structure of controlled predators, especially if threatened or endangered species are targeted (Thirgood *et al*. 2005; Treves & Naughton-Treves 2005). This was observed in the Cape Vulture (*Gyps coprotheres*) as poisoning (among other unnatural mortality factors, e.g. killing for traditional medicine and powerline collisions) contributed to their range reduction in the Eastern Cape, as well as this raptor being accorded 'Vulnerable' status by the IUCN (International Union for Conservation of Nature; Birdlife 2014). Transient leopards (*Panthera pardus*) have been recorded in the study area (*pers. comm.*) and are considered near-threatened by the IUCN (Henschel *et al.* 2008). Moreover, the major threat to leopards is that of persecution

(Henschel *et al.* 2008). Additionally, no records were documented of any bycatch which could aid in determining the overall effectiveness of each method. By assessing the possible impact of unselective lethal predator control methods, the impact on other species can be quantified.

Regardless of the perceptions surrounding non-lethal control, these methods of predator management may be more compatible with conservation goals (McManus *et al*. 2014). Assessing the effectiveness of predator control methods indicated that no one method proved to fulfill the land owners' anxiety over issues of conflict. Furthermore, few non-lethal alternatives can be used on wildlife ranches, but the predation upon game (particularly rare game species) is still viewed as an issue (Treves & Karanth 2003). Studies have indicated some success with the use of lethal control (Stahl *et al.* 2001), however long-term data suggests that this is only a temporary reprieve (Wielgus & Peebles 2014). Furthermore, the intense use of lethal predator control may only exacerbate the issue (Wielgus & Peebles 2014). Be it due to the plastic behaviour of the mesopredator in adapting to different methods of control (Brand *et al*. 1995; Brand & Nel 1997), the social perturbation or alteration in social structure (compensatory mortality hypothesis; Cooley *et al*. 2009), the change in the population make-up (selectively targeting a certain age class or sex) of the controlled animal, or the inappropriate use of the control method by the land owner (Treves & Naughton-Treves 2005), no single method of predator control is likely to stop conflict. However, using a combination of methods (both lethal and non-lethal) may decrease or prevent losses of livestock/game (Inskip & Zimmermann 2009). Moreover, methods may need to be varied so as not to allow for any behavioural adaptation by the predators (Brand *et al*. 1995).

Future studies should determine the effects of lethal control methods upon the population structure of the target predator during culling (e.g. does the compensatory mortality hypothesis manifest?). For example, in Australia is was found that with minimal human interference, the social structure of dingoes (*Canis lupus dingo*) was regulated by their pack size and that they exhibited fewer instances of livestock depredation when left to natural population fluctuations (Glen *et al*. 2007). Furthermore, increased livestock depredation was evident with an increase in the control of wolves (*Canis lupus*) in the USA due to compensatory demographic responses through social instability (Wielgus & Peebles 2014). Although not as social as dingoes or wolves, a similar scenario may be possible for black-backed jackals in South Africa. Moreover, no resource partitioning was evident in the diet of culled black-backed jackals in my study, and as such, all sexes and age classes may contribute towards issues of conflict (Livestock depredation). Additionally, as noted with the culling of wolves, a high turnover of breeding adults may result in the loss of knowledge surrounding natural prey sources for the pack, thereby increasing the risk of livestock depredation (Wielgus & Peebles 2014). Not only do black-backed jackals have a complex social structure (Skinner & Chimimba 2005), so this phenomenon could be evident, but they are also behaviourally plastic (Boydston *et al*. 2003; Holmern *et al*. 2007). Consequently, the blanket removal of monogamous, life-mated pairs may increase the number of transient unmated black-backed jackals if one of the pair is culled.

The competitive exclusion principle states that two species cannot coexist at stable population levels if resources remain the same (Hardin 1960). Intraguild predation suggests that one or more species can act both as the predator and the competitor in relation to other species on a similar trophic level (Polis *et al*. 1989; Fedriani *et al*. 2000). In South Africa, black-backed jackals and caracals are sympatric mesopredators with a similar distribution and similar but varied diet (Avenant & Nel 2002; Skinner & Chimimba 2005; Braczkowski *et al*. 2012; Kamler *et al*. 2012; Bergman *et al*. 2013). The removal of one species may facilitate an increase in the abundance of the other (Hardin 1960). In North America, the presence of sympatric predators affected the distribution of those on a similar trophic level (Fedriani *et al*. 2000). Results from a spatial utilization study on black-backed jackals in Botswana indicated that this canid depressed the population sizes of intraguild predators, such as caracals (Kaunda 2001). Therefore, by controlling one mesopredator may result in the increase in abundance of the other.

Low natural prey abundance is linked to livestock depredation by mesopredators (Graham *et al*. 2005). In Venezuela, to reduce jaguar (*Panthera onca*) predation, calves (*Bos primigenius*) were moved to higher ground, but this increased the potential for depredation by cougars (*Puma concolor*; Polisar *et al*. 2003). This was due to the lower prey abundance and diversity on the higher ground (Polisar *et al*. 2003). By having natural prey occur on stock/game farms, the impact of livestock depredation can be reduced as the selective consumption of wild prey species over sheep has been previously demonstrated (e.g. Eurasian lynx, *Lynx lynx*; Odden *et al*. 2006). Key to the diet of generalist predators, such as the black-backed jackal, is prey availability (*sensu* optimal foraging theory; MacArthur & Pianka 1966). The noticeable lack of livestock remains in the diet of the culled black-backed jackals in this study may have been due to a relatively high abundance of natural prey species within the study area (many wildlife ranches; Knight & Cowling 2012). Through predator-prey interactions, the predator plays a role in suppressing the numbers of the prey population (Preisser *et al*. 2005). Predators are also able to increase the diversity of ecosystems through influencing cascading trophic levels (Glen *et al*. 2007). Furthermore, within the Eastern Cape, warthogs and rock hyraxes (*Procavia capensis*) are often referred to as 'problem animals' (Chapter 4). The presence of these two species in the diet of the culled black-backed jackals indicates potential ecological benefits of black-backed jackals in reducing the numbers of these 'problem animals'. Thus the unselective removal of one/both mesopredators may impact upon the population of prey species, which can have other negative consequences for landowners. I would therefore recommend that more detailed assessments of the ecological roles of both the black-backed jackal and caracal be conducted (see Glen *et al*. 2007). This can be achieved through the assessment of whether mesopredator removals facilitate cascades (seen in the populations of other species, as observed with wolves in Yellowstone National Park; Berger *et al*. 2001; Ripple & Beschta 2003, 2004; Ripple *et al*. 2013), or if the presence of the mesopredator alters the distribution of other predators or prey species (e.g. mesopredator release).

While mesopredator release has been hypothesized to have occurred in the Eastern Cape, it has not been experimentally demonstrated. Demonstrated globally, the extirpation of apex carnivores will affect populations of mesopredators (Crooks & Soule 1999; Glen & Dickman 2006; Prugh *et al*. 2009; Brook *et al*. 2012; Ripple *et al*. 2013; Greenville *et al*. 2014). By assessing the population structure of mesopredators in areas with and without apex predators, we can begin to determine if this release is taking place within the Eastern Cape. Additionally, by assessing prey populations we can determine if prey species have dramatically decreased in number (Figure 4.1; Prugh *et al*. 2009; Ripple *et al*. 2013).

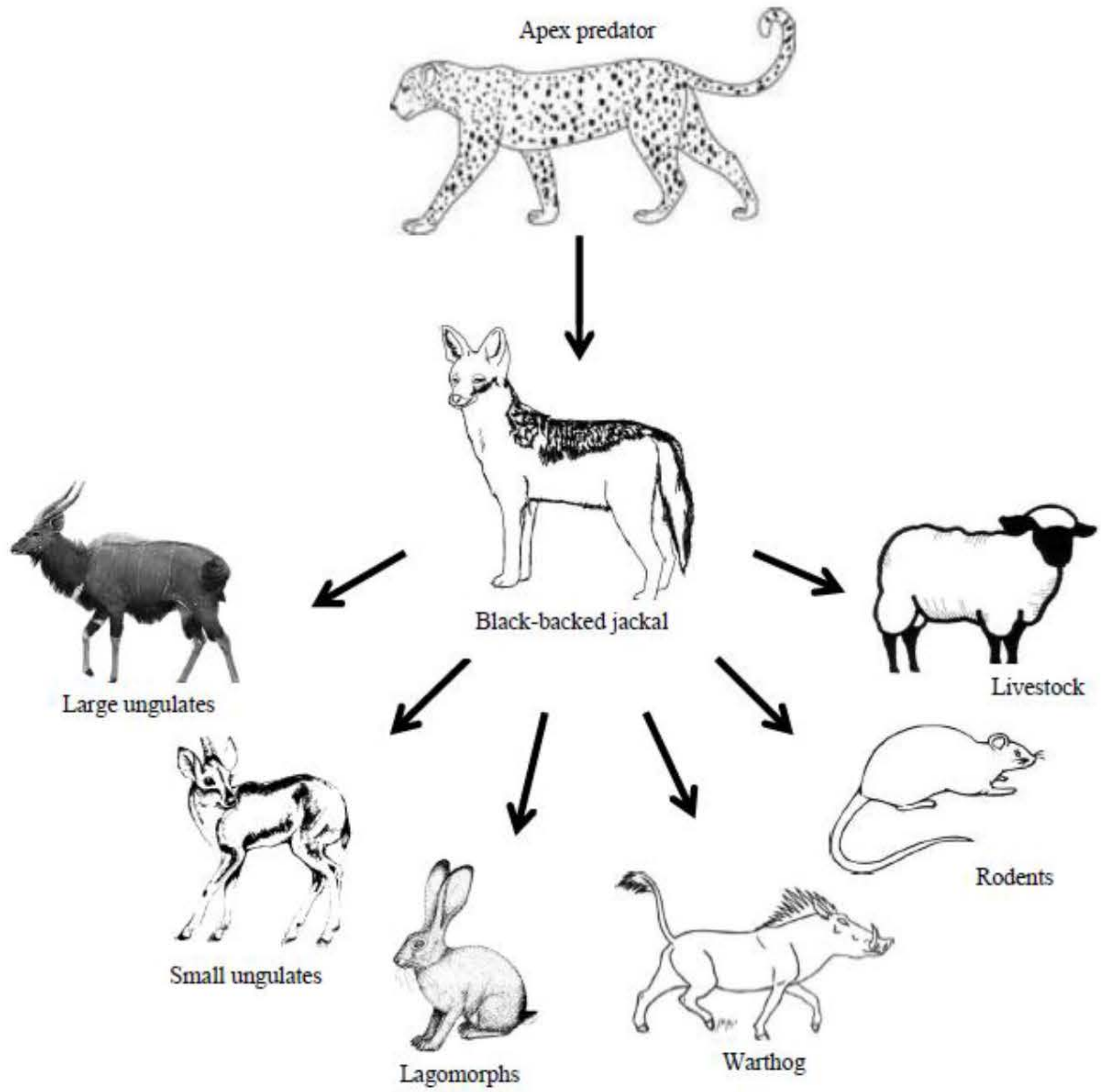

Figure 4.1: Conceptual linkages among apex predators, the black-backed jackal and mammalian prey species. This indicates the impact mesopredator release could have on mammalian prey (Concept from Ripple *et al.* 2013).

During the questionnaire data collection, it became evident that there was a lack of understanding and communication between the land owners and the scientists who conduct research on their properties (*pers. obs.*). This is termed the information deficit model (Sturgis & Allum 2004). While many studies have been conducted within this field of human-wildlife conflict (Baruch-Mordo *et al.* 2009), and even more mitigation procedures have been suggested, few attempts have been made to put these measures in place. Land owners will, generally, have a greater understanding of the ecological make-up of their property as they observe the day-to-day trends in animal populations than researchers. Thus the on-the-ground knowledge of land owners should not be overlooked, nor should there be a lack of communication prior to, during or after an academic study has been undertaken. By communicating the findings of any research with the land owners, conflict could be reduced (Marker *et al*. 2003).

Conclusions

My study has attempted to unravel the complexity of the driving forces behind the human-carnivore conflict of two mesopredators within the Eastern Cape, South Africa. My study has shown that perceptions surrounding both the black-backed jackal and caracal are based upon personal insights concerning a perceived risk or threat. Intense lethal control of both species has been undertaken, and still there appears to be no end to livestock/game depredation in sight. Without the knowledge surrounding the ecological impacts of this removal, we cannot predict the long-term outcomes. Long-term studies observing lethal control of predators have generally indicated a temporary reprieve (Stahl *et al.* 2001; Wielgus & Peebles 2014). Overall, studies have explicitly indicated the negative effects of human intervention within the environment (Treves & Naughton-Treves 2005; Graham *et al*. 2005; Berger *et al*. 2008; Inskip & Zimmermann 2009; Ritchie & Johnson 2009; Prugh *et al*. 2009). However, we cannot ignore the impacts faced by humans through financial losses. No single panacea can work effectively across the country, nor across the province and not even between neighbouring farms. My study has shown that the issue of human-mesopredator conflict is more complex than simply livestock depredation. It is the combination of social (risk awareness and negative reputation of the mesopredators), economic (perceived loss of livestock/game) and ecological (presence of mesopredator, dietary requirements of the predator) factors. By increasing our understanding of this complex issue, resources can be allocated accordingly, ultimately allowing for coexistence between humans and predators.

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Appendix I
Questionnaire

(1) GENERAL

1) Survey no.______________________________
2) Date:______________________________
3) Farm name:______________________________
4) Size of farm in Ha: ______________________________
5) Main land-use:______________________________

6) How many animals do you keep? Please indicate if you had large increases or decreases of animals in the last two years, and which if any animals receive vaccinations

	Sheep	Goats	Cattle	Donkeys	Horses	Poultry	Pigs	Dogs	Other
Quantity									
Increase/decrease									
Vaccinated									
Reason for decrease									

	Impala	Kudu	Hartbeest	Springbok	Bontebok/Blesbok	Duiker/Steen	Other
Quantity							
Increase/decrease							
Reason for decrease							

7) What are the main problems facing you as a farmer?

Score significance: 1 to 5; where 1 = no problem and 5 = major problem

Disease	Drought	Infertility	Poor grazing	Unreliable Market	Predators	Theft/poaching	Other

8) Which of these problems would you say is your biggest?______________________________

9) Do you believe that conflict with predators are increasing, decreasing or stable?______________
Reasons:______________________________
____

(2) PREDATION

10) Which predators have you seen or found signs of on your property

	Status: Absent Rare, common, unknown	Pop trend Last 5 years: Increase, decrease, stable	Do you loose Animals to This predator	If so, how Many	In your opinion What are the two main prey items of this predator
Jackal					
Caracal					
Brown Hyaena					
Leopard					
Other					

(3) MANAGEMENT

11) What is your preferred method of control?
LETHAL NON-LETHAL

BOTH NONE

Please rate the following predator control methods from 1 to 5, where 1 = least effective and 5 = most effective

12) Shoot	1	2	3	4	5
13) Cage trap	1	2	3	4	5
14) Gin trap	1	2	3	4	5
15) Herder	1	2	3	4	5
16) Poison	1	2	3	4	5
17) Calling	1	2	3	4	5
18) Dog Pack	1	2	3	4	5
19) Kraaling	1	2	3	4	5

20) Animal husbandry	1	2	3	4	5
21) Fencing	1	2	3	4	5
22) King collar/ Dead stop collar	1	2	3	4	5
23) Relocation of predator	1	2	3	4	5

24) If combination, which works best?_______________________

25) Which of the above methods do you think works best on your farm?

____

26) How often do you use this method on your farm?

Weekly	Every fortnight	Once a month	Every quarter	Every 6 months	Once a year	Other

27) How many have you killed on your farm in the last year?

Jackal	Caracal	Leopard	Brown hyena	Other

28) Overall, what was your stock/game loss to predators last year?

____

____

4) DEMOGRAPHICS

29) Name:____

30) Age:___________________________ 31) Sex: MALE / FEMALE

32) Education level: PRIMARY SCHOOL/HIGH SCHOOL/ MATRIC/ TERTIARY

33) How long have you lived in the area?____

Appendix II

The 14 statements and scoring methods used to generate the attitude index.

Statement		Score			
		Lethal	None	Non-lethal	Both
1. What is your preferred method of control on your farm?		-2	+1	+1	-1
2. Which method do you think is the most effective on your farm?		-1	+1	+1	
Likert scale					
3-14. Please rate the following methods indicating efficacy:		Effective	Has not used this method		
Lethal	Shooting	-5	0		
	Calling & shooting	-5	0		
	Cage traps & shooting	-5	0		
	Gin trap	-5	0		
	Poison	-5	0		
	Dog pack	-5	0		
Non-lethal	Herder	+5	0		
	Kraaling	+5	0		
	Animal husbandry	+5	0		
	Fencing	+5	0		
	King collars, Dead stop collars, Heart rate monitors	+5	0		
	Relocation of predator	+5	0		

Appendix III
R code – Chapter 3

The following is the code used in the statistical package R 3.0.2:

```
attach(Data)
str(Data)

#EXPLORATORY
#Boxplots - categorical data
boxplot(HI~ as.factor(Area), ylab="Attitude Index", xlab="Area")
boxplot(HI~ as.factor(Land.use), ylab="Attitude Index", xlab="Land use")
boxplot(HI~ as.factor(Language), ylab="Attitude Index", xlab="First Language")
boxplot(HI~ as.factor(Education), ylab="Attitude Index", xlab="Education level")

#Scatterplots for continuous data
plot(HI~ Size.of.farm, xlab="Size of farm", ylab="Attitude Index", pch=19)
abline(lm(HI~Size.of.farm), col="red")
plot(HI~ Mesopredator.killed, xlab="Mesopredators killed", ylab="Attitude Index", pch=19)
abline(lm(HI~Mesopredator.killed), col="red")
plot(HI~ Stock.loss, xlab="Stock loss", ylab="Attitude Index", pch=19)
abline(lm(HI~Stock.loss), col="red")
plot(HI~ Age, xlab="Age", ylab="Attitude Index", pch=19)
abline(lm(HI~Age), col="red")

#Normality test conducted on index
shapiro.test(HI)
hist(HI)
#Fail to reject Ho

x<-
glm(HI~Mesopredator.killed+Size.of.farm+Stock.loss+Age+as.factor(Land.use)+as.factor(Area)
+as.factor(Education)+as.factor(Language), data=Data)
#Use vif to check for colinearity
require(car)
vif(x)
#Less than 5 therefore not colinear
cor.test(Mesopredator.killed, Age, method="spearman", data=Data)
cor.test(Size.of.farm, Stock.loss, method="spearman", data=Data)
cor.test(Mesopredator.killed, Size.of.farm, method="spearman", data=Data)
cor.test(Mesopredator.killed, Stock.loss, method="spearman", data=Data)

model<- glm(HI~
as.factor(Land.use)+as.factor(Area)+as.factor(Language)+as.factor(Education)+Age+Mesopreda
tor.killed+Size.of.farm+Stock.loss, data=Data)
```

```
#Do AICc
require(MuMIn)
summary(model)
options(na.action="na.fail")
dredge(model)
require(car)
ncvTest(model)

aov1<- aov(HI~ as.factor(Area)*as.factor(Land.use)*Mesopredator.killed, data=Data)
summary(aov1)
plot(aov1)
#Normality and variance checked - good for global model

#Land use - individual variable
aov2<- aov(HI~ as.factor(Land.use), data=Data)
plot(aov2)
summary(aov2)
#Violated anova assumptions therefore non-parametric
kruskal.test(HI~Land.use)
require(pgirmess)
kruskalmc(HI, Land.use)

#Area as individual variable
require(car)
leveneTest(aov(HI~ as.factor(Area), data=Data))
aov3<- aov(HI~ as.factor(Area), data=Data)
plot(aov3)
summary(aov3)
TukeyHSD(aov(HI~ as.factor(Area)), data=Data)
plot(TukeyHSD(aov(HI~ as.factor(Area), data=Data)), las=2, cex.axis=0.5)

#Mesopredators as an individual variable
plot(HI~ Mesopredator.killed)
meso<- lm(HI~ Mesopredator.killed, data=Data)
summary(meso)
residuals(meso)
plot(meso)
#R2 cannot determine bias therefore you must assess the residual plots
plot(Mesopredator.killed, fitted(meso), main="Observed vs fitted values")
abline(0,1)
plot(residuals(meso))
#By plotting above - check if assumptions are satisfied - should behave randomly
shapiro.test(residuals(meso))
#Fail to reject Ho (normal) is larger than 0.05

#Stock loss as an individual variable
```

```
plot(HI~ Stock.loss)
stock<- lm(HI~ Stock.loss, data=Data)
summary(stock)
residuals(stock)
plot(stock)
#R2 cannot determine bias therefore you must assess the residual plots
plot(Stock.loss, fitted(stock), main="Observed vs fitted values")
abline(0,1)
plot(residuals(stock))
#By plotting above - check if assumptions are satisfied - should behave randomly
shapiro.test(residuals(stock))
#Fail to reject Ho (normal) is larger than 0.05

#Language as individual variable
require(car)
leveneTest(aov(HI~ as.factor(Language), data=Data))
aov4<- aov(HI~ as.factor(Language), data=Data)
plot(aov4)
summary(aov4)
TukeyHSD(aov(HI~ as.factor(Language)), data=Data)
plot(TukeyHSD(aov(HI~ as.factor(Language), data=Data)), las=2, cex.axis=0.5)
#Violated anova assumptions therefore non-parametric
kruskal.test(HI~Language)
require(pgirmess)
kruskalmc(HI, Language)

#Age as an individual variable
plot(HI~ Age)
age<- lm(HI~ Age, data=Data)
summary(age)
residuals(age)
plot(age)
#R2 cannot determine bias therefore you must assess the residual plots
plot(Age, fitted(age), main="Observed vs fitted values")
abline(0,1)
plot(residuals(age))
#By plotting above - check if assumptions are satisfied - should behave randomly
shapiro.test(residuals(age))
#Fail to reject Ho (normal) is larger than 0.05

#Size of farm as an individual variable
plot(HI~ Size.of.farm)
size<- lm(HI~ Size.of.farm, data=Data)
summary(size)
residuals(size)
plot(size)
```

```
#R2 cannot determine bias therefore you must assess the residual plots
plot(Size.of.farm, fitted(size), main="Observed vs fitted values")
abline(0,1)
plot(residuals(size))
#By plotting above - check if assumptions are satisfied - should behave randomly
shapiro.test(residuals(size))
#Fail to reject Ho (normal) is larger than 0.05

#Education as individual variable
require(car)
leveneTest(aov(HI~ as.factor(Education), data=Data))
aov5<- aov(HI~ as.factor(Education), data=Data)
plot(aov5)
summary(aov5)
TukeyHSD(aov(HI~ as.factor(Education)), data=Data)
plot(TukeyHSD(aov(HI~ as.factor(Education), data=Data)), las=2, cex.axis=0.5)
#Violated anova assumptions therefore non-parametric
kruskal.test(HI~Education)
require(pgirmess)
kruskalmc(HI, Education)

#Looking at area
plot(Stock.loss~ as.factor(Area), data=Data)
aov6<- aov(Stock.loss~ as.factor(Area), data=Data)
plot(aov6)
#Violated anova assumptions therefore non-parametric
kruskal.test(Stock.loss~Area)
require(pgirmess)
kruskalmc(Stock.loss, Area)

#Violated anova assumptions therefore non-parametric
kruskal.test(Mesopredator.killed~Area)
require(pgirmess)
kruskalmc(Mesopredator.killed, Area)
plot(Mesopredator.killed~ as.factor(Area))
```

Appendix IV
R code – Chapter 4

The following is the code used in the statistical package R 3.0.2:

```
#Chi squared test - age v control method
calling = c(8, 6, 7)
shooting = c(3, 0, 0)
dogs = c(1, 3, 4)
control = as.data.frame(rbind(calling, shooting, dogs))
names(control) = c('Juvenile', 'Subadult', 'Mature adult')
control
chisq.test(control)
#Produces error message therefore double check p value using Fisher Exact Test
fisher.test(control)
barplot(t(control), beside=T, ylim=c(0,10))
#No effect of age on control method

#Chi squared test - sex v control method
calling = c(13, 8)
shooting = c(2, 1)
dogs = c(4, 4)
control2 = as.data.frame(rbind(calling, shooting, dogs))
names(control2) = c('Male', 'Female')
control2
chisq.test(control2)
#Produces error message therefore double check p value using Fisher Exact Test
fisher.test(control2)
barplot(t(control2), beside=T, ylim=c(0,14))
#No effect on sex

#Chi squared test - land use v control method
calling = c(17, 4)
shooting = c(3, 0)
dogs = c(0, 8)
control3 = as.data.frame(rbind(calling, shooting, dogs))
names(control3) = c('Wildlife', 'Stock')
control3
chisq.test(control3)
#Produces error message therefore double check p value using Fisher Exact Test
fisher.test(control3)
barplot(t(control3), beside=T, ylim=c(0,18))
```