The Ecology of Black-Backed Jackal (*Canis mesomelas*) on Farmlands in the Midlands of KwaZulu-Natal, South Africa.

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ABSTRACT

Agricultural development is progressively being attributed as a cause of biodiversity loss. Despite this development, some species do successfully inhabit these transformed habitats and benefit from increased food and resource availability. Therefore it is important to understand how and why species persist in those altered landscapes to conserve remaining biodiversity. Black-backed jackals are an abundant mesopredator with an apparent success to these changing agricultural environments. An understanding of their ecology in agricultural areas can provide important ecological information on the species and elucidate possible reasons why this mesopredator is capable of adapting and surviving in agricultural lands. From 2013 to 2014, a study was conducted on the ecology of the black-backed jackal *Canis mesomelas* in the Midlands of KwaZulu-Natal, South Africa. The study examined the home range, habitat use and diet of the species. In addition species characteristics and conflict of black-backed jackal from a landowner's perspective were determined.

It was found that rodents comprised the most consumed item of prey by black-backed jackal, followed by domestic livestock. There was a significant diversity of prey species in the diet indicating the opportunistic and generalist nature of the species. The home range movements of the species were relatively large compared to previous studies on the species and juveniles generally had larger home ranges than adult males and females. Habitat selection within home ranges indicated jackals preferred bushlands in winter and spring, and croplands in summer and autumn. Landowner's reported regular predation on livestock by the species and suggest the increasing intensity of agriculture provides a greater food source of jackals. Some farmers used

mitigation strategies in an attempt to prevent livestock losses, however, 32 % of farmers confessed to having poor disposal techniques for dead animals.

This study provides important ecological information on black-backed jackal as a mesopredator species. Information on the spatial movement and diet of jackals in this study highlighted the variability in ecology of the species, providing information on the species' persistence and success in agricultural areas. Furthermore, feedback from farmers emphasised the importance of having collaboration between farmers to control jackal predation and reduce human-wildlife conflict.

PREFACE

The data described in this thesis were collected in the Republic of South Africa from February 2013 to October 2014. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg campus, under the supervision of Professor Colleen T. Downs and co-supervision of Doctor Tharmalingam Ramesh and Professor Trevor Hill.

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Science and Engineering, University of KwaZulu-Natal, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use has been made of the work of others, it is duly acknowledged in the text.

………………………….

Bruce D. Humphries
October 2014

I certify that the above statement is correct and as the candidate's supervisor I have approved this thesis for submission.

…………………………..

Professor Colleen T. Downs

Supervisor

October 2014

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DECLARATION 1 - PLAGIARISM

I, Bruce David Humphries, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

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DECLARATION 2 - PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis.

Publication 1

BD Humphries, T Ramesh and CT Downs

Diet of black-backed jackal (*Canis mesomelas*) on farmlands in the KwaZulu-Natal Midlands, South Africa. In review

Author contributions:

BDH conceived paper with CTD and TR. BDH collected and analysed data, and wrote the paper. CTD and TR contributed valuable comments to the manuscript.

Publication 2

BD Humphries, TR Hill, and CT Downs

Landowners' perspectives of black-backed jackals (*Canis mesomelas*) on farmlands in KwaZulu-Natal, South Africa. In review.

Author contributions:

BDH conceived paper with CTD and TRH. BDH collected and analysed data, and wrote the paper. CTD and TRH contributed valuable comments to the manuscript.

Publication 3

BD Humphries, T Ramesh, T Hill and CT Downs

Habitat use and home range of black-backed jackals (*Canis mesomelas*) on farmlands in the Midlands of KwaZulu-Natal, South Africa.

Author contributions:

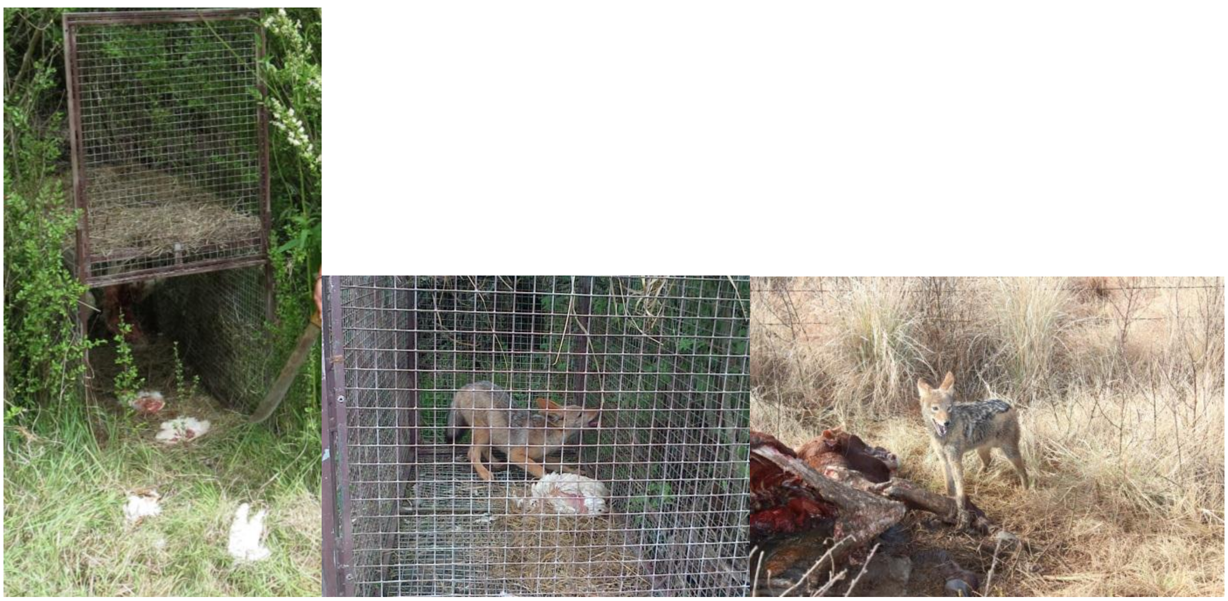
BDH conceived paper with CTD and TR. BDH collected and analysed data, and wrote the paper. CTD, TH and TR contributed valuable comments to the manuscript.

Signed: ……………………………………………………

Bruce Humphries
October 2014

FRONTISPIECE

Collared black-backed jackal (*Canis mesomelas*) on farmlands in the Midlands of KwaZulu-Natal



Captured black-backed jackals

Morphometric measurements of black-backed jackals

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CHAPTER 1

Introduction

Humans are considered as the core contributors to global environmental modification through excessive population increases, increased atmospheric pollution, degradation of soil fertility and water quality, and the depletion of the biotic system (Ojima *et al*., 1994; Chapin *et al.*, 2000; Pongratz *et al.*, 2008). The environment is increasingly overexploited and transformed to maintain rising human populations. Land use change has seen one third of the land surface area become devoted to either croplands or pastures, having profound effects on the decline of global biodiversity (Houghton, 1994; Vitousek *et al*., 1997; Foley *et al*., 2005; Lomolino *et al.*, 2006; Mouysset *et al*., 2013).

Since the development of agriculture there have been extensive modifications of natural vegetation cover on every continent except Antarctica (Lambin *et al.*, 2001). The expansion of human activities and the intensification of agriculture have led to the polarisation of systems of production and monoculture, often being hostile to wild species (Sotherton, 1998; Woodroffe, 2000; Green *et al.*, 2005; Reed *et al*., 2013). Land use and land cover change have regularly modified entire landscapes, often resulting in the alteration of many plant and animal communities (Houghton, 1994). Land management practises associated with agricultural activities such as fire breaks, grazing and tillage regularly effect natural ecosystem functioning, composition and the distribution of organic matter (Ojima *et al*., 1994; Chapin *et al.*, 2000). Furthermore, pesticides and fertilizers are having considerable effects on remaining wildlife species (Green *et al.*, 2005). These factors have resulted in land transformation becoming the primary driving force in the loss of biological diversity worldwide (Vitousek *et al.*, 1997).

Although land use is varied across the globe, the effects become a global phenomenon whereby the changes in land use contribute to global changes in climate through the increased emissions of greenhouse gases (Houghton, 1994; Vitousek *et al*., 1997). The changes in land use have been estimated to contribute to nearly 25% of the greenhouse effect whereby most of the contribution is through the release of carbon dioxide into the atmosphere from deforestation, however land changes also release significant quantities of other gases (nitrous oxide, methane and carbon monoxide) which affect properties of the atmosphere (Houghton, 1994). Although it is unclear as to what extents the changes in climate have on species extinction and threats against populations, climate change has become an important factor driving population declines and coupled with other factors such as changing land use may further increase the risk of species extinction (Angerbjhorn *et al.,* 2013).

History of agriculture and land use change in South Africa

Agriculture is arguably the single most important event in world history, giving rise to the development of human populations throughout the world (Storey, 2008). Approximately 2000 years before present, saw the introduction of agriculture into South Africa (Storey, 2008; Badenhorst, 2009). Until that time, human communities were dominated by hunter gatherers and subsistence farmers who survived by gathering wild plant foods and by trapping, hunting and scavenging for meat (Carruthers, 1993). The subsequent rise in agriculture saw the cultivation of many plants and the domestication of animals, however human's diet was still heavily supplemented by hunting and gathering of wild plant foods (Badenhorst, 2009). At the time when Europeans first settled in South Africa, both they and African populations of the region pursued wildlife for subsistence, profit and sport (Carruthers, 1989). The rise in colonialism saw increased access to markets, firearms and steel cables for snares and thus over time many herds of wildlife diminished (Carruthers, 1989). Carruthers (1993) argues that the reason wildlife was so prolific in the past was not due to reduced amounts of conflict between wildlife and humans but rather through limitations set by a lack of technology and a market for wildlife species. It is suggested that technological restraints and a lack of markets were the principal pre-colonial limitations to environmental destruction as firearms meant killing in large numbers were inefficient (Carruthers, 1993).

British colonization, although responsible for declining wildlife species, was more focused on the capitalization of resources and the expansion of their powers. South Africa was well known for its mineral production and use for shipping routes, however the British identified an important resource of cattle and sheep farming (Beinart, 1998). Although farming was always present in southern Africa, it was mainly driven through subsistence. The British brought a new means of agriculture, one which was technology driven and consisted of large scale domestication of animals and commercial trade. Merino sheep were introduced into the country to initiate intensive sheep farming to supply wool to British textile mills. The Colonial market provided the technology know how to gain control of the environment and the ability to transform the environment more radically and destructively than previously before (Beinart, 1990). Intensive burning, controls on water sources, the disappearance of bush and forest for new vegetation types and the development of fences as a result of competition for pastures by wild grazing animals all fundamentally altered the habitat for wildlife (Beinart, 1990). van Sittert (2002) similarly highlights the increase in domestic stock had profound impacts on the environment. From 1865 to 1891 the number of domestic sheep, cattle and goats increased from 13 million to 26 million, taking a huge toll on the environment (van Sittert, 1998, 2002).The new form of agriculture turned out to be unfavorable to wildlife species, as rangeland for free ranging wildlife decreased, conflict became associated between domestic and wild animals (Beinart, 1998).

In 1926, South Africa opened its first National Park beginning with Kruger National Park. It was designed to conserve wildlife, landscape, and later specific habitats (ecological zones), while making them accessible to visitors (Beinart and Hughes, 2007). John Terborgh in *Reqiem for Nature* (1999) suggests that parks provided a final defence, a bottom line, some last vestiges of the world before people damage it (Brockington *et al*., 2008). Outside national parks, conservation remained a provincial responsibility and in the case of English dominated Natal, the provincial parks board effectively took over game conservation after 1947 (Beinart and Coates, 1995). In the past, settler and colonial governments regarded conservation as an approach of exclusion of man towards its resources which would allow population numbers to grow. In more recent times conservation has adopted the approach of wise usage or management to ensure the long term viability of natural resources (Beinart and Hughes, 2007). It was not however until the1960s that the notion of protecting areas representative of all biomes came to light (Carruthers, 2008). Although conservation was seen as pivotal for many species survival, it was only really significant in National parks and game reserves where species were protected from outside influences. Outside of these protected areas wildlife became increasingly threatened. The initiative of taking conservation out of parks and game reserves and making it relevant to the lives and the land of the marginalized was done through Nick Steel. Steel (1975) suggested that farmers should collectively protect game through a farm patrol plan. In 1978 the first conservancy was established in the Balgowan district of KwaZulu-Natal Midlands. It was formed by local farmers using the guidance of the Natal Parks Board. The primary objective was to protect game on the farmlands and so this initiative became the first to protect natural areas outside of formally protected reserves. By 1993 one million hectares was protected in the Balgowan area (Draper, 1998).

The rise in conservation outside protected areas was as a result of a realization that global protected areas will not currently suffice for conserving biodiversity (Pasquini *et al*., 2009). The total land area covered by protected areas stands at 5 percent which is not only too small but also does not represent all habitat types (Cousins *et al.,* 2008). Pasquini *et al.* (2009) suggest conservation and sustainable development of natural resources is closely linked to the implementation of conservation activities on private lands. In South Africa more than 80 percent of the land is in private hands, including vast amounts of rare habitat. As a result protection of wildlife requiring conservation to look outside protected areas and involve private landowners (Cousins *et al.,* 2008).

Since the rise in conservation outside protected areas, two initiatives have been very successful, that of conservancies and stewardship programs. A conservancy is a group of farmers who manage their land according to mutually agreed upon conservation management plans and goals (Pasquini *et al*., 2009). Conservancies have provided a much needed green corridor for the movement of game, the protection of habitats, and maintaining the occurrences of rare and endangered flora and fauna (Pasquini *et al*., 2009). A stewardship program identifies areas of significance to conservation in terms of biodiversity (for example, a defined biodiversity hotspot, a threatened species, or an ecosystem). The area marked significant is then deemed stewardship status whereby conservation initiatives are taken to ensure greatest protection for that area. Since the adoption of the Convention on Biological Diversity in 1992, most countries have developed National Biodiversity Strategies and Action Plans (Wallace and Clearfield, 1997). Both these initiatives help to ensure landowners are conservation conscious and support wildlife growth. Since 1995 the expansion of areas under conservation protection has been considerable. However biodiversity is still being lost in South Africa and out of the 19 southern African countries, South Africa is the second highest in terms of the number of species listed as threatened making conservation that much more imperative (Cousins *et al.,* 2008).

Human wildlife conflict

Throughout the world biological diversity continues to decrease (Lomolino *et al.,* 2006). The growth in agriculture and its subsequent change in land use often results in deliberate attempts to exterminate wildlife populations (Lomolino *et al.,* 2006). There has been increasing evidence that land use change is causing severe and widespread decline in wildlife inhabiting farmlands (Saunders *et al*., 1991; Sotherton, 1998). Livestock grazing, agriculture, mining, alien invasive plants and pesticides have been labelled as major threats to biodiversity decline in the countryside (Sotherton, 1998; Hoffmann and Zeller, 2005). Agriculture and grazing can often disrupt habitat structure, cover and shelter for small mammals leading to higher predation risk (Hoffmann and Zeller, 2005). As land is converted to crops and pastures, less becomes available for free ranging wildlife. As a result wildlife is forced to live in increasing close proximity to humans (Carruthers, 1993). Often these circumstances promote competition between wildlife and people for space and food resources, leading to human wildlife conflict and the subsequent reduction in wildlife numbers (Carruthers, 1993; Woodroffe, 2000; Inskip and Zimmermann, 2009; Karanth and Chellam, 2009). In much of the developed world, potentially dangerous megafauna have already become exterminated as increasing human populations and associated increases in rates of resource use are forcing wildlife to live in increasing close proximity to humans (Muruthi, 2005; Inskip and Zimmermann, 2009). Throughout history, human-wildlife conflict has been regarded as conflict which occurs when the needs and behaviour of wildlife impact negatively on the goals of humans and can be traced back in history to the spread and development of herding societies (Madden, 2004; Sillero-Zubiri *et al.,* 2006).

In Africa many large mammals still roam freely in rangeland areas (Woodroffe, 2000; Muruthi, 2005). Indigenous communities regularly have to cope with wildlife conflict. Since the 1960s conflict between humans and wildlife has steadily increased to unprecedented extents (Muruthi, 2005). Wildlife regularly damage and destroy crops, eat livestock and compete for water and grazing (Woodroffe, 2000; Muruthi, 2005). One of the main causes identified for increasing wildlife conflict is rising human populations, nearly tripling in population from the 1960s (Muruthi, 2005). Agriculture has similarly spread throughout the continent, regularly encroaching on more marginal areas of land (Muruthi, 2005). In some areas conflict between farmers and wildlife is so bad that farmers are forced to change their cropping patterns or keep lands fallow due to regular crop raids by wildlife (Kumar, 2012).

Although killing conflict animals can reduce human-wildlife conflict and has regularly been used as an option, the relationship is rarely as straight forward (Muruthi, 2005). A reduction in a population of an animal can often result in alternate measures of survival such as, an increase in birth rates or a decrease in other causes of mortality (Smithers, 1983; Muruthi, 2005). Other issues resulting from the death of indigenous species is the introduction of new naive species or animals which could result in further conflict associations (Winterbach *et al.*, 2013). From an ecological perspective, the removal of certain species may upset the functioning of an ecosystem causing dramatic changes in the populations of other species (Blaum *et al.*, 2009). In the 20th century it has become unjustified to eliminate entire populations of animals but rather to enforce preventative measures of control (Muruthi, 2005; Blaum *et al.*, 2009). More regularly farming communities are using physical barriers such as mesh fencing and walls or measures of guarding crops and livestock as an act of conservation rather than obliteration (Muruthi, 2005). In some cases even fear provoking stimuli has been used to reduce conflict (Muruthi, 2005).

In South Africa most large mammals have already been removed from farming areas to increase agricultural production and minimize conflict associated with wild animals (van Sittert, 1998; Skinner and Chimimba 2005). An abundance of mammals are still prevalent in the country however most large mammals now only reside in game reserves and privately owned farms (Skinner and Chimimba 2005). Conflict between humans and wildlife in South Africa is still prevalent; however, occurrences of these discrepancies have become less frequent. Lions (*Panthera leo*) and hyenas (*Hyaenidae*) were typically the first species to be removed from areas of settlement and where vulnerable precisely because they were dangerous and inconspicuous (Beinart, 1998). Over time most of the potentially dangerous species were removed from farming areas and conflict soon become reduced, however some species such as: smaller wildcats, jackal (*Canis spp*.) and wild dogs (*Lycaon pictus*) were successful in hiding themselves from stock farmers and able to survive and continue hunting successfully (Beinart, 1998). These species became so successful that by 1814 bounties were enforced to reduce numbers (Beinart, 1998; van Sittert, 1998). Jackal and wild cats were valued at 1 rixdaler each in the 1810s, increasing to 7 shillings by the 1890s (Beinart, 1998). Throughout the 18th century bounties were considered an essential part of wildlife management by society, and a justifiable way to reduce and maintain wildlife populations. After the Second World War, bounties were made questionable as a growth in research and an understanding of predator/prey relationship made researchers question the usefulness of persecution and its effects on a region's ecological balances (van Sittert, 1998; Pohja-Mykra *et al.,* 2005).

Although damage to crops and pastures regularly results in conflict issues, carnivores constitute one of the most prominent human-wildlife conflict issues, having large home ranges and a protein-rich diet, often competing with humans for resources (Treves and Karanth, 2003; Gusset *et al*., 2012). Although wildlife conflict is experienced through a number of facets, the main persecution factor for carnivores is the predation of livestock (Atickem *et al.,* 2010). Often the potential cost of livestock losses is so high that it drives much pre-emptive killing (Atickem *et al.,* 2010). Predation on livestock and the frequency with which these occurrences take place are generally governed by the breed of animal, the way in which livestock is managed, predator density of the area and predator behaviour (Sillero-Zubiri *et al.,* 2006). Although carnivores can be highly detrimental for farmers, they do play an intricate role in ecosystems as they often limit or regulate prey numbers maintaining the functioning and structure of an ecosystem by crop sick, weak or otherwise compromised animals (Treves and Karanth, 2003; Hodkinson *et al.,* 2007; Blaum *et al.,* 2009; Karanth and Chellam, 2009). Although predator conservation is vital outside of protected areas, the degree to which communities will actively be involved depends upon the costs of livestock losses as opposed to the benefits of the presence of predators (Thorn *et al.,* 2012). Similarly without predators, grazers will outgrow the food supply of an ecosystem resulting in severe and adverse effects on grassland and savanna conditions (Hodkinson *et al.,* 2007). Small carnivores are similarly seen to regulate pests in farming areas, such as rodents and insects. It is suggested that if those numbers rise, severe crop damage can occur (Blaum *et al.,* 2009; Hodkinson *et al.,* 2007). Alleviating human-carnivore conflict therefore becomes important to conserving declining carnivore populations outside of protected areas.

Not all wildlife has however decreased outside protected areas. Many meso-predators and more specifically black-backed jackal (*Canis mesomelas*) have risen in numbers within farming communities and have become a major association with human-wildlife conflict (Carruthers, 1989; Beinart, 1998). These predators opportunistically fill an empty niche left by the removal of larger species and thrive in their absence (Beinart, 1998).

Black-backed jackal

Black-backed jackal also known as silver-backed jackal, are endemic to Africa, occurring in two disjunct distributional ranges, one in East Africa and one in southern Africa (Krofel, 2007; Loveridge and Nel, 2008; Klare *et al*., 2010). The species is abundant and widespread in both regions, however, they show a particular abundance in more arid regions (Loveridge and Nel, 2008). The northern most population extends from the Gulf of Aden south all the way to Tanzania, and the southernmost population occurs from south-west Angola, Zimbabwe and Mozambique, southwards to the tip of the African continent (Alderton, 1994). The populations are separated by as much as a 1000 km, being entirely absent from Central Africa and Zambia (Alderton, 1994; Loveridge and Nel, 2008). These two populations were once connected by regions of dry acacia bush and savannas, preferred habitat for black-backed jackal, and in years passed have become discontinuous and therefore disjunct distributions of the species (Loveridge and Nel, 2008). For the case of this literature review, this section of description and characteristics will look more specifically at the southern black-backed population, showing description and characteristics associated with these jackals.

Physical description

Black-backed jackals are a typical, long-legged canid, having a slender build with very large ears and a pointed muzzle (Nowak and Paradiso, 1983; Smithers, 1983; Skinner and Chimimba, 2005). The species has a distinctive characteristic feature of a well-defined black and silver marking running down their back, from the shoulder all the way to the tip of the tail (Alderton, 1994; Loveridge and Nel, 2008). Black-backed jackal are best described as having a general colouration of a reddish-cream, however the tail is brownish with a black tip and as one moves down the sides of the body, the underparts become paler (Nowak and

Paradiso, 1983). The head and body length is 680 to 745 mm, the tail length is 300 to 800 mm. Shoulder height is 300 to 480mm and they weigh between 7 and 13.5 kilograms with the males average weight being about a kilogram heavier than the females (Nowak and Paradiso, 1983).

Conservation status

In 2008 the International Union for the Conservation of Nature (IUCN) red list of threatened species described black-backed jackal as a species of least concern (Loveridge and Nel, 2008). In South Africa and Namibia, the species is so widespread and abundant that they have been considered vermin and regularly reported as pests (Loveridge and Nel, 2008). In game reserves and national parks, black-backed jackals are killed by large felids such as; lion, African wild dogs, hyenas and leopards (*Panthera pardus*) (Ray *et al.,* 2005). However outside of protected areas particularly in commercial farming areas where the majority of these large species have been persecuted, there are no recognised major natural threats to the species (Ray *et al.,* 2005). Jackal pups and sub-adults can however be vulnerable to smaller carnivore species and large raptors (Ray *et al.,* 2005). Humans are regularly recorded to persecute the species due to predation on livestock, however, persecution only temporarily reduces their numbers and thus appears largely ineffective (Loveridge and Nel 2008).

Habitat

Black-backed jackals are relatively unspecialized canids, resulting in a highly adaptive species, well suited for an opportunistic lifestyle (Beinard, 1998, Loveridge and Nel, 2008). As a result the species has a wide tolerance for a variety of habitats, regularly adapting to their surroundings (Loveridge and Nel, 2008). They are commonly found in areas of open countryside, particularly dry grassland and bushland (Nowak and Paradiso, 1983; Alderton, 1994; Hayward and Hayward, 2010). They have also been recorded in forests, mountains, arid coastal deserts (Caro and Stoner, 2003), farmland and scrubland (Loveridge and Nel, 2008). Black-backed jackals show a preference for open habitats and tend to avoid dense vegetation (Loveridge and Nel, 2008). In KwaZulu-Natal, they have been recorded from sea level to more than 3000 m a.s.l and in regions that receive more than 2000 mm of rainfall a year (Loveridge and Nel, 2008).

Reproduction

Black-backed jackals are one of a few mammal species that show characteristics of a long term bond between adult pairs (Moehlman, 1987; Rowe-Rowe, 1992). Rowe-Rowe (1992) suggests, adult jackal generally pair at three years, forming a bond for life. Mated pairs form territories which are marked and defended by both sexes (Nowak and Paradiso, 1983; Moehlman, 1987; Hayward and Hayward, 2010). Territory markings are done with urine and faeces, occurring at conspicuous sites throughout the territory such as small bushes and tufts of grass (Hayward and Hayward, 2010). Howling vocalizations are similarly used to inform visiting jackals of the residence of that pair. Occasionally large carcasses can attract neighboring jackal however trespassers remain for only brief periods, rarely more than two hrs. When foraging, resident jackals will scent-mark twice as often as solitary foragers and characteristically trespassers do not scent mark (Moehlman, 1987). The tandem marking from a resident jackal suggests both members of the pair are active and in residence (Moehlman, 1987).

Within the territory of the resident pair of black-backed jackals, a den is usually formed in an effort to rear pups (Alderton, 1994). These dens are usually created as a result of some excavating work done by another creature such as an aardvark (*Orycteropus afer*). The opportunistic nature of a black-backed jackal results in dens which are not created by the jackal but rather adapted to by the jackal, such as termite mounds or a water pipe (Alderton, 1994). The litter size of black-backed jackal are largely influenced by the age of the female, the younger or older the female, the less pups (Alderton, 1994). Characteristically it varies from between 1 and 8 with a mean litter size of 5, however mortality in the first few weeks is usually high resulting in only a few (if any) surviving (Rowe-Rowe, 1992; Alderton, 1994). Pups are generally born between June and September in KwaZulu-Natal with a peak in July, having a gestation of 60 days (Rowe-Rowe, 1992). Pups are born blind and open their eyes after eight to ten days. However, pups usually appear from their den for the first time at about two weeks old and are grey in colour (Alderton, 1994). Food is initially regurgitated by both parents for their pups, however after eight to nine weeks the pups are weaned (Nowak and Paradiso, 1983; Kaunda, 2000) and food is then carried back to the den in the mouths of the parents for the pups to eat. After they reach three months their coats become apparent at which time hunting begins with the parents (Rowe-Rowe, 1992; Alderton, 1994). After approximately 270 days, black-backed jackal young reach their age of independence where they are no longer reliant on their parents (Gittleman, 1989; Rowe-Rowe, 1992). After 6 months pups have all their permanent teeth and by 12 months they reach full adult size (Rowe-Rowe, 1992). This characteristically occurs when cubs are 8 to 9 weeks old (Nowak and Paradiso, 1983; Kaunda, 2000). From the period of February to April is the time when offspring from the previous litter disperse to find new territory and ranges. It is estimated that black-backed jackal do not survive for longer than 7 years in the wild (Rowe-Rowe, 1982) due to threats exerted upon them, however in captivity they have been recorded living twice as long (Alderton, 1994).

A characteristic which has been recorded in black-backed jackal populations is that the offspring will sometimes remain with the adult pair into the next breeding season and help raise the next generation of young, depending on the abundance of food in the region. This helps to prevent new males from gaining access to the female (Nowak and Paradiso, 1983; Moehlman, 1987; Bothma and Walker, 1999; Kruuk, 2002). Of known surviving pups, 24 % stay and help raise the next litter (Gittleman, 1989). As a result, pups' survival to the age of 14 weeks increased dramatically, having had a significant correlation with the number of adults in the family (Gittleman, 1989). Data however suggests that helpers will only be retained dependent on the available resources, territory and energetic needs of provisioning the pups (Gittleman, 1989). By allowing offspring to stay on parental territory an improvement in reproductive success was recorded as pup survival was higher, and females' future reproductive success was improved by the provisioning she received (Gittleman, 1989). Importantly, offspring were also in place to inherit the territory if the parents died and thus gained experience in familiar terrain which might increase their survival and the quality of their future parental care (Gittleman, 1989).

Territory

In terms of the density and range of black-backed jackal, territory size is governed by food availability and resources (Alderton, 1994; Loveridge and Nel, 2008). The higher the food availability, the greater the density of jackal (Loveridge and Nel, 2008). In the Drakensberg mountains of South Africa, a density was recorded of 0.34-0.40 jackal per km^2, while along the Namibian coast it varied from 0.1-0.53 jackal per km^2 along food scarce beaches and along the skeleton coast 7.0-9.0 per km^2 (Loveridge and Nel, 2008). In a rookery at Cape Cross where food is rich and plentiful, as high as 16.0-32.0 per km^2 (Loveridge and Nel, 2008). In terms of black-backed jackal ranges, some males have been recorded to cover a distance of 40 km or more in a night (Alderton, 1994). Optimal forage theory predicts that as food resources decrease, the niche breadth should increase (Kaunda and Skinner, 2003). A study undertaken in Giants Castle Game Reserve suggests that mated adults home ranges are

1900 ha and young (less than one year old) had a range of 900 ha and unmated adults was 3300 ha (Rowe-Rowe, 1982).

Black-backed jackal diet and behaviour

Black-backed jackals have been identified as having a broad diet which varies from region to region depending upon resources available (Ray *et al.,* 2005). They are often referred to as generalist feeders and aggressive competitors, able to displace other smaller predators from areas (Ray *et al.,* 2005). The diet of black-backed jackal in southern Africa has been extensively studied and is suggested that prey commonly consumed is small to medium sized mammals, ranging in size from insects and small rodents up to small antelope (Nowak and Paradiso, 1983; Caro and Stoner, 2003; Skinner and Chimimba, 2005; Krofel 2007; Loveridge and Nel, 2008; Kamler *et al*., 2012;), however, they have been observed to prey upon the fawns of large ungulates species, especially gazelles (Kamler *et al.,* 2009). They successfully hunt adult gazelles, adult impala, and adult springbok (Alderton, 1994; Kamler *et al*., 2009; Klare *et al.,* 2010). Klare *et al.* (2010, pp. 1037) emphasises, "canids show a large degree of intraspecific variation in their behaviour and diet, often related to differences in dispersion and abundance of food resources". It is similarly suggested that food selection varies according to different rainfall, habitat and times of the year (Skinner and Chimimba, 2005). The upper size limit of prey consumed is set by how successful larger animals can be captured by predators. The lower size limit depends upon how frequently smaller dietary morsels can be found and eaten (Owen-Smith and Mills, 2008). They have retained their original carnivore dentition of 42 permanent teeth and all post carnassials molars (Kok and Nel, 2004). Their upper canines are long and curved with a sharp pointed ridge on their posterior faces. The lower are similarly defined however have a slightly more recurved structure and are shorter in length (Skinner and Chimimba, 2005). Their dentition allows for flexibility in their diet and ability to change diet according to prey availability (Kok and Nel, 2004). A predator will include more prey species in its diet in areas of low productivity or scarce food regions as diversity is required to sustain energetic levels (Kaunda and Skinner, 2003). If food is minimal, prey will be diversified and in some instances result in threats to livestock (Kaunda and Skinner, 2003). Black-backed jackal are highly opportunistic and will take whatever prey is in greatest abundance or is most easily captured (Skinner and Chimimba, 2005). However they have a reputation for being a voracious predator of calves and small stock and are regularly blamed for mauling cows during birth (Ray *et al.,* 2005).

Black-backed jackals are cursorial hunters which chase their prey to exhaustion as a common technique for feeding (Kamler *et al.,* 2009). In larger ungulates it is suggested that kills are made by repeated biting and tearing of the sides of the prey until the victim dies (Kamler *et al*., 2009). They usually adopt a 'zig-zag' approach when in pursuit of rodents and insects, and a directional approach in pursuit of prey such as hares and antelope (Gittleman, 1985). Their general movement is at a trot, however when hunting they often walk slowly with their ears pricked high (Skinner and Chimimba, 2005). They have well developed smell and acute senses (Skinner and Chimimba, 2005). It is suggested that the species is largely independent of water however they will drink when available (Skinner and Chimimba, 2005). Characteristically it was recorded that among predatory species, population group size increases with prey size (Gittleman, 1989). Similarly feeding group sizes and foraging group sizes increase with an increase in prey size (Gittleman, 1989). This relationship is probably due to larger food resources which can support a greater number of individuals (Gittleman, 1989). Another variable in group and prey size was habitat. To hunt cooperatively, animals must fan out and maintain contact with other individuals, and be able to adjust positions during pursuits (Gittleman, 1989). Therefore the sizes of groups are dependent on habitat types (Gittleman, 1989). Sufficient dietary contribution to support jackal is governed by the frequency and carcass mass provided for consumption by the predator (Owen-Smith and Mills, 2008). Typically predators do develop a dietary niche relationship with prey in that a preference is shown for different prey species by the frequency of encounters observed by the predator and its prey (Owen-Smith and Mills, 2008). This plays a role in controlling relative abundance whereby focusing on one species will result in a drastic decline, and thus a possible trophic cascade on other species which are dependent on that prey's survival (Owen-Smith and Mills, 2008).

Changes in the environment in southern Africa have forced black-backed jackals into greater conflict with farmers and their livestock (Graham *et al.*, 2005). As human populations have spread, conflict has risen (Alderton, 1994). Actions of man have resulted in the changes in jackals habitats (Alderton, 1994). A good example is the extinction of lions outside reserves in South Africa (Alderton, 1994). In the past, jackals obtained a large portion of food through scavenging off lions. Since the removal of these felines, jackals were forced into a more predatorial lifestyle (Alderton, 1994). Similarly intensive hunting of antelope by man has resulted in food source depletion and thus further exacerbated the effects of conflict. The spraying of pesticides and insecticides on crops have similarly reduced rodent and insect populations, curbing the number of natural prey species for jackal and thus conflict has risen (Alderton, 1994).

Black-backed jackals will adopt a variety of activity patterns dependent on factors such as: social organization (age, sex and physiological status), food availability, competitive interactions, energetic requirements, population density and environmental conditions (Kaunda, 2000). In a case study done at Mokolodi Nature Reserve, Botswana from November 1995 to February 1997, activity patterns were witnessed for the number of black-backed jackal to fluctuate on a seasonal basis. There was a recorded increase in activity throughout winter, and reaching a lowest point in summer (Kaunda, 2000). Winter activity was consistent with established jackal breeding biology (Kaunda, 2000). Mokolodi jackals were seen to exhibit both crepuscular and nocturnal activity patterns and their peak activity patterns were recorded around 18h00 and 06h00 (Kaunda, 2000). Data collected revealed a 27.2 % activity in winter; spring = 21.7 %; and autumn = 20.8 % (Kaunda, 2000). In another study done at Giants Castle Game Reserve, KwaZulu-Natal, black-backed jackal had a circadian activity pattern with most activity occurring in the early evening followed by a second but less intense peak in the early morning (Rowe-Rowe, 1983). Their activity patterns have been synchronized with that of their important prey, particularly rodents such as vlei rats (*Otomys irroratus*) (Kaunda, 2000; Skinner and Chimimba, 2005). Black-backed jackals can have a crepuscular activity pattern (Gittleman, 1989), however in areas intensively settled by man, jackals have become nocturnal (Nowak and Paradiso, 1983).

Black-backed jackals which are actively threatened by hunting show spatio-temporal changes in their activity patterns (Kaunda, 2000). It was found that as a result of human conflict, activities for black-backed jackal were limited to particular areas where all needed resources were obtained and in addition they were able to evade human predators (Kaunda, 2000). There was considerable evidence that populations of jackal departed from those areas subject to sustained hunting pressure (Kaunda, 2000). However, Loveridge and Nel (2008) suggest that hunting has a minimal effect in controlling jackal populations. It is however suggested that the effects of predator control and high stocking rates reduce abundance and species richness throughout the carnivore guide (Loveridge and Nel, 2008). Grazing intensity also had a strong negative affect on the abundance of most carnivores as high stocking rates transformed grass-dominated savannas into shrub-dominated savannas where prey availability for most carnivores is low (Blaum *et al.*, 2009). The loss of carnivore species is suggested to have cascading effects on prey species as the balance of ecosystems shift, however these studies are skewed because carnivore-induced trophic cascades are often difficult to detect (Blaum *et al.,* 2009). Black-backed jackals are negatively affected by predator control measures however the consequences of their decline still remain unclear (Blaum *et al.*, 2009).

As mentioned, in some areas in South Africa, black-backed jackals have resorted to farm livestock as a source of food. Jackals have been identified as the main culprits of killing lambs up to the age of three or four months old (Rowe-Rowe, 1992). Prey is killed and fed upon in a stereotyped manner, the jackal bites at the throat, on either side of the windpipe (much like larger carnivores) and retains its grip until the prey dies of suffocation (Rowe-Rowe, 1992; Hodkinson *et al.,* 2007). The throat bite generally has a distance of 23 to 29 mm between the upper canine and it has been recorded that jackal characteristically opens the carcass on the flank between the hip and the bottom of the ribs (Hodkinson *et al.,* 2007). The parts eaten are usually the kidneys, liver, heart and tips of the ribs (Rowe-Rowe, 1992).The amount eaten is small (500g) and generally no large bones. Black-backed jackal have been identified as being a very neat feeder capable of removing flesh under the skin of carcasses, resulting in the remains having a hollowed out appearance (Rowe-Rowe, 1992). They do not move the carcass, and seldom return to feed on it again, however occasionally small portions are carried away for the pups (Rowe-Rowe, 1992; Hodkinson *et al.,* 2007).

It has been documented that black-backed jackals play a significant role in maintaining an ecological balance in areas where dominant predators such as lions, leopards and cheetahs are non-existent. Wildlife ecology and balance has an important role in ecosystem dynamics and species diversity. An abundance of predator or prey species will lead to perceived drastic effects on the environment as diversity will diminish and veldt density will increase (Blaum *et al.,* 2009). Smaller carnivores play a significant role in maintaining diversity and dynamics of ecosystems. Without these smaller predators, prey species would fluctuate resulting in both environmental and social conflicts such as overgrazing of land and erosion (Blaum *et al.*, 2009).

Aim

The aim of this project was to determine the seasonal diet, home range and habitat use of black-backed jackal in farmland in the KwaZulu-Natal Midlands areas in an effort to understand the behavioral dynamics of the species, and why the species is capable of adapting and surviving in these areas.

Objectives

- To determine the seasonal diet of black-backed jackals in agricultural areas.
- To determine landowners perceptions of Black-backed jackal in agricultural areas.
- To determine the home range and habitat use of black-backed jackals in agricultural areas.

Arrangement of thesis

This thesis is presented as chapters with some prepared as manuscripts for submission to international peer-reviewed Journals as follows;

Chapter 2: Seasonal diet of black-backed jackal on farmlands in the KwaZulu-Natal Midlands, South Africa.

Chapter 3: Landowners' perspectives of black-backed jackals on farmlands in KwaZulu-Natal, South Africa.

Chapter 4: Habitat use and home range of black-backed jackals on farmlands in the Midlands of KwaZulu-Natal, South Africa.

Chapter 5: Conclusions.

As some chapters have been prepared as stand-alone manuscripts, some overlap and repetition between chapters has been unavoidable.

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CHAPTER 2

Diet of black-backed jackal (*Canis mesomelas*) on farmlands in the KwaZulu-Natal Midlands, South Africa.

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Abstract

Black-backed jackals (*Canis mesomelas*) are one of the most commonly implicated conflict animals on farming areas in southern Africa. To determine the diet and prey of black-backed jackals, and to understand their possible predation effects on domestic livestock, a study was conducted using faecal analyses of scats in the Nottingham Road/Mooi River agricultural areas, KwaZulu-Natal, South Africa. We collected and analysed 154 black-backed jackal scat samples from two seasons (summer and winter). Jackals consumed 19-21 taxa per seasons, including a number of rodents and shrews, domestic and wild ungulates, birds, insects, reptiles and grass. Rodents comprised the most consumed item of prey seasonally (53-55 percentage of occurrence), illustrating they were the main food source of black-backed jackals. Another important food source were domestic livestock comprising between 16%

(winter) and 19% (summer) seasonally. A comparison between seasons showed that black-backed jackals consumed a wide range of prey categories throughout the year, however, there was a slight increase in prey diversity during the winter period. A high diversity of prey species in the diet of jackal confirmed the opportunistic and generalist nature of the species. Domestic stock contributed an important food source in the diet of black-backed jackal in this modified agricultural landscape. Therefore appropriate management measures are needed to avoid growing human-wildlife conflict in agricultural farmlands.

Keywords: diet, conflict, livestock, ungulates, farmland, carnivore, scavenger.

Introduction

Human-wildlife conflict has been labelled as a major influence of declining biodiversity and it has become a critical endeavour for wildlife conservation and management to understand how species persist in human-altered landscapes (Woodroffe et al. 2005; Thorn et al. 2010). Humans have progressively transformed and altered landscapes, displacing and reducing species across the globe (Alroy 2001; McKee et al. 2004). Information on how many farmland species persist and the effects agricultural change is having on predator abundance and predator patterns is still scarce (Pita et al. 2009). Therefore acquiring information on species occurrence, abundance, spatial and temporal patterns and diet is vital to improve management techniques for remaining wildlife species in these areas (Kaunda and Skinner 2003; Thorn et al. 2010). Such information, however, is often lacking for many carnivores and elusive wildlife species, therefore finding efficient and practical ways to acquire such knowledge has become essential (Treves and Karanth 2003; Inskip and Zimmermann 2009; Thorn et al. 2010).

Throughout southern Africa most large carnivores have already been removed from private agricultural lands, leaving medium-sized black-backed jackal (*Canis mesomelas*) and caracal (*Caracal caracal*) as the top predators in many of these ecosystems, yet their role in this ecosystem is poorly understood (Falkena 2000; van der Waal and Dekker 2000; Klare et al. 2010). Research is required to understand the functional role they play in ecosystems as predators, because results may have important ecological and management implications for the region (Kaunda and Skinner 2003; Klare et al. 2010). Although the diet of black-backed jackal has been extensively studied through faecal and stomach content analyses, revealing a wide range of food items, the extent of this variation and the nature of the prey species have received little attention. The species is a generalist feeder consuming mostly small and medium-sized mammals, birds, carrion, insects and fruit (Grafton 1965; Stuart 1976; Rowe-Rowe 1983; Loveridge and Nel 2004; Skinner and Chimimba 2005). However, in some areas, larger wild ungulate species were consumed as well as some domestic ungulates (Bothma 1971; Rowe-Rowe 1976; Klare et al. 2010; Kamler et al. 2012). Thus the diet does vary according to food availability and an understanding of the species' food habits is essential to a study of its ecology (Grafton 1965; Smithers 1983).

In South Africa black-backed jackal have often been regarded as a predator of domestic animals, continually being persecuted as a problem animal for humans and noted as a vermin species (Bothma 1971; Loveridge and Macdonald, 2003; Kamler et al. 2012). In many farming areas black-backed jackals have been labelled as significant predators of domestic sheep, goats and cattle although the topic has been highly controversial and uncertain (Ferguson 1986; Rowe-Rowe 1976). To understand why black-backed jackal have turned towards the consumption of domestic ungulates, it is essential to compare its habits in agricultural areas with those in natural areas such as game reserves and national parks (Bothma 1971).

Scat analysis is a widely used technique to study the feeding ecology of elusive wildlife species (Ciucci et al. 1996; Kelly and Garton 1997; Rühe et al. 2008; van der Merwe et al. 2009). The technique is increasingly being used to determine the diets of canids (dogs, foxes, coyotes and wolves), felids (cats), mustelids (otters and badgers), and viverrids (civets and genets) (Trites and Joy 2005). The technique is regarded as being non-invasive, inexpensive and having an added benefit of being able to collect relatively large samples (Litvaitis 2000). It allows for the identification and quantification of identifiable parts of prey that have passed through the digestive systems of mammals (Kelly and Garton 1997; van der Merwe et al. 2009). It is a useful tool to obtain a basic description of a carnivore's diet, especially when other methods are difficult to conduct (Marucco et al. 2008). However, scat analysis can have potential biases such as partial or total digestion of remains and underrepresentation of smaller prey items (Arim and Naya 2003).Most species consumed can be identified through the use of reference collections of potential food items, for example tooth shapes and structures to identify different species of rodents (de Graaff 1981). Through the analysis of scats, one can estimate the number of prey species and the number of individuals killed by a carnivore, providing knowledge on prey preference, prey overlap of sympatric carnivore species, and responses to changing prey densities of species (Loveridge and Macdonald 2003; Kok and Nel 2004: Rühe et al. 2008).

To understand the seasonal diet and prey of black-backed jackals in farmlands of dominantly beef and dairy livestock, a study was conducted in the Midlands of KwaZulu-Natal, South Africa. The residents' (pers. comm.) experience conflict, on a regular basis, with a variety of wildlife species, commonly the vervet monkey (*Chlorocebus pygerythrus*), bushpig (*Potamochoerus porcus*), baboons (*Papio ursinus.*), and black-backed jackals. Large carnivores such as lions (*Panthera leo*), leopards (*P. pardus*), and spotted hyenas (*Crocuta crocuta*), historically occurred in this region, but all were extirpated by humans prior to 1900

(Skinner and Chimimba 2005). The absence of these carnivores could have a significant positive impact on smaller carnivore species as there are no longer any natural predators to maintain population levels (Rowe-Rowe 1992). It was felt that the knowledge of food habits of the black-backed jackal in dominantly cattle-farming areas which includes such details will go far in providing basic ecological information and elucidating the reasons for jackal predation upon domestic stock (Grafton 1965). It was expected that consumption of domestic cattle by black-backed jackal would be low considering the size and nature of the animal compared with jackal.

Methods

The study was conducted on a number of private commercial farms in the Nottingham Road/Mooi River area in the Midlands of KwaZulu-Natal. The central co-ordinates for each study site are: Fort Nottingham E 29° 57’ 21.6”, S 29° 25’ 30.0” and Mooi River E 108 29° 13’ 27.7”, S 29° 55’ 24.4” (Figure 1). The district is an intensive farming region situated in north western KwaZulu-Natal and is located between the towns of Pietermaritzburg and Harrismith. The primary land use practices are beef and dairy cattle farming, utilizing indigenous grasslands, pastures, crops such as maize and potatoes, and patches of plantation forests (*Pinus patula* and *Eucalyptus* spp.) (Ramesh and Downs 2013). The majority of the land is privately owned, however, portions of land are owned by government and outside organizations (pers. obs.). The farmlands are generally fenced by five-strand barbed-wire fencing, marking farm boundaries as well as fencing internally into camps to allow for rotational grazing (pers. obs.). These fences do not restrict wild animal movements through the farmlands.

The average annual minimum and maximum temperatures for the region are 9.2^{0}C and 31.8^{0}C respectively, and the average annual rainfall is 975.4 mm (Weather Station, Fort

Nottingham). Most rainfall occurs in the summer months and snow typically occurs twice a year. The altitude is ≥ 1200 m above sea level and the topography varies from undulating hills, with rivers and wetlands in the valleys. The dominant vegetation type is Mooi River highland grassland and Drakensberg foothill moist grassland with patches of indigenous bush clumps (Killick 1990; Mucina and Rutherford 2006). There are patches of invasive black wattle (*Acacia meansii*) scattered throughout the lowland regions and hill slopes.

The region is known to have many naturally occurring wild ungulate species (Rowe-Rowe 1992) and is considered a conservation priority by local conservation authorities as indigenous forests, natural grasslands, wetlands and wildlife persist despite changing land use (Ezemvelo KZN Wildlife 2012). Information on the exact number and species of wild ungulates is largely unknown. However, southern reedbuck (*Redunca arundinum*), blesbok (*Damaliscus pygargus phillipsi*), oribi (*Ourebia ourebi*) and common duiker (*Sylvicapra grimmia*) are regularly seen throughout the study area (pers. obs.). The region does have several carnivore species such as; large-spotted genet (*Genetta tigrina*), large grey mongoose (*Herpestes ichneumon*), white-tailed mongoose (*Ichneumia vitticollis*), water mongoose (*Atilax paludinosus*), black-backed jackal, serval (*Leptailurus serval*), caracal, which may prey on the wildlife and at times farm livestock.

Scat collection and laboratory procedures

During this study, black-backed jackal scats were opportunistically collected whenever encountered over the study period. Scats were collected over large areas of land (approximately 28000 ha) throughout the collection period (May to August 2013-winter and January to March 2014-summer) and thus assumed not to be biased towards single feeding events and would represent feeding habits of several individuals in the study area. Scats from black-backed jackals were distinguished from other species based on size and shape (Chame 2003) and the tendency of black-backed jackals to deposit scats on conspicuous objects such as rocks and tufts of grass along roads (Ferguson et al. 1983; Hayward and Hayward 2010). Only fresh jackal scat was collected to ensure scat represented the collection season. Scats were collected in brown paper bags and labelled with the date, farm name and position of collection and subsequently air-dried until analysis.

Each scat was soaked in a bowl of water until completely fragmented. It was then placed in a 1 mm sieve and thoroughly rinsed under running water following Rowe-Rowe's (1983) technique for scat analyses. Scats were then air-dried and analysed. Small mammals were identified mainly from jaws and teeth shape structures which were compared to reference samples (UKZN reference material, C.T. Downs) and available literature (de Graaff 1981; Skinner and Chimimba 2005), and the help of local experts who verified difficult samples. One criterion alone may not be sufficient enough to identify species in scat samples (Harrison 2002), thus hair structures were also used to determine species in scat samples. Hairs in each sample were identified by their microstructure, shape and cuticular colour according to various keys (Perrin and Campbell 1980; Keogh 1983, 1985). Negative imprints were created by placing single hairs on slides thinly covered with transparent nail polish (Klare et al. 2010). Once nail polish had dried, hairs were peeled away using forceps leaving behind a scale cast impression of the hair which was then viewed under a light microscope (100× to 400× magnification). Where ever possible, scat samples were identified to species level, however birds, reptiles and insects were left at class level. In some scats, species were difficult to identify and thus classified as unidentified mammals. We visually estimated volume of each undigested food item in the scat to the nearest 5% and noted trace items that contributed <5% to the whole scat. Jackal hair was discarded from further analyses as it was presumably ingested when grooming.

We calculated percentage of occurrence (number of occurrences of a food category/total number of occurrence of all food categories × 100: Ramesh et al. 2012) and relative percentage of occurrence (number of occurrences of a food category/total number of scats × 100: Ramesh et al. 2012) of each prey item, to provide a measure of how often black-backed jackal feed on certain types of food and as a measure of importance of that food type in the diet (Loveridge and Macdonald 2003). In most of the previous studies done on black-backed jackal, percentage occurrence was the most commonly used technique for scat analysis (Bothma 1971; Stuart 1976; Rowe-Rowe 1976, 1983; Kaunda and Skinner 2003; Loveridge and Macdonald 2003; Kok and Nel 2004; van der Merwe et al. 2009; Goldenberg et al. 2010; Forbes 2011) therefore, percentage occurrence was determined to compare with past studies. It is acknowledge that percentage occurrence can produce errors in results as several scats may contain particles of a single large meal, and the importance of small commonly consumed items may be overestimated (Atkinson 2002; Loveridge and Macdonald 2003; Klare et al. 2010). Percentage occurrence does however help in understanding characteristics of a carnivores ecology such as its role as a specialist, generalist or an opportunist species and additional information on rare food items (Klare et al. 2010). It is however acknowledged that biomass figure would give a more accurate indication of the amount of prey consumed by the species, unfortunately, measurement were not taken of the mass of each scat collected and thus I was not able to do biomass calculations. (Klare et al. 2011). To ensure sample adequacy for diet diversity found in the scat, we used Shannon Diversity Index by randomizing the original order of scat samples (1000 iterations) using the software EstimateS (Colwell et al. 2012). To test for potential variation in prey consumption between two seasons, we used the Kruskal-Wallis one-way analysis of variance (Spurrier 2003).

Results

We collected and analysed 154 black-backed jackal scat samples from two seasons (summer and winter) (Table 1). Analyses revealed a number of different prey items in their scat remains over the winter (21) and summer (19) period. There was no significant difference in consumption of species in summer and winter (Kruskal—Wallis; $p < 0.005$). Rodents were the dominant prey group consumed by black-backed jackal across both seasons (range = 53.5—55.2% of occurrence, Table 1). Ten rodent species were identified in scat samples, with *Otomys auratus* and *Rhabdomys chakae* being the most common prey species. Domestic ungulates were the second most important prey group consumed across seasons (16.2—19.3%), followed by wild ungulates (6.9—9.1%), plants (7—10.3%), birds (6—6.2 %), insects (0—6 %), and reptiles (1.4—2 %). The Shannon diversity index reflected that the cumulative dietary diversity index for 21 items of prey collected over the winter period was between 75 - 85 scat samples where H is 2.4796 with an evenness of 0.8277 (Figure 2a). Similarly the cumulative dietary diversity index for 19 species collected over the summer period appeared to reach asymptote at about 60 - 70 samples where H is 2.6236 with an evenness of 0.8910 (Figure 2b). This indicated that for both seasons, the species had broad diet diversity.

The bulk of the diet consumed by black-backed jackal in summer was contributed by *O. auratus* (29.9% percentage occurrence) followed by domestic cattle (19.4%) and *R. chakae* (14.9%). Other food items that appeared to be of importance were insects, birds, reedbuck, *Mus minutoides* and grass, each contributing 9% (Figure 3). Diet consumption was similar in winter, with *O. auratus* (31%), domestic cattle (27.6%) and *R. chakae* (24.1%) again as dominant prey categories. In winter there was no trace of insects present in the diet; however, reedbuck (10.3%), grass (14.9%) and birds (10.3%) still appeared to be of importance to black-backed jackal diet. Other mammal species were consumed only sporadically (0—4%) across seasons (Table 1).

Discussion

The diet of carnivores is highly variable and affected by a number of factors including the abundance of different prey items, the prey items' vulnerability and ability to avoid predators, nutritional demands of the predator, and interspecific interactions with other predators (McFarland 1987; Mills and Gorman 1997; Atkinson et al. 2002; Loveridge and Macdonald 2003; van der Merwe et al. 2009). Most of the previous studies done on the diet of black-backed jackal were conducted on either farmlands with dominantly sheep as livestock (Bothma 1971; Stuart 1976; Rowe-Rowe 1976; Kok and Nel 2004; van der Merwe et al. 2009; Klare et al. 2010; Forbes 2011; Kamler et al. 2012) or in nature reserves where the dominant animals were antelope (Grafton 1965; Rowe-Rowe 1983; Loveridge and Macdonald 2003; Kaunda and Skinner 2003; Goldenberg et al. 2010; Brassine 2011; Forbes 2011). In our study area, where beef and dairy cattle were the most common livestock species, we recorded the consumption of rodents as the dominant food resource. In a study done in Giant's Castle Game Reserve (Rowe-Rowe 1983), similar results were found whereby rodents accounted for 55 % of the diet consumed by black-backed jackal, and were dominated by *O. auratus* and *R. chakae*. It was suggested that the high occurrence of these species was possibly due to similar activity patterns to that of black-backed jackal and high prey availability (Rowe-Rowe 1983).

In South Africa, black-backed jackal have long been regarded a problem species due to their predation on livestock (van der Merwe 1953; Grafton 1965; Beinart 1998; van Sittert 1998; Loveridge and Nel 2004). However, being a predominantly cattle-farmed area, and the size and nature of cattle as an ungulate species, one expected a much lower consumption percentage, if any. There was nevertheless a relatively high consumption rate of cattle. However, scat analysis does not allow for the differentiation of killed versus scavenged prey, therefore one is unable to determine that exact percentage of livestock killed by the species (Klare et al. 2010). During scat collection we were aware of the death of cattle in the area and the consumption by black-backed jackal thereafter (pers. obs.). As a result we can ensure that some degree of consumption on domestic cattle was from scavenging. We have, however, observed jackal actively hunting sick domestic cattle and killing newly born calves. This shows that jackal are capable of hunting these large prey animals. Scat analyses do not, however, allow for the precise number of individuals consumed (Mills 1996) and thus it is difficult to quantify the exact damage (financial loss) for farmers by the black-backed jackal.

Sheep, goats and horses were consumed by black-backed jackal in the current study, however, to a much lesser degree to that of cattle. This is probably influenced by the density of those domestic animals in the area where cattle were most prevalent (pers. obs.). Regardless, results show that any form of domestic ungulate can fall prey to black-backed jackal. It is emphasised that a large problem with domestic animals is that they no longer exhibit effective anti-predator behaviour, which makes them more vulnerable to predators (Kruuk 1972). Furthermore, the commercialisation and expansion of livestock may compete with wild herbivores for resources and as a result, reduce the abundance of wild prey for carnivores forcing them to feed on livestock (Sillero-Zubri and Laurenson 2001). The low prevalence of reptiles and birds as food items suggests they were not of particular importance for black-backed jackal in the Nottingham Road/Mooi River area. It is however suggested that birds are generally difficult to catch, and canids have a high failure rate between catches (Kaunda and Skinner 2003). Similarly due to an abundance of prey available in the area, time and energy need not be wasted in actively foraging for invertebrates that contribute little to energy requirements.

Studies have shown that regions with scare food resources will encourage high prey diversity to maintain metabolic processes (Kaunda and Skinner 2003; Kok and Nel 2004). If food abundance is low, prey consumed by black-backed jackals will be diversified and in some instances this will result in threats to livestock (Kaunda and Skinner 2003). We found that jackal preyed on a large spectrum of species even in areas of high productivity, consuming any prey available to them. Thus we felt that although scarce food resources can lead to a broad diversification in prey, black-backed jackals naturally diversify prey species to survive in numerous landscapes. When looking at previous studies done on the species, black-backed jackal generally had a high diversity of prey regardless of the productivity or food available (Grafton 1965; Bothma 1971;Stuart 1976; Rowe-Rowe 1976, 1983; Loveridge and Macdonald 2003; Kaunda and Skinner 2003; Kok and Nel 2004; van der Merwe et al. 2009; Klare et al. 2010; Goldenberg et al. 2010; Brassine 2011; Forbes 2011; Kamler et al. 2012). The opportunistic nature of black-backed jackal combined with its foraging capabilities allow for the species' broad diversity of prey and subsequent increases in population size (Kaunda and Skinner 2003; Macdonald and Sillero-Zubiri 2004).

Although it is suggested that black-backed jackal naturally have a high variety of prey, it was felt that a more realistic appraisal of the diet could be obtained through a comparison of previous studies done on the food of black-backed jackal (Table 2). From previous studies it was evident that there was a significant variation of certain prey items between studies. A comparison of studies done on farmland as opposed to reserves indicated a marked increase in consumption of domestic ungulates and birds on farmlands and an increase in insects on reserves. Vegetation comparisons also showed a marked change in species diet depending on vegetation types. In desert type areas birds and insects were dominant whilst in savannah areas wild ungulates were dominant. This variation suggests that black-backed jackal merely switches between whichever particular prey species is present and thus has no specific preference for food sources. Therefore a species can have a high diversity of prey in an area of high biodiversity. Analyses of diet from previous studies did however show that land use change, type of vegetation and the nature of the areas' current human activity can affect the diet of the species.

Although it is acknowledged that there was no tests done to determine the exact prey availability or abundance of a given species in our study site, conclusions were drawn that the study site had high species spectrum due to a number of factors; 1) Based on the high prey variety (21) found in scat samples; 2) Based on self-observation of high abundance of species in the study site; 3) Based on feedback on species seen by local residence; 4) Pervious study done on abundance of mammals in the area (Rowe-Rowe, 1983; 1994) and rodents (Bowland and Perrin 1993); and 5) Camera trapping done in the study area (Ramesh and Downs 2013).

In the current study, a seasonal comparison indicated that most prey categories were consumed throughout the year with minimal seasonal variation. It is suggested that diet will be more diverse during the lean season and prey diversity will expand in response to decreased availability of preferred food types (Begg et al. 2003). As is evident from results, the most often consumed prey type in our study area remained relatively consistent and there was no significant change in diet diversity between seasons. Therefore we could infer that due to high yearly prey abundance and diversity of species in the region, one sees relatively consistent prey consumption rates. There was however a slight seasonal dietary change observed during winter whereby the consumption of wild ungulates increased and that of insects decreased. In a study done in Giants Castle Game Reserve, Rowe-Rowe (1983) observed a similar trend of high consumption of ungulates and suggested that it was as a result of animals succumbing to the harshness of the weather.

Black-backed jackal's ability to survive in a variety of habitats is not surprising considering the variability of prey consumed through studies done on the species throughout its distribution. The spectrum of prey consumed, independent of resources available, is testament to the foraging capabilities and the opportunistic nature of the species, showing their ability to adapt and adopt foraging strategies dependent on food availability and changing land use. When looking at comparisons between game reserves and farming areas in a similar region, there were comparable consumption trends for species present in both landscapes. However there was a variation in diet of species not present in both landscapes such as domestic animals, regularly consumed on farmlands but not in game reserves. Although the study confirms that domestic stock can fall prey to black-backed jackal regardless of their size, a number of pest species that farmers consider harmful to their crops were also consumed by the species. Therefore managing black-backed jackal is a complex issue as the species exerts considerable ecological influence in ecosystems however also result in livestock losses towards farmers. Therefore it is felt appropriate black-backed jackal control measures should be applied with caution and should be selective towards only problem individuals.

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Figure 1: Map showing the location of the study area and the habitat mosaic in the Nottingham Road/Mooi River farming district, KwaZulu-Natal Midlands, South Africa where black-backed jackal (*Canis mesomelas*) scats were collected.

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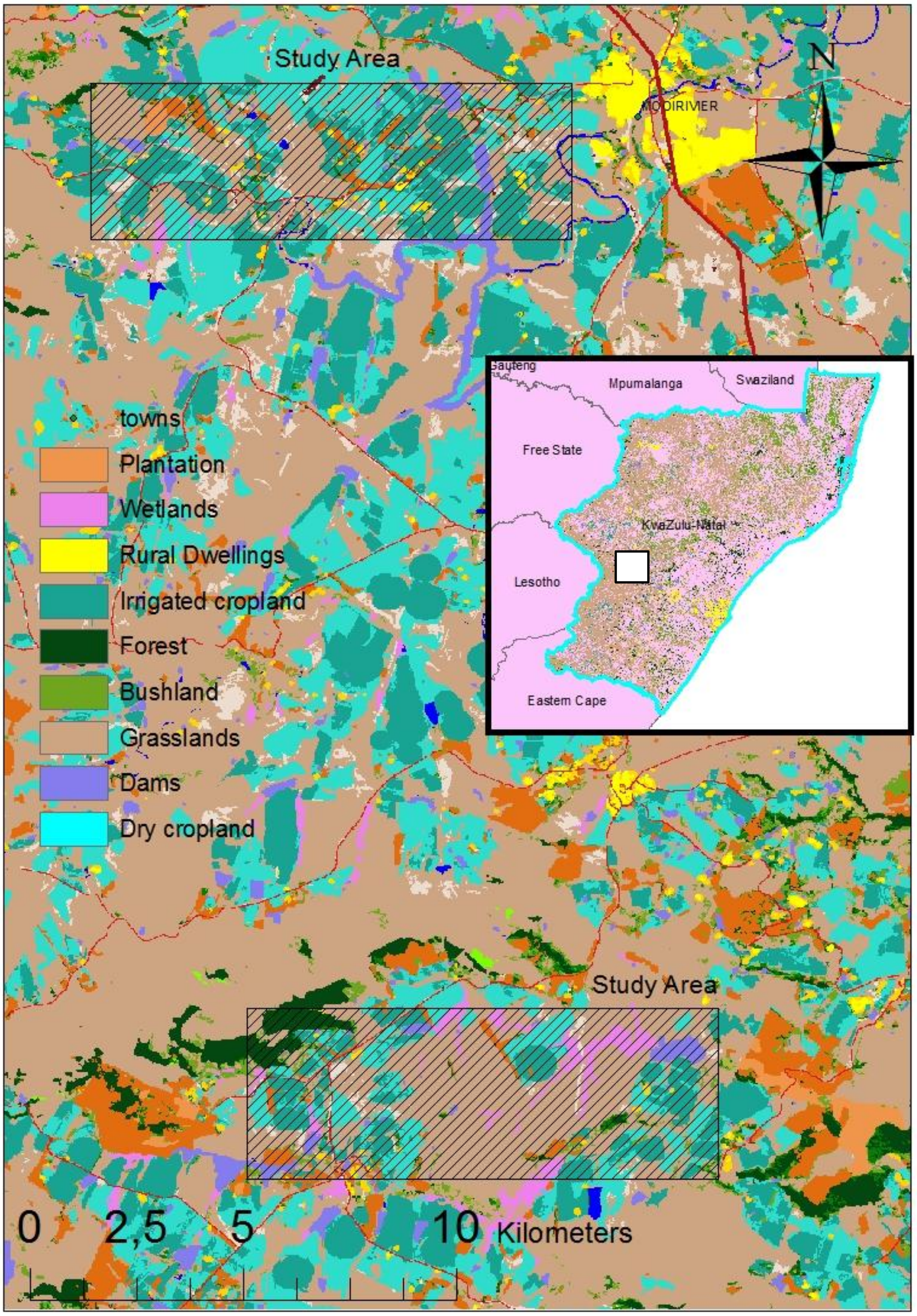
Figure 3: Percentage occurrence of prey remains found in scats of black-backed jackal in summer and winter in the Nottingham Road/Mooi River district, KwaZulu-Natal, South Africa.



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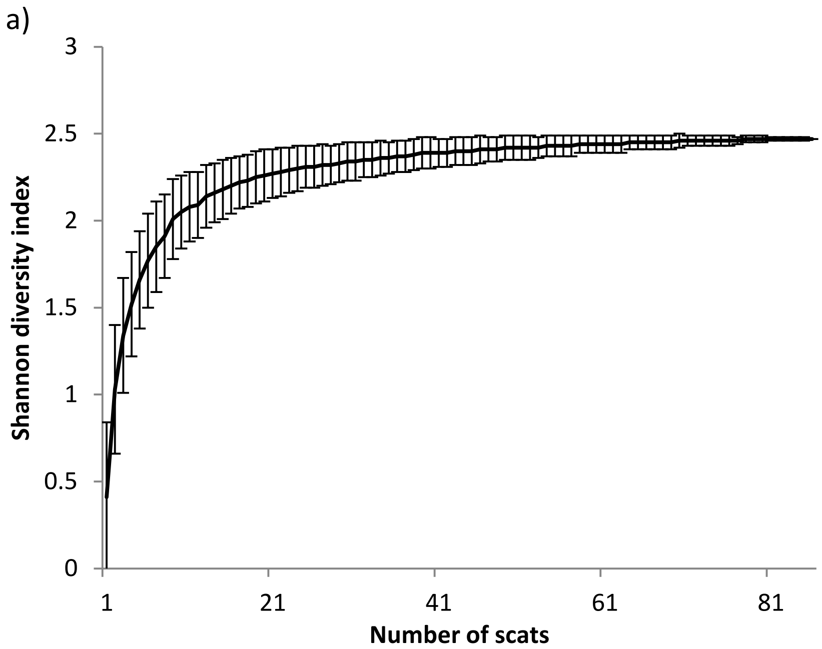

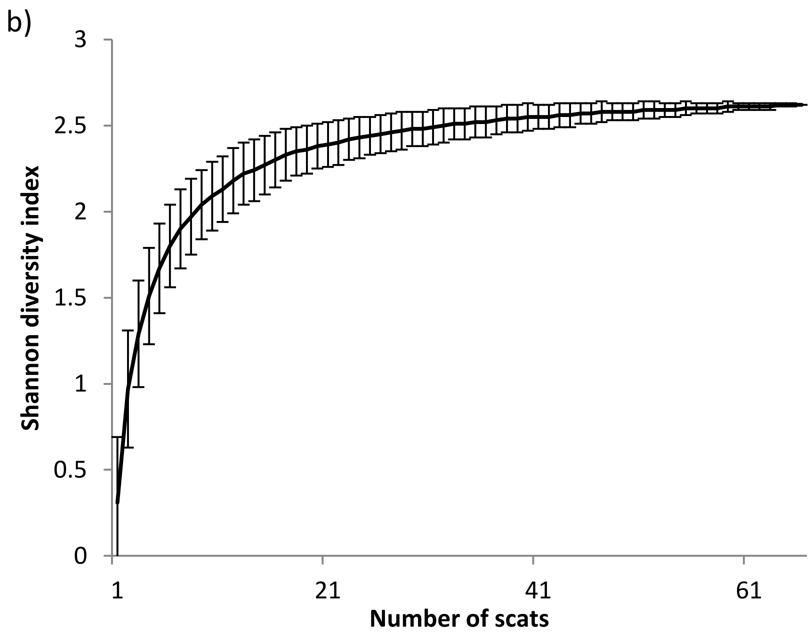

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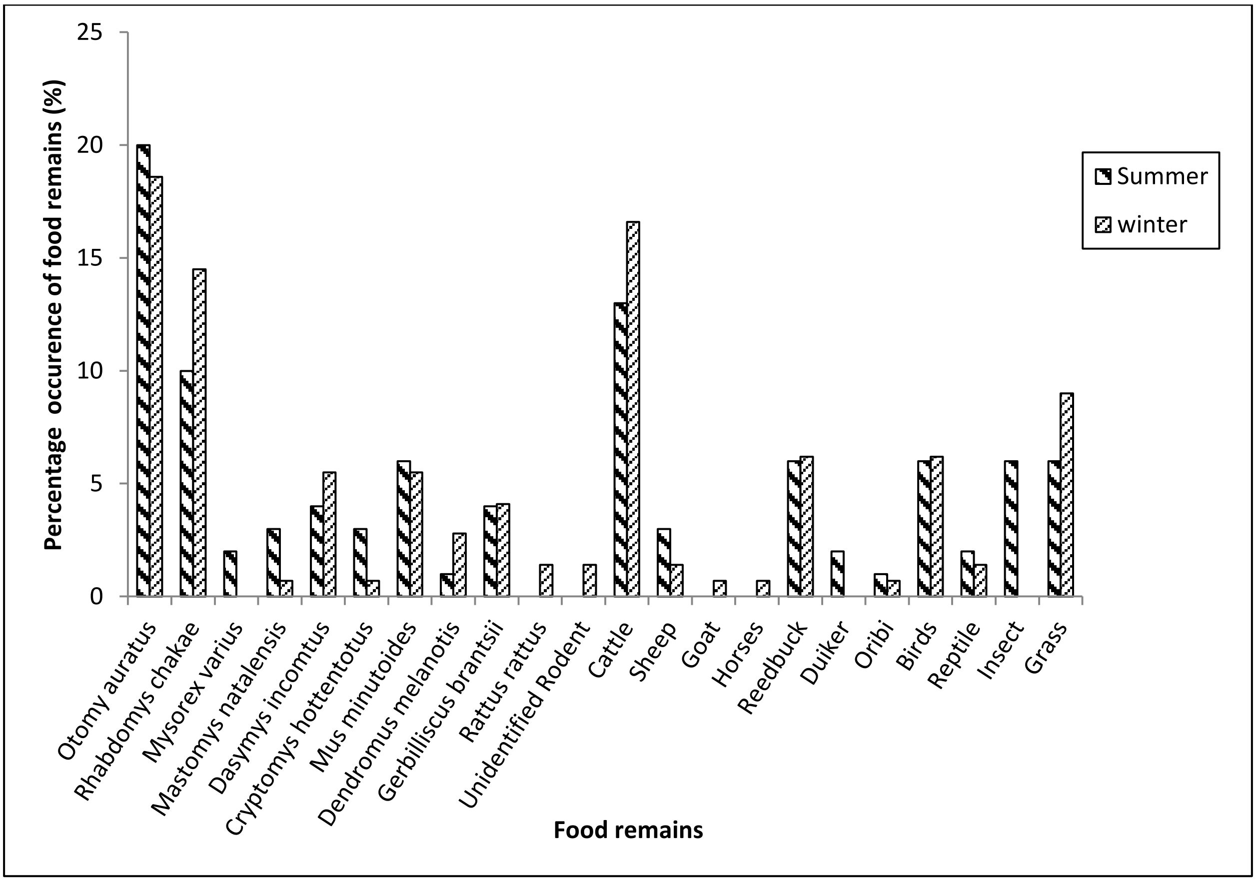

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Table 1: Overall prey species consumed during summer and winter by black-backed jackal (*Canis mesomelas*) based on scat analyses in the Nottingham Road/Mooi River district, KwaZulu-Natal, South Africa.

	Summer (n=67)			Winter (n=87)		
Species	Occurrence of remains	Relative percentage of occurrence	Percentage of occurrence	Occurrence of remains	Relative percentage of occurrence	Percentage of occurrence
Rodentia						
Otomys auratus	20	29.9	21.7	27	31	20.9
Rhabdomys chakae	10	14.9	10.9	21	24.1	16.3
Mastomy natalensis	3	4.5	3.3	1	1.2	0.7
Dasymys incomtus	4	6	4.3	8	9.2	6.2
Myosorex varius	2	3	2.3	0	0	0
Cryptomys hottentotus	3	4.5	3.3	1	1.2	0.7
Mus minutoides	6	9	6.5	8	9.2	6.2
Dendromus melanotis	1	1.5	1.1	4	4.6	3.1
Gerbilliscus brantsii	4	6	4.3	6	6.9	4.7
Rattus rattus	0	0	0	2	2.3	1.6
Unidentified Rodent	0	0	0	2	2.3	1.6
Wild Ungulates						
Redunca arundinum	6	9	6.5	9	10.3	6.9
Sylvicapra grimmia	2	3	2.2	0	0	0
Ourebia ourebi	1	1.5	1.1	1	1.2	0.7
Domestic Ungulates						
Cattle	13	19.4	14.1	24	27.6	18.6
Sheep	3	4.5	3.3	2	2.3	1.6
Goats	0	0	0	1	1.2	0.7
Horses	0	0	0	1	1.2	0.7
Birds	6	9	6.5	9	10.3	6.9
Reptiles	2	3	2.2	2	2.3	1.6
Insects	6	9	6.5	0	0	0

Table 2: Summary of diet studies done on black-backed jackal throughout Africa.

Study area (Country/Province)	Protected Area or Farmland	Land use/ Vegetation Type	Technique Used	Author	Dominant Food category
Western Natal (Highland Region)	Reserve	Hilly and Mountainous <1600m	Stomach content	Rowe-Rowe, 1976	Antelope/Carrion
Western Natal (Highland Region)	Farmland	Mooi River/ Lions River	Stomach content	Rowe-Rowe, 1976	Sheep
Natal Drakensberg	Giants castle Game Reserve	Hilly and Mountainous	Scat analysis	Rowe-Rowe, 1983	Rodents
Transvaal/ South Africa	Farmlands	Varied throughout Transvaal	Stomach content	Bothma, 1971	Antelope
Free State	Farmlands	Eastern Mixed Nama Karoo	Scat analysis	Kamler et al., 2012	Sheep/Antelope
South West Africa, Gobabeb)	Central Namib Desert (Farmland)	Desert	Scat analysis	Stuart, 1976	Insects
South West Africa, Sandwich Harbour)	Protected area	Beach environment	Scat analysis	Stuart, 1976	Birds
Free State/ South Africa	Farmland	Varied but mostly Desert biome	Stomach content	Kok & Nel, 2004	Antelope
North west Zimbabwe	Hawange National Park	natural grass and woodland	Scat analysis	Loveridge & Macdonald, 2003	Insects
Kalahari Gemsbok Park	Kalahari Gemsbok Park	Varied	Scat analysis	Bothma, 1965	Insects
Transvaal/ South Africa	Both	Varied	Stomach content	Grafton, 1965	Antelope/Insects
Eastern Cape/South Africa	Great Fish River Reserve	Savanna and Albany Thicket Biome	Scat analysis	Brassine, 2011	Insects
Eastern Cape/South Africa	Kwandwe Private Game Reserve	Savanna and Albany Thicket Biome	Scat analysis	Brassine, 2011	Insects/Antelope
Eastern Cape/South	Great Fish River	Savanna and	Scat analysis	Forbes, 2011	Insects/Antelope

Africa	Reserve	Albany Thicket Biome			
Eastern Cape/South Africa	Shamwari Private Game Reserve	Savanna and Albany Thicket Biome	Scat analysis	Forbes, 2011	Insects/Rodents
Eastern Cape/South Africa	Farmlands (Connaugh Farm)	Savanna and Albany Thicket Biome	Scat analysis	Forbes, 2011	Antelope/Insects
Eastern Cape/South Africa	Farmlands (Sweetkloof Farm)	Savanna and Albany Thicket Biome	Scat analysis	Forbes, 2011	Sheep/Antelope
North west, South Africa	Farmlands and Nature Reserves	Varied	Scat analysis	van der Merwe et al., 2009	Rodents/Antelope
Botswana	Mokolodi Nature reserve	Sandveld and Hardveld vegatation	Scat analysis	Kaunda & Skinner, 2003	Rodents/Antelope
Kimberly	Game Ranches	Savanne/ Nama Karoo and Sandy highveld grassland	Scat analysis	Klare et al., 2010	Antelope
South West Africa	Namib desert	Varied but mostly Desert biome	Scat analysis	Goldenberg et al., 2010	Insects
Cape Province	Farmlands	Varied	Stomach content	Stuart, 1981	Rodents
East Africa	Reserve	National Park	Scat analysis	Lamprecht, 1978	Antelope
Eastern Cape/South Africa	Reserve	Semi-Arid Karoo	Scat analysis	Van de Ven et al., 2013	Antelope
Eastern Cape/South Africa	Great Fish River Reserve	Savanna and Albany Thicket Biome	Scat analysis	Do Linh San et al., 2009	Antelope

CHAPTER 3

Landowners' perspectives of black-backed jackals (*Canis mesomelas*) on farmlands in KwaZulu-Natal, South Africa

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Abstract

Land use change and the intensification of farming systems increase pressure on biodiversity. Despite human interference, black-backed jackals (*Canis mesomelas*) are considered an abundant mesopredator in agricultural land across South Africa, resulting in increased human-wildlife conflict and an ongoing concern for farmers and wildlife managers. We conducted questionnaire surveys and semi-formal interviews with farmers throughout KwaZulu-Natal, examining farmers' livestock husbandry, land-use changes, and perspectives towards jackals as a perceived threat to livestock. Many (75%) respondents acknowledged expanding agricultural activities on their farmlands since the onset of their farming careers. However these changes placed perceived little pressure on mesopredators as farmers reported frequent daily (25%) and weekly (31%) sightings of jackal, and regular predation on livestock (72%). Some landowners (31%) reported between one and five livestock losses annually. Some farmers used mitigation strategies in an attempt to prevent livestock losses, however, 32% of farmers admitted to having poor disposal techniques for dead animals. Farmers suggested the increasing intensity in agricultural practices provided a greater food source for jackals allowing them to thrive in new agricultural conditions. Feedback from farmers emphasized the importance of having collaboration between farmers to control jackal predation and reduce human-wildlife conflict.

Key words: *Canis mesomelas*, survey, conflict, carnivore, land-use change

Introduction

Over the past century economic and technological incentives have resulted in a rapid growth and intensification of the agricultural sector, increasing uniformity of landscapes, and placing greater pressure on global biodiversity (Houghton, 1994; Benton,Vickery & Wilson, 2003; Foley *et al*., 2005; Lomolino, Riddle & Brown, 2006). The sustainability and management of these altered systems depends on achieving and maintaining a balance between human uses and biodiversity (Messmer, 2000). As more land is converted to agriculture the functionality of ecosystems is threatened and as a result, human-wildlife conflict intensifies. Human-occupied areas are progressively overlapping with home ranges of wild animal species which significantly increases human-wildlife conflict (Muruthi, 2005; Gusset *et al*., 2008; Browne-Nuṅezi & Jonker, 2008; Thorn *et al*., 2012). As a consequence, many carnivore species have undergone distribution shifts and population decline resulting in ecosystem disruptions such as mesopredator release and increases in herbivore prey (Thorn *et al.*, 2013; Bagniewska & Kamler, 2013; Ripple *et al.*, 2014). Mesopredators are often efficient hunters and are buffered against population collapse by their capacity to have a highly variable prey spectrum. As a result mesopredators often achieve densities in areas of human occupation that are relatively high (Bagniewska & Kamler, 2013; Güthlin, Storch & Küchenhoff, 2013; Ripple *et al.*, 2014).

In both developed and developing countries there has been a recent call for conservation outside protected areas, with a realization that current protected areas (5% of worldwide land cover) will not suffice for conserving biodiversity as it is not only too small but does not represent all habitat types (Cousins, Sadler & Evans, 2008; Pasquini *et al.*, 2009; Trimble & van Aarde, 2014). Pasquini *et al*. (2009) suggest that conservation and sustainable development of natural resources are generally linked to the implementation of conservation activities on private lands. Conservationists argue that the co-existence of human and wildlife species is possible if measures are taken to reduce conflict (Muruthi, 2005; Thorn *et al.*, 2012). To have sustainable conflict management strategies, Thorn *et al.* (2012) suggest that the support of local people is imperative for success and it is important to balance human interests with biodiversity conservation objectives. As a result, a number of measures have been adopted to reduce conflict in non-protected areas, such as conservancies, stewardship programs, and a number of community based management initiatives (Lowenhaupt Tsing, Brosius & Zerner, 1999; Fabricius *et al.*, 2004).

In South Africa, black-backed jackals (*Canis mesomelas*) are considered a common and abundant mesopredator outside protected areas, especially in some farmlands (Sillero-Zubiri, Hoffmann & Macdonald, 2004). The species has long been considered vermin and a source of ongoing conflict with farmers, and as a result, have received no legal protection (Thorn *et al.*, 2013). Predation on livestock can generate negative attitudes towards carnivores and increase persecution (Muruthi, 2005). The extent to which commercial farmers tolerate damages associated with black-backed jackal is often influenced by various socio-economic factors, such as relative wealth, magnitude of wildlife associated costs, levels of education, personal values towards problem animals, and the extent to which people derive monetary benefits from relative losses (Zimmermann, Walpole & Leader-Williams, 2005).

As sustainable conflict mitigation strategies should balance human interests with biodiversity conservation objectives (Thorn *et al*., 2012), understanding which factors influence attitudes towards problem animals can ensure conflict management. As farmers are major landholders and influence depredation-related management decisions, understanding their attitudes may be critical to managing human-wildlife problems on agricultural lands (McIvor & Conover, 1994). Knowledge of black-backed jackal from a landowner's perspective is essential as landowners can provide useful insight regarding the species' movements, predation and control measures. To understand these socio-ecological factors between black-backed jackal and farmers, we conducted a study using interviews and surveys with farmers in KwaZulu-Natal (KZN), South Africa. We expected that conflict between humans and black-backed jackal would be high considering their reputation of livestock predation.

Methods

We conducted a pilot study in June-July 2012 in the Karkloof farming region of KZN, using interviews to determine farmers' perspectives towards black-backed jackals. A semi-structure interview was used as it is a qualitative method, allowing for a broad range of data collection as each interview unfolds in many different directions. It provides a means of collecting 'rich data' as it allows the researcher to gain large amounts of data quickly (Cousins *et al.*, 2008). A structured interview or a survey, although highly useful, only allows specific information to be collected on specific topics. Whereas a semi-structured interview ensures topics are covered whilst one has flexibility to questioning and gather opinions (Cousins *et al.,* 2008).

Questions pertaining to predation of livestock by black-backed jackal, farm husbandry and landowner perspectives of the species were asked. The pilot study tested the efficiency of the questions asked and how successful a semi-structured interview would be in collecting required information. The semi-structured interviews were conducted face-to-face for approximately 45 min. Farmers were interviewed individually or with a farm manager, thus not as a collective farming community. Each interview was recorded with the consent of the landowner, allowing for efficient data collection as it ensured all information was captured during the interview.

The pilot study revealed that interviews, although useful, were time consuming and difficult to organize with farmers who were generally busy. It was decided that a questionnaire survey would improve data collection as it was easier to distribute questionnaires to farmers and questionnaires could be forwarded to others. The pilot study did however reveal that interviews allowed farmers to express their views about black-backed jackal regardless of questions asked. Therefore in the questionnaire survey we included an open-ended section at the end for farmers to share detailed comments and/or personal views. An e-mailed survey was utilized as it provides numerous benefits over interviews and other qualitative methods of data collection such as cost efficiency, speed of data collection, ability to have a larger data set in a shorter time frame, and reduced interviewer bias (Sheehan, 2006). It is however acknowledged that emailed surveys have limitations as only farmers with sufficient computer literacy, or internet access would respond.

Following the pilot study we developed an electronic questionnaire survey consisting of 28 questions divided into three sections namely: Section A: Landowner's farming history (area farmed, years farmed, farm size, etc.); Section B: Landowner perceptions of black-backed jackal on farmlands (How often jackal are seen, location of jackal sightings, population change, need for control, etc.);and Section C: Livestock husbandry practice (livestock losses, livestock protection methods and management, livestock disposal strategies, etc.). This was followed by the comments section.

The questionnaire survey was designed as a self-completion survey (Appendix 1). To determine landowner attitudes and opinions towards black-backed jackal, we e-mailed an electronic survey to private commercial farmers throughout KZN. Attached was a letter explaining the study and a request to forward the survey to others. It is suggested that follow-up emails sent to farmers can increase response rates by up to 25% (Sheehan, 2006) and a number of reminders yield greater response rates than once-off reminders (Heberlein & Baumgartner, 1978). Therefore, after two months a reminder was sent to encourage farmers to participate before one final reminder was sent out to return surveys.

We grouped answers according to questions asked in regard to black-backed jackal, livestock management, and control measures. Due to similarities in questions in both surveys and interviews, we were able to combine the two data sets, of which 50 surveys were collected and 9 interviews were performed. Chi^2 was used to test the significance of predation level of black-backed jackal and other carnivore species on agricultural lands. Questions that were discussed in interviews but not asked in surveys were removed from further analysis. Once answers were group, they were analyzed and discussed. A separate analyses was determined for interviews and questionnaires however responses reflected similar results, therefore we pooled both methodologies together. Due to the nature of the topic being focused around the impact and influence of black-backed jackal on livestock, only farmers with more than ten animals and had an area of greater than 20 ha of land was considered for analysis. Comment and opinions from those not falling into this category were still utilized however was not considered for analysis.

Results

A sample of fifty-nine commercial farmers completed surveys or interviews across KZN. Of respondents, the average years spent farming was 29 (15± SD) years, with a minimum of 4 years and a maximum of 65 years. Most (75%) of the respondents reported an expansion in agricultural activities on their farmlands since the onset of their farming careers. This included an expansion of crop lands, pastures and an increase in livestock numbers. Of those respondents, 20% confirmed an expansion by up to 20% of their farms since the onset of their farming careers. A further 8.5% of those landowners suggesting a 30, 40 and 80% increase in agriculture activities on their farmlands respectively (Fig. 1). The majority of respondents were beef (34%) and dairy cattle (31%) farmers, followed by crops (10%), sheep (8%) and sugar cane (8%), with timber and game farming making up the remainder.

Weekly sightings of black-backed jackal were reported by 31% of farmers, while 25% suggested daily sightings. There was minimal seasonal change in sightings as 86% of farmers reported seeing jackal throughout the year, although 14% of respondents suggested an increase in winter sightings. More than half the respondents (70%) perceived a rise in jackal populations in more recent times. Most (85%) farmers reported this rise in jackal numbers in the past ten years. When farmers were asked why they felt jackal populations had increased, 84% emphasized population increase was a result of food abundance, coupled with an ideal environment where their natural predators were non-existent. Farmers thought that as food became easier to obtain, territories became smaller and therefore more jackals became residents within the region.

The three most commonly used methods of disposal of dead livestock by farmers were burying of carcasses (41%), leaving them for vultures (vulture restaurant) (27%), or just doing nothing (32%). The majority of the farmers (90%) acknowledged that disposal habits and nature of farming activities could increase jackal numbers.

Livestock

Many (64%) farmers reported a loss of livestock to wild animals. It was suggested that black-backed jackal were responsible for the most deaths of livestock (72%) followed by caracal (*Caracal caracal*) (14%), domestic dogs (*Canis familiaris*) (6%) and baboons (*Papio ursinus*) 4%. Some farmers (31%) reported between one and five livestock losses p.a. and over 20% reported ten or more losses p.a. with one farmer having as many as 122 sheep lost in one year. When asked what mechanisms were used to protect livestock against predation, farmers reported lethal methods such as shooting, poisoning, and trapping, and bio-control methods such as donkeys, jackal proof fencing, and protection dogs. The protection methods most used by farmers were lethal methods (27%) and bio-control (22%). Shooting was the most frequently used method (17%), followed by donkeys (11%). There was however a large portion of farmers who did not use any control mechanisms (36%).

Farmers were asked if they felt there was a change in ungulate populations within their area. A mixed response was received with 32% suggesting no change in population number, 27% suggesting an increase in antelope numbers and 41% suggesting a decrease in numbers. When asked if jackal numbers should be controlled, 59% suggested the species should be controlled, and 41% suggested they should be self-controlled.

A number of farmers shared comments and views of black-backed jackal and what experiences they have had (Table 3). Some (12%) percent of respondents suggested the use of dog hunting packs to control jackal populations while 8% suggested that in years past provincial conservation agencies had hunting dogs to control jackal populations. There were however some individuals (12%) who suggested that killing jackals is unnecessary and does not reduce jackal numbers over the medium to long term.

Discussion

Black-backed jackals are active mesopredators in agricultural areas, rising in numbers, and becoming a source of human-wildlife conflict (Rowe-Rowe, 1976; Klare *et al*., 2010; Kamler, Klare & Macdonald, 2012). It is suggested that the growth in human population and expansion of human activities has increased conflict with wild animals (Mclvor & Conover, 1994; Graham, Beckerman & Thirgood, 2005). In this study, the majority of farmers reported regular sightings of jackal throughout the year, with 85% suggesting a marked increase over the last ten years, coinciding with land use changes in agriculture as noted in other studies (Sotherton, 1998). This suggests that land use change and possibly human expansion could play a role in population increase of black-backed jackal. Interestingly, farmers did acknowledge that their farming activities could be the cause of jackal population growth. More than 30% of respondents admitted doing little to prevent carnivores from accessing poorly disposed livestock carcasses. Similarly 27% of respondents mentioned vulture restaurants as a technique of livestock disposal.

These restaurants are generally easily accessible to carnivores, providing an opportunistic food source to support population growth (Yarnell *et al.*, 2014). Similarly livestock scavenging opportunities provided by farmers may condition predators to prey on livestock. A study on coyotes (*Canis latrans*) in southern California (Fedriani, Fuller & Sauvajot, 2001) showed that food provided by humans resulted in higher coyote densities. It was found that in the most human-impacted area, coyote densities were eight times higher than that of the more natural area as a result of ease of access to food (Fedriani *et al*., 2001).

Interviews and surveys have the ability to provide important contextual data on people's attitudes and beliefs of a species. It is, however, acknowledged that such data can be biased for a number of reasons, such as: i) If stock abundance is poorly monitored then declared predation rates might be wrong; ii) Livestock losses might be deliberately inflated as a result of hatred towards a species or alterior motives (Rasmussen, 1999); iii) An incorrect assumption that predation is the cause of death; and iv) Respondents might fear prosecution and thus provide skewed data for question such as lethal control. Nevertheless, data collected from affected communities provides important information from a landowner's perspective of problem animals that may not be available from other sources (Thorn *et al*., 2013). Such information is essential to help conservation managers predict the response and support of local people towards wildlife policies and designing effective human-wildlife conflict solutions (Browne-Nuṅez & Jonker, 2008; Thorn *et al*., 2013). Furthermore, data collected from respondents with an average of 29 years of farming experience as in the current study can provide valuable information.

Over 60% of farmers reported yearly predation losses of livestock, with black-backed jackal assumed as the main culprit. A study on sheep losses in KZN reported similar results, whereby 68% of farmers reported sheep losses by black-backed jackals (Lawson, 1989).

However, Roberts (1986) suggested that although black-backed jackal are often considered responsible for farm stock losses that was often not the case. From 395 post-mortem examinations on sheep over two years, domestic dogs were the biggest culprits (83%) with black-backed jackal only responsible for 13% of the deaths (Roberts, 1986)**.** Predators may regularly kill domestic breeds due to a loss of anti-predatory behaviour shown by domestic animals, coupled with high densities of domestic animals available (Linnell *et al*., 1999; Graham *et al*., 2005). High stocking rates can transform landscapes, reducing natural prey available to black-backed jackal (Blaum, Tietjen & Rossmanith, 2009), which can in turn increase the likelihood of attacks on livestock (Graham *et al*., 2005). However, studies have shown that livestock losses are unrelated to predator densities but rather a function of prey available to predators (Conner *et al*., 1998; Knowlton, 1999; Landa *et al*., 1999; Mizutani, 1999). Therefore although farmers reported an increase in abundance of black-backed jackal on farmlands, this might not be related to increases in livestock losses but rather as a result of human activities changing prey availability. This being highlighted by diet study, whereby the presence of rodents consumed were higher than domestic stock across seasons and, in an area of high prey availability, a high diversity of species were consumed showing the opportunistic nature of the species (Humphries, Ramesh & Downs, in prep). It is however stressed that domestic consumption by predators is not a replacement of food but rather an addition to their normal diet (Kok & Nel, 2004).

Although it is evident that black-backed jackals do cause livestock losses on farmland (Bothma, 1971; Rowe-Rowe, 1976; Kok & Nel, 2004; Kamler *et al*., 2012), there has been very little success in controlling this problem species (Sillero-Zubiri *et al*., 2004). Lethal control measures are a widely used technique to reduce predators (Holmern, Nyahongo & Roskaft, 2007). A widespread belief that lethal control of black-backed jackal is necessary to prevent overpopulation and predation has resulted in intense long term persecution yet jackal are still common and abundant (Thorn *et al*., 2013). In the current study, one landowner recalled shooting 51 black-backed jackals in 2011, losing 122 sheep and 49 lambs. In 2012 he shot 39 jackals and lost 70 sheep and 69 lambs, and in 2013 he shot 54 jackals and lost 68 sheep and 33 lambs. This suggests that: i) local black-backed jackal populations are high due to a vast numbers of individuals being shot every year; ii) black-backed jackals are quick to occupy territory where individuals have been removed and; iii) shooting jackal does little towards solving the problems of jackal predation as new populations move into the area once jackals have been exterminated. It is however stressed that more research needs to be undertaken to find out the exact effects, if any, shooting is having on jackal populations and the movement patterns of jackal their after. Alternatively a food source can lead to a greater concentration of jackal, giving the impression of increased abundance. Graham *et al*. (2005) emphasises that lethal control often results in the removal of predators for a short-term as the same species rapidly re-establish themselves. Kowalczyk *et al*. (2009) emphasizes that compensatory reproduction is known for some species of canids such as red foxes (*Vulpes vulpes*), coyotes (*C. latrans*) and wolves (*C. lupus*). Lethal management of jackal can have a negative implication towards livestock predation as new naïve species can move into the vacant territory and possibly be more troublesome than the previous exterminated residents. However, it can however be argued that shooting a problem jackal can have a positive influence as new jackals that move into the resulting vacant territory could be less prone to predate on livestock and thus reduce conflict. This is however speculation and more research in needed in this regard.

From surveys in the current study, a landowner recalled regularly hearing and seeing black-backed jackal on their property, however, never once was a sheep or lamb taken by a jackal. It was emphasised that the neighbours did not harass them so they presumed there was a stable pair living in the area, keeping out the rogues. Black-backed jackals are known to form territories which are actively defended by both sexes (Norwak & Paradiso, 1983; Moehlman, 1987; Hayward & Hayward, 2010). Territory sizes vary depending on food availability and resources and can vary from 0.34 to 16 or more jackal every 1 km^2 (Rowe-Rowe, 1982; Loveridge & Nel, 2008). However, Ferguson *et al.* (1983) showed that on farmlands black-backed jackal can have home ranges (95%) of up to 575km^2. Woodroffe *et al*. (2005) suggests that lethal control may have indirect effects through impacts on behaviour. In surveys, two farmers reported seeing jackal pups in March, however, studies show that the usual pupping periods reported for the species are from June to September (Rowe-Rowe, 1974). This suggests that they might be breeding throughout the year on farmlands to counteract lethal predation. Persecution might cause the species to speed up breeding cycles and increase litter sizes to sustain populations. However, a higher prey availability might also result in jackal breeding throughout the year (pers. opinion).

An alternatively solution to shooting black-backed jackal could include calving camps with jackal proof fencing. Lawson (1989) reported that farmers successfully used electric fences as a predator deterrent. In this study a number of farmers suggested the possibility of using hunting dogs to reduce jackal populations. Some farmers commented that in years past, the provincial conservation agencies had hunting dogs which controlled jackal populations. In a previous study on the effectiveness of hounds controlling black-backed jackals, Bigalke and Rowe-Rowe (1969) showed that hounds are more selective towards hunting males than females and therefore did not kill in natural ratios. They suggested that, to have effective control of jackal populations, breeding females should be taken in ratios they occurred in the population. Therefore using hunting dogs as a means to control jackal populations may slow populations but disrupt breeding patterns which is not desirable (Bigalke & Rowe-Rowe, 1969).

Conclusions

Agriculture and land use change is significantly reducing land available to wildlife, making wild animals increasingly dependent on areas occupied by humans. As a result, insight into socio-ecological factors from a farmer's perspective provides valuable information which can help conserve remaining farmland biodiversity. Although predation on livestock by black-backed jackal is evident (Rowe-Rowe, 1976; Kok & Nel, 2004; Kamler *et al*., 2012), results from this study show that there are a number of factors involved in livestock predation, such as; carrying capacity, density and diversity of prey, and the stocking rates of domestic stock. Although black-backed jackal populations might be increasing this does not necessarily have a direct correlation on livestock losses. Equally, the use of hunting dogs and lethal shooting is not always a viable and successful method of control (Bigalke & Rowe-Rowe, 1969). Insight from surveys revealed preventative methods such as jackal proof fencing may be a more successful conflict-mitigation strategy. In addition, results from surveys suggest a need for knowledge conversion between farmers. Often farmers establish ways of controlling jackal problems and do not provide feedback to others. It is recommended that farmers in areas with black-backed jackal problems should create forums and discuss strategies to limit predator-farmer conflict. The best way to reduce conflict in an area might be for all farmers in a community to work together on a solution (pers. opinion). The best solution for conflict might not necessarily be a reduction of jackal but rather different farming habits such as livestock disposal or jackal proof fencing throughout the community, etc. Although black-backed jackals are regularly regarded as a source of conflict, management plans need to incorporate farmers attitudes and beliefs to develop sustainable mitigation strategies.

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Table 1 Interviews with landowners showing black-backed jackal population change over time, and the perceived impact on wild ungulates.

Questions with answers	%
Have you noticed a change in jackal populations?	
Yes	70
No	30
Over what time period?(Years)	
No change	30
1-10	59
10-20	11
20 +	0
Have antelope numbers changed?	
No change	32
Increase	27
Decrease	41

Table 2 Interviews with landowners showing the perceived predation threat in agricultural lands and various mechanisms used to reduce livestock losses.

Questions with answers	%
Have you ever lost livestock to predators?	
Jackal	72
Dogs	6
Serval	2
Caracal	14
Baboons	4
Other	2
How regularly?	
Daily	3
Every second day	13
Weekly	11
Every second week	13
Monthly	3
Every six months	18
Yearly	40
How many?	
0	36
1-5	31
5-10	14
10 +	20
Mechanisms of control:	
None	43
Shoot	20
Hunting dogs	2
Poison	6
Traps	4
Donkeys	13
Fencing	11
Alpacas	2

Table 3 Landowners comments and personal views of black-backed jackal.

Comment	Response
1 landowner	I never used to have problems with jackal predation until one year the neighbour shot a few, since then I have had continuous problems! I am not sure if livestock losses are related to shooting or if there is just more jackal around, either way my problems coincidently started when those jackal were shot.
1 landowner	While we farmed sheep we regularly heard jackal and saw them on the property but never once was one sheep or lamb taken by a jackal. Our neighbour's did not harass them so I presume we had a stable pair living here keeping out the rogues.
2 landowners	While driving around my farm I saw a mother with pups and that was in March
1 landowner	Two or three years ago we could lose an animal a month, but since we have fenced a specific hospital/calving camp with jackal proof fencing these loses have almost stopped even though we hear jackals almost every night and see spoor all over the farm
7 landowners	We need to use a pack of hunting dogs to reduce jackal populations
3 landowners	In the past Natal Parks Board had a dogs pack which controlled jackal populations
5 landowners	Jackal should be controlled as they have a large cost implication to farmers
1 landowner	Caracal seem to be on the increase and leopard, not having been seen for nearly a century, have been sighted on a few occasions during the past couple of years
1 landowner	I do not have a problem with the Jackals. I have seen them very near the cattle when a calf had been born, they seemed to be after the afterbirth, the cows were completely calm so I assumed that they felt no threat, I have never had a calf harmed and my cattle usually leave the herd to give birth on their own and stay apart from the herd for a few days so there little protection for the calf except for the mum.
1 landowner	I believe jackal numbers have increased as more farmers have given up sheep farming. Pressure on the jackal by sheep farmers (trapping, dog packs, baits, etc) has diminished. At the same time, reedbuck and oribi numbers have declined partly due to dog hunting, but also because they have now become a source of food to replace lambs. In addition, my feeling is that game bird number have been affected by the explosion in jackal numbers
7 landowners	Jackal numbers should not be controlled. Farmers should take preventative measures

	if they have direct evidence that jackals are causing a significant loss of livestock on their farms. Killing jackals is unnecessary and does nothing to reduce their numbers over the medium to long term. The unintended consequences of an increase in other predators is not normally appreciated
1 landowner	Certain Game reserves – for example Itala, have very low jackal populations and would welcome additional numbers from capture. Is this not a possibility?
1 landowner	My biggest concern is for small mammals and ground nesting birds. I believe the over-population of Black-Backed Jackal is having a significant impact on these populations. While the decline in species such as Guinea Fowl and Hares is easily noticeable one worries what the impact on lesser known/seen species is like

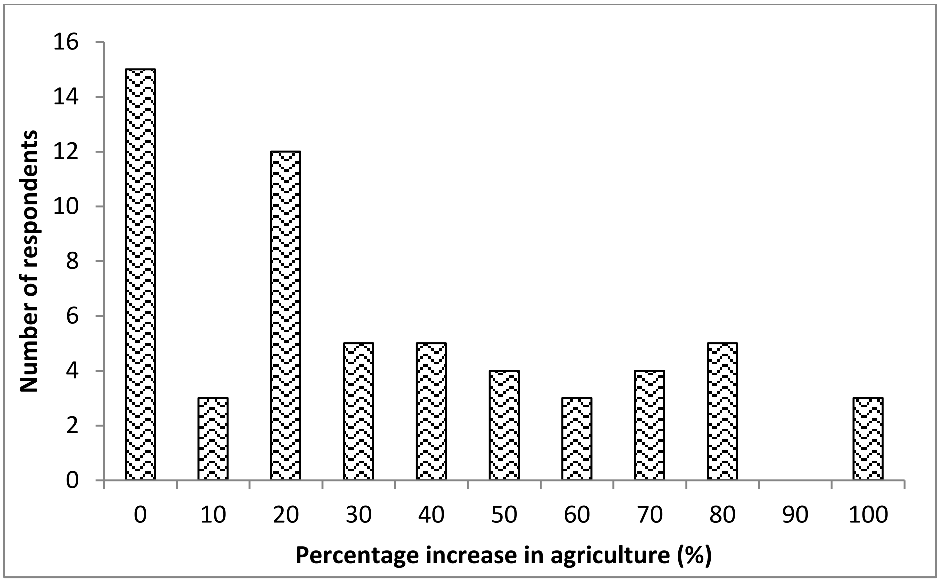

Fig 1 Agricultural expansion undertaken by landowners on their farmlands since the onset of their farming careers. This includes the expansion of crop lands, pastures and an increase in livestock numbers.

Appendix 1: Questionnaire sent to commercial farmers throughout KwaZulu-Natal.

Survey of the Status and Management of Black-backed Jackals in KwaZulu-Natal, South Africa

Participant Information

1. Name (optional) ____
2. Address ____
3. Telephone ____
4. E-Mail____
5. Farm size (Hectares) ____

6. How long have you been involved in farming?______________________________

7. Since owning the farm, have you expanded in agriculture?

   Yes No

   If yes, roughly how much?

10 %	20 %	30 %	40 %	50 %	60 %	70 %	80 %	90 %	100%

8. What is your dominant land use? (Crops/Timber/Dairy/Beef/Sheep/Grass-land/ other (please specify) in %)

____

Thank you for that information, the following questions deal with livestock.

Livestock Questions

9. How many animals do you have on your farm? State the number of each.

Year	Cattle	Sheep	Goats	Other
2013				

10. How do you dispose of dead animals on your farm?

    ____

11. As a farmer, do you think your disposal strategies for dead animals are partly contributing to increased population of predators?

____

____

12. Do you think you as a farmer help to increase numbers of predators?

____

____

____

13. With your knowledge about the area, what wild mammal species is commonly seen?

____

14. Do you feel those numbers have changed?

Yes No

If yes, increased or decreased? And what do you think has been the main contributing factors to this change? (E.g. Smaller rangelands, predators, poachers, etc)

____

____

____

15. Have you ever lost livestock to predators?

Yes No

If yes, what type of predator was it?____

16. How frequently do you lose livestock to predators?

Daily	Every Two days	Weekly	Every second week	Monthly	Every Six Months	Yearly

17. How much livestock have you lost to predators over the past 3 years?

Year	Cows	Calves	Sheep	Lambs	Goats	Kids

2011						
2012						
2013						

18. What mechanism do you use to protect your livestock against predation (E.g. Shoot, poison, donkeys, Anatolian Shepherd dogs, etc)

____

____

Thank you for that information, the following questions deal with Black-backed Jackal.

Jackal Questions

19. How often do you see Black-backed Jackals in the area and more specifically on your farm?

	Daily	Every Two days	Weekly	Every second week	Monthly	Every Six Months	Yearly
Area							
Farm							

20. Are these sightings continual throughout the year? Or do they increase over certain periods? If so when?

____

21. How much livestock have you lost to Black-backed Jackal over the past 3 years?

Year	Cows	Calves	Sheep	Lambs	Goats	Kids
2011						
2012						
2013						

22. Where are jackals most commonly seen on your farm? (e.g.; around your calving camps, near district roads, timber plantation, etc)

____

____

23. Have you noticed any change in jackal populations?

    Yes No

    If yes, increase or decrease? And over what time period have you seen these changes?__________
    ____

24. In your opinion what do you think the reason is for this change?
    ____
    ____
    ____

25. Should jackals be controlled and why?
    ____
    ____
    ____

26. Approximately how many Black-backed Jackals have you destroyed on your farm in the last year? If any!
    ____
    ____

27. What other predators have you seen in the area and when was the last sighting?
    ____
    ____
    ____

Any further comments:

CHAPTER 4

Habitat use and home range of black-backed jackals (Canis mesomelas) on farmlands in the Midlands of KwaZulu-Natal, South Africa

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Abstract

Black-backed jackals (*Canis mesomelas*) are an abundant mesopredator in agricultural areas across South Africa. Given their ability to survive and apparent success in changing agricultural environments, knowledge of spatial movements can provide important ecological information on the species and elucidate possible reasons why this mesopredator is capable of adapting and surviving in agricultural lands. From 2013 to 2014, we captured, collared and monitored five black-backed jackals in KwaZulu-Natal to determine their home range and habitat use on farmlands. The 95% kernel density home range sizes showed relatively large home ranges for both adult males and juveniles. Seasonal analysis showed a marked seasonal variation in home range movement by the species. One adult male dispersed 150 km over two seasons (winter and spring) and thereafter settled into a home range which it sustained. Habitat selection within home ranges indicated jackals preferred forest with bushlands in winter and spring, and croplands in summer and autumn. Variable habitat used and large home ranges in this study confirmed the species' ability to adapt to agricultural areas in order to survive. Information on the spatial movement of black-backed jackals as a carnivore species in this study provided important information on the species' persistence and success in agricultural areas.

Key words: Home range, habitat use, radio-tracking, dispersal, movement

Introduction

Worldwide one of the greatest threats to mammals is human development and a changing land use (Barnes, 2000; Green *et al*., 2005; Ripple *et al.*, 2014). As inter-specific conflict becomes exacerbated, humans resort to forced removal techniques for problem species (Kruuk, 2002). This has a variety of consequences on species inhabiting farmlands as it affects their behavioural physiology, activity patterns and disrupts regions' ecological balance (Muruthi, 2005; Kamler *et al.,* 2013). Despite human interference, many mesopredators have increased in population, achieving relatively high densities within farming communities and have become a major concern for farmers and points of conflict (Bagniewska & Kamler, 2013). These predators opportunistically fill an empty niche left by the removal of larger species and thrive in their absence (Beinart, 1998). Given their apparent success in changing agricultural environments, an understanding of the relationship between habitat attributes and population dynamics of mesopredators through migrational movement is critical to understanding how these complex ecosystems function for farmers and wildlife managers (Beasley *et al*., 2011).

Home-range is one of the most fundamental ecological parameters for understanding a species (Nilsen *et al*., 2005). An animal's home range is best described as an area within which an animal moves when preforming its normal activities, such as: searching for food, mating, and caring for young (Kaunda, 2001; Nilsen *et al.,* 2005; Downs & Horner, 2008; Grant, 2012). However, this definition excludes dispersal of individuals and/or erratic wondering and is therefore not the entire area an animal covers during the course of its lifetime (Kaunda, 2001; Grant, 2012). An estimation of an animal's home-range can be derived by outlining the boundary of the home range from point locations obtained from collared animals, and computing the area that the animal occupies (Downs & Horner, 2008). This is accurately obtained through use of Global Positioning Systems (GPS) collars which allow the continuous monitoring of an animal's movement and locations, providing accurate and cost-effective information (Millspaugh *et al*., 2006). Knowing the size of a species' home range is important as it reflects on the animal's habitat selections, population densities, and their relationship with resources and other individuals (Kaunda, 2001; Nilsen *et al*., 2005; Grant, 2012; Tucker *et al*., 2014). Many factors determine the size of an animal's home range depending on the age of an individual, sex, physiological status, availability of food, competitive interactions of individuals, and human persecution (Ferguson *et al.,* 1983; Kaunda, 2001). Evaluating the spatial scale of an animal's movement is fundamental to making informed decisions in wildlife management and conservation and is especially relevant in agricultural areas where predator patterns and persistence is scarce (Nilsen *et al*., 2005; Pita *et al*., 2009).

Black-backed jackal (*Canis mesomelas*) are one of the most abundant and diverse mesopredators in southern Africa farmlands, occurring in arid, semi-arid and savannah regions (Lamprecht, 1977; Ferguson *et al*., 1983; Kaunda, 2001). A generalist ecological approach has allowed the species to adapt to environmental changes and consume a high diversity of prey (Kaunda, 2001; Kamler *et al*., 2013). As a result, the species has successfully maintained stable population sizes and expanded their ranges in agricultural areas, while other carnivores of similar size have succumbed to human pressures (Kaunda, 2001). How carnivore species interact with humans in agricultural landscapes can have important implications for other species found in these areas (Gehrt & Prange, 2007). The effects of hunting and human interference can have severe effects on the behaviour, reproduction and activity of mesopredators on agricultural landscapes (Kaunda, 2000; Kamler *et al*., 2013). Black-backed jackal, however, are known to exploit man-introduced food sources such as livestock and have long been regarded as a problem species for farmers (van der Merwe, 1953; Grafton, 1965; Beinart, 1998; van Sittert, 1998; Loveridge & Nel, 2004). Regardless, black-backed jackals are regarded as an important medium size predator in these farming regions, maintaining the diversity and dynamics of ecosystems which provide an ecological balance for wildlife where larger predators are non-existent (Blaum *et al.*, 2007; 2008).

An understanding of how carnivores respond to hunting and human interference in these areas could show important spatial and temporal changes in the utilization and social organization of mesopredator species (Kaunda, 2000; Kamler *et al*., 2013). Black-backed jackals are often heavily controlled on private lands in southern Africa and as a result have developed an acute wariness of humans (Kaunda, 2001; Kamler *et al*., 2012). There is however a lack of information on habitat use patterns of black-backed jackals under current land use transformation pressure in the farmlands of KwaZulu-Natal. Knowledge of spatial movement of black-backed jackals can provide important ecological information on movement patterns of the species, and elucidate possible reasons why this mesopredator is capable of adapting and surviving in agricultural lands. Furthermore, knowledge of seasonal and yearly variations in black-backed jackals' activity can provide valuable information to making informed decisions in wildlife management and conservation (Nilsen *et al*., 2005). The present study sought to examine spatial resource utilization of black-backed jackals in agricultural farmlands, where persecution is present, using GPS/UHF collars.

Methods

Study Area

The research was conducted on private commercial farms in the Nottingham Road/Mooi River area in the Midlands of KwaZulu-Natal. The central co-ordinates for each study site are: Fort Nottingham E 29° 57' 21.6", S 29° 25' 30.0" and Mooi River E 29° 13' 27.7", S 29° 55' 24.4". The dominant vegetation type is Mooi River highland grassland and Drakensberg foothill moist grassland with patches of indigenous bush clumps (Killick, 1990; Mucina & Rutherford, 2006). There are patches of invasive black wattle (*Acacia meansii*) scattered throughout the lowland regions and hill slopes. Land use is comprised of a mosaic of crops (mainly maize and potatoes), and indigenous grasslands, extensively used as pastures (mainly beef and dairy cattle). Farmlands consist of irrigated and non-irrigated agricultural fields. The majority of the land is privately owned, however, portions of land are owned by government and external organizations (pers. obs.). The farmlands are generally fenced by five strand barbed wire fencing, marking farm boundaries and internal fencing into camps to allow for rotational grazing (pers. obs.). These fences do not restrict wild animal movements through the farmlands.

The average annual minimum and maximum temperatures for the region are 9^0 C and 32^0 C respectively, and the average annual rainfall is 975 mm (Weather Station, Fort Nottingham, pers. comm.). Most rainfall occurs in the summer months (Dec- Feb) and has a distinct cold and dry period during winter (Jun-Aug). Intermediate rainfall and temperatures are associated with spring (Sep-Nov) and autumn (Mar-May). The topography is mountainous, consisting of undulating hills with rivers and wetlands in the valleys, and an altitude of ≥ 1200 m above sea level.

The region is known to have many naturally occurring wild ungulate species (Rowe-Rowe 1992), however, most large (>15 kg) carnivore species were extirpated from this area prior to 1900 (Skinner & Chimimba, 2005). Information on the exact number and species of wild ungulates is unknown however southern reedbuck (*Redunca arundinum*), blesbok (*Damaliscus pygargus phillipsi*), oribi (*Ourebia ourebi*) and common duiker (*Sylvicapra grimmia*) are regularly observed throughout the study area (pers. obs.). The region does have several carnivore species: genet (*Genetta tigrina*), mongoose (*Herpestidae*), black-backed jackal, serval (*Leptailurus serval*) and caracal (*Caracal caracal*), which may prey on wildlife and at times farm livestock (Ramesh & Downs, 2013). Black-backed jackals are regularly persecuted in the study areas by both professional hunters and dog packs as they are considered a threat to domestic livestock.

Data collection

The capture, collaring and tracking of black-backed jackal was conducted between May 2013 and September 2014. We captured and collared 5 individuals, two adult males, one adult female and two juveniles. The individuals were captured using cage traps (50x50x100 cm and 70x60x120 cm) and Victor 1.5 Soft Catch foothold pads **(**F&T Fur Harvester's Trading Post**,** Bushey Road, Alpena, U.S.A.). Trap sites were chosen in locations where greatest animal movement was present, determined by a concurrent study in the area utilizing camera traps (Ramesh & Downs, 2013).

Initially cage traps were chosen as the preferred capture method due to their relatively simple setup and operation procedure, and as they have been used successfully in previous studies with few trap mortalities (Kamler *et al*., 2003). The cages were designed as a double-door system with a pressure pad trigger plate, and camouflaged by indigenous grasses, branches and available trees and placed in densely vegetated areas to create a feeling of a dense thicket. The floor of the cage was covered with soil and grass, reducing the effects of wire underfoot. Cages were baited with dead chickens which were cut open and intestines smeared on the cage to reduce human scents. Traps were set in the late afternoon and were checked early morning (06h00). A total of five cages were baited daily over the capture period (total trap nights = 685; 137 days/5 traps). After two months and minimal success, soft catch foothold pads were acquired as an alternative.

Soft catch traps have successfully been used to catch black-backed jackal and a number of other canis species while sufficiently excluding smaller species with a high pan extension (Linhart & Dasch, 1992; Admasu *et al*., 2004; Kamler *et al.,* 2008; 2012). We set foot hold traps throughout our study area in places where natural objects such as rocks and grass tufts could form a channel where jackal would have to pass through. Similarly to cage traps, we set foot hold traps in areas of high species movement identified by a camera trap study (Ramesh *et al.*, 2013). A spade was used to dig a shallow hole to accommodate the foot trap, chain and peg. After placing the trap in the hole and anchoring it down, a cotton cloth was placed over the trigger plate to prevent soil from getting under it, and then subsequently buried. Stones were place at the entrance of these channels to narrow access thereby reducing chance of a jackal's foot missing the pressure plate. A small stick was dipped into bait and placed 300 mm from the trigger pan. The bait used was either a mixture of putrefied mincemeat and canned sardines or jackal faeces soaked in water following Rowe-Rowe and Green (1981) method of catching black-backed jackal. Dead cattle, calves and lambs were opportunistically used as bait throughout the study area whereby foot traps were set and buried around the carcass. A total of six foothold traps were baited and used daily over the capture period (trap nights = 618; 103 days/ 6 traps).

Once black-backed jackals were trapped, a local veterinarian was on-site to dart the animals with a mixture of ketamine and medetomisine. Once the individual was fully immobilised, it was removed from the traps and morphometric measurements were taken. Measurements included mass, total length, body length, tail length, chest girth, neck girth, incisor length and foot dimensions. Black-backed jackals were fitted with GPS-GSM/UHF collars (Wireless Wildlife Cc, Pretoria, South Africa) weighing 220 g. We left a two finger gap under each collar for comfort and neck growth (if any), however this was sufficient to prevent removal or excessive movement. Collars recorded date and time, GPS full first time co-ordinates, on-board temperature, log time and positional dilution of precision (PDOP). Data were stored on the collars and downloaded through a UHF receiver base station, which was a remote receiver that was left in the field. The base station searches for any GPS collars within range (approximately 10 km) via UHF signal. When a collar falls within this range, all the stored data is transferred to the base station. If the base station is not in range of the collar then the collar saves the GPS points until it comes into proximity of a base station where that information is then downloaded. The base stations transferred this data to a remote server through a global system for mobile communication (GSM) where data was saved. A drone (handheld aircraft) was used to retrieve stored data from roaming individuals, having the capability to retrieve information from a distance of 30 km from the collar. GPS collars were set to log GPS fixes every hour throughout the day and night for a minimum of one year.

Home range analyses

Data from each of the collars were downloaded and formatted appropriately in Microsoft Excel, then imported into ArcGIS 9.3 (ESRI, Redlands, CA, USA) and projected to UTM (WGS 1984 UTM Zone 35S). To avoid autocorrelation we scheduled collar GPS fixes to record at equal intervals spaced 1 h apart. As a result we had 24 fixes a day, spaced consistently over 24 h. Home ranges were constructed using both 95% and 50% minimum convex polygon (MCP) and fixed kernel (FK) method for all individuals. The home range tools extension (HRT) (Rodgers & Kie, 2011) for ArcGIS was used to calculate the home ranges. We removed duplicate GPS points that represent the same point from the total GPS fixes using spatial analysis tool in ArcGIS. Seasonal home range comparisons were made for each individual whereby any fixes falling within a season were calculated. Seasons used were: summer (1 Dec- 28 Feb), autumn (1 Mar-31 May), winter (1 Jun- 31 Aug), spring (1 Sep- 30 Nov). A minimum of 100 GPS points were used to calculate individual seasonal home ranges. If there was less than 100 points for an individual for a particular season then that home range was not calculated for that season. If collars recorded GPS points for longer than a year, only the annual home range during the first year was used.

Minimum convex polygons (MCP) were calculated for home ranges as it has been widely used as a home range estimator in previous studies and thus allows for a comparison to those previous studies. It is however acknowledged that there are a number of limitations and thus Kernel Utilisation Distribution (UD) methods were also calculated as they provide more accurate and meaningful home range estimates and habitat use have been shown to be unbiased (Worton, 1989; Seaman & Powell, 1996; Swihart & Slade, 1997; Seaman *et al.*, 1999; Borger *et al*., 2006).

The fixed kernel (FK) estimate is considered a more robust and least biased estimators of home range due to its better performance with varying sample sizes, shape of utilization distribution, auto-correlated data, and outlier data (Worton, 1989; Gitzen *et al*., 2006; Jhala *et al*., 2009). Although 95% kernel estimate provides a standard measure of the home range area, we also measured a 50% kernel estimate to provide an indication of core area used (Seaman & Powell, 1996; Campioni *et al*., 2013). An *ad hoc* bandwidth selection was used for home ranges as it allows for the reference bandwidth (*h*ref) to be reduced until the smallest home range with a contiguous polygon is determined, thus reducing over-smoothing and unnecessary fragmentation of home ranges.

Habitat use

We determined the habitat use and availability of land use types within home ranges of jackal for 3^{rd}-order resource selection (Johnson, 1980) using the South African National Land-cover Database to identify habitat types (SANBI, 2002). To determine habitat types used by black-backed jackal we estimated the potential seasonal home range using 95% FK method to represent the area of habitat available to each jackal on a seasonal basis. The original land use categories present in home ranges were reclassified into five habitat types: grassland, cropland, wetland, forest with bushland and plantation. The proportion of each habitat type for the 95% FK home ranges we determined using ArcGIS 9.3. Daily location was overlaid onto the vegetation map to provide the observed number of positions within each habitat, using Hawth's Analysis Tools for ArcGIS, version 3.27 (Beyer, 2004).

To assess the habitat utilized by black-backed jackals we used R statistical language, version 2.13.1 (R Development Core Team, 2012) along AdehabitatHS package (Calenge, 2006). Habitat selection of jackals was computed using Manly's compositional analysis of habitat selection ratios combined with 95% Bonferonni simultaneous confidence intervals (CI) (Manly *et al*., 2002). We determined which habitats were selected and avoided by individuals, when non-uniform habitat use was indicated by selection ratios (used/availability) to determine which habitats were used disproportionately more or less than their availability (Manly *et al*., 2002). Selection ratios from zero to one represent habitat types that are used less than available or 'avoided', while selection ratios above one designate habitat used more than available or 'preferred' (Calenge & Dufour, 2006).

We described habitat selection as differences in observed use in comparison to expected availability of land-cover types (Gehrt *et al*., 2009) using Log-likelihood chi-square test to test for overall habitat selection. Significance was determined at $P < 0.05$ using randomization to eliminate distributional assumptions (Manly, 1991). Habitat classifications with large numbers of habitat types are more likely to include habitats where the study animals were never located; which has been identified as problematic for compositional analysis (Aebischer *et al*., 1993;

Thomas & Taylor, 2006) and has been shown to increase Type I error rates (Bingham & Brennan, 2004). Aebischer *et al*. (1993) suggest replacing the zero for available but unused habitats with a value smaller than the smallest non-zero proportion; in our case we replaced zero values with 0.01. We could not test for differences in habitat selection between genders or age due to the small sample size, so our analysis of habitat selection used locations from all five jackals and pooled 95% FK home ranges for each season for a year. Although habitat selection analyses described here can determine habitat use of a species, it is highlighted that analyses on a small sample of individuals, as in this study, can result in bias and inaccurate results regardless of the effort made to reduce errors, thus the results must be considered exploratory.

Results

A total of five individuals were captured, collared and observed over a period that varied from 17 to 365 days, during which time 195 - 4070 GPS fixes were made on different individuals between July 2013 and September 2014 (Table 1). Four individuals: one adult male, one adult female, and both juveniles, stayed within the same area they were captured in, throughout the time they were monitored. One adult male (J 1) however dispersed over 150 km during winter and spring and thereafter settled into a home range which it sustained over summer and autumn. Home ranges were initially calculated as 95% minimum convex polygons (MCP) showing home ranges for both males 44.7 km² and 10.6 km² (excluding dispersal of J1in winter and spring), the female (6 km²), and both juveniles 212.2 km² and 215.4 km². This appeared an over-exaggeration of the home ranges, thus we calculated the 95% fixed kernel density estimate. The 95% FK home range for both adult males (excluding dispersal over winter and spring) was 52.4 km² and 11.4 km², the female jackal 5.48 km² and both juveniles 141.2 km² and 104.1 km². The small sample size precludes any accurate statistical comparisons related to gender and age differences in home ranges, however, home ranges of males appeared to be larger than females (Fig. 1).

For one adult male, the female and one juvenile, we calculated seasonal home ranges for all four seasons (autumn, winter, spring, summer). For one juvenile male we were able to calculate three seasonal home ranges (summer, autumn, winter), and for one adult male we were only able to calculate a winter home range before the collar failed. The average number of GPS locations for jackals across seasons was; winter (577: n = 5), spring (693: n = 3), summer (1006: n = 4), autumn (984: n = 4). The mean 95 % FK for pooled black-backed jackals in summer was (6.5 km^2), autumn (44 km^2), winter (437 km^2) and spring (542 km^2).

Seasonal home ranges for black-backed jackals showed, the adult female (J 2) had a relatively constant 95% FK throughout seasons (Table 1). Her greatest home range was over summer (6 km^2) and winter (6 km^2), and the smallest home range was during autumn (4.5 km^2). One adult male (J 1) was caught at the start of winter and thereafter dispersed out of the study area during winter and spring, thus having extremely large home ranges over those seasons, 1874 km^2 and 1619.5 km^2 respectively (Table 1). During summer and autumn the adult male (J 1) appeared to stabilize a home range, having a 95% FK of 15.7 km^2 in summer and 7.1 km^2 in autumn. One juvenile (J 5) which was caught in spring, progressively increased its home range through summer (1.7 km^2) and autumn (124.6 km^2) and then decreased its home range during winter (56.7 km^2). The other juvenile male (J 4) caught in summer similarly increased its home range across seasons, summer (2.6 km^2) autumn (39.8 km^2) and winter (196 km^2) (Table 1).

Habitat use

Habitat use analyses indicated that black-backed jackals' habitat use varied seasonally (Fig. 2). Compositional analysis of Log-likelihood test (Khi2L) demonstrated that home range selection by jackals was not uniform within the individuals home range (Autumn: Khi2L = 52.53, df = 16, P = 0,000; Winter: Khi2L = 56,88, df = 20, P = 0,000; Spring: Khi2L = 128,15, df = 12, P = 0,000; Summer: Khi2L = 63,46, df = 16, P = 0,000). Black-backed jackal's preferred forest with bushlands more than what was available in spring and winter, while they preferred croplands in summer and autumn. During summer and spring grasslands were least utilized whereas in autumn and winter plantations and wetlands were least utilized (Fig. 2). Although pooled selection ratios indicated no uniformity of habitat use, habitat selection with low confidence intervals suggesting habitat selection shared by all jackals, whereas habitat selection with large confidence intervals indicates variability in preference among telemetered individuals, suggesting no habitats consistently selected or avoided by black-backed jackals (Fig. 2).

Discussion

The most striking result in this study was that black-backed jackals had large home ranges across farmlands in KwaZulu-Natal. Annual home ranges for adult males (31.9 km²) and juveniles (122.6 km²) were large in comparison to those reported for *C. mesomelas* in other parts of southern Africa and theoretically predicted by body size (McNab, 1963; Fuller *et al*., 1989; Kaunda, 2001). What makes these results appear even more significant is that they were calculated using 95% FK with a smoothing factor to reduce unused areas. The 95% MCPs gave average annual home ranges for males 27.6 km² and for juveniles it nearly doubled to 213.8 km². There is a strong relationship between home range size and body mass, suggesting the home range of an animal is governed by cost of locomotion and metabolic requirements with increasing body mass (McNab, 1963; Tucker *et al*., 2014). For an animal with a body mass of 8 kg (approximately the size of a black-backed jackal) it is theoretically predicted to have a home range of 23 km² (McNab, 1963). Throughout southern Africa, the home range of collared black-backed jackal have been measured a number of times, with home ranges varying between 10-40 km² per individual for adults, 30-35 km² for sub-adults, and < 10 km² for juveniles (Fuller *et al*., 1989; Kaunda, 2001). Juveniles have been recorded dispersing up to 842 km² from natal dens (Ferguson *et al*., 1983). Rowe-Rowe (1976) and Ferguson *et al.* (1983) found similar movement patterns whereby black-backed jackals had larger ranges on farmlands than in protected areas. It was found that three immature jackals moved between 91.5 - 229 km² on farmlands in the Gauteng (formally the old Transvaal) (Ferguson *et al*., 1983). Thus, one can assume the species is capable of moving considerable distances regardless of its size.

The large variation in home range size could be an indication of the adaptability of the species to divergent ecological circumstances (Ferguson *et al*., 1983). Previous studies have shown that hunting can have an effect on the expansion of home ranges of animals, affecting their behavioural physiology (Grant, 2012; Kamler *et al*., 2013). In this study a number of farmers controlled jackal populations through the use of dog hunting packs and shooting which could result in larger home ranges. It is likely that where jackals are subjected to sustained hunting pressures, movement patterns may depart from those reported from unexploited populations (Rowe-Rowe, 1982; Kaunda, 2000). Ferguson *et al*. (1983) found a variation in home range sizes of black-backed jackal on farmlands as opposed to natural areas which he attributed to prey availability and divergent plant community types, however no comment on differences between jackals on nature reserve and farmland and the effects of hunting was made.

A number of factors can however play a role in the home range size of a species such as prey availability, population density, social organisation, and influences of environmental conditions (Ferguson *et al.,* 1983: Kaunda, 2000).

Activity patterns often relate to dependence on food and environmental conditions. An abundance of food could allow greater movement of the species as energy requirements are easily sustained (Kaunda, 2000). However a greater availability of food could also reduce home range sizes as the need for food requirements is reduced (Ferguson *et al*., 1983; Gittleman & Harvey, 1982). Since the female in our study had a small home range and both males and juveniles had large home ranges it could be argued that the sparse movement was as a result of the need for available habitat and/or a partner. Once individuals find a mate, a distinct home boundary is set and movement is reduced (Ferguson, 1978; Ferguson *et al*., 1983). It is however suggested that medium-sized canids (6-13 kg) often exhibit equal adult sex ratios resulting from similar rates of emigration and philopatry between sexes (Kamler & Macdonald, 2013), therefore suggesting other factors might be involved in large home ranges.

Range sizes over 12 months varied significantly through seasons with the mean 95% FK for pooled black-backed jackals in summer being (6.5 km^2), autumn (44.0 km^2), winter (437.0 km^2) and spring (542.0 km^2). Winter and spring had incredibly large home ranges as a result of the movement of one adult male (J 1) who dispersed over 150 km during winter and spring and thereafter settled into a home range which was sustained over summer and autumn. The dispersal of immature wild canids is not unusual as they have an extremely strong drive to disperse, Ferguson *et al.* (1983), reporting a two stage dispersal of a juvenile male 116 km from the release site. In our study, however, the male that dispersed was regarded as an adult of 3 years old so this is considered unusual behaviour for an adult jackal.

Comparison of adults and juveniles home ranges may vary due to differences in social roles between the age groups and metabolic needs (Gittleman & Harvey, 1982). Adults may require different energetic constraints when compared to immature (Rowe-Rowe, 1976; Moehlman, 1979; Macdonald, 1983). In the present study it was apparent that home range of the female did not vary significantly seasonally however there was a slight increase in movement over winter and summer. This was consistent with other studies whereby it was reported that females increase winter activity in response to their breeding biology (Rowe-Rowe 1976; Moehlman, 1979). In winter all males (both adults and juveniles) had large home ranges (52.4 km^2 -1873.9 km^2) which was consistent with previous studies where it was proposed that males begin mate searching and pairing at the beginning of winter, often involving the extensive movement by individuals (Kaunda, 2000; Loveridge & Nel, 2004). The extent to which jackal social status influences spatial utilization on farmlands could not be determine conclusively in the present study due to small sample sizes. However, seasonal movement by black-backed jackals showed similar trends to those reported by other studies whereby movement increased during pair mating and the establishment of territories and was relatively low during denning (Kaunda, 2000).

Habitat use

Black-backed jackals used nearly all available habitats within their home range in farmlands, however, they showed a preference for forest with bushland habitats in spring and winter, and croplands in summer and autumn. Shrubs and woodlands provide a suitable environment for carnivores and are usually structurally highly diverse (Salek *et al.*, 2014). These habitats offer cover and serve for protection against human hunting pressure (Kaunda, 2001; Admasu *et al.*, 2004; Salek *et al*., 2014). A number of studies have however reported that black-backed jackals tend to avoid thick vegetation and woodlands (Stuart, 1981; Smithers, 1983; Loveridge & Macdonald, 2003), and in shrub dominated areas prey availability for most carnivores is low (Blaum *et al*., 2008). Fuller *et al*. (1989) however suggest that persecution and disturbance is more intense in agricultural landscapes compared with protected areas and therefore in agricultural areas jackals would prefer shrubs and bushlands for cover.

In summer and autumn jackals showed a preference for croplands. This might be because it contained more prey species than other habitat types, although we did not determine prey abundance in our study area. Agricultural areas provide a rich food source, having rodents, game and livestock as prey items in those area (Kaunda, 2001). Similarly an abundance of dead livestock can enhance agricultural areas for jackal as a source of food (Kaunda, 2001). Loveridge and Macdonald (2003) similarly found black-backed jackals using human habitats more than expected and suggested this was presumably as they provided sufficiently rich resources for their use. A preference for these habitats on farmlands can however provoke conflict between humans and black-backed jackals (Kaunda, 2001). The exact reasons for seasonal change in habitat used by black-backed jackal were not clear, but they could have been related to a number of factors, such as changes in vegetative cover and prey species. Croplands exhibits the most seasonal changes of all habitat types as crops often change seasonally (Kamler *et al*. 2005). Depending on the crop and vegetation type it may govern the use by black-backed jackals as cover might be minimal and/or prey availability could be reduced.

Grasslands were regularly used less than what was available across seasons. Kaunda (2001) suggests that black-backed jackals may avoid grasslands because of a lack of cover for security and less food availability. However, when studying the telemetry locations, the highest number of points was recorded on grasslands, suggesting grasslands were regularly used, however, as the area covered by grasslands was extensive it could give a lower use than what was available. Loveridge and Macdonald (2003) suggest jackals are coursing predators adapted to open terrain, therefore grasslands should be a favourable habitat for them as they can see prey and move around easier to hunt.

Conclusion

Among carnivores there is considerable variation in social and spatial organisation between and within species over space and time (Jenner *et al*., 2011: Admasu *et al*., 2004). The apparent success of black-backed jackal as a mesopredator in agricultural environments might be a consequence of their adaptability to the environment and their variability to changing environments. The large home ranges found in this study could be as a result of a number of factors however it could be an indication of how carnivores respond to hunting and human interference. Despite our small sample size, we think these large home ranges are of interest and could be as a result of hunting pressures, highlighting how little we know about black-backed jackals in farmlands. This aspect of the ecology of black-backed jackals is important especially when control efforts are launched, as contrary to previous belief, a single problem jackal may well be responsible for damages over a fairly extensive area.

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List of Figures

Table 1 Home range estimates for black-backed jackals captured and radio-collared in Nottingham road/ Mooi River, KwaZulu-Natal South Africa. Where FK = Fixed kernel density estimate, and MCP = minimum convex polygon.

					Autumn			Winter			Spring			Summer			Overall			
Jackal ID	Sex	Mass (kg)	Fixes	Age Class	95% MCP	95% FK	50% FK	95% MCP	95% FK	50% FK	95% MCP	95% FK	50% FK	95% MCP	95% FK	50% FK	100% MCP	95% MCP	95% FK	50% FK
J 1	M	10.9	2690	III	6.0	7.1	1.3	3509.5	1873,9	162.8	1667,2	1619.5	158.2	15.2	15.7	2.8	4431.3	4296.7	1635.8	58.0
J 2	F	9.4	4070	II	4.2	4.5	1.0	4.8	6.0	1.6	5.8	5.9	1.3	5.3	6.0	1.1	27.9	6.0	5.5	1.2
J 3	M	9.9	195	III	—	—	—	44.7	52.4	5.0	—	—	—	—	—	—	78.2	44.7	52.4	5.0
J 4	M	6.1	3832	I	57.7	39.8	4.0	212.2	196.0	40.8	—	—	—	4.3	2.6	0.4	315.5	212.2	141.2	6.8
J 5	M	5.8	2131	I	189.3	124.6	17.1	77.7	56.7	6.2	0.4	0.6	0.1	1.3	1.7	0.5	269.2	215.4	104.1	10.2

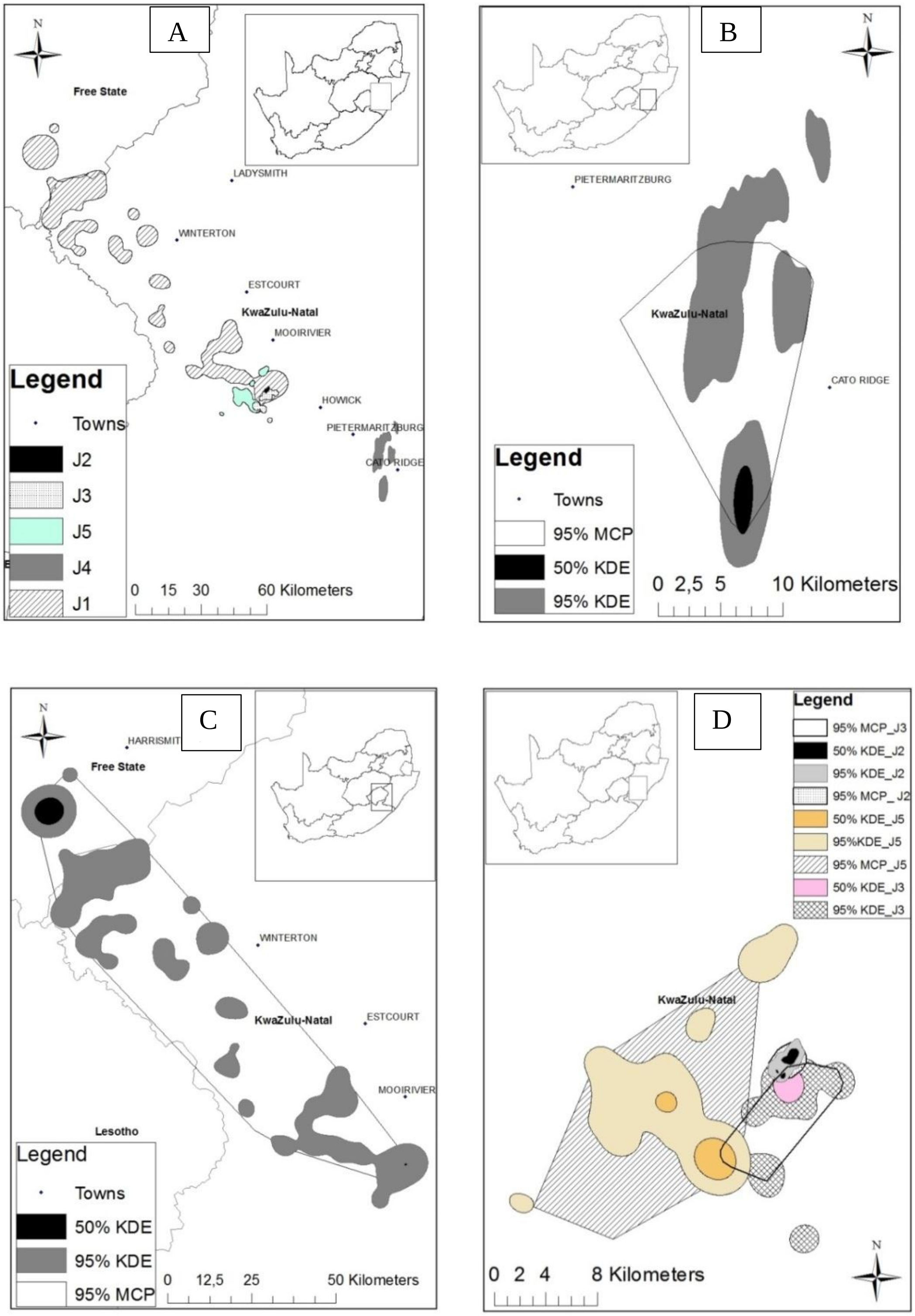

Fig 1 Annual home range estimates for black-backed jackals showing 50 % and 95 % fixed kernel density estimates (FK) and 95 % Minimum Convex Polygons (MCPs). Where A) is the 95 % FK estimates for all jackals: B) Is yearly home ranges of a jackal (J4) caught in Tala Game Reserve; C) is the yearly home ranges an adult male (J1) that dispersed to Harrismith; D) is the home ranges of three jackals (J2, J3 and J5) That remained in the study site after capture. Jackals were captured at Fort Nottingham.

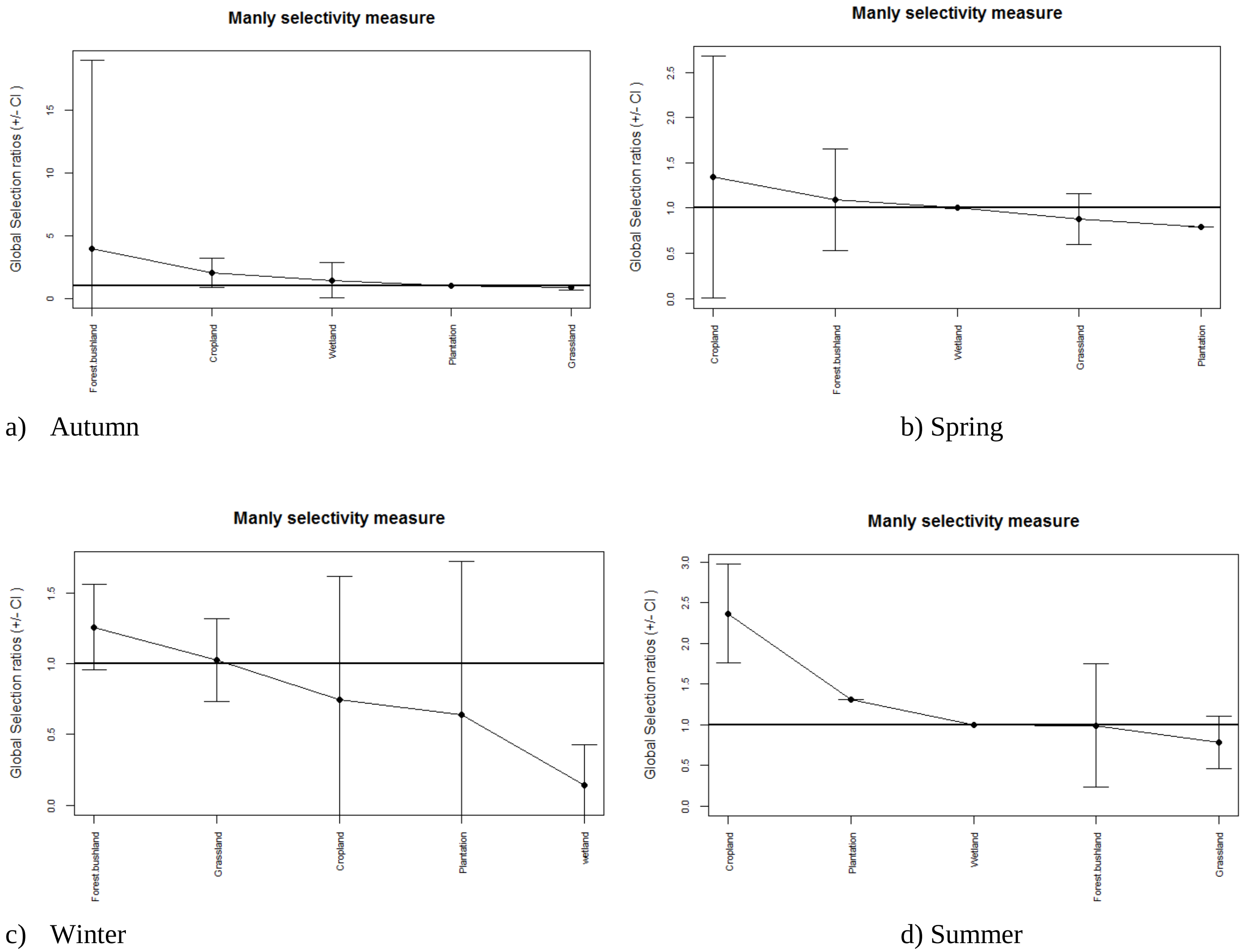

Fig 2 Habitat use versus availability in pooled 95% fixed kernel based on the reclassified land use map across seasons. We considered significant habitat preference of jackals as most preferred if the lower CI limit was above one and avoided if the upper CI limit was below one. Habitats preference is sorted so that the left type is the most preferred habitat and the right type is the most avoided habitat.

CHAPTER 5

Conclusions

Black-backed jackals (*Canis mesomelas*) are an abundant mesopredator in agricultural areas across South Africa. Given their ability to survive and apparent success in changing agricultural environments, an understanding of their ecology can provide important ecological information of their relationship between habitat attributes and population dynamics of the species. The present study reveals much about the ecology of black-backed jackals in developing agricultural areas. We found that jackals preyed on a high diversity of species in an area of high productivity, consuming any prey available to them (Chapter 2). Although rodents were the dominant food resource consumed by the species in our study, cattle, sheep, horses and goats fall prey to black-backed jackals. Previous studies showed a large degree of variability in the feeding ecology exhibited by the species throughout its distribution (Chapter 2). Suggesting the species merely switches between whichever particular species is present and thus has no specific correlation between its food sources. Thus we felt that black-backed jackals will naturally diversify prey species to survive in numerous landscapes, and the opportunistic nature of the species, combined with its foraging capabilities allow for the species' broad diversity of prey and subsequently increase in population size (Kaunda and Skinner, 2003; Macdonald and Sillero-Zubiri, 2004).

From surveys, farmers provided valuable socio-ecological insight into the characteristics of jackals and their relationship with the species (Chapter 3). It was suggested that there was a marked increase in the sighting of black-backed jackals over the last ten years, coinciding with land use changes in agriculture as noted in other studies (Sotherton, 1998). This suggests that land use change and possibly human expansion could play a role in the population increase of black-backed jackal, and this being related to an increase in abundance of the species in farmers' opinions. Similarly it was suggested that jackals were regularly responsible for predation on livestock and felt this was related to the increase in abundance of the species (Chapter 3). Studies have however shown that livestock losses are unrelated to predator densities but rather a function of prey available to predators (Conner *et al*., 1998; Knowlton, 1999; Landa *et al*., 1999; Mizutani, 1999). Therefore although farmers reported an increase in abundance of black-backed jackal on farmlands, this might not be related to increases in livestock losses but rather as a result of human activities changing prey availability. This being highlighted in the diet study (Chapter 2), suggesting that a number of rodent species were selectively consumed over domestic livestock across seasons and, in an area of high prey availability, a high diversity of species were consumed showing the opportunistic nature of the species.

As a result of predation and a perceived abundance of the species, a large number of farmers looked to control jackal populations through the use of dog hunting packs and shooting (Chapter 3). Woodroffe *et al*. (2005), suggests that lethal control may have indirect effects on species, impacting on their behaviour. Previous studies have similarly shown that hunting can have an effect on the expansion of the home ranges of animals, affecting their behavioral physiology (Grant, 2012; Kamler *et al*., 2013). It is likely that where jackals are subjected to sustained hunting pressures, movement patterns may depart from those reported from unexploited populations (Rowe-Rowe, 1982; Kaunda, 2000). The present study revealed much about the home range size of black-backed jackals were it was found that collared individuals had large home ranges across farmlands (Chapter 4). Thus a number of farmers might be seeing the same individuals, perceiving the species to be abundant. Analysis of habitat use showed a preference for bushland habitats in spring and winter and croplands in summer and autumn (Chapter 4). It is suggested that bushland habitats provide suitable cover from human hunting pressures, and agriculture provides a rich food source, having rodents, game and livestock as prey (Kaunda, 2001). A preference for agricultural habitats could provoke conflict between humans and jackals and therefore the utilization of bushland habitats as a means of cover from hunting pressures.

As is evident, black-backed jackals have considerable variation in social and spatial organisation between and within species over space and time (Jenner *et al*., 2011: Admasu *et al*., 2004). The large variation in home range size and the high diversity of prey consumed, independent of resources available is testament to the adaptability of the species to divergent ecological circumstances. Their ability to coexist with humans is not surprising considering the variability of habitat use, activity patterns and feeding ecology exhibited by the species. Although black-backed jackal populations might be increasing this does not necessarily have a direct correlation on livestock losses. Equally, the use of hunting dogs and lethal shooting is not always a viable and successful method of control (Bigalke and Rowe-Rowe, 2013). Rather, insight from surveys revealed preventative methods such as jackal proof fencing might be a more successful conflict-mitigation strategy. Alternatively, the surveys suggest a need for knowledge translation between farmers. Often farmers establish ways of controlling jackal problems and do not provide feedback to others. It is recommended that farmers in areas with black-backed jackal problems should create forums and discuss what works and what does not. The best way to reduce conflict in an area might be for all farmers in a community to work together on a solution (pers. opinion). The best solution for conflict might not necessarily be a reduction of jackal but rather different farming habits such as livestock disposal or jackal proof fencing throughout the community, etc. Although black-backed jackals are regularly regarded as a source of conflict, managing black-backed jackal is a complex issue as the species exerts considerable ecological influence in ecosystems, therefore it is felt appropriate measures of control should be applied with caution and should be selective towards only problem individuals and management plans need to incorporate farmers attitudes and beliefs to develop sustainable mitigation strategies.

Although this thesis provided a good investigation into the autecology of black-backed jackals in agricultural landscapes, it was felt that the study was limited by the small sample size of jackals collared and monitored in the study. A small sample size reduced the studies ability to infer home range and habitat use differences between gender and age. Similarly biomass calculations of scat would provide a more accurate reflection of food consumed by the species. The thesis provide an good understanding of the ecology of jackal in farmlands however it was felt that future research is needed on the effects of shooting as a mechanism of control and the role diseases play in controlling population densities of the species.

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