Comparative abundance and ranging behaviour of brown hyaena (*Parahyaena brunnea*) inside and outside protected areas in South Africa

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Abstract

Global biodiversity is declining at an unprecedented rate, principally as a consequence of increasing human population. Effects of this expansion are exemplified by the extent to which many carnivores are now in conflict with humans, particularly in unprotected rangelands. One such species is the brown hyaena (*Parahyaena brunnea*), classified as 'Near Threatened' (Wiesel *et al.*, 2008). The IUCN SSC hyaenid specialist group identified that brown hyaena are under threat due to human persecution and noted that greater understanding of their distribution and abundance is needed. With the principal aim of assessing the distribution and abundance of brown hyaena in South Africa, this study responds to that challenge. Five specific objectives were established: to utilise local knowledge to map the distribution of carnivores across South Africa; to determine the factors driving attitudes and perceptions of South African farmers to carnivores; to determine differences in relative abundance of carnivores in protected areas compared to unprotected in the North West and Limpopo Provinces; to compare home range estimates and movement patterns of free living brown hyaena inside and outside protected areas in the same provinces; to determine what variables influence brown hyaena home range size.

Distribution of brown hyaena and other carnivores, and attitudes to them, were determined using a web-based questionnaire involving multiple stakeholder groups. The results confirmed current knowledge on carnivore distributions but, critically, revealed wider distribution of brown hyaena and other key species than are currently known by IUCN (2013). Responses demonstrated that cultural group and land use type significantly affected attitudes towards all carnivores, with Afrikaans livestock farmers demonstrating the most overtly negative attitudes to all carnivore species. An encouraging finding was that 25% of land owner respondents had positive attitudes to brown hyaenas and were therefore likely to be well disposed to engaging in conservation activities. Further information on the abundance and movement ecology of brown hyaena was gained through an intensive field study in the North West and Limpopo Provinces, which are under-researched. The study was conducted in protected and unprotected areas since brown hyaenas are found in both but are subject to different pressures. The use of remote camera traps demonstrated that the relative abundance of brown hyaena was four times lower in unprotected areas than in the protected areas. A significant finding was that mesopredators showed higher relative abundances in the unprotected areas. This suggests probable further human-wildlife conflict if mesopredator release continues to occur. Low levels of abundance in the unprotected areas, in conjunction with persecution, led to the conclusion that conservation efforts should be focused here.

GPS collars were used to determine differences between brown hyaena home range across the protected and unprotected areas, to gain insights into their habitat use, and to establish their movement patterns through the fragmented landscape. The study demonstrated that home range sizes in the unprotected areas were not only significantly smaller than in the protected areas but also substantially smaller than those found across the entire hyaena's range. Reasons for the variation are suspected to be higher levels of persecution and greater biomass availability outside the protected areas in conjunction with the relatively high density of apex predators inside the protected areas. In conclusion, large carnivore research is critically required outside protected areas where carnivores are currently involved in the most conflict and are at the greatest risk.

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Chapter 1: Introduction

Global biodiversity is changing at an unprecedented rate (Sala *et al.*, 2000; Magurran and Dornelas, 2010; Pereira *et al.*, 2012), it is predicted that 37 % of terrestrial species will be lost by 2050 (Bradford and Warren, 2014). Many conservationists argue that we are experiencing the sixth global extinction crisis (Eldredge, 2001; Wake and Vredenburg, 2008; Barnosky *et al.*, 2011; Pievani, 2014). The major driver of current biodiversity loss is the continued and rapid growth of the global human population, which has expanded by at least three orders of magnitude over the past 400 generations (Keinan and Clark, 2012). Between 2005 and 2010, the global human population has increased by 1.2 %, with growth rates in developing countries (1.4%) being higher than those in developed countries (0.4%) (United Nations, 2013). With the human population now over 7 billion and growing, there is an increasing demand for natural resources and/or the space that they occupy. To compound the problem of human population growth and biodiversity loss, the areas with the highest biodiversity and endemism are also those experiencing the highest rates of human population growth; i.e. those in the tropical developing countries (Myers *et al.*, 2000). Consequently, humans are now the leading agents of disturbance on the planet as no ecosystem on Earth's surface is free of human influence (Vitousek *et al.*, 1997ab).

The rates of biodiversity loss become very clear when the conservation status of taxonomic groups are evaluated. For example, species extinction is now in the order of 100 to 1000 higher than the background rate of extinction, with one-quarter of Earth's bird species already extinct due to human activities (Vitousek *et al.*, 1997b; Pimm *et al.*, 2005). Furthermore, 25 % of mammals, 13.5 % of birds and 41 % amphibians are categorised as 'Critically Endangered' to 'Vulnerable' on the IUCN Red List of Threatened Species to be known here on as IUCN Red List (IUCN, 2013). Out of 5,429 mammals 1.4 % of species are now extinct, 0.004 % are extinct in the wild, 3.6 % 'Critically Endangered', 8.1 % 'Endangered', 9.1 % 'Vulnerable' and 15.2 % are 'Data Deficient' (IUCN, 2013).

In order to reduce the rate of biodiversity loss, it is important that conservationists have a clear picture of the status and distribution of species. Therefore the first step in the conservation process is determining levels of biodiversity and whether species are threatened. Once we have that information, informed management decisions about how best to manage our biodiversity in a sustainable manner can be delivered (Foresman and Pearson, 1998; Pettorelli *et al.,* 2010).

1.1. Drivers of Global Biodiversity Loss

The major drivers of biodiversity loss are habitat fragmentation and loss (Lambin *et al.,* 2001; Geldmann *et al.,* 2013), global climate change (Araujo, 2005), invasive species (Vitousek *et al.,* 1997a; Olson, 2006), overexploitation (Fa *et al.,* 2006; Lindsey *et al.,* 2013) and persecution (Miquelle *et al.,* 2011; Palazy *et al.,* 2012). All of these originate from human population growth, with habitat loss and fragmentation regarded as being the greatest threat to biodiversity (Wessels *et al.,* 2000). Widespread changes in land use and land cover have occurred, with between one-third and one-half of the Earth's land surface being transformed by human activities (Vitousek *et al.,* 1997b; Chaplin *et al.,* 2000). This has had an unprecedented impact on species inhabiting these habitats. For example, the forest islands in Thailand's Chiew Larn Reservoir have suffered 25 years of ongoing fragmentation and isolation which has lead to the near-total loss of all native small mammals (Gibson *et al.,* 2013).

Globally threatened and endangered species have been found to reside in areas where a large proportion of the land use has been altered from its original state (Wessels *et al.,* 2000). A reduction in natural and semi-natural habitat will reduce the area available to species that depend on that habitat which leads to reduced population sizes. Even where remnant pockets of fragmented habitat remain, the populations of species that exist there are typically small and much more vulnerable to extinction than larger, better connected populations.

In response to habitat loss and fragmentation, many countries now have a network of protected areas that have been identified to protect remaining wild habitats (Geldmann *et al.,* 2013). However, human dominated landscapes also have a role to play in conservation efforts as many species utilise these areas. For example, most of the mammalian species in India were found to range both inside and outside protected areas (Karanth *et al.,* 2009). Therefore land-use planning to maintain refugia and incentives to prevent further habitat fragmentation are critical to halting the biodiversity loss process (Graham *et al.,* 2009).

Climate change has created multiple shifts in both species distribution and abundances (Thomas *et al.,* 2004) the most extensive carnivore range contractions have been across Europe, south eastern North America and western and central Africa (Ripple *et al.,* 2014). In terms of species distribution, understanding the influences of past climatic events will lead to a greater awareness of the potential responses of species to present and future climate change (Araujo, 2005). As the current observed distributions of species reflect multiple range determinants both historical and ecological (Araujo, 2005). Species are said to be in equilibrium with the climate if they occur in all suitable areas whilst being absent from all unsuitable ones (Hutchinson, 1957). It has been predicted that on the basis of a mid-range climate-warming scenarios for 2050, 15 % to 37 % of species will be 'committed to extinction' (Thomas *et al.,* 2004). As a result species will now be required to disperse rapidly through fragmented landscapes in order to keep pace with the changing climate (Gibbon *et al.,* 2000). Climate change has already had wide ranging effects for examples decline in migrant avian species due to habitat loss (Both *et al*., 2010).

Biological invasions are a widespread and a significant component of human-caused global environmental change causing a breakdown of the regional distinctiveness of Earth's flora and fauna (Vitousek *et al.,* 1997a). Biological invasions have the ability to alter the structure and function of pristine ecosystems as well as threaten native biological diversity (Vitousek *et al.,* 1997a). Of 256 vertebrate extinctions with an identifiable cause, 109 are known to be caused by biological invaders (Olson, 2006). Invasions also interact synergistically with other components of global change, in particular land use change (Vitousek *et al.,* 1997a). As habitats are opened up they become susceptible to invasive species such as rat species which are becoming increasingly common in human-modified landscapes (Gibson *et al.,* 2013).

Land-use and land-cover changes affect key aspects of the Earth's functioning (Lambin *et al.,* 2001), including a direct impact on global biodiversity (Sala *et al.,* 2000). It is estimated that since 1850, the global expansion of croplands has converted six million km² of forest/woodlands and 4.7 million km² of savannahs/grasslands/steppes with a respective 1.5 and 0.6 million km² of this cropland then being abandoned (Ramankutty and Foley 1999). A consequence of these human modifications on the natural environment is the expansion of rangelands and semi-natural habitats. Widespread changes in land use and land cover have occurred as between one-third and one-half of the land surface have been transformed by human action and is the single most important cause of species extinctions (Vitousek *et al.,* 1997b; Chaplin *et al.,* 2000).

Human demography and land use are important factors in mammal distribution especially if the protected areas are small and fragmented (Karanth *et al.,* 2009). Protected areas have been identified to experience lower rates of habitat loss than areas that are not protected (Geldmann *et al.,* 2013). Another consequence of habitat loss and a growing human population is that it brings people into close proximity to wildlife leading to a rise in human-wildlife conflict (Inskip and Zimmermann, 2009; IUCN, 2013). Humans have been exploiting wild animals for furs and food for millennia and more recently for sporting or cultural reasons (Thirgood *et al.,* 2005). Human-wildlife conflict has been shown to be a critical threat to multiple species, which is why the topic is increasingly being acknowledged and investigated by conservation biologists (Dickman, 2010). The main driver of human-wildlife conflict has been cited as direct wildlife damage to either crops or livestock (Dickman, 2010). The issue of human-wildlife conflict encompasses a huge diversity of situations and species, from grain-eating rodents to man-eating tigers (*Panthera tigris*) (Pimentel *et al.,* 2005; Barlow, 2009). Human-wildlife conflict is cross continental and affects, for example; Asian elephant (*Elephas maximus*) (Zhang and Wang, 2003) and African elephant (*Loxodonta africana*) (Hoare 1999; Madhusudan, 2003) in the same way.

The relative frequency of reported conflict with wildlife was significantly related to the human density on lands adjacent to protected areas (Newmark *et al.,* 1994). Large bodied animals were found to increase problems in low density human areas and vice versa for small bodied animals, control of smaller animals was less effective in comparison to the large (Newmark *et al.,* 1994). Multiple mitigation methods have been used globally in order to reduce the levels of human wildlife conflict (Dickman, 2010). For example, methods to minimise wildlife incursions on agricultural land range from digging trenches, using tin cans, posting guards and shooting but success of a control measure is species dependent (Newmark *et al.,* 1994). Other methods such as the beehive fence have been developed to have a two-fold effect firstly as a deterrent to crop raiding elephants but secondly as a source of income for the local community (King *et al.,* 2009). To minimise conflict the ideal scenario would be to have land uses associated with low human density and non-attractive to the wildlife adjacent to the protected area (Newmark *et al.,* 1994).

1.2. Carnivore Conservation

Carnivores comprise 287 extant species in 123 genera belonging to 16 families (Karanth and Chellam, 2009). Carnivores are important components of the ecosystem as they maintain biodiversity and function as well as often acting as keystone species (Linnell and Strand, 2000; Ripple *et al.,* 2014). The removal of apex predators from the system may result in unknown fluctuations of other mesopredator and prey species, altering the dynamics of the ecosystem, termed 'mesopredator release' (Treves and Karanth, 2003; Blaum *et al.*, 2009).

Large carnivores are currently facing severe threats and are experiencing substantial declines in their populations and geographical ranges around the world (Ripple *et al.,* 2014). Out of 285 carnivore species that have been investigated by the IUCN, 2.8 % are listed as 'Critically Endangered', 7.7 % 'Endangered', 13.7 % 'Vulnerable' and 6.3 % are 'Data Deficient' (IUCN, 2013). Indeed some of the most endangered species on the planet belong to the Carnivora such as the black-footed ferret (*Mustela nigripes*) (Miller and Reading, 2012) and the Ethiopian wolf (*Canis simensis*), which is world's rarest canid with fewer than 500 animals worldwide (Kennedy *et al.,* 2010). Large carnivores are particularly vulnerable to extinction and are often the focus of conservation studies due to four common factors: 1) they are sensitive indicators of ecosystem integrity, 2) they are wide ranging, 3) they live in small isolated populations and are therefore prone to extinctions and 4) they suffer directly from human interference.

Multiple factors have been found to influence the risks to large carnivore extinction ranging from; ecological (interspecific competition, ranging behaviour, prey availability, livestock predation); socio-economic (people's attitudes and behaviours); and political (policy development and implantation, land use) (Winterbach *et al.,* 2012; Ripple *et al*., 2014).

Hunting and harvesting of natural populations of large predators has caused historic and current carnivore extinctions (Vitousek *et al.,* 1997a). For example, due to early man hunting large carnivores, such as the gigantic 'bear otter' (*Enhydriodon dikikae*), there was a marked reduction in the diversity of large carnivores and the ecological niches they filled around two million years ago (Tollefson, 2012). More recently the Tasmanian tiger

(*Thylacinus cynocephalus*), native to mainland Australia and Tasmania, was declared extinct in the 1930s after a century of intensive hunting as farmers feared that they were killing sheep (Paddle, 2002).

1.3. Carnivores, Habitat Loss and Fragmentation

Habitat loss and degradation is currently one of the greatest threats to the survival of large carnivore species worldwide (Inskip and Zimmermann, 2009). Consequently many carnivores exist in semi degraded or human dominated landscapes, which increases levels of human carnivore conflict. Therefore, conservation efforts in mixed-use landscapes are crucial for sustaining viable carnivore populations (Schuette *et al.,* 2012). For example, the Amur tiger (*Panthera tigris*) only persists in areas of low human population density and their distribution is highly dependent on the preservation of source habitat in these zones and the linkages between pristine habitat blocks (Carroll and Miquelle, 2006). A similar picture is revealed in Kenya, where lion (*Panthera leo*) populations are declining due to loss and fragmentation of dense cover and riparian habitat, due to nomadic pastoralists altering their way of life and becoming settled communities (Schuette *et al.*, 2012). Furthermore, suitable leopard (*Panthera pardus*) habitat in South Africa has become highly fragmented and future population viability depends upon dispersal corridors being created and maintained through suitable habitat (Swanepol *et al.*, 2012).

1.4. Carnivores and Conflict

As the human population continues to grow the rate at which it consumes resources also increases leading to habitat loss. This inevitably brings people into close proximity to wildlife, leading to a rise in human-wildlife conflict (Inskip and Zimmermann, 2009). Human-wildlife conflict is a risk to 31% of carnivore species that are listed as either ‘Threatened’ or ‘Data Deficient’ by the IUCN Red List (IUCN, 2013). People’s attitudes towards wildlife can be determined by multiple factors including household wealth, residency status and type and extent of an outreach programme, if any (Holmes, 2003).

Anthropogenic threats or human interference can impact carnivore populations either directly or indirectly (Burton *et al.,* 2012). Both small and large bodied carnivores can undergo direct persecution by being hunted as trophies (Palazy *et al.*, 2012); over-exploited for bushmeat (Courchamp *et al.*, 2006; Lindsey *et al.*, 2013); organs traded (Shepherd and Nijman, 2008) and in retaliation in defence of livestock (Treves and Karanth, 2003). For example, with only 5,000 individuals remaining worldwide, the demand for bone in traditional Chinese medicine continues to push three of the world's remaining five subspecies of tiger, (South China Tiger (*Panthera tigris amoyensis*); Siberian Tiger (*Panthera tigris altaica);* Sumatran Tiger (*Panthera tigris sumatrae*)), to the brink of extinction (Driscoll *et al.*, 2009). In the forests of Monte Mitra, Equatorial Guinea, 10 carnivore species were found to be captured and killed for the bushmeat trade, including the leopard and the 'Near Threatened' African golden cat (*Profelis aurata*) (Fa and Yuste, 2001; Henschel *et al.*, 2008).

Carnivores are highly susceptible to human wildlife conflict as they are wide ranging and their protein rich diet often negatively impacts on people's livelihoods (Treves and Karanth, 2003; Inskip and Zimmermann, 2009). Livestock predation by large carnivores is the most wide spread cause of conflict and retaliatory killing by people is one of the most serious threats to carnivore survival (Woodroffe *et al.*, 2005). Although all carnivores are affected by human wildlife conflict, conflict has been shown to be most severe in relation to large cats, in particular; caracal (*Caracal caracal*), cheetah (*Acinonyx jubatus*), leopard and lions as, apart from caracal, the other species have either a moderate or large body mass which is a significant factor affecting severity of conflict (Inskip and Zimmermann, 2009).

Often carnivores are subjected to indirect and direct effects of human conflict at the same time, usually exacerbating risks of extinction. For example, jaguar (*Panthera onca*) populations have been declining not only due to direct persecution by being hunted for their skin but indirectly by their prey base collapsing due to bushmeat hunting pressures (Wallace *et al.*, 2003). The Amur tiger is also directly poached for medicinal purposes and their wild prey base is also in decline which combined has resulted in less than 1,000 individuals remaining (Carroll and Miquelle, 2006; Miquelle *et al.*, 2011).

People who coexist with free-ranging large carnivores bear the brunt of conservation costs (Winterbach *et al.*, 2013). Levels of fear were found to impact on the extent to which predators are accepted. In Brazil it was discovered that people's attitudes towards two main carnivores, the jaguar and puma (*Puma concolor*), were not based on the level of predation but firstly on fear of the two species and secondly on a presumption that jaguars had been released into the area by local authorities (Conforti and Cesar Cascelli de Azevedo, 2003). Furthermore, fear was also found to have created negative attitudes towards the re-introduction of wolves into Norway (Zimmermann *et al.,* 2001).

In some areas where carnivore conflict was taking place conservation management and strategies have been put in place to ensure the long-term survival of carnivore species. Eurasian Lynx (*Lynx lynx*) survival was secured in Finland due to the increased level of protection it was afforded (Ripple *et al.,* 2014). To arrest population decline of the gray wolf (*Canis lupus*), a multidimensional approach was taken by enhancing legal protection levels, reintroduction programmes and supporting natural re-colonisation (Ripple *et al.,* 2014). These methods have proven to be successful (Ripple *et al.,* 2014).

Mitigation methods have been used worldwide to reduce the level and type of human-wildlife conflict present in specific areas. For example, the aardwolf (*Proteles cristata*) was being persecuted across South Africa as they were perceived by farmers to be like hyaenas and jackals (Anderson and Mills, 2008). However, through dietary research, evidence was provided that facilitated a change in perception and a reduction in the level of persecution (Anderson and Mills, 2008). In Kenya it was determined that ownership of land title deeds created a positive attitude towards predators and that additionally community members would become more tolerant if they were also able to derive an income from eco-tourism or trophy hunting (Romanach *et al.,* 2007). To conserve the snow leopard (*Uncia uncia*) in India a pilot scheme was set up to offset livestock losses, create livestock free areas and generate alternative income sources from handicraft to restrain local communities from poaching and retaliatory killings (Mishra *et al.,* 2003). However, a major limitation noted was the spatial scale on which the scheme needed to be undertaken in order to be effective across the entire snow leopard’s range (Mishra *et al.,* 2003). Anti-poaching efforts for specific species such as the tiger (*Panthera tigris*) in certain areas have appeared to be successful (Kawanishi and Sunquist, 2004). Even so, the slightest increase in poaching can greatly increase the probability of extinction (Kawanishi and Sunquist, 2004). When the level of persecution has been reduced, some species have recovered, as demonstrated by an increase in their population numbers as well as expansion in their range (Lovell *et al.,* 1998).

1.5. Carnivores and Protected Areas

Globally apex carnivore populations have experienced rapid declines (Schuette *et al.*, 2012). Local extirpation due to anthropogenic pressures has meant that many large carnivore populations are now restricted to protected areas (Schuette *et al.*, 2012). Protected areas have been traditionally recognised by the conservation community as the best approach to conserving biodiversity, which is reflected by terrestrial protected areas globally increasing by 5.7 % between 1990 and 2012 (UNEP-WCMC, 2012). For example, in India the once widespread carnivores such as the tiger and brown bear (*Ursus arctos*) are now confined only to protected areas (Karanth *et al.,* 2009).

Many protected areas are often under-funded, small, or both, and in many cases are not suitable for large carnivore conservation (Leader-Williams and Albon 1988; Newmark *et al.*, 1993; James *et al.,* 1999). The small sizes of protected areas are especially important when considering carnivore conservation. Indeed, a number of studies have shown that the majority of protected areas are too small to maintain a viable populations or large carnivores. This has led to carnivore home ranges spreading across both protected and unprotected areas (Woodroffe and Ginsburg, 1998; Inskip and Zimmermann, 2009). For example, the majority of lion and cheetah populations have been found to exist outside protected areas in the rangelands of Southern and East Africa (Chardonnet, 2002; Marker and Dickman, 2005). Furthermore, a lack of fencing allows such species to leave the confines of the protected area and encounter the dangers associated with the human dominated surrounding lands, which can have detrimental impacts on population viability. For example, in Zimbabwe lions were being hunted for trophies outside and on the boundaries of the protected areas (Loveridge *et al.,* 2007). The hunting targeted both adult and sub-adult males, which has led to a skew in the adult sex ratio and increased rates of infanticide when new males fill vacant home range areas (Loveridge *et al.,* 2007).

By examining the relationship between protected areas and extinctions rates, recent studies have found that a combination of small protected areas and human-induced mortality contributes more to the extinction of large carnivores isolated in reserves than any other stochastic event (Caughley, 1992; Woodroffe and Ginsburg 1998). An example of apex predator decline within the supposed sanctuary of protected areas is the decline of 75 % of the continent-wide lion population with less than 25,000 individuals remain within the protected area network in Africa compared to 100,000 in the 1970s (Bauer *et al.,* 2012; Schuette *et al.,* 2012).

Many protected areas in South Africa are bordered by impenetrable fences. Fences act as barrier and are utilised in a variety of forms from electrified predator proof to keep in large carnivores in protected areas (Hayward and Kerley, 2009) to four strand cattle fencing in the farmland. The aim of the fence is to maintain and protect the biodiversity inside from outside threats such as human development, poaching and invasive species (Margules and Pressey, 2000). In turn the fenced reserves should provide a safe area in which biodiversity can thrive. Fences have an ecological impact by potentially blocking daily or wider migration movements, restricting the range use of biodiversity which may have consequences such as; overabundance, inbreeding and isolation and restriction of evolutionary potential (Hayward *et al.,* 2009b; Hayward and Kerley, 2009). Fences also have a more immediate impact by causing indiscriminate mortality of firstly the game they seek to keep in and secondly small to large bodied animals that are moving across the landscape. Fences can create greater capture rates of prey leading to reduce hunting effort and increase the size of the prey captured as highlighted by wild dogs (*Lycaon pictus*) who exploit the fences to their advantage (Davies-Mostert *et al.,* 2013). The long-term impacts of fences are that they confine individuals to a fixed area. Without the ability to disperse, carnivore abundance may exceed their available resources leading to a potential rapid decline of the population or local extinction (Hayward and Kerley, 2009).

Fences are heavily utilised in South Africa as a management tool, from marking individual farms to national park boundaries and keep economically valuable game in and predators out (Kesch *et al.,* 2013). In Botswana aardvark (*Orycteropus afer*), black-backed jackal (*Canis mesomelas*) and brown hyaena (*Parahyaena brunnea*) have been found to dig and move through holes in just one night thus easily moving through the human-dominated landscape (Kesch *et al.,* 2013). The fencing is often electrified to keep valuable game species enclosed (Lindsey *et al.,* 2005; Hayward *et al.,* 2009b). In areas bordering reserves high levels of carnivore mortality have been recorded on both sides of the fence (Balme *et al.,* 2010). Consequently the management approach needs to include both the reserve and a buffer zone outside of reserve if large carnivores are to be conserved effectively (Balme *et al.,* 2010).

Due to the time lag between implementation of conservation strategies and the known effects on slow growing carnivores, fences may prove to be a short-term fix producing complex issues in the long-term. Adaptive management combined with a commitment to long-term monitoring has been recognised as crucial in order to maintain and sustain biodiversity within a reserve system (Margules and Pressey, 2000).

It is clear therefore, that protecting areas for carnivores is not the panacea it was once thought to be and consequently, effective conservation management is of paramount importance to wide-ranging carnivores living in human-dominated landscapes outside of protected areas (Muntifering *et al*., 2005). An open landscape without fences may allow people, livestock, native ungulates and carnivores the ability to make spatial adjustments in response to environmental and anthropogenic pressure therefore avoiding conflict (Schuette *et al.,* 2012). Livestock husbandry in Kenya, such as adequate boma construction and watch dogs, has been shown to be a key factor in reducing the level of carnivore and livestock conflict and therefore implementing similar and targeted practices globally increases the potential for co-existence (Ogada *et al.,* 2003).

The creations of conservancies are one solution that may help reduce carnivore conflict in human dominated rangelands (Lindsey *et al.,* 2005; Cousins *et al.,* 2008). The aim is to combine small ranches into a larger land parcels by removing the fences. Cousins *et al.,*'s (2008) study found that wildlife ranchers contributed positively to conservation by providing resources to support reintroduction programmes for threatened species as well as maintaining the natural habitat. These larger areas permit the reintroduction of indigenous mammals and result in land use changes from high-off take, low value consumptive utilisation towards higher value forms of hunting ecotourism (Lindsay *et al.,* 2009). Across conservancies, landowners were found to be more tolerant of predators in comparison to livestock and sheep farmers making them an ideal land use for carnivore conservation (Lindsey *et al.,* 2006). In Namibia conservancies have proven to be successful, currently 17 are adjacent to protected areas substantial increasing the buffer area and in turn reducing the impact of the edge effect (Woodroffe and Ginsberg, 1998; Weaver and Skyer, 2003). In conjunction with a marked change in the attitudes of communal area residents, highlighted by the communities integrating wildlife and tourism enterprises into their livelihood strategies (Weaver and Skyer, 2003).

At a time of unprecedented change, carnivore conservation has reached a critical juncture. It will only be with collaboration across multi-disciplinary groups, ranging from governments and scientists to the general population that strategies appropriate to the ecological needs of carnivores will be determined. The critical outcome will be whether a species and populations will survive. In order to conserve large carnivores it is necessary to understand their abundance in the human dominated landscapes, which is where the real conservation action is needed through an interdisciplinary and adaptive approach (Winterbach *et al.,* 2012). However Balme *et al.,* (2013) heeds that research projects should not only be multi-disciplined but also based outside protected areas and not just one dimensional i.e. ecology or diet.

1.6. Carnivore Ecology

Carnivores play a critical role in the ecosystem. However, even for key apex predators such as the lion and leopard, relatively little is known about their ecological effects (Ripple *et al.*, 2014). The current research suggests that top predators promote species richness or are associated with it in relation to: dependence on ecosystem productivity; trophic cascades; resource facilitation; sensitivity to dysfunctions; selection of heterogeneous sites and links to multiple ecosystem components (Sergio *et al.*, 2008). Furthermore, carnivores may function as structuring agents and biodiversity indicators in certain ecosystems (Sergio *et al.*, 2008). Cascading effects due to the loss of predators can occur in a variety of forms from mesopredator release (Prugh *et al.,* 2009) to seed dispersal (Roemer *et al.,* 2009). Schmitz *et al.*, (2000) synthesised from multiple studies that trophic cascades linking the removal of carnivores to changes in plant communities were more commonplace in the terrestrial systems than was currently believed. Many carnivores have proven to be wide ranging, extremely adaptable and prolific across their geographical range. Having adaptable and varied diets ensures persistence across fragmented landscapes. Examples include the jackal (Kaunda and Skinner, 2003) and red fox (*Vulpes vulpes*) (Devenish-Nelson *et al.*, 2012).

Carnivores often exist at low density due to their relatively high position in food webs. Existing at low densities makes them more susceptible to extinction caused by demographic and environmental stochasticity, which can lead to local extinctions (Karanth and Chellam, 2009; Pettorelli *et al.*, 2009). Carnivore density has been shown to be significantly influenced by factors such as habitat fragmentation (Creel, 2001), prey availability (Macdonald, 1983; Kaunda and Skinner, 2003; Hayward *et al.*, 2007; Hayward and Kerley, 2008; Burton *et al.*, 2012) and inter-species competition (Linnell and Strand, 2000; Rich *et al.*, 2012).

One of the key questions in carnivore ecology is whether their numbers are regulated by their prey or whether they regulate their prey density? Prey density is a fundamental determinant of carnivore density both within and across species, therefore consistent prey density is critically important to ensure stable carnivore populations in the future (Carbone and Gittleman, 2002). Carnivore densities are closely tied not only to prey size but also to prey biomass in their preferred weight range (Carbone and Gittleman, 2002; Hayward *et al.*, 2007). When a carnivore reaches 21.5 kg or more it cannot be sustained with small prey items such as invertebrates as the necessary energy intake requirements exceed that obtained from the food, therefore larger prey items are required (Carbone *et al.*, 1999).

Of all the large African predators, wild dog and cheetah have evolved the smallest dietary niche and, additionally, have the greatest degree of dietary overlap. This is recognised as one of the reasons for their low population numbers and for the fact that they are the most threatened in any area, protected or not (Hayward and Kerley, 2008). In comparison lions and spotted hyaenas (*Crocuta crocuta*) have very rich and varied diets and competition does not affect them especially as the lion fills the dietary niche at the top end of the predator's guild (Hayward, 2006; Hayward and Kerley, 2008).

The optimal foraging theory predicts as the availability of prey resources decreases the utilisation of that particular resource will increase (Krebs and Davies, 1984). The theory concludes that in areas of low productivity the predator increases the range of prey it sources; this is also the case if prey becomes scarcer.

Carcasses are more valuable than live prey as there is not an associated energy or risk cost to stealing in comparison to chasing and killing prey, therefore interference competition between carnivores is usually associated with kleptoparasitism (Creel, 2001).

Determining landscape level area requirements based on preferred prey carrying capacity rather than habitat requirements gives a more accurate representation in order to maintain large carnivore populations (Hayward *et al.,* 2007). As large carnivores are predominately restricted to protected areas this may artificially increase interspecific competition due to higher densities of predator populations leading to possible extinctions (Hayward and Kerley, 2008). Therefore, active management of the prey base is required to ensure all dietary niches are fulfilled (Wiens, 1993; Hayward and Kerley, 2008).

The resource dispersion hypothesis predicts that territory size is determined by the dispersion pattern of food patches (Macdonald, 1983; Kruuk and Macdonald 1985). Therefore, the larger the spread of food patches the greater the size of the territory. Similarly the smaller the patches the smaller the territory. One group will have to work harder to acquire the same amount of recourses in the patch of low abundance thus making their home range larger to compensate (Owens and Owens, 1978; Mills, 1982; Macdonald, 1983; Kruuk and Macdonald, 1985; Dyk and Slotow, 2003). Among carnivores, there is extensive intraspecific variation in home-range size even within similar habitats, which could be affected by the dispersion of food or variation in food availability (Macdonald, 1983). Resource dispersion may therefore set the limits of home range size and group size in a carnivore society (Macdonald 1983). Red foxes' (*Vulpes vulpes*) home range sizes varied between 0.45 km^2 in food-rich rural areas and greater than 10 km^2 in the upland moors, identifying how patch prey richness can dramatically vary home range sizes (Macdonald, 1981). In nature, resources are not homogeneously distributed therefore uneven distribution and patchiness of resources will influence individual interactions (home range, behaviour, movement) with the environment (Johnson *et al.,* 2002; Elmhagen *et al.,* 2014). Home range size may be correlated with group size in carnivores that hunt communally for large ungulates (Macdonald, 1983). As prey availability tends to be very difficult to measure whereas habitat patches are easily defined units that in turn, if distinct enough, can represent variation in prey richness (Greffen *et al.,* 1992; Johnson *et al.,* 2001; Valeix *et al.,* 2012). Mean number of herbivore herds was used as a proxy to patch richness and biomass carrying capacity to determine African lion (*Panthera leo*) group size in Hwange National Park, Zimbabwe (Valeix *et al.,* 2012). However, issues arise when artificial and/or supplementary food resources are brought into the environment. For example Newsome *et al.,*'s (2013) study found that, when dingos (*Canis lupus dingo*) acquired additional food resources created by a supply of food waste at the mines, their home range size diminished. This observation supports the resource dispersion hypothesis.

The resource dispersion hypothesis also predicts that territory size is independent of group size (Johnson *et al.,* 2001). Instead, group size is independently determined by the richness of resources whilst territory size is determined by the spatial dispersion of resources, which is the case for the brown hyaena (Kruuk and Macdonald, 1985) and other surveyed species: Arctic fox (*Alopex lagopus*) (Eide *et al.,* 2004); Blanford's fox (Greffen *et al.,* 1992), (*Vulpes cana*); Eurasian badgers (*Meles meles*) (Rosalino *et al.,* 2005); red foxes (Macdonald, 1981; Johnson *et al.,* 2001; Elmhagen *et al.,* 2014); spotted hyaena (*Crocuta crocuta*) (Mills, 1982). In agreement with Johnson *et al.,* (2003) it was determined that any hypothesis of territory formation cannot be based purely on the defence of food but multiple factors including; patch richness, dispersion and seasonality. For example, Eurasian badger density was found to be influenced by the availability of den sites in Mediterranean cork-oak woodlands, rather than food, as was the case in the UK (Rosalino *et al.,* 2005). In turn white-nosed coatis (*Nasua narica*) home ranges were three times larger in the dry season due to the dispersion of the water sources and not correlated to food abundance (Valenzuela and Macdonald, 2002). The coyote’s (*Canis latrans*) home range sizes are influenced by multiple drivers, in high resource areas territory sizes are determined by contender pressure and an inability to defend larger areas (Wilson and Shivik, 2011). Whereas in low resource areas prey abundance and dispersion rather than intrusion rates are the key drivers of territory size due to the lower density of conspecifics (Wilson and Shivik, 2011). However, it has also be determined that the pattern of resource availability, in both space and time also influences group size as several individuals can exploit resource patches in common areas without creating a cost to energy levels (Johnson *et al.,* 2002). Overlaps of territories are possible if patch richness exceeds the resource requirements of the primary animal some or all the time, allowing for a second to be supported. As was shown to be case for the Cape clawless otters (*Aonyx Capensis*), males were shown to have overlapping home ranges with both other males and females due the high density food patches found in the reed beds (Somers, 2004). Acquisition of conclusive evidence from field studies to support the carnivore group size versus territory size hypothesis has been limited, as sample sizes in GPS radio tracking studies are limited (Johnson *et al.,* 2001).

Carnivore densities are also influenced by competitive interactions with other carnivores in the community. Competitive predator interactions can be based on exploitation or interference (Linnell and Strand, 2000). Interspecific competition can have strong influences on the distribution and abundance of carnivores and should be an essential consideration in their conservation (Creel, 2001).

Lethal encounters are widespread amongst mammalian carnivores, either the individual is predated or interspecific killing occurs where the individual is killed for reasons other than food (Linnell and Strand, 2000). Interspecific killing is not random but influenced by trophic relationships, and taxonomic relatedness, body size and dietary overlap, with large-bodied carnivores able to exclude small ones from habitat patches or prey carcasses (Creel, 2001; Donadio and Buskirk, 2006). The greater the dietary overlap the higher the intensity of killing interactions however when the body sizes of the competitors become similar the intensity decreases (Donadio and Buskirk, 2006; Richie and Johnson, 2009; Pereira *et al.*, 2014).

Apex predators may control smaller 'mesopredators' through intraguild interactions. The removal of these apex predators may lead to changes to the intraguild interactions. This has the potential to create the increase in mesopredator numbers termed 'mesopredator release', leading to increase in predation on smaller prey (Prugh *et al.*, 2009; Richie and Johnson, 2009). More than 95 % of the studies involving apex predators and mesopredators found evidence to support either mesopredator release and/or suppression showing that this phenomenon is both widespread globally and taxonomically (Ritchie and Johnson, 2009). For example, when Eurasian badgers were culled for disease control the decline lead to a release and increase in density of the mesopredator, red fox (Trewby *et al.*, 2008). As apex predator numbers decline and become locally extinct in areas previously suppressed population are undergoing 'mesopredator release'. For example in North America over the past 200 years 60 % of mesopredator ranges have expanded, whereas all apex predator ranges have contracted (Prugh *et al.*, 2009). Further to this, as mesopredators are less vulnerable to extinction than larger carnivores, their rise to apex predator status is likely to become more common (Roemer *et al.*, 2009). In light of this across much of the world, mesocarnivores are now filling the roles of apex predators in their communities, due to the removal of large carnviores by anthropogenically driven extinctions (Roemer *et al.*, 2009). By contrast, an increase in apex predator abundance can lead to a disproportionate four fold negative effect on mesopredator abundance (Ritchie and Johnson, 2009). However, not all mesopredators are prone to 'release'. Those that occur in highly specialised habitat niches or poses specialised defensive mechanisms, such as the repellent chemicals sprayed by skunks (*Mephitis mephitis*), have been found to be unaffected and do not adhere to the process of 'mesopredator release' (Ritchie and Johnson, 2009). It is important to understand the most effective methods of predicting and managing mesopredator release as there are currently high social, economic and ecological costs arising from mesopredator outbreaks.

In Africa body size, tooth morphology and killing technique are similar within the assemblages of large sympatric felids (e.g., cheetah, lion and leopard), subsequently cheetahs have been found to move into areas of low lion and spotted hyaena density to avoid immediate risk and cub predation (Durant, 2000; Donadio and Buskirk, 2006; Broekhuis *et al.*, 2013; Mills and Mills, 2013). In areas without apex predators, survival of cheetah cubs was substantially higher, therefore the cheetah's inherent need to find food and procreate has to be balanced by its need to avoid predators leading to a reactive response to risk (Broekhuis *et al.,* 2013; Mills and Mills, 2013). Counter-intuitively wild dogs and cheetahs will probably survive best in areas of low prey densities and subsequently low predator densities. Interestingly, for these species the current conservation strategy of conserving areas of high density and biodiversity may be detrimental, with areas of low productivity needed for their specific conservation (Linnell and Strand, 2000; Hayward *et al.,* 2007).

Certain carnivores alter their activity patterns to avoid direct inter-specific competition (Hayward and Hayward, 2006). Behavioural factors leading to differential use of space can facilitate predator co-existence within an area (Creel and Creel, 1996). Hyaenas, leopards and lions are predominately nocturnal and so the cheetahs and wild dogs avoid the large predators by being crepuscular (Mills and Briggs, 1993). Large bodied carnivores present in a human dominated landscape may utilise the same instinctive behaviour towards the human population. For example, wolves (*Canis Lupus*) were influenced by intraspecific competition and availability of resource as well as anthropogenic threats (lethal control) (Rich *et al.,* 2012).

Some carnivores also alter their behaviour in relation to habitat type, the denser the vegetation the closer two competing carnivores will coexist as the visibility consequently the detection rates will be lower (Broekhuis *et al.*, 2013). In turn the rate of kleptoparasitism is reduced as carcasses are well concealed in comparison to open plains (Creel, 2001).

Africa's large predator guild competes for a limited food resource base, of which the lion and spotted hyaena are the largest in the guild with their preferred and actual dietary requirements overlapping, therefore these two carnivores interact intensely (Hayward and Hayward, 2006; Pereira *et al.,* 2014). However, these two key predators are absent from the unprotected areas in South Africa, and the remaining carnivores use similar resources and therefore have a dietary niche overlap (Hayward and Kerley, 2008), such as the brown hyaena and black-backed jackal (Yarnell *et al.,* 2013). As the density of apex predators is typically higher inside the protected areas of South Africa this factor may mean that the home ranges of mesopredators inside the reserves are larger, due to the inter-specific competition driving the mesopredators to transverse over larger areas to avoid direct conflict (Owens and Owens, 1978; Mills, 1982; Dyk and Slotow, 2003). However the presence of apex predators is double edged as they may benefit some mesopredators such as the brown hyaena by providing a constant and predictable source of carrion to scavenge and therefore the quantity of available food is higher inside the protected areas compared to the rate of natural mortality found in the unprotected areas (Mills, 1990; Merwe *et al.*, 2009; Yarnell *et al.*, 2013). Conversely in some areas the brown hyaena is utilising other large predators such as leopard and cheetah, as surrogates for the role of the lion in terms of ungulate kills and carrion creation (Stein *et al.,* 2013).

As relationships of carnivores based on hunting versus scavenging strategies are flexible, they in turn undergo changes in response to their circumstances (Pereira *et al.,* 2014). Therefore with apex predators missing from the unprotected areas in South Africa, it may be that some mesopredators have changed their functional role in the ecosystem to become the apex predators (Merwe *et al.,* 2009; Yarnell *et al.,* 2013), which is likely to increase human carnivore conflict.

1.7. Focal Study Species: Brown Hyaena

The brown hyaena belongs to the Hyaenidae family in the Order Carnivora. Only four species (in four genera) of hyaena are extant today: *Crocuta* (spotted hyaena), *Hyaena* (striped hyaena), *Parahyaena* (brown hyaena) and *Proteles* (aardwolf) (Koepfli *et al.*, 2006). In 1972 the brown hyaena was deemed the rarest large carnivore in Africa and listed as ‘Endangered’ by the IUCN Red List (formerly Red Data Book) (Skinner, 1976; Mills, 1978). Under the South Africa Biodiversity Act 2004 (Act 10 of 2004) the brown hyaena is listed as a protected species which means the species is of national importance and requires national protection (Department of Environmental Affairs and Tourism, 2007). However if the species is deemed to be causing damage to stock or poses a threat to human life a permit can be obtained under the Act to dispose of the individual using a variety of sanctioned methods: environmental friendly poison; bait and traps (excluding gin traps); dogs, for flushing or retrieving purposes; suitable firearms; luring by smell or sound; motorised vehicles and aircraft; and flood/spotlights (Department of Environmental Affairs and Tourism, 2007).

Brown hyaena occur within a restricted distribution range in the South West Arid Zone of Southern Africa and the estimated global population equates to <10,000 mature individuals (Wiesel *et al.*, 2008). Botswana has the largest population of brown hyaena estimated to be 3,900 (Hofer and Mills, 1998) with numbers in Namibia to be estimated between 522 and 1187 (Hanssen and Stander, 2004). The brown hyaena is now classified as ‘Near Threatened’ by the IUCN Red List (Wiesel *et al.,* 2008), with approximately 2,500 free ranging brown hyaena remaining in South Africa (Friedmann and Daly, 2004) updated from 1,700 in 1998 (Mills and Hofer, 1998ab). The entire population is deemed to be declining (Wiesel *et al.*, 2008) however in some areas of Namibia it is thought to be locally increasing (Maude and Mills, 2005).

The brown hyaena has predominately been studied in the north and west of its range in the Kalahari regions of Botswana and South Africa, with other studies focusing on the coastal populations of Namibia. In the majority of their South African range, brown hyaena studies are relatively rare (Burgener and Gusset, 2002; Maude, 2005). The majority of the research focus has been in North West Province of South Africa determining brown hyaena occupancy and farmers attitudes towards carnivores (Thorn *et al.,* 2009; 2011ab; 2012; 2013). Therefore, this study has pinpointed a gap in the current research firstly by conducting a national questionnaire of farmer's attitudes towards carnivores, including the brown hyaena. Secondly by understanding the extent to which the brown hyaena interacts both inside and outside protected areas across South Africa using remote camera traps and GPS collars. The brown hyaena within this specific environment is poorly understood. Therefore, this study aims to fill a gap within our knowledge and understanding of this species in South Africa.

The habitat preference of brown hyaena varies from open desert or semi-desert such as the Namib and Kalahari to the dry open scrub and woodland savannah, Mopani scrub and tree savannah the sweet bushveldt of the northern Transvaal and bushveldt areas of Southern Africa (Skinner, 1976). The brown hyaena is a nocturnal and elusive carnivore that lives in clans and forages alone. It can travel large distances to find food, with some records indicating movements of over 50 km per night (Mills, 1982). The movement patterns of the brown hyaena in the Kalahari were found to be negatively influenced by the local density of spotted hyaena and lions (Mills and Mills, 1982). A large component of brown hyaena diet is made up of carrion, which it finds with a well-developed sense of smell as well as acting on visual and auditory cues (Mills, 1978; 1982; 1990).

The physiology of a brown hyaena is well suited to its habitat (Mills, 1990). In conjunction with being nocturnal the hyaenas have adapted to become water independent, which means they do not need to directly rely on open water sources but can instead absorb water directly from their food, giving them greater flexibility in their habitat selection.

The brown hyaena's diet ranges from plant matter, fruits, invertebrates, reptiles and ostrich eggs (*Struthio camelus*) to game meat (Mills and Mills, 1978; Mills, 1990; Burgener and Gusset, 2002; Merwe *et al.,* 2009; Yarnell *et al.,* 2013), which makes the species very adaptable to difficult environments. Meat from large mammals often makes up the largest component of the diet, with the other proportions of the dietary content from insects and vegetable matter varying in line with the available resources of the area (Mills, 1990; Maude and Mills, 2005; Merwe *et al.,* 2009; Wiesel, 2010; Yarnell *et al.,* 2013). Along the Namib Desert coastline the diet has become specialised almost exclusively on Cape fur seals (*Arctocephalus pusillus*) due to their abundance in the region (Siegfried, 1984; Kuhn *et al.,* 2008; Wiesel, 2010). The hyaenas in the Kalahari have been known to hunt these species: bat-eared foxes (*Otocyon megalotis*), springbok lambs (*Tidorcas marsupialis*), springhares (*Pedetes capensis*), small rodents and two bird species the black (*Afrotis afraoides*) and red crested (*Lophotis ruficrista*) korhaans (Mills, 1978). However, brown hyaenas are predominantly scavengers and only opportunistic primitive hunters demonstrated by 4.7% of 128 kill attempts in the Kalahari being successful (Mills, 1978; 1990). The hyaena will remove pieces of the carcass and carry it off for undisturbed consumption and predator avoidance as well as burying or 'caching' pieces of leg bone, hide or ostrich eggs in a variety of places (bush, tall grass, down a hole) to act as store and food resource that can be utilised later (Mills, 1978).

The brown hyaena's relationship with other large carnivores may have implications for its persistence in both protected and unprotected areas (Ray *et al.,* 2005). Some evidence for competition between brown and spotted hyaena has been found in the Kalahari by Mills (1990) but the impact of introduced spotted hyaena to protected areas, on local brown hyaena populations is unknown. In addition, other large predators in the ecosystem may be beneficial and at the same time detrimental to brown hyaena populations. On the one hand, brown hyaena can benefit from the presence of other large carnivores as they will have more scavenging opportunities in terms of prey remains which may positively influence density (Mills, 1982; Merwe *et al.,* 2009; Yarnell *et al.,* 2013). If this is true, then brown hyaena populations that exist without lions, and spotted hyaena might be limited by the number of scavenging opportunities available to them. In contrast, brown hyaena could be negatively affected by the presence and interspecific competition associated with other large predators which also take scavenging opportunities (Mills, 1982; 1990). The brown hyaena might also be killed directly by either spotted hyaena or lions (Mills, 1990).

The relationship between black-backed jackal and brown hyaena is not constant and dependent on the area in which they reside. In areas with apex predators, brown hyaenas and black-backed jackals can be defined as mesopredators whereas in unprotected areas where apex predators are locally extinct the two species may act as the apex predators (Merwe *et al.,* 2009; Yarnell *et al.,* 2013). Increased resource availability (biomass) provided by apex predators can lead to a decline in interspecific competition however in the unprotected areas limited resources and differences in body size can lead to niche partitioning.

Different carnivore species exhibit different feeding behaviour, for example leopards are known to take their kills into trees to avoid competition with apex predators. However, the brown hyaena has been observed under the trees collecting the scraps of carrion dropped from the carcass (Mills, 1978). In the unprotected areas the leopard's behaviour has been observed to have partially altered in that there is a reduction in the number of kills lifted into trees, probably because of the lack of apex predators. In turn brown hyaenas have been found scavenging at some of these carcasses (Stein *et al.,* 2013). In the Namibian farmlands the leopard and, to some extent, the cheetah have taken on the role of the lion providing a continuous supply of medium-large sized ungulate prey carcasses that the brown hyaena feed on (Stein *et al.,* 2013). Currently stock losses in the area are low due to the abundance of wild prey, in turn tolerance to carnivores is high (Stein *et al.,* 2013). Consequently maintaining a healthy population of leopard and cheetah in the farmlands will directly benefit the brown hyaena. Nevertheless, the brown hyaena is adaptable and capable of surviving in the absence of these large predators, exploiting natural carrion and other food resources (Yarnell *et al.*, 2013).

The density of brown hyaena varies geographically from southern Kalahari approx. 1.8/100km² and the Kgalagadi Transfrontier Park, South Africa, 2.4/100km² (Mills and Mills, 1982; 2013); Makgadikgadi area of Botswana ≤2.0/100km² (Maude, 2005); Pilanesberg National Park, South African 2.8/100km² (Thorn *et al.,* 2009), agricultural land, North West province, South Africa 0.15/100km² (Thorn *et al.,* 2011b); western Botswana 2.3 - 2.88/100km² (Kent and Hill, 2013). Overall the density of brown hyaena has been to found to be significantly higher in protected areas compared to the unprotected farmland areas (Thorn *et al.,* 2009; Yarnell *et al.,* 2013).

In line with the densities of the brown hyaena the known home range sizes also vary geographically; the coastal region of the Namib Desert was 31.9 to 220 km² (Skinner *et al.,* 1995) and between 420 and 1250 km² (Wiesel, 2006); 170 km² in the wet season and 400 km² in the dry season (Owens and Owens, 1978, 1979, 1996); Central Kalahari, Makgadikgadi area in Botswana, 447 km² inside a protected area and 192 km² outside the protected area (Maude, 2005); Southern Kalahari, average 330 km² (range 276 to 481 km²) (Mills, 1982; 1984). The brown hyaenas on average spend 65% of their time within their core home ranges areas in comparison to 35% in the peripheral areas (Mills, 1983). Home ranges, when varying in size never overlap more than 20% with neighbouring ranges

(Mills, 1982). The density and home range size has been shown to fluctuate according to the varying levels of protection (Marker and Dickman, 2005; Maude, 2005). For example, in the Makgadikgadi area of Botswana the home range sizes in unprotected cattle ranch areas were less than half the size than those of the hyaenas inside the protected areas (Maude, 2005).

The study of the brown hyaena's social structure has determined that males are four times more likely to become nomadic compared to females (Mills, 1990). Nomadic males can make up to 33 % of the adult male segment and 8 % of the total population and have been shown to have the largest home ranges (Mills, 1990; Wiesel, 2006). Brown hyaenas are unusual amongst social carnivores even though they live in permanent clans the adults are rarely together (Owens and Owens, 1996). Scent marking in the form of pastings on grass stems and latrines are deposited at a significantly greater rate along territorial boundaries (Mills, 1980; Skinner *et al.,* 2005) as fellow group members can recognise each other's pastings (Mills, 1983). Brown hyaenas are unique among hyaenas as they produce a scent mark with not one but two distinctive pastes (Mills, 1980). Dominant males scent mark their territory at a significantly greater rate than subordinates and nomadic males (Owens and Owens, 1996). Throughout their geographical range brown hyaenas have shown a strong preference towards the utilisation of the road network within their respective home range areas (Mills, 1990; Burger and Gusset, 2003; Thorn *et al.,* 2009; Hulsman *et al.,* 2010). Roads are used as territorial boundaries, which the hyaena marks by continuous scent marking, defecation (latrines) and patrols (Mills, 1990; Burger and Gusset, 2003; Thorn *et al.,* 2009; Hulsman *et al.,* 2010). Latrines have been found to be located on prominent land marks and their usage to vary around the brown hyaenas' geographical range from low (South Africa, Hulsman *et al.,* 2010) to high (Kalahari, Mills, 1982) depending on variations in the resources that drive social organisation and density.

There are no significant size differences between genders however due to the hierarchical structure females are dominant over males at carcasses (Owens and Owens, 1996). Clan members defend a common territory but they do not jointly defend caresses against other carnivores (Owens and Owens, 1996). Females and other clan members are drawn to the location of any breeding dens as it is the focal point of society (Mills, 1990). All females, including those without cubs, participate in the raising of the young by bringing food to the den (Owens and Owens, 1979). There are several types of dens, the day den where hyaenas rest during the day but are not permanent and the communal den where a mother suckles cubs (Owens and Owens 1979; Mills, 1983; 1990). Dens will only be located in areas surrounded by a forging area which can fulfil the female and cubs energy requirements (Mills, 1982). The resource dispersion hypothesis can account for the majority of variability in relation to group and clan size, as clan size is affected by food patch richness and clan size is influenced by distance to food (Mills 1982; Mills, 1990; Skinner *et al.*, 1995).

Outside protected areas, brown hyaena population trends are unknown but numbers are presumed to be declining due to a variety of anthropogenic threats: shooting, poisoning, trapping and hunting with dogs in predator eradication or control programmes; inadvertent killing in non-selective control programmes and habitat fragmentation (Mills, 1998; Mills and Hofer 1998; Maude and Mills, 2005; Wiesel *et al.*, 2008; Kent and Hill, 2013). The main driver of persecution is that brown hyaena are perceived livestock killers by farmers, a concept that has largely been found to be untrue with very few cases of reported livestock predation (Skinner 1976; Mills and Hofer, 1998; Maude and Mills, 2005; Thorn *et al.*, 2009; 2011b; 2012). Where livestock has been taken by brown hyaena it has been found to be a few problem individuals that have been responsible (Skinner, 1976). Furthermore, brown hyaenas are inefficient hunters, therefore the landowner perception that brown hyaena are a threat to livestock and cause a major economic loss may not be based on hard evidence and could have lead to the indiscriminate and unjustified persecution of this species (St John *et al.,* 2011). Therefore, if brown hyaenas are indeed a low risk threat to livestock, these risks can be mitigated by effective livestock husbandry.

Brown hyaena occupancy of an area outside of the protected areas is influenced by the attitudes of the landowners, with positive attitudes leading to greater occupancy (Thorn *et al.*, 2011b). In recent years the brown hyaena has demonstrated resilience within the unprotected areas even though occupancy is low in the extensive croplands (Thorn *et al.*, 2011a). Of all Africa’s large carnivores, the brown hyaena is least likely to cause livestock losses and consequently the carnivore that has the ecological attributes to allow co-existence with humans in livestock areas.

In South Africa the brown hyaena historically occurred from the Southern Cape throughout the south west arid zone to northern south west Africa (Eaton, 1976; Mills and Hofer, 1998). Specifically for brown hyaenas four major surveys using questionnaires and expert opinions have been undertaken to determine the species distribution across southern Africa. Eaton (1976), Mills and Hofer (1998) reassessed the status of the brown hyaena through the utilisation of questionnaires and experts as part of the IUCN species action plan (Figure 1.1.). Followed by Friedmann and Daly (2004) in conjunction with the African Mammal Conservation Assessment and Management Plan (CAMP) Report for South Africa reviewed the distribution of the brown hyaena for just South Africa (Figure 1.2.). As part of the re-assessment by the IUCN/SSC Hyaena Specialist Group and the Red List for brown hyaena in 2008 the distribution map was updated (Wiesel *et al.*, 2008) (Figure 1.3.).

The results from all four studies have provided crucial information on the distribution of brown hyaena. Indirect information from field studies, museum records, informal sightings, literature, hearsay and belief can all yield distribution data (Friedmann and Daly, 2004). The distribution map produced by Mills and Hofer (1998) (Figure 1.1.) followed by Friedmann and Daly (2004) (Figure 1.2.) and subsequently Wiesel *et al.*, (2008) (Figure 1.2.) illustrates the changes in the known distribution of the brown hyaena over time from initially being predominately based in the provinces that make up the northwest of South Africa (Limpopo, North West, Mpumalanga, Gauteng) and subsequently moving down into the Free State and then onward into the Eastern Cape (Figure 1.3.) Other areas of high density included; northeast of KwaZulu-Natal (KZN) and in the far north of the Northern Cape inside the Gemsbok National Park. The Western Cape has the lowest density of brown hyaenas (Figure 1.3.). The distribution of brown hyaena in 2008 has been substantially increased as it now covers the majority of South Africa, with the exceptions being found along the south and eastern coastlines (Figure 1.3.).

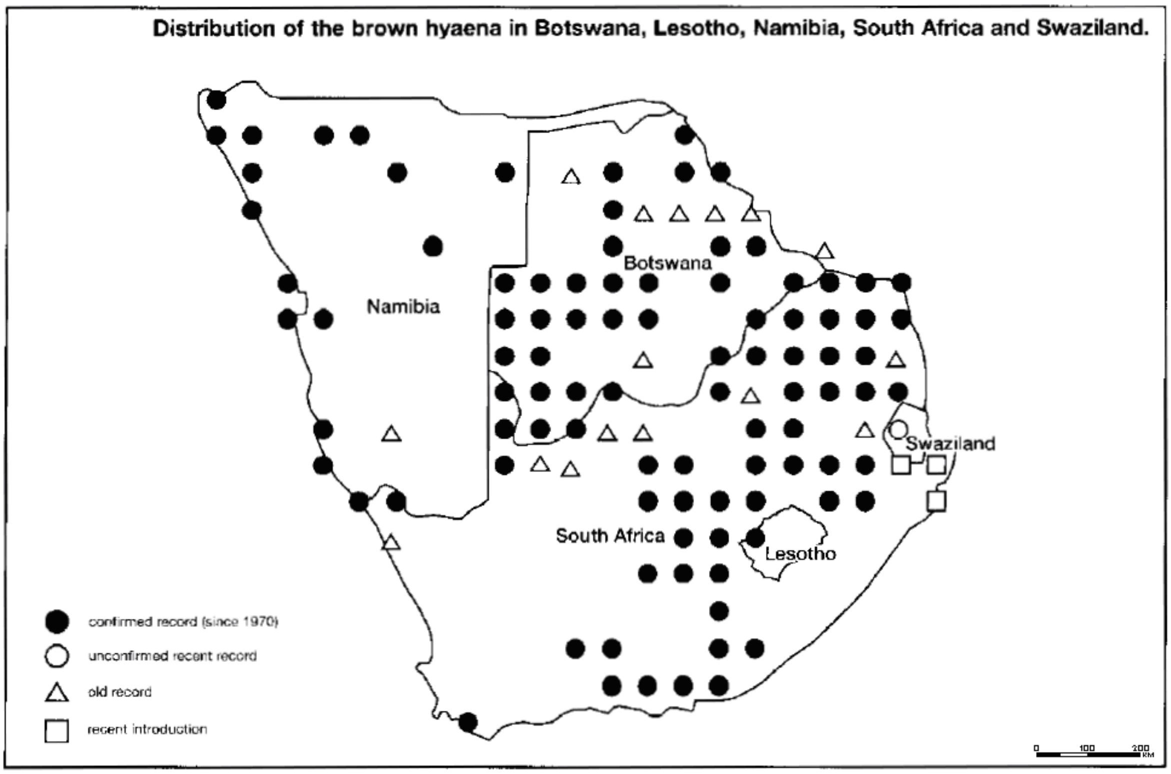

Figure 1.1. The distribution of brown hyaena across southern Africa, as determined by confirmed, unconfirmed, old records and recent introductions since 1970 (taken from: Mills and Hofer, 1998).

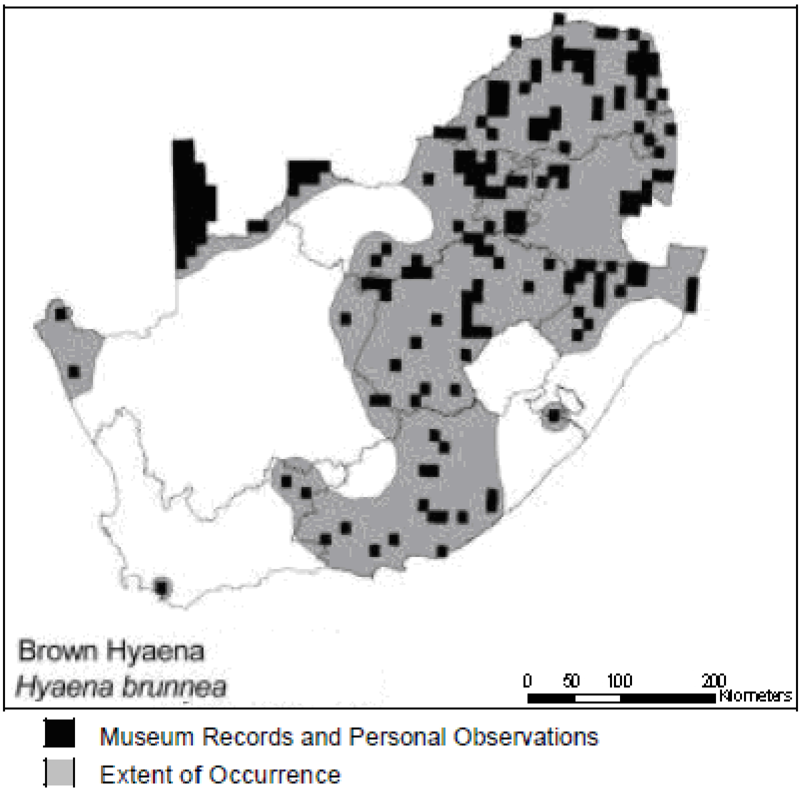

Figure 1.2. The extent of occurrence of the brown hyaena across South Africa, produced by the African Mammal Conservation Assessment and Management Plan Report for South Africa (taken from: Friedman and Daly, 2004).

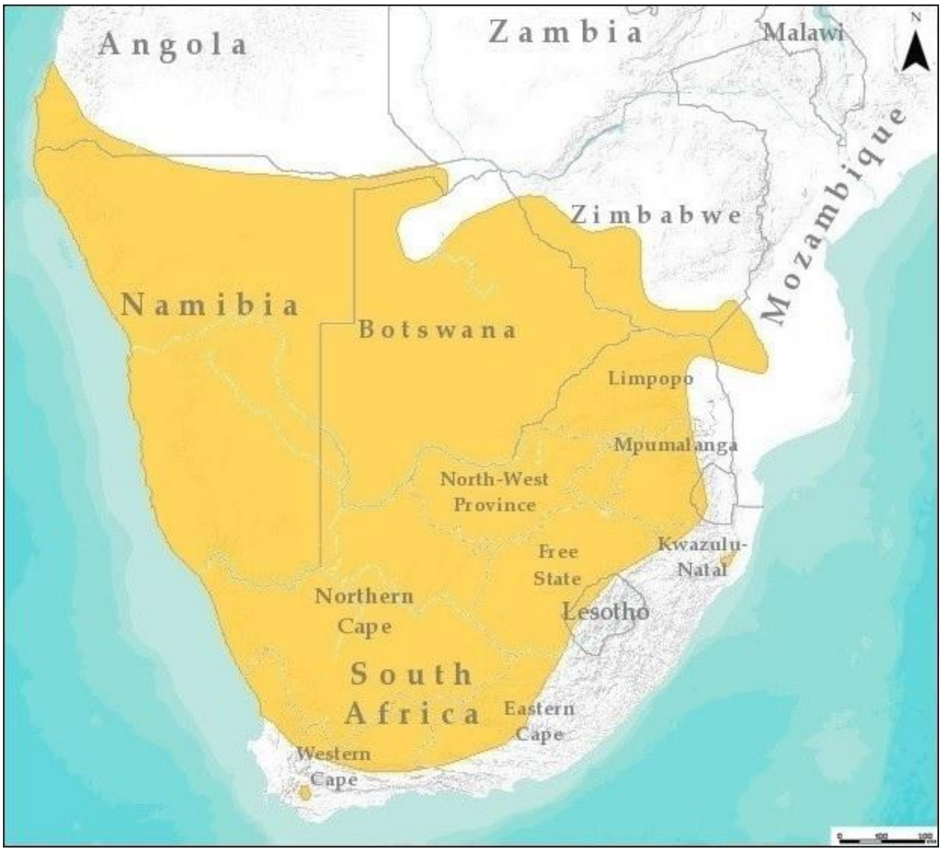

Figure 1.3. The extent of occurrence of the brown hyaena across Southern Africa, produced by IUCN Red List of Threatened Species, (Version 2013.2.) (Wiesel *et al.,* 2008).

In the Eastern Cape reintroductions of brown hyaenas began in 1986 (Hayward *et al.*, 2007a), these trends have continued to the present day (Hayward *et al.,* 2007b). Known reintroductions areas include Great Fish River (1986), Shamwari (2001), Kwandwe (2002), Mountain Zebra National Park (2005) in the Eastern Cape (Hayward *et al.,* 2007b), Doornkloof nature reserve and Mokala National Park, Northern Cape (Eric Hermann, Dept Nature Conservation Northern Cape, *pers. comm.,* 2011 and Marna Herbst, SANParks, *pers. comm.,* 2011) and Pidwa Wilderness Reserve, Limpopo Province. However on release from Mokala National Park the two brown hyaenas went outside the park boundaries onto farmland where one was shot by a farmer after a confirmed killing of livestock therefore the other had to be recaptured and removed from the area a taken back to a rehabilitation centre (Marna Herbst, SANParks, *pers. comm.,* 2011). Between 1976 and 1985 in an attempt to conserve the species, 30 hyaenas were relocated into conservation areas, however only five were radio collared and the fate of the majority was unknown (Skinner and van Aarde, 1987). Inadequate monitoring of brown hyaena in some of reserves has continued and consequently prevented a full assessment of the reintroductions success (Hayward *et al.*, 2007a).

Unlike Eaton (1976), Mills and Hofer (1998) identified that brown hyaenas were found in many of the smaller game reserves. In South Africa an area of 33,205 km² has been set aside for conservation or multiple use wildlife areas by private individuals or groups (Pinnear, 1991), which is potentially suitable habitat for brown hyaenas and other medium-large bodied carnivore species (Lindsay *et al.*, 2005). Out of 22 national parks across South Africa brown hyaena were found to be present in 50 % (Table 1.1.).

Table 1.1. Presence/absence data on brown hyaena in the 20 designated National Parks in South Africa.

National Parks	**Brown hyaena pres/ab**
Addo Elephant	Present (reintroduced)
Agulhas	Absent
Augrabies Falls	Present
Bontebok	Absent
Camdeboo	Absent
Garden Route (Knysna lakes, Tsitsikamma section, Wilderness section)	Absent
Golden Gate Highlands	Absent
Karoo	Absent (used to be present)
Kgalagadi Transfrontier	Present
Kruger	Present (north)
Mapungubwe	Present
Marakele	Present
Mokala	Present
Mountain Zebra	Present
Namaqua	Absent
Richtersveld Transfrontier	Present
Table Mountain	Absent
Tankwa Karoo	Present
West Coast	Absent
Wilderness	Absent

1.8. Other Carnivores in the Study

African civet (*Civetticus civetta*) to be known here on as civet is classified as 'Least Concern' on the IUCN Red List (Ray *et al.,* 2008). The civet is only found in sub-Saharan Africa, specifically tropical rainforests and dry savannahs where the preferred habitat is thickets (Abebe, 2003). The species is common and widely distributed across its range, which includes both protected and unprotected areas (Ray *et al.,* 2008). There are no major threats to the species and the population trend is unknown (Admasu *et al.,* 2004; Ray *et al.,* 2008; Tsegaye *et al.,* 2008). However, they can be found within the bushmeat trade and markets. They are used in traditional medicine in which their perineal gland secretion 'musk' is extracted and exported (Admasu *et al.,* 2004; Ray *et al.,* 2008; Tsegaye *et al.,* 2008). The civet is predominately nocturnal (Ray, 1995; Admasu *et al.,* 2004). Its diet consists of these major items: wild fruit, berries, eggs, invertebrates, carrion and rodents as the species is omnivorous (Ray, 1995; Abebe, 2003). The civet is not deemed to be an excellent hunter and it detects prey using smell and sound (Ray, 1995). The civet is a solitary animal that occupies well-defined territories in Ethiopia with a home range size of 11.1 km^2 (Ray, 1995; Admasu *et al.,* 2004). The civet utilises scent marking concentrated on road sides on prominent natural (plants) and man-made objects (Admasu *et al.,* 2004). In areas without permanent apex predators it is expect that the abundance of civets, will increase due to a reduction in competition.

Black-backed jackal (*Canis mesomelas*) to be known here on as jackal, is classified as 'Least Concern' on the IUCN Red List (Loveridge and Nel, 2008). Jackals are persecuted for their role as livestock killers and as vectors of rabies, their population is described as stable (Loveridge and Nel, 2008). Jackals are the most common of the larger carnivores in Sub-Saharan Africa and are divided into two distinctive populations, Eastern and Southern Africa (Kaunda and Skinner, 2003; Loveridge and Nel, 2008; Klare *et al.,* 2010). Throughout southern Africa they are abundant and widespread, favouring the more arid regions (Kaunda and Skinner, 2003). Jackal home range sizes varies from: 0.7 km^2 and 3.5 km^2 in Kenya (Fuller *et al.,* 1989); 2.6 km^2 to 5.2 km^2 south-western Kalahari, (Ferguson *et al.,* 1983); 0.20 km^2 to 11.11 km^2 on the coastline in Namibia (Jenner *et al.,* 2011); 17.8 km^2 South African game farm (Kamler *et al.,* 2012) and have been found to travel up to 20 km to find food (Jenner *et al.,* 2011). The jackal's diet fluctuates in relation to temporal, spatial and seasonal changes which in turn affects the availability of prey. Jackals are opportunistic predators with the propensity to utilise numerous sources of prey depending on its availability (Kaunda and Skinner, 2003; Loveridge and Nel, 2008). The varied diet of the jackal ranges from seeds, fruits, invertebrates, birds and small rodents to medium-large mammals (>15 kg) including springhares, gazelle adults and fawns in particular springbok (Klare *et al.,* 2010; Yarnell *et al.,* 2013). Jackals live in pairs and family groups and are often seen hunting and foraging in pairs (Lamprecht, 1978). Jackals have been found to switch to animal diets in response to increased demand for protein, energy and other nutrients as a result of their reproductive activities (Kaunda and Skinner, 2003). The relationship of hunting to scavenging for the jackal is reliant on the level of resources. Where apex predators are present and high volumes of carrion are available then it may be presumed that the jackal becomes predominantly a scavenger although further evidence is required (Lamprecht, 1978; Kaunda and Skinner, 2003; Yarnell *et al.*, 2013). High densities of large-bodied carnivores competition at carrion has a direct influence on jackal's feeding ecology, hunting behaviour and social organisation, which lead to the utilisation of insects, fruits and small rodents only (Lamprecht, 1978; Kaunda and Skinner, 2003; Yarnell *et al.,* 2013). Alternatively where apex predators are not present, jackal were seen to be becoming active hunters of prey (Kaunda and Skinner, 2003).

The Leopard (*Panthera pardus*) is classified as 'Near Threatened' on the IUCN Red List (Henschel *et al.*, 2008). Under the South Africa Biodiversity Act 2004 (Act 10 of 2004) the leopard is listed as a vulnerable species which means the species is facing a high risk of extinction in the wild in the medium-term future (Department of Environmental Affairs and Tourism, 2007). However, if the species is deemed to be causing damage to stock or pose a threat to human life a permit can be obtained under the Act to dispose of the individual (Department of Environmental Affairs and Tourism, 2007). The leopard has the widest distribution of all the cats in Sub-Saharan Africa (Henschel *et al.,* 2005; 2008). Leopards are under threat from habitat loss and fragmentation of their range as well as being hunted for trade, trophies and pest control (Henschel *et al.*, 2008). This had led to the decline of the population across large parts of its range, which if continued may lead to the species being re-classified as 'Vulnerable' (Henschel *et al.,* 2008). Densities of leopard vary with prey availability, habitat and degree of threat ranging from one per 100 km² to over 30 per 100 km² (Henschel *et al.,* 2008). The leopard's prey base consists of medium-sized ungulates species which range in size from 20 kg - 80 kg accounting for 59 % of the total biomass consumed in Gabon (Henschel *et al.*, 2005) to impala (*Aepyceros melampus*), bushbuck (*Tragelaphus scriptus*) and common duiker (*Sylvicapra grimmia)* (10 kg - 40 kg) on the African savannahs (Hayward *et al.*, 2007). In Phinda Private Game Reserve, South Africa leopards preferred hunting in habitats where prey was easier to catch rather than in areas with higher prey abundance (Balme *et al.*, 2007). In Namibia the leopard's home range size was related to prey abundance (Marker and Dickman, 2005). The leopard is highly adaptable and can survive across numerous landscape types as well as not being constrained by boundary fences and therefore freely moves across the landscape (Balme *et al.*, 2007). Leopards are one of the few apex predators that occurs both within and outside protected areas and are the least affected by competition from lions and spotted hyaenas (Mills and Briggs, 1993).

The Lion (*Panthera leo*) is classified as 'Vulnerable' on the IUCN Red List due to a population decline of approximately 30 % over the past two decades (Bauer *et al.*, 2012). Lions are found in most countries across Sub-Saharan Africa the extent of occurrence is estimated at over 4.5 million km², 22 % of historical range, with the majority being in eastern and southern Africa (Bauer *et al.,* 2012). Lion status is still currently unknown over large parts of Africa (Bauer *et al.,* 2012). Lions are under threat from indiscriminate killing (primarily as a result of retaliatory or pre-emptive killing to protect life and livestock) and prey base depletion (Bauer *et al.*, 2012). Habitat loss and conversion has led to a number of populations becoming small and isolated and has lead to the population trend being described as declining (Bauer *et al.*, 2012). The size of prey species ranges from 190 kg - 550 kg with a preference for 350 kg ungulates (Hayward and Kerley, 2005). In the Kruger National Park lions were responsible for removing over 50% of the biomass killed by the large predators (Mills and Briggs, 1993). The lion is predominantly nocturnal and applies a group hunting strategy as well as also being an opportunistic hunter taking prey such as a warthog (*Phacochoerus africanus*) (Mills and Briggs, 1993; Hayward and Kerley, 2005). Lions have been recorded killing other carnivores such as wild dogs (Mills and Briggs, 1993) and spotted hyaenas (Henschel and Skinner, 1991). Their relationship with brown hyaena is poorly understood.

The spotted hyaena (*Crocuta crocuta*) is classified as 'Least Concern' on the IUCN Red List and remains widespread in a number of countries across Africa (Honer *et al.,* 2008). Under the South Africa Biodiversity Act 2004 (Act 10 of 2004) the spotted hyaena is listed as a protected species (Department of Environmental Affairs and Tourism, 2007). The total global population is estimated to be between 27,000 and 47,000 mature individuals (Honer *et al.,* 2008). The spotted hyaena is under threat from: persecution; incidental snaring; shooting, trapping; poisoning and habitat loss leading to a continuing decline in populations both inside and outside protected areas (Hofer and Mills 1998; Honer *et al.,* 2008). They are perceived as a livestock killer which in Tanzania has been shown to be the case. Conversely in Botswana the hyaenas were found to be primarily feeding on wild species (Kissui, 2008; Kuhn, 2012). However the current level of threat does not merit an alteration in the classification to 'Threatened' (Honer *et al.,* 2008). The legal classification of spotted hyaena varies from "vermin" to fully protected in conservation areas particularly in southern Africa; including Kruger National Park and Kgalagadi Transfrontier Park (Honer *et al.,* 2008).

Spotted hyaenas live in a clan system and are territorial, spending a proportion of their total activities on territory patrol by scent-marking posts, particularly in border regions (Henschel and Skinner, 1991). The spotted hyaena is predominately a nocturnal hunter but undertakes opportunistic scavenging. In some areas the hyaena has been found to have the widest dietary breadth of the larger carnivores, utilising non-mammal food items (Mills and Briggs, 1993). The spotted hyaena's diet consists of medium-large sized mammals ranging from 56 kg to 182 kg including zebra (*Equus burchelli*) and gemsbok (*Oryx gazella*) in Namibia and impala, kudu (*Tragelaphus strepsiceros*) and ostrich in Botswana (Henschel and Tilson, 1988; Hayward, 2006; Kuhn, 2012). The spotted hyaena has a 69 % overlap of preferred prey species with lions (Hayward, 2006). Spotted hyaenas have been known to chase 14 % of cheetahs off their kill but not wild dogs (Mills and Briggs, 1993). Food consumption ranges between 1.5-2 kg/day (East Africa) and 3.8 kg/day (South Africa), it has been found that adult clan members can consume up to 8.7 kg/night including 2 kg/night of skin and bones (Henschel and Tilson, 1988). Population densities are limited by resource distribution, water, shelter, intrusion pressure and territory defence (Henschel and Tilson, 1988; Henschel and Skinner, 1991). The spotted hyaena is regarded as the main competitor of the brown hyaena (Mills, 1990).

1.9. Aims and Objectives

1.9.1. Overall Aim

The primary aim of this research was to understand the fundamentals of conflict dynamics at work in the human-dominated rangelands compared to the protected areas of South Africa. The brown hyaena was used as a model organism for the wider carnivore guild. Specifically, the study aimed to establish the distribution and abundance of brown hyaena and the importance of the protected areas for maintaining a viable population. In conjunction with broadening our understanding of brown hyaenas and other carnivore species within the rangelands of South Africa, which can lead to a comprehensive management strategy for their monitoring and conservation to be created and activated.

The study aimed to significantly enhance our knowledge base in relation to the differences in species richness and relative abundance of individual carnivore species, including the elusive brown hyaena, between areas that are distributed across the protected and human dominated rangelands. By obtaining the distribution of brown hyaena and the relative abundance of individual carnivore species across both protected and unprotected areas a comprehensive picture can be created of how the level of protection and varying apex predator density influences the relative abundance and distribution. An assessment of landowner attitudes to carnivores across the country of South Africa will also be undertaken, the first of its kind, to identify social factors which may lead to carnivore persecution. The national survey will also give an up to date national distribution of large carnivores in South Africa, which is essential for the prioritisation and targeting of conservation management and resources.

1.9.2. Objectives

The objectives of the study were therefore:

i) To utilise local respondent knowledge to map the distribution of medium to large carnivores using the presence absence data gathered from the national questionnaire across South Africa.

ii) To determine the influential factors that drive the attitudes and perceptions of South African farmers towards medium to large carnivores, specifically brown hyaenas, using a web based national questionnaire.

iii) To determine whether there was an overall difference of relative abundance of carnivores between protected and unprotected treatment areas in the North West and Limpopo Provinces of South Africa.

iv) To compare home range estimates and movement patterns of free living brown hyaena inside and outside protected areas in the North West and Limpopo Provinces of South Africa.

v) To determine what ecological and environmental variables influence brown hyaena home range size in the North West and Limpopo Provinces of South Africa.

1.10. Thesis Outline

This thesis is divided into eight chapters.

Chapter 1 illustrates previous work and gives motivation for the work undertaken in this thesis. It also introduces the focal species, brown hyaena and the other medium to large bodied carnivore's discussed throughout the thesis. Chapter 2 describes the regional and individual study areas that were utilised in this study. Chapter 3 presents the distributions and attitudes of landowners towards South Africa's carnivores ascertained through a national questionnaire survey. Chapter 4 compares the relative abundances of multiple carnivore species between protected and unprotected areas in the North West and Limpopo Provinces of South Africa. Chapter 5 specifies the drivers of brown hyaena home range sizes inside and outside protected areas, across the North West and Limpopo Provinces of

South Africa. Chapter 6 summarises the main discussion points and conclusion of the thesis and presents an outlook for future work and management recommendations. Chapter 7 is the references found throughout the thesis. Chapter 8 contains five appendices consisting of the national questionnaire, email sent to respondents, carnivore distribution maps, non-target species captured by the remote camera traps and individual brown hyaena home range maps.

Chapter 2: Characteristics of the Study Area

South Africa makes up 4 % of the African continent and covers five major biomes, containing a rich biodiversity and human population of 51,452 million (Pinnear, 1991; United Nations, 2013). South Africa is made up of nine provinces (Figure 2.1.) and has been ranked the third most biologically diverse country on Earth based on an index of species diversity and endemism, and is one of 12 mega diverse countries which collectively contain more than two-thirds of global biodiversity (Friedmann and Daly, 2004; UNEP-WCMC, 2012).

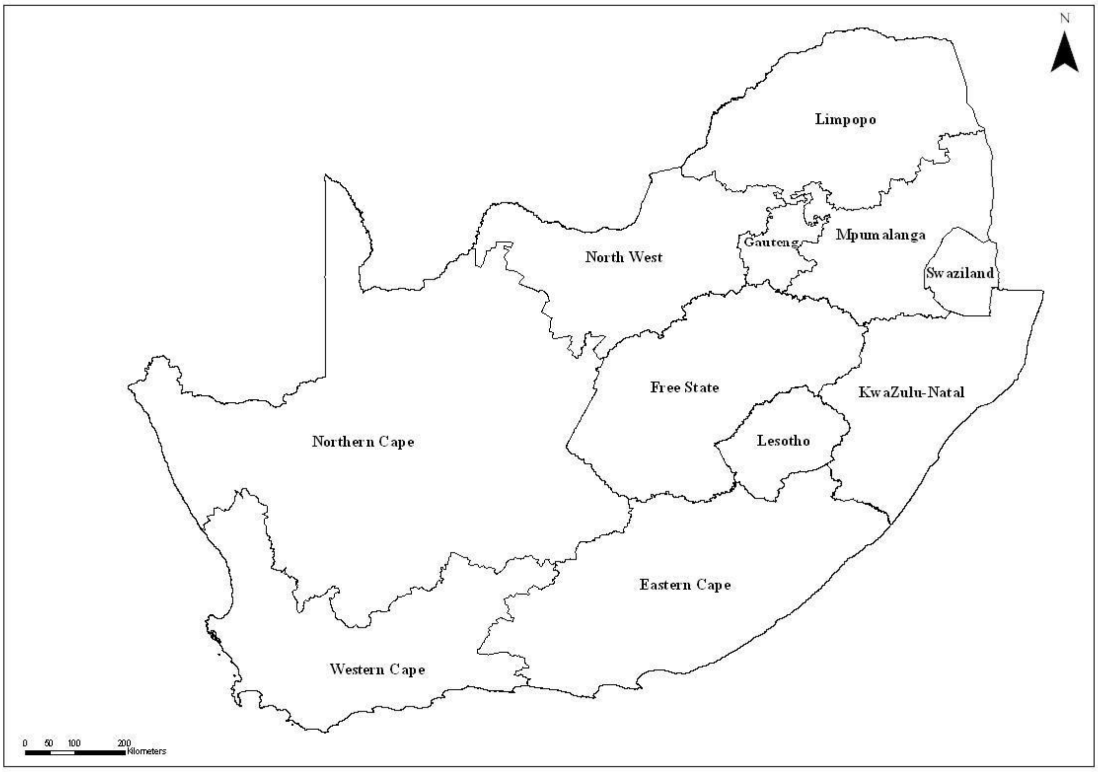

Figure 2.1. Location of the nine provinces across South Africa.

Terrestrial protected areas only cover 6.2% (75,904.69 km²) of South Africa's total land area (UNEP-WCMC, 2012). Between 2000 and 2012 there has been a decline from 7.02% to 6.2% (10,194.38 km²) in the terrestrial area designated as protected (UNEP-WCMC, 2012). With only 6.2% protected in 2012, leaving 93.8% (1,143,506.42 km²) as unprotected rangelands (UNEP-WCMC, 2012). The 6.2% of protected areas represents 20 national parks covering 40,909 km² of which Kruger National Park makes up a significant proportion (19,624 km²) (Pinnear, 1991; Ferreira, 2014). State owned conservation areas contribute to 2.81 % of the total protected areas the breakdown of which can see been in Table (2.1.).

Table 2.1. Breakdown of the 428 state-owned conservation areas in South Africa by land use type (km²) (Pinnear, 1991; Ferreira, 2014).

Type of conservation area	Total number of parks/reserves	Total area covered (km²)
Transvaal (now North West and Limpopo) now Provincial Nature Reserve	50	2,245
Other	138	6,705
Orange Free State (now Free State) Provincial Nature Reserve	14	1,583
National Park	20	40, 909
Natal (now KwaZulu-Natal) parks and nature reserves	79	5,860
Cape (now Northern, Western, Eastern Cape) Provincial Nature Reserve	130	20,003

In 2004, The Red Data Book of the mammals of South Africa identified 57 mammals out of a total 295 species and subspecies of South African mammals to be either threatened or at the risk of extinction in the near future (Friedmann and Daly, 2004). The 57 (19.3%) were assigned threat categories according to the IUCN Red List criteria; 10 (3.4%) ‘Critically Endangered’; 18 (6.1%) ‘Endangered’; and 29 (9.8%) ‘Vulnerable’ (Friedmann and Daly, 2004). A total of 38 (12.8%) species were categorised as ‘Near Threatened’; 53 (18%) species were categorised as ‘Data Deficient’ and 147 (49.8%) as ‘Least Concern’ (Friedmann and Daly, 2004).

In 2013 IUCN stated that 24 (5.2%) of mammal species, 43 (9.3%) of birds, 21 (4.6%) of reptiles and 19 (4.1%) of amphibians are categorised as ‘Critically Endangered’ to ‘Vulnerable’ in South Africa (IUCN, 2013). Out of the carnivore taxa in South Africa according to the IUCN Red List criteria; 5 (0.2%) species are extinct; 44 (1.7%) ‘Critically Endangered’; 108 (4.1%) ‘Endangered’; 208 (7.8%) ‘Vulnerable’; 162 (6.1%) ‘Near Threatened’; 1,891 (70.9%) ‘Least Concern’; and 245 (9.2%) are ‘Data Deficient’ (IUCN, 2013). In relation to endemic species, South Africa has 31 mammals of which 11 (35.5%)

are threatened, 15 bird species (15, 33.3% threatened) and 42 amphibians (16, 38.1% threatened).

Of the total land area of South Africa (1,223,201 km²) 68.9 % is designated as grazing land; 13.7 % potential arable; 9.6 % nature conservation; 1.2 % forestry and 6.9 % as other (Department of Agriculture, Forestry and Fisheries, 2011). The total population of South Africa as counted in 2011 (51,770,560) has increased by 11.2 million since 1996 (Statistics South Africa, 2012). The province with the largest population is Gauteng, which has overtaken KZN (Statistics South Africa, 2012). Uncontrolled population growth was highlighted by Pinnear (1991) as the most deadly threat to South Africa's environment. South Africa's landscape is a consequence of the socioeconomic transformations that have turned original livestock keepers into sedentary farmers (Torquebiau *et al.,* 2012). In 2007 13 % of South Africa's total land area was used for game ranching, which also utilises a third of the country's potential grazing land for game and game related purposes (Bothma, 2005; Cloete *et al.,* 2007). The reason is that game ranching is more profitable than cattle as it generates a higher gross margin per hectare (Cloete *et al.,* 2007). Game ranching systems are typically characterised by high value, multiple use potential and low stocking rates with a combination of exotic (sable (*Hippotragus niger*)/roan (*Hippotragus equinus*)/Cape buffalo (*Syncerus caffer*)) and common species being utilised, as it allows for the greatest financial potential from conversion from cattle to game (Krieuter and Workman, 1992; Cloete *et al.,* 2007).

The main factors impacting on the landscape are cattle herd size, management and soil fertility management practices, including fallowing (Torquebiau *et al.,* 2012). South Africa has the potential to move towards a multifunctional landscape, provided that the relationships between farmers' practices and biodiversity are better formalised and there are tangible benefits for farmers (Torquebiau *et al.,* 2012). However, this is made harder in South Africa by land tenure security problems arising from overcrowding and high population in relation to land availability (Mutangadura, 2007).

2.1. Regional Study Areas: North West and Limpopo Provinces, South Africa

The North West and Limpopo Provinces (Figure 2.1.) provide ideal areas to investigate the fundamental objectives of this study: distribution; land owner attitudes; abundance and home ranges of the focal species, brown hyaena, as well as other carnivore species. These areas provide examples of the differing ecological constraints that exist in South Africa's protected and unprotected areas.

The human populations range from 3,253,000 in the North West to 5,555,000 in the Limpopo Province (Department of Agriculture, Forestry and Fisheries, 2011). The Limpopo Province has a history of relative isolation from major urban and industrial centres and is one of the poorest provinces with nearly 70% of the population living below the poverty line as unemployment is estimated at 60% and 43% of households are landless (McCusker, 2004; Eastwood *et al.,* 2006; Boonzaaier, 2010). The dominant language in the Limpopo and North West Provinces are Sepedi and Setswana respectively (Statistics South Africa, 2012). In the North West and the Limpopo Provinces the majority of the land is privately owned, mostly by whites followed by tribal lands and state land (10%) (Tladi et *al.,* 2005; Eastwood *et al.,* 2006). The Limpopo Province is farmed by both West African and white farmers. The farming practices of the province include extensive livestock, dryland maize, game, beef, potatoes, vegetables and citrus (Eastwood *et al.,* 2006). Centrally there is limited cropping and livestock (Eastwood *et al.,* 2006). In the south of the province, dryland maize and sorghum predominate with limited livestock (Eastwood *et al.,* 2006). Mining also forms a significant land use for the North West but only in specific areas. Examples of materials extracted include; uranium, gold, iron, chrome, manganese, platinum, coal, granite, marble, slate, limestone, wonderstone, andalusite, stone crushing, clay and sand pits (Tladi *et al.,* 2005). Agriculture in some areas is assisted by large irrigation schemes found on the Crocodile, Vaal and Harts Rivers (Tladi *et al.,* 2005). The North West Province has been described by the United Nations as "affected dry lands" (UNCCD 1994), which are perceived to be ecologically sensitive as they are more vulnerable to major ecological disturbances (Mangold, 2002).

The Limpopo and North West Provinces lie within the savannah and grassland biomes (Acocks, 1988). The savannah biome is the largest biome which occurs across 46 % of southern Africa (FAO, 2004). The savannah biome is characterised by a grassy ground layer and a distinct upper layer of woody plants which is referred to as Shrubveld (White, 1983: Acocks, 1988). The environmental factors creating the biome are complex as altitude ranges from sea level to 2,000 m with rainfall varying from 235 to 1,000 mm per year (Acocks, 1988; Low and Rebelo, 1996). The grassland biome is dominated by a single layer of grasses. A major factor delimiting of the biome is the lack of sufficient rainfall which prevents the upper tree layer from dominating, due to the fires and grazing the grass layer remains dominant (Acocks, 1988; Low and Rebelo, 1996). There are two categories of grass plants, sweet grasses (low fibre) and sour grasses (high fibre) (Acock, 1988)

The lower Limpopo Valley is subjected to a high variability of rainfall (Ekblom *et al.*, 2012). There is a north - south rainfall gradient ranging from 375 - 420 mm/year in northern Pafuri to 600 mm/year in the Massingir area (Venter *et al.*, 2003; FAO, 2004). The Limpopo and North West Provinces have similar habitats due to clay thorn bushveldt being widely distributed across both and the vegetation is dominated by Acacia species and turf grasses (*Ischaemum afrum*) (FAO, 2004). In the Limpopo River Valley the vegetation structure is mostly short and shrubby in conjunction with sweet bushveldt. Trees such as *Terminalia sericea*, *Rhigozum obovatum* and *Acacia tortilis* are the most common with grasses dominating the herbaceous layer (Venter *et al.*, 2003; FAO, 2004). The mixed bushveldt vegetation varies from a dense, short bushveldt to a rather open tree savannah, which covers most of the Limpopo Province and the northern area of the North West Province (Venter *et al.*, 2003; FAO, 2004). On the eastern side of the Limpopo Province a mixed lowveldt bushveldt can be found in conjunction with dense riverine woodland (White, 1983: FAO, 2004).

The Waterberg biosphere reserve (2001) designated by the United Nations Educational, Scientific and Cultural Organization's (UNESCO) programme on Man and the Biosphere is located in Limpopo’s Bushveldt district covering 4,145.71 km² and is only one of six such designated areas throughout South Africa. In the Limpopo and North West Provinces land use for domestic livestock farming and game ranching equates to 31.3 % and 35.2 % (totaling 79,552 km²), 9.7 % and 6.4 % is set aside for nature conservation (Department of Agriculture, Forestry and Fisheries, 2011). In 2001 wildlife ranches covered 33,256.52 km² in the Limpopo Province (Bothma, 2005). According to exemption permits, from the 1960s onwards there has been a steady increase in the number of wild ungulates on ranches in South Africa due to the decline in cattle farming in favour of game ranching activities (van der Waal and Dekker, 2000). Game ranching, of which hunting makes the largest contribution to the annual turnover, contributes significantly to the economy, followed by the live game trade and ecotourism (R17 million/yr) (Wessels *et al.,* 1999; van der Waal and Dekker, 2000). The conversion from livestock to wildlife ranching in the Limpopo Province is taking place at a rate of 2.5 % per year. The economic and ecological advantages of land use change are evidenced by this conversion (Bothma, 2005). In 1998 the North West Province contained 2,300 game ranches compared to ten in the 1960s covering 3.6 million hectares equating to 26 % of the total land area, with a mean game ranch size of 1717 ha (van der Waal and Dekker, 2000; Bothma, 2005). Currently there are >14,000 game farms with land conversion identified to be increasing by 3-5,000 km^2 per annum (Bothma, 2005; Thorn *et al.,* 2012). However, it was discovered that 38 % of game ranch manager owners lived outside the province border, which has led to the neglect of game and veldt management.

Grassland and savannah vegetation types of veldt constitute the major proportions of the game ranches of South Africa in turn North West and Limpopo provinces (Trollope, 1990). Stocking rates of different game species will be primarily a function of the grazing and browsing capacity of the veldt (Trollope, 1990). There are three types of grazers; bulk (cattle, buffalo, zebra, waterbuck (*Kobus ellipsiprymnus*)), concentrate (sheep, wildebeest (*Connochaetes taurinus*), gemsbok, reedbuck (*Redunca redunca*), blesbok (*Damaliscus pygargus*), impala) and browsers (goat, giraffe (*Giraffa camelopardalis*), eland (*Taurotragus oryx*), kudu, bushbuck, duiker, steenbok (*Raphicerus campestris*)) (Trollope, 1990). Game farms are populated by a variety of grazer types to maximise the veldt potential and carrying capacity (Trollope, 1990; Cloete *et al.,* 2007). Stocking rates in the North West were estimated to be 48 times higher than the recommended stocking rates, which can lead to overgrazing and habitat degradation (Schwalbach *et al.,* 2001). In semi-arid wildlife areas receiving less than 700 mm of rainfall there is a significant relationship between large herbivore biomass and predicted above-ground primary production, highlighting a clear empirical association between mean large biomass and annual rainfall (Coe *et al.,* 1976). Sustained grazing may alter the botanical composition of semi-arid rangelands from long-lived perennials to short-lived perennials with an affiliated decease in production and therefore carrying capacity (Snyman, 2005).

The western half of North West Province is semi-arid with open grassland and savannah in the central regions with the eastern region containing the greatest diversity of vegetation due to the high rainfall (Wessels *et al.,* 2004; Thorn *et al.,* 2012). Annual rainfall is between 200-650 mm with maximum mean daily temperatures of 32º C in January and minimum mean daily temperatures of 1º C in July. The Drakensberg escarpment that runs along the middle of the Limpopo Province acts as a transition zone between the higher, dyer savannah plains to the west and south and the lower, moister region to the east and the Limpopo River Valley in the north (McCusker, 2004). The region to the east has the most productive agricultural land, with the large timber, tea and fruit plantations being almost exclusively owned or managed by white populations (McCusker, 2004). The low altitude northeast savannah areas contain high species diversity and are well conserved (e.g. Kruger National Park). However, potential conflict arises in the central and eastern regions where areas of high biodiversity merge with suitable agricultural land (Reyers, 2004). The rainfall pattern between 1991 and 2003 has been significantly affected by either El Nino or La Nina causing either extremely dry or wet seasons, which have been more extreme than in any other period in the last 35 years, making rainfall in the area highly unpredictable (Wessels *et al.,* 2004).

2.2. Individual Study Areas

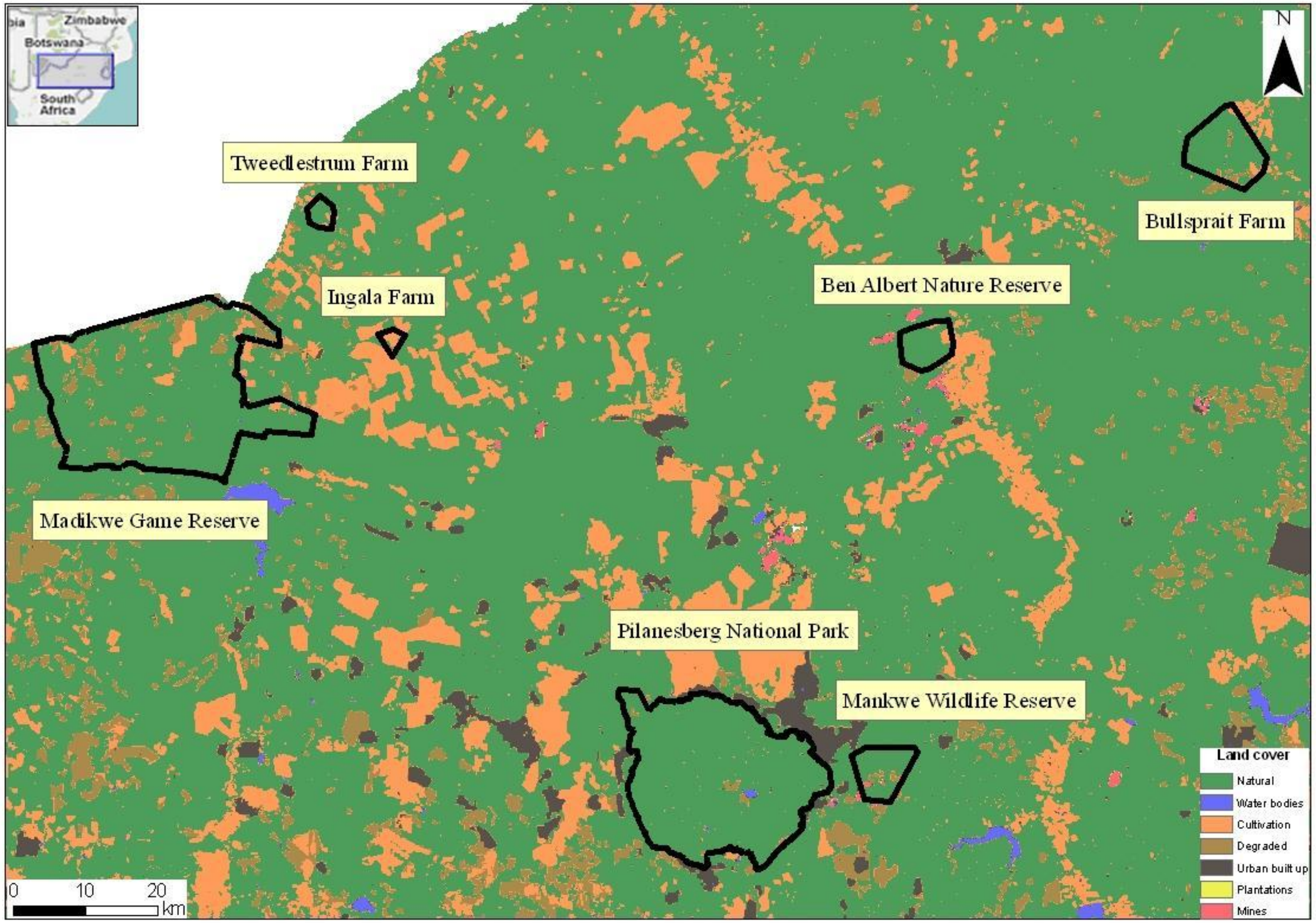

Figure 2.2. Location of the two protected areas and the unprotected area farms, in the North West and Limpopo Provinces, South Africa

2.2.1. Protected Area 1: Madikwe Game Reserve

Madikwe Game Reserve (24º44’44.20"S 26º17’43.08"E) covering 580 km^2 is situated in the North West Province of South Africa and is managed by the North West Parks and Tourism Board (Figure 2.2.). The park was designated as a protected area in 1991, prior to which, the area was covered by degraded cattle farms (Hudak, 2004). The reserve is classified as an arid region as the rainfall varies between 475 mm in the north-east and 520 mm in the south (Table 2.2.). Annual rainfall averaged 520 mm ± 171 mm across 35 area stations from 1909 to 2002 (Hudak, 2004). The altitude ranges from elevation 872 m to 1474 m (Hudak, 2004). Due to this the vegetation has been divided into two main classifications, broad-leaved and microphyllous (fine leaved) communities. The reserve supports a wide diversity of species within its electrified boundary predator proof fence, which creates a closed population (Table 2.3.). The lion and wild dog populations are the only long term actively managed and monitored carnivores within the park. Using the capture mark re-capture technique the current estimate for the spotted hyaena population is between 30 and 53 individuals (Ball, 2007) giving a mean density of 0.09/km^2. There are no estimates for the brown hyaena population inside the reserve. The water supply comes from several man made dams sporadically located across the reserve.

2.2.2. Protected Area 2: Pilanesberg National Park

Pilanesberg National Park (25º14’44.74"S 27º03’30.99"E) lies within the North West Province of South Africa and was established in 1979 (Figure 2.2.). The park covers approximately 550 km^2 its purpose is the conservation of African biodiversity and eco-tourism (Slotow and van Dyk, 2001). The park is managed by the North West Parks and Tourism Board. As the park is situated in the remains of an extinct volcano the terrain is very undulating (Slotow and van Dyk, 2001). The park is situated in the transition zone between the arid Kalahari and the moister eastern savannahs of southern Africa. The habitat consists of mixed Acacia and broad-leaf bushveldt which ranges from thickets to open grassland patches (Table 2.2.) (van Dyk and Slotow, 2003, Thorn et *al.*, 2009). The annual rainfall is approximately 630 mm falling between October and February year (Slotow and van Dyk, 2001). The temperature ranges between *c*. 1 - 5º C in the winter and *c*. 28 - 31º C in the summer (van Dyk and Slotow, 2003). Prior to its creation the most common land use consisted of cattle ranching and arable farmland. Between 1979 and

2003 over 6000 individual herbivores made up of multiple species were reintroduced into the park. The reintroductions also included lions in 1993 (van Dyk and Slotow, 2003). The park contains the majority of the large carnivore guild (lion, leopard, wild dog, cheetah, brown hyaena) except the spotted hyaena (Table 2.3.). The lion and wild dog populations are the only actively managed and monitored carnivores within the park, currently only three cheetah remain. Annual aerial surveys are conducted in both Pilanesberg National Park and Madikwe Game Reserve protected areas to monitor the large herbivore populations. The water supply comes from one main dam in the centre and several smaller dams and springs sporadically located across the park. The movement of wildlife is restricted within the reserve by the electrified boundary predator proof fence surrounding the reserve leading to a closed system.

2.2.3. Unprotected Area: Mankwe Wildlife Reserve

Mankwe Wildlife Reserve (25º14'58.49"S 27º19'17.04"E) is located 10km east of Pilanesberg National Park, in the North West Province of South Africa (Figure 2.2.). The reserve was established in 1982 by fencing off 48 km² of farmland, which is acting as a buffer zone around an explosive factory (Yarnell *et al.,* 2008). The annual rainfall is 650 mm of which >80% falls between November and March creating a sub-arid climate (Yarnell *et al.*, 2007). The mean daily temperatures range from *c.* 11º C in July to *c.* 23º C in December (Yarnell *et al.,* 2008). The reserve is on the transitional vegetation zone producing a landscape dominated by pediment grassland interspersed with deciduous and acacia woodland (Table 2.2.). Yearly fire management is undertaken within the reserve on a rotational basis to maintain the productivity of the veldt and thus to maintain the high density of herbivore species (Yarnell *et al.*, 2007). Even though it is fenced, animals such as leopard and brown hyaena can still move freely between the reserve and the farmland by utilising warthog and aardvark holes created in the fence line (Table 2.2.). This means that the brown hyaena population on the reserve is transient and not a closed permanent population as with the protected areas. A vulture restaurant is present on this site, which provides carrion on a regular basis for vulture research. This may affect the density and behaviour of the carnivores in the area as the carrion provides an additional and easily accessible food source.

2.2.4. Unprotected Area: Farmland

The farmland area, which includes the Ben Alberts Nature Reserve, Bullsprait Farm, Ingala Farm and Tweeldstrum Farm (see Figure 2.2., Table 2.2. and 2.3.) are a mosaic of privately owned blocks all divided by game fencing which is electrified and utilises a mixture of electric strands and wire mesh (Lindsey *et al.*, 2005; Hayward *et al.*, 2009b). Game farming, livestock farming, arable farming, eco-tourism and hunting comprise the main land use types of the area (Wessels *et al.*, 1999; van der Waal and Dekker, 2000). The largest land use type in the area is commercial game farming, which entails the penning of high economic value game using high quality electric predator proofing fencing (Cloete *et al.*, 2007). The remaining game of low economic value are held in larger, less managed areas, managed with semi-permeable fencing (cattle fencing) open to wild animal movement. The second largest land use is mixed farming of both livestock and arable. Solely arable is a minority land use. The livestock farms are sub-divided by low quality fencing which permits the free movement of wild animals, including carnivores such as the brown hyaena and leopard, across the farmland.

Table 2.2. Attributes of the protected and unprotected area study sites (data source: North West Parks and Tourism board (protected areas) and individual farm owners (unprotected areas)).

	Protected Areas		**Unprotected (Farmland) Areas**				
Sites/Attributes	**Pilanesberg National Park**	**Madikwe Game Reserve**	**Mankwe Wildlife Reserve**	**Ben Alberts Nature Reserve**	**Bullsprait Farm**	**Tweeldstrum Farm**	**Ingala Farm**
Established	1979	1991	1982				
Latitude/Longitude	25º14’44.74"S 27º03’30.99"E	24º44’44.20"S 26º17’43.08"E	25º14’58.49"S 27º19’17.04"E	24º40’25.15"S 27º21’02.22"E	24°32'21.67"S 26°31'24.81"E	24°27'58.34"S 27°46'24.26"E	24°41'44.29"S 26°37'16.59"E
Size (km²)	550	580	48	11	18	45	18.5
Protection type	Protected	Protected	Unprotected	Unprotected	Unprotected	Unprotected	Unprotected
Management purpose and land use	Biodiversity conservation, ecotourism	Biodiversity conservation, ecotourism	Commercial game farming, hunting, ecotourism	Commercial game farming, hunting	Commercial game, hunting and livestock farming	Commercial game, hunting and livestock farming	Commercial game, hunting and livestock farming
Management type	Northwest Parks and Tourism Board - Government agency	Northwest Parks and Tourism Board - Government agency	Private	Private	Private	Private	Private
Average rainfall (mm)/yr	630	520	107	530	480	700	300
Elevation (m)	1687 to 1120	872 to 1474	1053 to 1165	916 to 1014	904 to 925	1522 to 1751	971 to 1031
Vegetation (Acocks, 1988)	Sour bushveldt/Sourish mixed bushveldt	Kalahari thornveld/Shrub bushveldt/Mixed bushveldt	Sourish/Mixed bushveldt	Sourish/Mixed bushveldt/Other turf thornveld	Sour Bushveldt	Arid sweet bushveldt	Mixed bushveldt/Other turf thornveld
Fencing	Predator proof - Closed	Predator proof - Closed	Game fencing – Open	Game fencing – Open	Game fencing - Open	Game fencing - Open	Game fencing - Open
Predator populations	Resident Lion, Leopard, Wild dogs, Brown hyaena populations	Resident Lion, Leopard, Wild dogs, Spotted and Brown hyaena populations	Free roaming Leopard and Brown hyaena populations	Free roaming Leopard and Brown hyaena populations	Free roaming Leopard and Brown hyaena populations	Free roaming Leopard and Brown hyaena populations	Free roaming Leopard and Brown hyaena populations

Table 2.3. Breakdown of stocking densities of the protected and unprotected area study sites per 100km² (data source: North West Parks and Tourism board (protected areas) and individual farm owners (unprotected areas)).

	Stocking densities (count)/100km²						
Species/Site	**Pilanesberg National Park**	**Madikwe Game Reserve**	**Mankwe Wildlife Reserve**	**Ben Alberts Nature Reserve**	**Bullsprait Farm**	**Tweeldstrum Farm**	**Ingala Farm**
Blesbok	0	0	395.6	0	55.6	2,222.2	0
Buffalo	30.1	114.5	0	0	0	0	0
Bushbuck	0	0.3	0	0	0	0	21.6
Duiker	0	6.0	4.4	30.3	55.6	111.1	32.4
Eland	15.0	0.7	157.8	151.5	5.6	266.7	37.8
Elephant	37.8	121.0	0	0	0	0	0.0
Gemsbok	0.4	15.7	66.7	60.6	100	0	0
Giraffe	22.7	20.5	33.3	0	0	0	0
Impala	406.7	544.5	1,102.2	1,060.6	1,111.1	666.7	540.5
Klipspringer	0	0.3	0	30.3	0	144.4	0
Kudu	93.9	133.4	173.3	121.2	222.2	222.2	243.2
Nyala	0	0	0	60.6	0	0	0
Ostrich	3.9	0	102.2	60.6	16.7	0	0
Red Hartebeest	9.2	11.6	173.3	121.2	16.7	333.3	0
Reedbuck Common	0.8	0	0	0	0	111.1	10.8
Reedbuck Mountain	16.2	1.9	44.4	0	0	111.1	0
Rhino Black	9.6	7.0	0	0	0	0	0

Table 2.3. A breakdown of stocking densities of the protected and unprotected area study sites per 100km² (data source: North West Parks and Tourism board (protected areas) and individual farm owners (unprotected areas)) (continued).

	Stocking densities (count)/100km²						
Species/Site	**Pilanesberg National Park**	**Madikwe Game Reserve**	**Mankwe Wildlife Reserve**	**Ben Alberts Nature Reserve**	**Bullsprait Farm**	**Tweeldstrum Farm**	**Ingala Farm**
Rhino White	52.9	25.9	26.7	0	0	0	0
Sable	0.9	0.2	0	0	0	0	0
Springbok	10.5	9.7	0	0	0	0	0
Steenbok	0	15.9	8.9	0	0	111.1	0
Tsessebe	12.4	0.2	68.9	0	0	0	0
Waterbuck	26.1	16	82.2	60.6	0	177.8	135.1
Wildebeest Blue	312.8	143.4	502.2	90.9	177.8	0	0
Zebra Burchell	310.2	200.7	351.1	90.9	83.3	155.6	16.2
Livestock							
Cattle	0	0	0	0	444.4	2,222.20	3,243.20
Sheep	0	0	0	0	166.7	0	0
Goat	0	0	0	0	600	0	0
Carnivores							
Lion	2.4	5.1	0	0	0	0	0
Wild Dog	1.3	3.6	0	0	0	0	0
Spotted hyaena	0	9.1	0	0	0	0	0

Chapter 3: Distribution and Threats: a national questionnaire survey to ascertain carnivore distribution and attitudes of landowners towards South Africa's carnivores

3.1. Introduction

As the human population continues to expand its associated growth in the rate of resource use and in turn habitat loss inevitably brings people into close proximity to wildlife leading to a rise in human-wildlife conflict (Inskip and Zimmermann, 2009; IUCN, 2013). Consequently 31 % of carnivore species are either 'Threatened' or Data Deficient' (IUCN, 2013). The management of natural resources and conservation of threatened species often relies on the successful management of people's behaviour (Romanach *et al.,* 2007; St John *et al.,* 2012), as people's perceptions of human-wildlife conflict are critical to managing the conflict (Sillero-Zubiri *et al.,* 2007). Therefore, identifying the key stakeholder groups ensures that interventions are group-specific and effective (St John *et al.,* 2012). Equally, knowing who to target is imperative to maximise results within a limited budget. It is thus necessary for conservationists to understanding how land owners react to the presence of wildlife such as carnivores on their land as this information can be used to develop mitigation plans that may reduce human-carnivore conflict (Inskip and Zimmermann, 2009).

For the purpose of this study, it was determined that the use of questionnaires was likely to be the most appropriate methodology both for acquiring stakeholder knowledge to map small-large bodied carnivores distribution and for identifying attitudes of South African farmers. Evidence from recent, related investigations shows that questionnaires have become a valuable tool for investigating species distributions (Groves and Peterson 1992; Lovell *et al.,* 1998; Lariviere *et al.,* 2000; Nunez-Quiros, 2009; Karanth *et al.,* 2009), human-wildlife conflict around protected areas (Newmark *et al.,* 1994), attitudes towards critically endangered vegetation (Winter *et al.,* 2005) and landowner attitudes towards carnivores (Zimmermann *et al.,* 2001; Lindsey *et al.,* 2005; Arjunan *et al.,* 2006; Balm *et al.,* 2009; St John *et al.,* 2012; Thorn *et al.,* 2012). For the purposes of an investigation into the conflict between humans and carnivores the assessment of people's attitudes to carnivores is clearly valuable.

Questionnaires have mainly been used in studies involving the impacts of species and/or their conservation in relation to human-wildlife conflict (White *et al.,* 2005b), and have provided a range of information on South African carnivores and land owner attitudes towards them (Thorn *et al.,* 2011b; 2012; 2013). Reflecting the objectives of this study, White *et al.,* (2005) emphasised that questionnaires enable researchers to ‘quantify human behaviour, for example perceptions or attitudes towards conservation strategies and/or the implantation of environment conservation directives.’ A questionnaire is able to capture three types of attitudes; affective (feelings and emotions), cognitive (beliefs) and behavioural (Winter *et al.,* 2005; 2007), all of which are necessary to understand the mechanisms and thought processes behind human-wildlife interactions and conflict.

Some brief examples of the outcomes of questionnaire based attitudinal surveys lead to interesting conclusions with direct relevance to this study. Most findings indicate that, compared to areas of livestock farming, conservancies are more positive towards the presence of carnivores (Thorn *et al.*, 2009). Thorn *et al.,* (2013) determined that the major influencing factors in human-wildlife conflict were high elevation, mixed purpose farming (i.e., stocking both game and livestock), dense vegetation cover and high perceived financial losses. For example, in Namibia, carnivore presence was tolerated in areas where income from wildlife was higher, income from livestock was lower, and financial losses from livestock depredation were lower (Lindsey *et al.*, 2013). Tolerance for losses is strongly influenced by socio-economic factors. For example, financial loss is a determinant of lethal control being undertaken in retaliation for livestock killings (Sillero-Zubiri *et al.,* 2006; Thorn *et al.,* 2012; 2013). In addition, cultural grouping has been found to influence the proportion of lethal control that is undertaken in an area (Thorn *et al.*, 2012). Furthermore, farmers have been shown to undertake a range of predator control methods to protect their livestock and game from perceived predation events (Lindsey *et al.,* 2005; Blaum *et al.*, 2009), with target species varying between geographical locations (Lindsey *et al.,* 2005; Blaum *et al.,* 2009). The overall consensus is that, for attitudes towards wildlife to be positive, land owners need to achieve economic benefit in the form of ecotourism, benefit from a compensation scheme if livestock is lost, or be provided with financial incentives for predator conservation (Romanach *et al.,* 2007). By increasing research and developing conservation activities relating to small and medium-sized carnivores in southern Africa, in conjunction with landowners, suitable habitat could be utilised allowing an expansion of the current populations (Lindsey *et al.*, 2005; Blaum *et al.*, 2009).

In adopting the questionnaire approach, it was recognised that a degree of caution must be applied. Close study of recent literature highlights the advantages and limitations of this method. An advantage to questionnaire data is that it can reveal the distribution of species efficiently (Karanth *et al.*, 2009). However, factors such as population size require further ecological study (Groves, 1988). Nevertheless, Rushton *et al.*, (2004) state that the use of questionnaires for collecting distribution data has considerable potential and warrants further study. For example, the distribution of six apex predators, including the brown hyaena, across the Namibian farmlands was successfully determined through questionnaires (Lindsey *et al.*, 2013), and in Mozambique, structured interviews of local people were used to indicate lion presence and areas of human-lion conflict (Jacobson *et al.*, 2013). Carnivores, which occur at low densities, are secretive and difficult to observe and identify in the field. The acquisition of data from questionnaires, utilising different sources such as hunters and park managers, may therefore prove beneficial (Lovell *et al.*, 1998; Nunez-Quiros, 2009). Survey work where species are rare can also be very expensive, and this has provided a strong financial incentive for analysing data derived from casual and non-systematic surveys (Rushton *et al.*, 2004). Berg *et al.* (1983) and Groves and Peterson (1992) state that the overall advantage of using mail-based questionnaires is that valuable data is collected in the form of new distributional and occurrence data, as well as clearly indicating the inadequacy of the current data set for the region. However, there is the need to be aware that biased sampling may result if the response rate is not the same for the different categories of interest on the questionnaire (Rushton *et al.*, 2004). For example, respondents who may be involved in harmful behaviours may be unwilling to discuss that specific topic, most particularly if the activity is illegal (St John *et al.*, 2012).

It is critical to note that there are further limitations with questionnaire surveys, such as misidentified species, geographical bias towards populated areas, and the translation of terminology (Groves and Peterson 1992; Nunez-Quiros 2009). However, data obtained from questionnaires has been compared to data obtained through more traditional survey methods such as indirect survey signs and radio tracking, and has been found to provide accurate distribution data (Blaum *et al.*, 2009; Nunez-Quiros, 2009; Thorn *et al.*, 2009). In addition, Gros (1998) states that "comparisons of carnivore densities derived from interview and long-term field studies showed that interviews are a valid approach to surveying large carnivores". Consequently, questionnaire and field survey data can be cross-referenced to confirm the validity of data sets obtained from each methodology. The distribution of the respondents surveyed must be representative of the study area otherwise geographical bias can skew results (Groves 1988; Groves and Peterson 1992). In a similar observation Lovell *et al.* (1998) conceived that the questionnaire did provide a randomly sampled data set and, with the information provided, informed management decisions could be completed. Other forms of bias that are little explored in relation to natural resource management are the false consensus effect and a person's knowledge of the rules; as people's perceptions of the law vary so will their responses (St John *et al.,* 2012). Giving respondent's anonymity assists with the discussion of sensitive topics such as predator control methods (St John *et al.,* 2012).

Observations on the relative effectiveness of communication media to conduct surveys were also considered in order to inform this study. The majority of ecological questionnaires undertaken up to 2003 have been conducted using postal surveys followed by in-person interviews and telephone surveys (White *et al.,* 2005b). In the past, questionnaires were limited by the distribution methods available to the user, such as postal, fax and interviews, both one to one and in groups (Smee and Brennan, 2000). However, Smee and Brennan (2000) state that "the phenomenal growth of the internet and World Wide Web means this electronic medium offers great potential as a survey research vehicle". Online survey providers, such as Surveymonkey, have been used predominately in the social sciences (Coomber, 1997; Davis, 1999; Fox *et al.,* 2002) and medical research (Kushniruk, 2000; Oenema, 2001; Kongsved, 2007) for several years, and according to Denscombe (2008) the "use of online questionnaires is replacing the use of paper questionnaires in many aspects of social research". Frazier and Rohmund (2007) identified that the online questionnaire is a cost-effective approach for tapping into opinions on an ongoing basis. The advantages are deemed to be that: it allows people to be surveyed exclusively on specific topics; it offers a quick turnaround of results at a lower cost; it might ease the access to traditionally hard to reach sectors of the population and it reduces data entry errors. The disadvantage of using online surveys is that it excludes people without internet access, which in turn may under-represent some sectors of the population (Frazier and Rohmund, 2007). For example, the internet user base in South Africa grew by

15 % from 4.6 million in 2008 to 5.3 million in 2009, which represents just over 10 % of the population (WorldWideWorx, 2010). This level of access must be taken into consideration when initialising a web-based questionnaire that is looking to ascertain data on a national level for respondents that are predominantly in rural areas.

Nevertheless, White *et al.* (2005b) state that "web-based surveys, although likely to suffer from substantial response biases that are difficult to quantify, can provide large data sets that can be used to examine the interrelationships among variables, employing multivariate techniques". Smee and Brennan's (2000) study, comparing web-based and email based surveys, identified that the web-based survey produced much faster and higher rate of responses than email. However, a caveat was that the web-based survey had much higher non-completion rates. Consequently, this means that a larger database of contacts for web-based studies are required as well as a plan to follow up requests to respondents. Yet, Denscombe's (2008) findings indicated that administrating a questionnaire online might have little impact on the non-response rates for fixed-choice questions but the non-responses to open-ended questions were reduced.

3.2. The Status of Brown Hyaena in South Africa

It is anticipated that the application of a web-based questionnaire to this aspect of the study would contribute significant new information on the spatial distribution of carnivores and land owners attitudes towards them across South Africa. Outside protected areas, brown hyaena numbers are thought to be declining as the species is experiencing a measure of deliberate and incidental persecution (Mills, 1990; Wiesel *et al.*, 2008). A 10 % population decline over three generations would cause brown hyaena to be re-classified from its current status of 'Near Threatened' to 'Vulnerable' (Wiesel *et al.,* 2008). The main driver of persecution is that brown hyaena are perceived as livestock killers by farmers, a concept that has largely been found to be untrue with very few cases of reported livestock predation (Skinner 1976; St John *et al.,* 2012).

Eaton (1976), Mills and Hofer (1998) and Friedmann and Daly (2004) have all aimed to periodically review the biology, status and conservation of brown hyaenas across Southern Africa. The distribution map produced by Mills and Hofer (1998) (Figure 1.1.) and subsequently Friedmannn and Daly (2004) (Figure 1.2.) illustrates the distribution of the brown hyaena to be predominately based in the provinces that make up the northwest of South Africa (Limpopo, North West, Mpumalanga, Gauteng), flowing down into the Free State and then below into the Eastern Cape (Figure 3.2.). Other areas of distribution include the north east of KZN and the far north of the Northern Cape inside the Gemsbok National Park. The Western Cape has the smallest distribution of brown hyaenas (Friedmannn and Daly, 2004) (Figure 3.2.).

As part of the re-assessment by the IUCN/SSC Hyaena Specialist Group and the Red List of Threatened Species for brown hyaena, the distribution map was updated in 2008 (Wiesel *et al.*, 2008) (Figure 1.3.). The distribution of brown hyaena has been substantially increased as it now covers the majority of South Africa, with the exceptions being found along the south and eastern coastlines (Figure 1.3.). A more recent study (Thorn *et al.*, 2011a) stated that in the North West Province brown hyaenas displayed the greatest increase in extent and area of occupancy in comparison to the other medium-large resident carnivores post Friedmannn and Daly's (2004) study. These findings highlight that carnivore species distributions are constantly changing in consequence of increased human pressures (Inskip and Zimmermann, 2009) and therefore having up to date national distributions for individual species is essential for the prioritisation and targeting of conservation management and resources. The importance of knowing current distributions is critical, as demonstrated by the IUCN Red List using changes in distribution as one of their criteria for assessing the conservation status of species (IUCN, 2013).

Using questionnaires the brown hyaena and five other large apex predators' distributions have now been recently updated and mapped, specifically across the Namibian farmlands (Lindsey *et al.*, 2013). However, no nationwide questionnaire on the status and distribution of brown hyaena across South Africa has been undertaken to date. This information is critical if we are to safeguard the future of the brown hyaena. Similarly, although regional studies in South Africa have taken place (Lindsey *et al.*, 2005; Thorn *et al.*, 2009; 2011b; 2012), a national questionnaire to determine both medium-large bodied carnivore distribution and farmers' attitudes towards these species across the whole of South Africa has never been undertaken. The majority of the current global brown hyaena population exists in unprotected farmland (Mills and Hofmer, 1998). Therefore, the primary threat to brown hyaenas is conflict with humans (Weisel *et al.*, 2008; Inskip and Zimmermann, 2009), so engaging directly with the landowners who interact with carnivores, to understand their attitudes towards them, is of utmost importance to the persistence of carnivores (Thorn *et al.,* 2012).

3.3. Objectives

The study's objectives were to use a web-based questionnaire to: i. utilise local respondent knowledge to map the distribution of medium to large carnivores using the presence absence data gathered from the national questionnaire across South Africa, ii. determine the influential factors that drive the attitudes and perceptions of South African farmers towards medium to large carnivores, specifically brown hyaenas, using a web based national questionnaire.

It was expected that brown hyaenas would be found to be widely distributed across South Africa, with the greatest concentration found in the North East region (Friedmannn and Daly, 2004). It was predicted that brown hyaena would be found to be actively targeted by predator control methods (Mills and Hofer, 1998; Thorn *et al.,* 2012) and that, of all land users, livestock farmers were likely to hold overtly negative attitudes to carnivores on their property, given the findings of previous research (Lindsey *et al.,* 2005; 2009; 2013, Thorn *et al,* 2009; 2011a; 2012).

3.4. Method

The research was conducted between June 2010 and November 2011 via an internet-based survey (http://www.surveymonkey.com/). The full questionnaire can be seen in Appendix 1. This approach was chosen as it was deemed the most appropriate method for gathering data from a large geographical area (Gordon, 2002), and it was the most cost-effective and logistically-suitable method due to its ease in reaching large numbers of potential respondents (Van Selm and Jankowski, 2006). Responses of participants were anonymous in order to protect the confidentiality of respondents. Where necessary, to indicate level of agreement or disagreement, a five-point Likert scale was used where three was deemed neutral (Drinkwater, 1965). The questionnaire was first tested on a group of thirty people, none of whom was associated with the target audience, following guidance by White *et al.*, (2005). Subsequently several changes were made to the questionnaire to aid clarity.

The questionnaire was aimed at all major farming groups across South Africa that may be affected by human-wildlife conflict. The main groups were agriculture (crop) farming, game farming, livestock farming (cattle or sheep/goats) and tourism. To ensure that all five groups were represented, societies, organisations and individuals within each sector e.g. cattle breeding societies like the Beefmaster Cattle Breeders' Society of South Africa; Nguni Cattle Breeders' Society of South Africa, South African National Biodiversity Institute (SANBI); Southern African Wildlife Management Association (SAWMA); Africa society of crop production; Dorper Breeders Association of South Africa; Boer Goat Breeders' Association of South Africa were contacted. These societies and organisations emailed their members via an identical pre-constructed email containing a brief overview of the research project, the importance of their role within the research and reasons why their participation was needed. Two hyperlinks to an English or Afrikaans version of the questionnaire were provided (Appendix 2). As the internet address was sent to individual landowners and society administrators for dissemination, the actual number of individuals who received access to the questionnaire is unknown.

In order to determine the location of the farm and thus plot the presence or absence of carnivores across South Africa, respondents were asked for their farm name, distance to nearest town, direction of farm from town and a description of how to get to the farm from the town. The information acquired from the four location questions meant that each farm's latitude and longitude coordinate, determined using Google Earth, was as accurate as possible (Google Inc, 2011). In addition to the responses via the internet-based survey, 14 individuals included additional brown hyaena location information in their direct personal communications. This information was a GPS location, farm name, area location or province, from which a data point could be added to the primary brown hyaena location data set acquired through internet-based survey. Finally, South Africa's National Park management (SANParks) and other local experts were contacted to determine the presence and absence of brown hyaena across the 22 designated conservation areas. The national carnivore distribution maps were created in ArcView ver.9.3 GIS software, by converting the presence/absence data for all twelve carnivore species provided in the questionnaires into a point layer file in association with the responding farm coordinates. A sighting was defined as the respondent either sighting an individual carnivore or finding evidence (spoor (tracks) or middens) on their property in the last twelve months. In this study an 'absent' record represents the sites where that carnivore was not seen in the last year. Therefore the distribution maps created for individual carnivore species were based upon presence data. To standardise the species distributions, the proportion (percent) of farms containing each carnivore species was determined across the nine provinces. In relation to vegetation type (as defined by White, 1983), the distribution was calculated by determining the total area (km^2) per vegetation type across all nine provinces and then comparing the results to the proportion of presence distribution for the brown hyaena.

The majority of questions were closed-format with selected options. There were also open-ended questions that attempted to learn more about the respondents' opinions and feelings on certain topics. Several questions were formulated from previous questionnaires (Lindsey *et al.*, 2005; Thorn *et al.*, 2009), which have been successfully executed, to ascertain data on the status of carnivores in both the North West and Limpopo Provinces. This provided an opportunity to directly validate the data collected on a national level against studies where data were collated using interviews on a smaller intensive scale (as recommended by Browne-Nunez and Jonker, 2008). The questionnaire comprised 27 questions in three areas of interest: (1) 'Respondents and their properties' regarding background information on farmers and farm characteristics which may have an influence on carnivore presence e.g. property size (Lindsey *et al.*, 2005), fencing characteristics (Hayward *et al.*, 2009) and land use (Winterbach *et al.*, 2012); (2) 'Predators and predator control' pertaining to the occurrence of, and attitudes towards, twelve species of mammalian carnivore (aardwolf, bat-eared fox, brown hyaena, cape fox (*Vulpes chama*), caracal, cheetah, jackal, leopard, lion, serval (*Leptailurus serval*), spotted hyaena, wild dog) to determine whether predator control is practised, methods used, target species, and frequency of control; (3) 'Questions relating specifically to brown hyaena and their presence and attitudes towards them' where farmers were asked to indicate their attitudes towards brown hyaenas, their reason for these attitudes, and whether they agreed or disagreed with a number of statements relating to brown hyaena (Appendix 1).

The dominant land use type of each respondent was determined by using the highest percentage answer given when asked 'What are the activities that take place on your property?' The number of farmers with positive and negative response for twelve predator species was compared using chi-squared tests (SPSS ver 19.0) in relation to three characteristics; (1) primary language (2) land use and (3) stock value. Agriculture as a land use group had to be removed from the chi-squared test analysis as the sample sizes were too small and there was not a similar land use group that it could be combined with. To ensure an adequate sample size other similar land uses were combined; 'cattle' and 'sheep/goat' farming were combined into a 'livestock' group and 'game' and 'tourism' were combined into a 'game' group.

Stocking values were calculated for livestock and wild ungulates with a body mass >35 kg (e.g. springbok) as stock value (Rand) units per km^2. As wild game prices varied between 2010 and 2011 stocking values (Rand/km^2) were calculated in accordance to which year the survey was completed to ensure that the price variations were taken into consideration. Wild ungulates and poultry with a body weight <35 kg (e.g. common duiker and steenbok) were excluded from the stock value calculation because individual animal values were unknown. The wild game values were determined using average collated live game auction prices (2010: 56 auctions; 2011: 55 auctions) (Cloete, 2012). Livestock values were acquired from individual livestock societies for the most common species found in South Africa within each group; Brahman cattle (*Bos primigenius indicus*), Dorper sheep (*Ovis aries*) and Boer goat (*Capra hircus*). All livestock prices were based upon commercial group individuals rather than breeding or trophy stock. Individual farm stock values were stacked into three groups: low (0-1000 £/km^2), medium (1001-2000 £/km^2) and high (≥2000 £/km^2).

National removal (killing) rates were determined in order to facilitate a direct comparison between this study and a study conducted in the North West Province only (Thorn *et al.*, 2012). The total number of reported annual removals (killings) of individual carnivore species was calculated from the respondents' answers to the question 'How many predators have been killed/removed by each method in the last year?'. The total species removed (killed) was then divided by the total farm area to obtain a density of species/100km^2.

3.5. Results

3.5.1. National Distribution Maps for Carnivores across South Africa

The respondents (n = 190) to the questionnaire gave presence and absence data for all twelve carnivore species based upon sightings, spoors and middens on their property in the last 12 months (Figure 3.4.). An additional 14 respondents gave brown hyaena presence/absence information outside of the questionnaire. These points were then incorporated with the questionnaire data leading to 204 respondents for brown hyaena only.

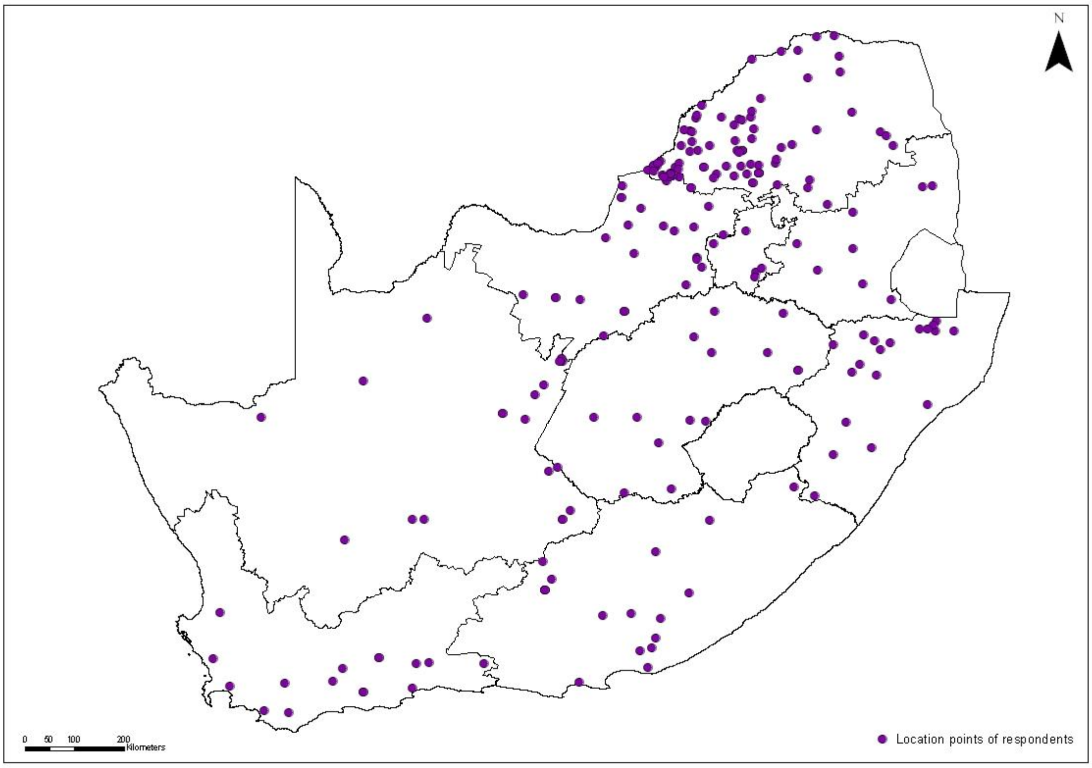

Figure 3.1. GPS locations of all questionnaire respondents across the nine provinces in South Africa.

The mean number of farms per Province was 19.6 ± 22.8, and the brown hyaena was present at 61.1 % of farms (Table 3.1.). Jackal was the most widely distributed species (present at 76.7 % of farms) followed by caracal and brown hyaena, and the least common species was lion (present at 1.7 % of farms) followed by wild dog, cheetah and spotted hyaena (Table 3.1.). Wild dog and cheetah were primarily recorded in the Limpopo province, brown hyaena and serval in Mpumalanga, cape fox, lion and bat-eared fox in Eastern Cape, caracal in Western Cape, jackal and aardwolf in Free State and spotted hyaena in KZN (Table 3.1). Brown hyaenas were recorded across all nine Provinces but were present on over 77 % of farms in the Limpopo, Mpumalanga and North West Provinces. Lion, the least recorded species, were not recorded in 98.3 % of the farms, followed by wild dog (95 %), spotted hyaena (91.7 %) and cheetah (79.4 %) (Table 3.1). The Province of Gauteng had the highest number of absent records, with 50 % of the carnivore species not recorded (Table 3.1).

Table 3.1. Percentage of farms occupied by each species, based on questionnaire respondent sightings in the last 12 months (n = 190 for brown hyaena, all other carnivores n = 176), across South Africa.

	Species Num. of farms	Aardwolf	Bat-eared fox	Brown hyaena	Cape fox	Caracal	Cheetah	Jackal	Leopard	Lion	Serval	Spotted hyaena	Wild dog
Province	**(fr)**	**%P**	**%P**	**%P**	**%P**	**%P**	**%P**	**%P**	**%P**	**%P**	**%P**	**%P**	**%P**
Eastern Cape	12	50	75	23	67	75	8.3	83	8.3	8.3	42	0	0
Free State	14	71	36	40	29	50	0	93	0	0	36	0	0
Gauteng	4	50	0	50	0	25	0	50	25	0	50	0	0
KZN	16	25	13	42	13	75	0	81	38	0	69	25	6.3
Limpopo	79	42	41	77	1.3	73	42	82	72	2.5	44	14	10
Mpumalanga	7	43	29	78	0	29	0	71	14	0	71	0	0
North West	20	45	20	71	5	45	15	85	25	0	20	0	0
Northern Cape	12	50	58	29	17	67	0	75	0	0	25	0	0
Western Cape	12	25	67	21	33	83	0	33	42	0	17	0	0
%Mean	**19.6**	**42.2**	**38.3**	**61.1**	**12.2**	**64.4**	**20.6**	**76.7**	**42.2**	**1.7**	**40.0**	**8.3**	**5.0**
%(±SD)	**23**	**41.8**	**41.8**	**81.2**	**11.1**	**75.2**	**47.3**	**83.7**	**79.8**	**3.1**	**45.5**	**16.3**	**11.5**

The distribution of the eleven carnivores species (IUCN red list category) based on the study's results from the questionnaire survey showed that:

1. Aardwolf 'Least Concern'

The highest level of distribution of aardwolf was found in the Free State, followed by the two Cape Provinces (Northern, Eastern) and Gauteng. The lowest distribution was found in the North East region of South Africa (Limpopo, Mpumalanga, North West, KZN) and down in the Western Cape (Appendix 3. Figure 3.18.).

2. Bat-eared fox 'Least Concern'

The highest distribution of bat-eared fox was found in the coastal regions, in particular the Eastern and Western Cape Provinces, followed by the Northern Cape. Overall the remaining provinces had similar low levels of distribution across the bat-eared fox's range (Appendix 3. Figure 3.19.).

3. Cape Fox 'Least Concern'

The highest distribution of cape fox was found in the Eastern Cape Province followed by the Western Cape and Free State Provinces. The lowest levels of distribution were found in the landlocked North West region (Limpopo, Mpumalanga, Gauteng) (Appendix 3. Figure 3.20.).

4. Caracal 'Least Concern'

The distribution of caracal showed that they are common and widespread across South Africa. With the highest distribution being identified in the Western Cape Province and the lowest distribution found across the Mpumalanga and Gauteng Provinces (Figure 3.2.).

5. Cheetah 'Vulnerable'

The distribution of cheetah was limited to three provinces: Limpopo, North West and Eastern Cape. Limpopo Province overall had the greatest level of distribution with distribution in the other two being equal (Appendix 3. Figure 3.21.).

6. Jackal ‘Least Concern’

The distribution of jackal showed that they are common and widespread across South Africa. The highest distribution was found in the Free State Province with the lowest being in the Western Cape Province (Figures 3.3.).

7. Leopard ‘Near Threatened’

Leopard distribution was split across South Africa, the highest distribution was in the Limpopo Province, followed equally by KZN and the Western Cape Provinces. Eastern Cape, North West, Mpumalanga and Gauteng Provinces showed minimal distribution whereas the Northern Cape and Free State showed zero distribution (Appendix 3. Figure 3.22.).

8. Lion ‘Vulnerable’

The distribution of lion was limited to two provinces: Limpopo and Eastern Cape, which showed the highest distribution (Appendix 3. Figure 3.23.).

9. Serval ‘Least Concern’

The highest distribution of serval was found in the Eastern region of South Africa in a cluster of two Provinces (Mpumalanga and KZN). The remaining distribution over South Africa was evenly spread (Appendix 3. Figure 3.24.).

10. Spotted hyaena ‘Least Concern’

The distribution of spotted hyaena was limited to two provinces: Limpopo and KZN, which had the highest levels distribution (Appendix 3. Figure 3.25.).

11. Wild dog ‘Endangered’

The distribution of wild dog was limited to two provinces: KZN and Limpopo, which had the highest levels distribution (Figure 3.4.).

The majority of these distributions are in line with current known occurrences (IUCN) of the species. This indicates that the species distributions are accurate across the study.

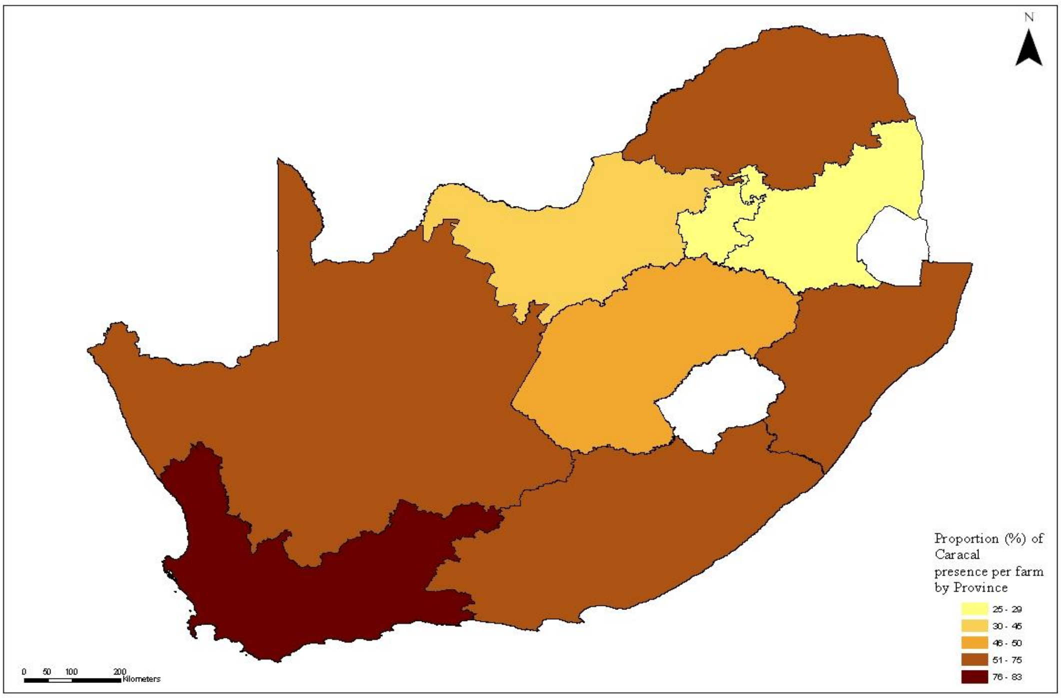

Figure 3.2. The distribution of the caracal across the nine provinces of South Africa, based upon the percentages of farms reporting presence (%).

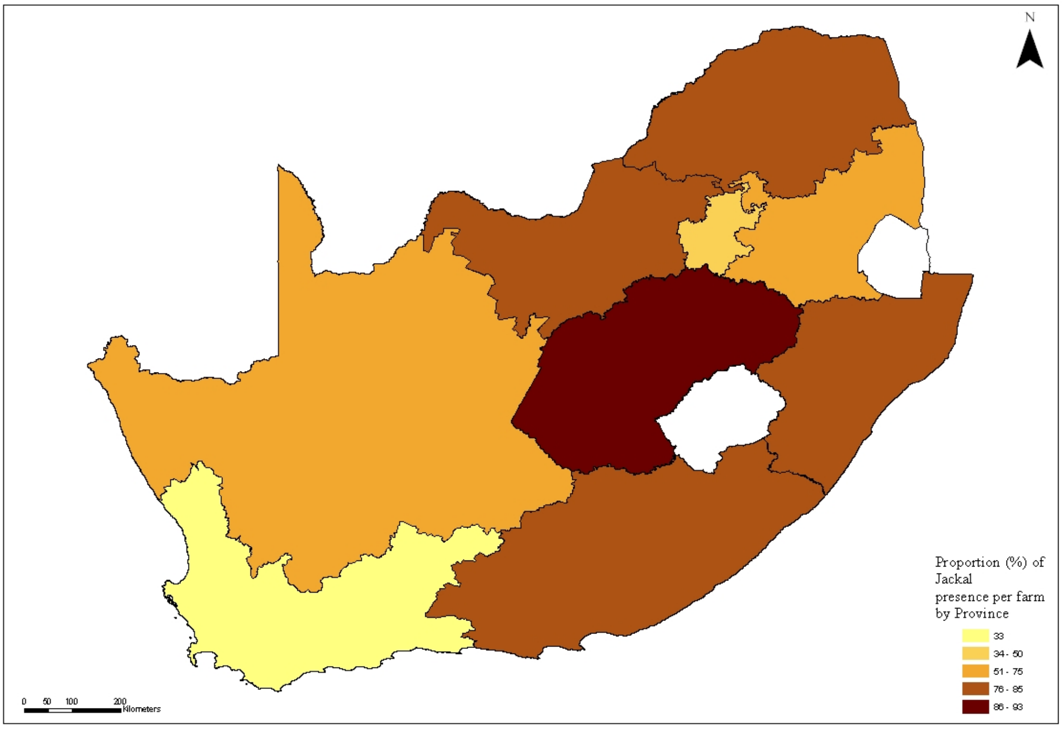

Figure 3.3. The distribution of the jackal across the nine provinces of South Africa, based upon the percentages of farms reporting presence (%).

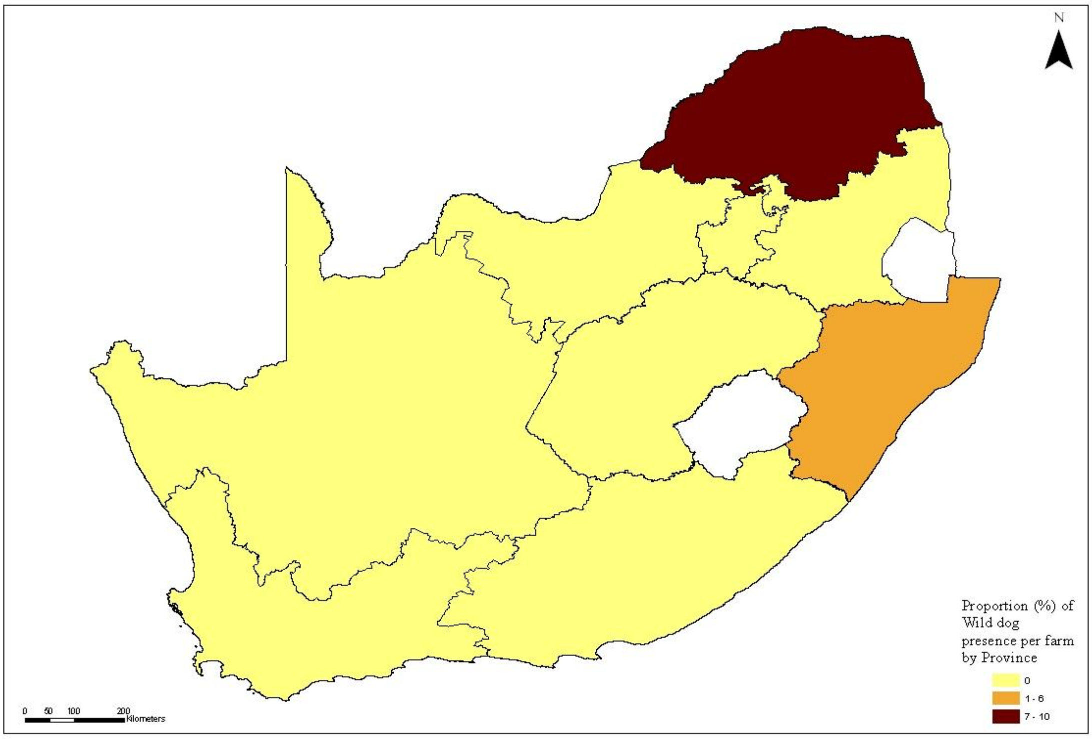

Figure 3.4. The distribution of the wild dog across the nine provinces of South Africa, based upon the percentages of farms reporting presence (%).

3.6. Brown Hyaena Distribution across South Africa

Brown hyaenas were more likely to be found in the Limpopo, Mpumalanga and North West provinces in comparison to the Eastern and Western Cape (Figure 3.5.). Overall, the coastal regions showed an absence of brown hyaena, with the majority of presence points being found landlocked within the north-eastern region of South Africa. The greatest occurrence of brown hyaenas was found in areas within the high rainfall transitional zone, 300-2,000 mm annually, situated between the arid Kalahari and the moister eastern savannahs of southern Africa.

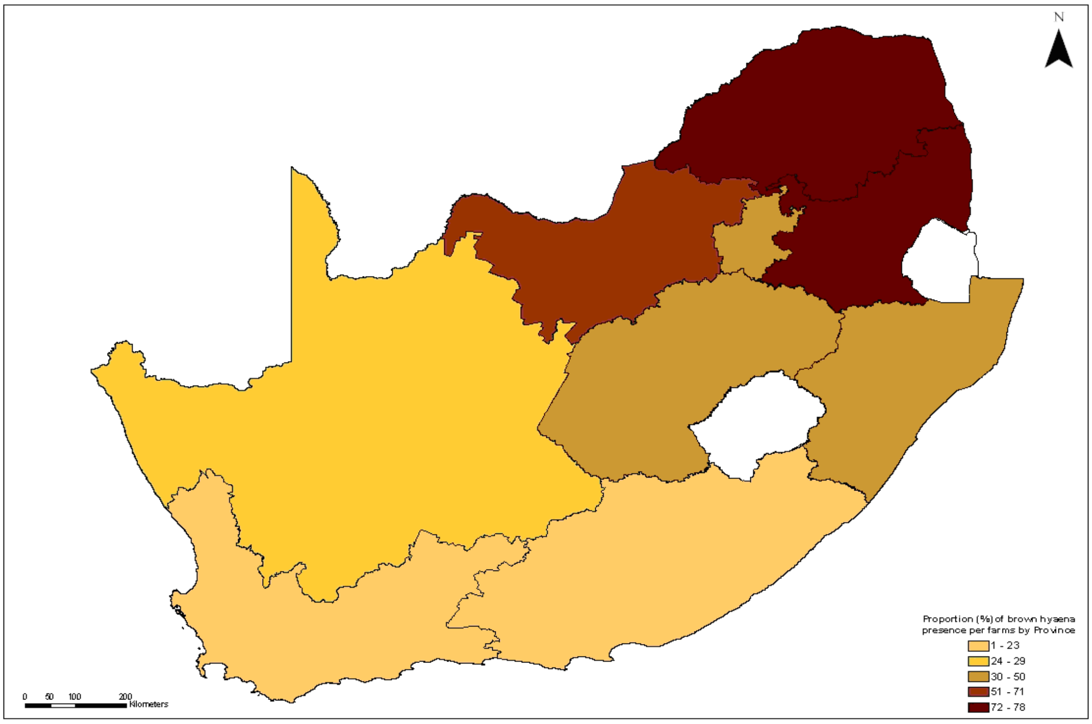

Figure 3.5. The proportion of distribution of the brown hyaena across the nine provinces of South Africa, based upon the percentages of farms reporting presence (%).

In relation to vegetation type (as defined by White, 1983 (Table 3.2.)) the greatest proportion of brown hyaena presence points in relation to vegetation area (km²) per Province, was found in the semi-desert, followed by woodland, grassland and bushland and thicket (Table 3.3.). The greatest proportion of presence points across the semi-desert and bushland and thicket vegetations were found in the Eastern Cape (Table 3.2.). The presence in woodland was highest in the Limpopo Province and presence in grassland was greatest in the Free State (Table 3.2.). The lowest proportion of presence was found in the altimontane followed by azonal and transitional scrubland vegetations, which are present across Eastern Cape, Free State and KZN (Table 3.2.).

Table 3.2. Area (km^2) covered by the twelve major vegetation types across South Africa by province (as described by White (1983)).

	Province									
Vegetation type	**Eastern Cape**	**Free State**	**Gauteng**	**KZN**	**Limpopo**	**Mpumalanga**	**North West**	**Northern Cape**	**Western Cape**	**Total (km^2) per vegetation type**
Altimontane	81	254	-	748	-	-	-	-	-	**1,083**
Azonal	337	-	-	516	-		-	-	-	**853**
Bushland and thicket	26,772	7,873	10	4	10,140	460	51,816	55,416	-	**152,492**
Cape Shrubland	14,675	-	-	-	-	-	-	629	57,175	**72,479**
Desert	-	-	-	-	-	-	-	9,128	-	**9,128**
Forest Transitions and mosaics	60,915	8,218	-	70,910	10,053	21,980	-	-	2,359	**174,435**
Grassland	12,180	83,875	11,506	-	996	26,123	31,803	111	-	**166,596**
Grassy shrubland	35,936	28,938	-	-	-	-	-	37,215	7,026	**109,116**
Semi-desert	15,507	613	-	-	-	-	-	272,182	61,291	**349,592**
Transitional scrubland	-	-	-	7,282	-	-	-	-	-	**7,282**
Woodland	-	-	5,024	12,572	103,101	28,091	21,177	-	-	**169,966**
Woodland mosaics and transitions	-	-	-	-	1,377	-	1,583	-	-	**2,960**
Total (km^2) vegetation per province	**166,403**	**129,771**	**16,541**	**92,031**	**125,668**	**76,655**	**106,379**	**374,681**	**127,851**	**1,215,980**

Table 3.3. Overall percentage (%) of farms with presence and absence of brown hyaena (*n* = 190) within the twelve major vegetation types across South Africa (as described by White (1983)).

Vegetation type	**Percentage (%) of farms with brown hyaena present**	**Percentage (%) of farms with brown hyaena absence**
Altimontane	0	0.0
Azonal	0	0.0
Bushland and thicket	17.4	13.0
Cape Shrubland	0.8	11.6
Desert	0	0.0
Forest Transitions and mosaics	6.6	17.4
Grassland	8.3	15.9
Grassy shrubland	1.7	13.0
Semi-desert	3.3	13.0
Transitional scrubland	0.8	0.0
Woodland	55.4	13.0
Woodland mosaics and transitions	5.8	2.9
Mean (%)	**8.3**	**8.3**
±SD (%)	**15.7**	**7.0**

The highest percentage of brown hyaena presence was found in woodland (55.4 %, Table 3.3.) compared to the transitional and Cape shrubland (0.8 %, Table 3.3.), forest transitions and mosaics had the highest level of hyaena absence (17.4 %, Table 3.3.). Brown hyaenas were not recorded by this questionnaire in 25 % of the vegetation types (*n* = 3) (Table 3.3.). Chi-squared was used to assess the association between brown hyaena presence and absence to vegetation type across South Africa, several similar vegetation categories where combined. The three categories were grassland, shrubland and forest (Table 3.4.).

Table 3.4. Results of a Chi-squared test for association between brown hyaena presence and absence to three vegetation categories across South Africa.

Vegetation categories	**Cell contents**	**Brown hyaena Presence**	**Brown hyaena Absence**	**Total**
Shrubland	Count	25	26	51
	Expected count	33.71	17.29	
	Contribution to Chi-square	2.251	4.39	
Grassland	Count	10	11	21
	Expected count	13.88	7.12	
	Contribution to Chi-square	1.085	2.116	
Woodland	Count	82	23	105
	Expected count	69.41	35.59	
	Contribution to Chi-square	2.285	4.456	
Total		117	60	177

There was a significant association between brown hyaena absence and both shrubland and woodland (Pearson Chi-Square test, $\chi^2 = 16.58$, d.f. = 2, $P < 0.001$), where there were significantly more absences than expected in shrubland and fewer absences than expected in woodland (Table 3.4.). Therefore, this shows that brown hyaenas are actively avoiding shrubland and showing a preference for woodland.

There were 29 data points collected by the questionnaire outside of the historically recognised extent of brown hyaena in 2004 (Friedmann and Daly, 2004). Here brown hyaena were present at 31 % (n = 9) of farms and absent at 69 % (n = 20) (Figure 3.6.). Further to this, in comparison to the IUCN Red List current known extent in 2013 (Wiesel *et al*., 2008), a total of 44 data points were outside the range with brown hyaena being present at 34 % (n = 15) of the farms and absent from 66 % (n = 29) (Figure 3.7.). In combination with the historically recognised extent (2004) and the IUCN Red List current known extent (2013), 15 data points were outside both ranges with brown hyaena present at 25 % (n = 3) of the farms and absent from 75 % (n = 13).

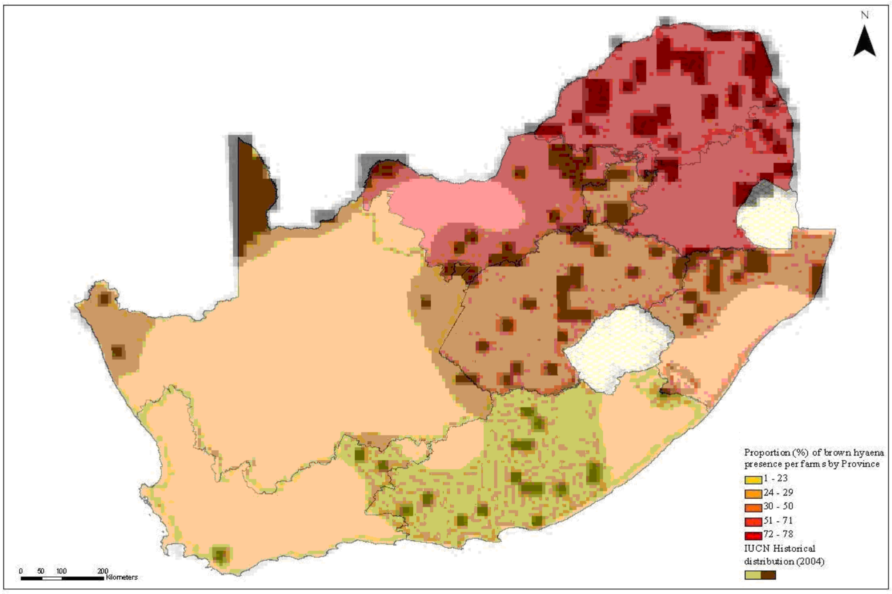

Figure 3.6. The distribution of brown hyaena present across South Africa, based upon presence/absence data recorded by respondents to the national human-carnivore questionnaire (*n* = 204), overlaid on a map showing the known extent of occurrence of the brown hyaena across South Africa, produced by the African Mammal Conservation Assessment and Management Plan Report for South Africa (Friedmann and Daly, 2004).

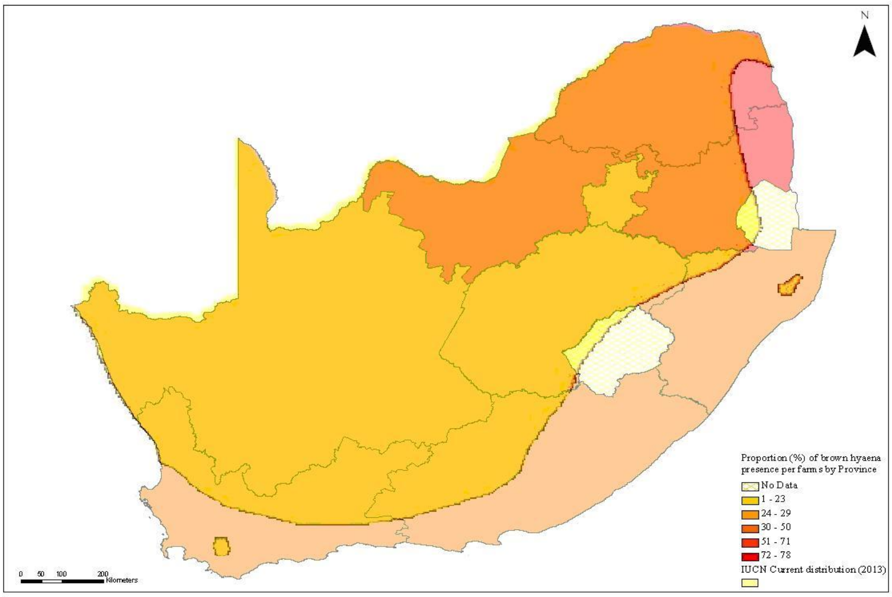

Figure 3.7. The distribution of brown hyaena present across South Africa, based upon the presence/absence data recorded by respondents to the national human-carnivore questionnaire (*n* = 204), overlaid on a map showing the known extent of occurrence of the brown hyaena across South Africa, produced by the African Mammal Conservation Assessment and Management Plan Report for South Africa (Friedmann and Daly, 2004) and the extent of the brown hyaena produced by IUCN Red List of Threatened Species, (Version 2013.2.) (Wiesel *et al.*, 2008).

Based on the information provided from SANParks and other local experts, it was found that, out of the 20 National Parks in South Africa, 50 % contain brown hyaena populations (Table 1.1.). Some absences are expected due to the ecosystem of the areas i.e. Agulhas National Park, where the dominate vegetation is fynbos communities and renoster shrubland (Lombard *et al.,* 1997) and there are limited terrestrial mammals. In addition, brown hyaena used to be present within the Karoo National Park but have become locally extinct there, and in Kruger National Park the hyaenas are now only found in the northern section of the reserve. Conversely, as discussed in Chapter 1, the brown hyaena is part of a reintroduction programme to areas such as the Addo Elephant Reserve. Other known reintroduction areas include Great Fish River (1986), Shamwari (2001), Kwandwe (2002), Mountain Zebra National Park (2005) in the Eastern Cape (Hayward *et al.,* 2007b), Doornkloof nature reserve and Mokala National Park, Northern Cape (Eric Hermann, Dept Nature Conservation Northern Cape, *pers. comm.,* 2011 and Marna Herbst, SANParks, *pers. comm.,* 2011) and Pidwa Wilderness Reserve, Limpopo Province.

3.7. National Attitudes towards Carnivores in South Africa

A total of 237 questionnaires were returned, of which 82 % (n = 195) were completed in full. The dominant position held by the respondents was the owner of the property (76 %, n = 173), followed by the manager (11 %, n = 25), lease holder (7 %, n = 16) and other (6 %, n = 13), which consisted of sons of the landowner, a part owner and manager or lease holder, game rangers and reserve assistants. The two main languages of the respondents were Afrikaans (65 %, n = 147) and English (31 %, n = 69), with a minority speaking Setswana (2 %, n = 5) and Sepedi (0.4 %, n = 1). A total of 205 respondents submitted information on their property from all nine provinces across South Africa (Figure 3.11.). The majority of respondents came from the Limpopo, North West and Free State Provinces, which reflects the individuals' level of engagement rather than any farming biases (Table 3.6.). The average farm size was 30.29 ± 61.0 km^2 (SD) with a minimum of 0.1 km^2 and a maximum of 490 km^2. There was no significant difference between the farm sizes found across all nine provinces (Kruskal-Wallis test, W = 13.45, d.f. = 8, P = 0. 097).

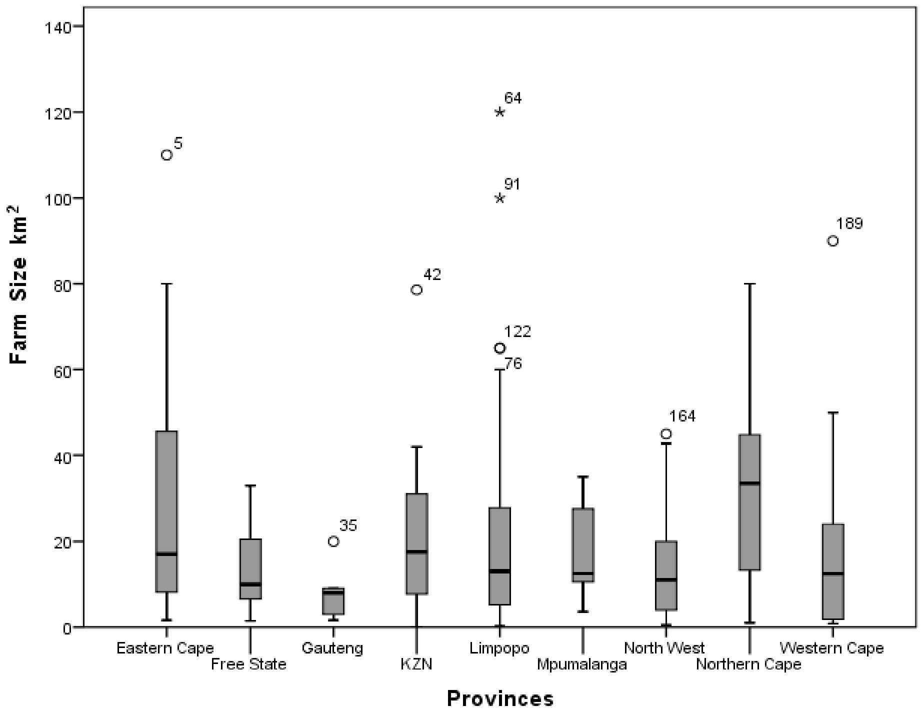

Figure 3.8. Variation in the respondents' farm sizes (km²) across the nine provinces, in South Africa (*n* = 205).

The mean number of respondents across each province was 23 (± 25 SD). The total area covered by the respondent's farms represents 6.5 % of South Africa total land coverage. Limpopo, followed by Gauteng, had the greatest density of respondents per km², whilst the Northern Cape had the lowest (Table 3.5.).

Table 3.5. Number of questionnaire respondents per province of South Africa, calculated by density per km².

Provinces of South Africa	**Number of respondents**	**Size of Province (km²)**	**Representation of respondent density (km²)**
Limpopo	86	123,910	1,441
North West	27	116,320	4,308
Free State	18	129,480	7,193
Kwa-Zulu Natal	19	92,100	4,847
Northern Cape	14	361,830	25,845
Eastern Cape	16	169,580	10,599
Western Cape	13	129,370	9,952
Mpumalanga	7	79,490	11,356
Gauteng	5	17,010	3,406
Total	**205**	**1,219,090**	**78,947**
Mean (±SD)	**23 ± 25**	**135,454 ± 94,884**	**8,772 ± 7,274**

The mean area (km²) covered for individual land use types from the questionnaire was 1.1 % (±1.4 % SD) in relation to the total land use coverage across South Africa. The land use type with the greatest representation in the questionnaire was nature conservation followed by grazing then arable (Table 3.6.).

Table 3.6. Area (km²) of each land use type (Department of Agriculture, Forestry and Fisheries, 2012, classification) per province compared to respondents' total farm area (km²).

Province	Land use	Total area (km²)	Respondents' total area (km²)	Proportion of total area represented (%)
Limpopo	Nature conservation	11,616	651	5.61
	Arable	17,004	45	0.26
	Grazing land	88,478	2,003	2.26
Mpumalanga	Nature conservation	23,319	490	2.10
	Arable	17,349	35	0.20
	Grazing land	32,439	47	0.15
North West	Arable	33,605	1	0.00
	Grazing land	67,380	378	0.56
Northern Cape	Nature conservation	42,951	10	0.02
	Grazing land	290,894	684	0.24
Western Cape	Nature conservation	7,307	113	1.55
	Arable	24,548	71	0.29
	Grazing land	91,058	60	0.07
Freestate	Arable	42,214	244	0.58
	Grazing land	75,387	189	0.25
Eastern Cape	Nature conservation	6,234	200	3.21
	Grazing land	136,448	434	0.32
Gauteng	Grazing land	3,900	42	1.07
KZN	Nature conservation	13,779	307	2.23
	Grazing land	53,296	357	0.67
Total		**1,079,207**	**6,360**	**0.59**
All land uses mean (±SD)		**53,960 ± 65,760**	**318 ± 450**	**0.59 ± 0.68**
Nature conservation mean (±SD)		**17,534 ± 13,862**	**295 ± 240**	**1.68 ± 1.73**
Arable mean (±SD)		**26,944 ± 7,803**	**79 ± 29**	**0.29 ± 0.37**
Grazing land mean (±SD)		**93,253 ± 83,083**	**466 ± 615**	**0.5 ± 0.74**

When considering all the categories land use types (Table 3.6.) the respondents' farm areas covered 6,360 km², which represents 0.59 % of the total known land use areas across South Africa. Cattle farming was the main land use reported by respondents, followed by game farming, sheep and goat farming, tourism and finally agriculture (Table 3.6.). Game farming was prevalent in Limpopo Province, whereas cattle farming was dominant in Eastern Cape, Free State, Gauteng, KZN, Mpumalanga and the North West (Table 3.7.). Sheep and goat farming was the main land use in the Northern Cape, with agriculture being high in the Western Cape (Table 3.7.). Across South Africa grazing land covers 77.8 % of the total land utilisation, followed by 12.5 % for arable and 9.7 % for tourism (Department of Agriculture, Forestry and Fisheries, South Africa, 2013). Therefore, the proportions of respondents, (85 % for grazing land: cattle, sheep and goats and game; 8 % tourism; 7 % agriculture) fall largely within the wider national categories.

Table 3.7. Percentage of total respondents (n = 200) per land use group each of the nine Provinces..

	Land use (% of total respondents per land use group)				
Province	Tourism	Sheep/goat farming	Cattle farming	Game farming	Agriculture
Eastern Cape	0.5	2.5	4.5	0.5	0
Free State	0	1	6.5	0	1.5
Gauteng	0	0	2	0.5	0
KZN	1	0	7	1	0.5
Limpopo	4.5	2.5	10	22	2
Mpumalanga	0.5	0.5	2	0.5	0.5
North West	0	1	10	2	0.5
Northern Cape	0.5	3.5	2.5	0	0
Western Cape	1.5	2	1.5	0	1.5
Total	**8.5**	**13**	**46**	**26.5**	**6.5**
Mean	**1.70**	**1.44**	**5.11**	**2.94**	**0.72**
(±SD)	**2.74**	**1.24**	**3.41**	**7.17**	**0.75**

When sub-divided the number of respondents who stated both their language in combination with their farming type came to 59 (Table 3.8.). The majority of respondents stated that their primary language was Afrikaans (69.5 %, n = 41), with the highest number of Afrikaan respondents being cattle farmers. English was the second language with the highest number of respondents again being cattle farmers (Table 3.8.). In South Africa the white population involved with agriculture, hunting, forestry and fishing makes up 8.04 %, in comparison to the black population of 71.5 %, of the total economically active population (Stats SA, 2012). The language of Afrikaans across all population groups represents 13.3 % of the total population compared to English (8.2 %), and IsiZulu which represents the most frequent language of the South African population at 23.8 % (Stats SA, 2012).

Table 3.8. Primary language of the respondents by farming type (*n* = 59).

Language	Farming type	Percentage of respondents (%)
Afrikaans	Agriculture	1.7
Afrikaans	Cattle farming	37.3
English	Cattle farming	8.5
Afrikaans	Game farming	23.7
English	Game farming	1.7
Afrikaans	Sheep/goats farming	20.3
English	Sheep/goats farming	6.8

The majority of the farms were surrounded by perimeter game fencing (2-3m fencing with 17-25 wire strands of 1-2m with four strands for cattle fencing). Responses to the question, 'which species respondents had seen on their property in the last twelve months' showed that the mean number of carnivores found on each property varied according to land use type with the highest proportion being sighted on game farms and tourist reserves (Figure 3.9.).

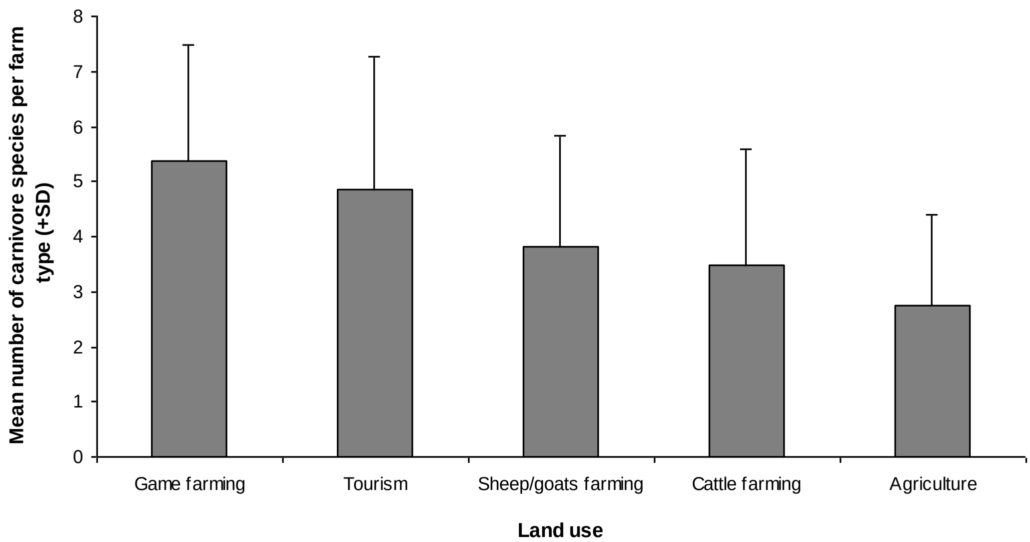

Figure 3.9. The mean (+SD) number of carnivore species present, per respondent's farm by land use type.

Jackals were the most widespread carnivore, being sighted on 78 % of farms (*n* = 181); followed by caracal 65 %; brown hyaena (56 %); leopard and aardwolf (43 %); serval (40 %); bat-eared fox (38 %); cheetah (20 %); cape fox (13 %); spotted hyaena (9 %); wild dog (6 %) and lion (2 %). For brown hyaena, the greatest mean number of individuals was found in game and tourism areas followed by sheep and goats, cattle and then agriculture (Figure 3.10.). There is a significant difference between the land use types and number of carnivore species present (Kruskal-Wallis test, $W = 29.22$, d.f. = 4, $P < 0.001$).

Respondent's attitudes towards carnivores varied from highly favourable to highly unfavourable depending on species (Table 3.9.). Only the brown hyaena appeared to divide opinion with 25 % of respondents stating they were highly favourable compared to 26 % stating they were highly unfavourable. The most favourably regarded species were the small-bodied carnivores; bat-eared fox, aardwolf and cape fox. The least favourably regarded species were the large apex predators; wild dog, spotted hyaena, cheetah and leopard.

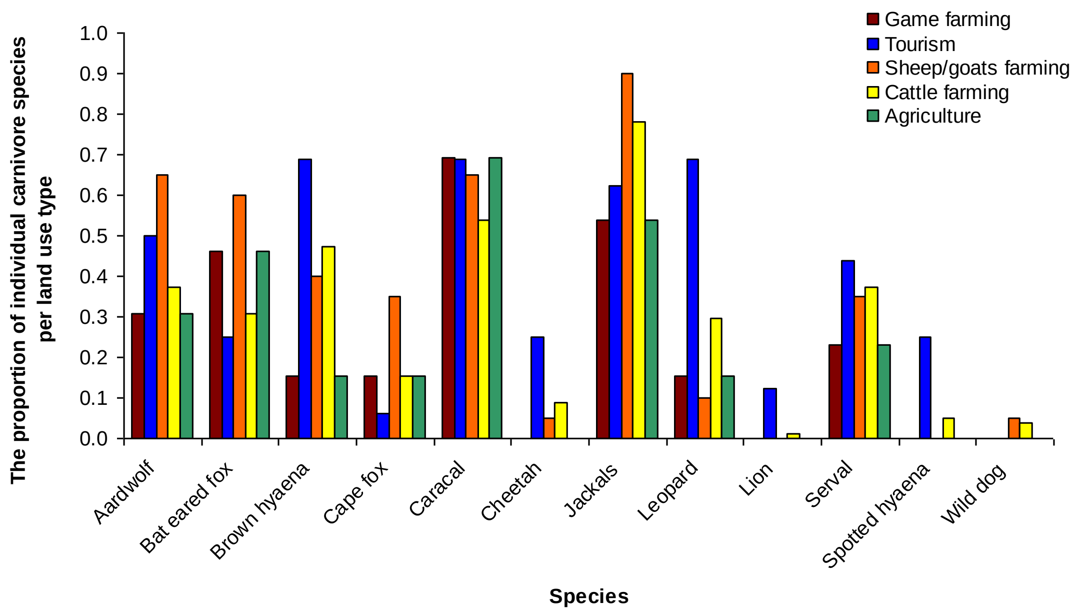

Figure 3.10. The proportion of individual carnivore species sighted per respondent' farm by land use type.

Table 3.9. Respondents' attitudinal responses (% highly favourable, % highly unfavourable) towards twelve carnivore species.

Species	**Highly favourable (%)**	**Number of respondents (*n*)**	**Highly unfavourable (%)**	**Number of respondents (*n*)**
Aardwolf	58	*98*	8	*14*
Bat-eared fox	60	*105*	6	*11*
Brown hyaena	25	*46*	26	*47*
Cape fox	30	*45*	14	*22*
Caracal	15	*27*	37	*22*
Cheetah	11	*20*	48	*83*
Jackals	12	*23*	36	*68*
Leopard	17	*31*	42	*75*
Lion	9	*8*	34	*29*
Serval	32	*55*	13	*22*
Spotted hyaena	7	*11*	52	*88*
Wild dog	7	*12*	63	*109*
Mean	**24.0**	***40.1***	**32.0**	***49.2***
(±SD)	**18.6**	***32.3***	**18.4**	***33.8***

There was a significant difference between the answers provided by the different land user groups (Figure 3.11.) and the resulting mean attitude score for all 12 carnivore species (Kruskal Wallis test, $W = 24.6$, d.f. = 4, $P < 0.001$, mean rank: sheep/goat = 18.5; cattle = 23.6; agriculture 24.5; game = 36.3; tourism = 49.5). Respondents from tourism followed by game properties owners had the most positive attitudes towards all carnivore species, whereas respondents from sheep and goat properties followed by the cattle owners had the least positive attitude towards all carnivores. There was also a significant difference between the answers provided by respondents of all land use types and the mean attitudinal score for all 12 carnivore species (Kruskal Wallis test, $W = 28.05$, d.f. = 11, $P = 0.003$).

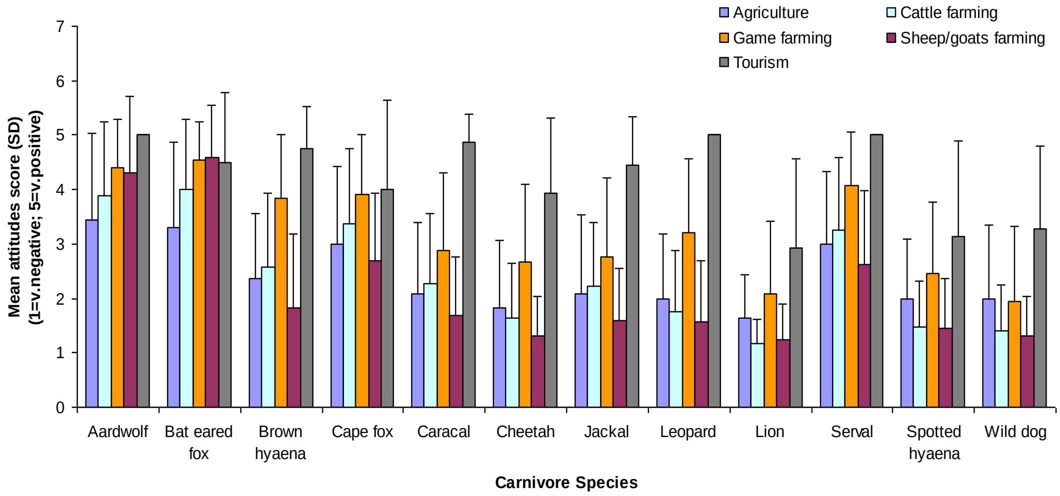

Figure 3.11. The mean attitudinal scores of respondents to each of twelve carnivore species (1 = v.negative; 5 = v.positive) (±SD), by land user type.

As discussed in the methods section 3.4. agriculture as a land use group was removed from the analysis as the sample size was too small and there was not a similar land use group that it could be combined with. Therefore, only livestock (cattle and sheep/goat) and game (game and tourism) groups were used for subsequent analyses. A significant result was that both land use groups felt either highly favourable or highly unfavourable to the idea of the majority of species being present on their property. The aardwolf, bat-eared fox and lion showed no significant association one way or the other. It is worth noting that there was a strong tendency for all farmers to have unfavourable attitudes towards wild dogs, spotted hyaena, leopard, cheetah, jackals and caracals. However, the chi-square results (Table 3.10.) revealed that there was a stronger than average association between game farmers and highly favourable attitudes. The significant findings for the above species were that more game farmers than expected felt that it was highly favourable to have these species present on their property (Table 3.10.). A further significant finding for the brown hyaena, cape fox and serval was that more game farmers than expected felt that it was highly unfavourable to have these species present on their property (Table 3.10.).

Table 3.10. Chi-Squared test results for responses of livestock farmers, compared to game farmers, to the statement: 'Indicate how you feel about having (or how you would feel about having) each of the following species on your property by giving each species a score'.

Species	χ^2	**d.f.**	***P***	**Causing significance (z-scores)**
Aardwolf	3.77	1	0.052	
Bat-eared fox	1.99	1	0.157	
Brown hyaena	38.69	1	0.000***	Livestock + Game liked
Cape fox	4.88	1	0.027*	Livestock + Game liked
Caracal	17.04	1	0.000***	Livestock + Game disliked
Cheetah	28.37	1	0.000***	Livestock + Game disliked
Jackal	21.46	1	0.000***	Livestock + Game disliked
Leopard	48.97	1	0.000***	Livestock + Game disliked
Lion	2.59	1	0.107	
Serval	19.6	1	0.000***	Livestock + Game liked
Spotted hyaena	23.02	1	0.000***	Livestock + Game disliked
Wild dog	14.04	1	0.000***	Livestock + Game disliked

* significant to $P < 0.05$, ** significant to $P < 0.01$,*** significant to $P < 0.001$

Predator control was used by 32 % of all respondents (n = 198). Game farmers only undertook predator control in one province, Limpopo. However, in the remaining provinces predator control was only undertaken by livestock farmers (Table 3.11.). Overall, the Western Cape Province has the greatest proportion of predator control (57 %), followed by Free State (47 %), Northern Cape (46 %) and Eastern Cape (44 %). The two provinces with the lowest rate of predator control were Mpumalanga (14 %) and North West (15 %) (Table 3.11.). Of the total number of respondents that stated both their primary language and whether they undertook predator control (n = 198), 40 % (n = 55) of Afrikaners but only 16 % (n = 9) of English speakers undertook predator control. Setswana was the only other language recorded. Of this group 100 % did not undertake predator control methods. Sheep and goat farmers undertook the largest proportion of predator control (75 %) followed by 31 % of cattle farmers and 27 % of game farmers (Table 3.11.). When combining first language and farming type (n = 198) English speaking cattle farmers (18 %) were least likely to undertake measures to reduce predator numbers but English speaking sheep/goat farmers were the most likely (80 %), followed closely by Afrikaans sheep/goat farmers (74 %). Tourism and agriculture were the two land uses in which 0 % predator control measures were undertaken across all languages (Table 3.11.).

Table 3.11. Percentage of the total respondents (n = 198), across the five land use types and all language groups, that undertook predator control on their property.

Provinces	Predator control (%) of total respondents / Language	Land use types: Sheep/goats farming	Cattle farming	Game farming	Tourism	Agriculture	All Uses
Eastern Cape	Afrikaans	100	50				67
	English	75	29	0	0		38
	Other						
	Setswana						
	Total	**80**	**33**	**0**	**0**		**44**
Free State	Afrikaans	100	45				50
	English	100	50			0	40
	Other						
	Setswana						
	Total	**100**	**46**			**0**	**47**
Gauteng	Afrikaans		25				25
	English			0			0
	Other						
	Setswana						
	Total		**25**	**0**			**20**
KZN	Afrikaans		57	0			44
	English		17		0	0	11
	Other		0				0
	Setswana						
	Total		**36**	**0**	**0**	**0**	**26**

Table 3.11. Percentage of the total respondents (*n* = 198), across the five land use types and all language groups, that undertook predator control on their property (continued).

Provinces	**Predator control (%) of total respondents / Language**	**Land use types: Sheep/goats farming**	**Cattle farming**	**Game farming**	**Tourism**	**Agriculture**	**All Uses**
Limpopo	Afrikaans	60	44	39	0	0	38
	English		0	0	0		0
	Other				0		0
	Setswana						
	Total	**60**	**35**	**32**	**0**	**0**	**29**
Mpumalanga	Afrikaans	100	0			0	20
	English		0		0		0
	Other						
	Setswana						
	Total	**100**	**0**		**0**	**0**	**14**
North West	Afrikaans	0	20	0			16
	English		25	0			17
	Other						
	Setswana		0			0	0
	Total	**0**	**20**	**0**		**0**	**15**
Northern Cape	Afrikaans	71	33		0		55
	English		0				0
	Other						
	Setswana						
	Total	**71**	**20**		**0**		**46**
Western Cape	Afrikaans	100	50		0	0	67
	English		0				0
	Other						
	Setswana						
	Total	**100**	**33**		**0**	**0**	**57**
All Areas	Afrikaans	74	37	35	0	0	40
	English	80	18	0	0	0	16
	Other		0		0		0
	Setswana		0			0	0
	Total	**75**	**31**	**27**	**0**	**0**	**32**

The main predator control method undertaken was hunting (shooting) which accounted for 55 % of cases, followed by trapping 26 %, poison 9 % and hunting with dogs 9 %. Afrikaners utilised hunting (shooting) as a method more than the English. However, in all remaining three methods the English speakers had a greater percent of use (Table 3.12.). The use of poison and trapping, both indiscriminate and illegal, were evenly utilised between both groups. The Free State used poison more than any other province, Northern and Western Cape had the highest proportional use of traps as a method of control, and the only two provinces to use all four control methods were the Free State and Western Cape. Only cattle, sheep/goat and game land use stated that predator control was undertaken on their property, therefore no predator control methods were used in tourism and agricultural areas. Hunting with dogs was only used by the livestock farmers (cattle, sheep/goat).

Jackal (52 %) and caracal (30 %) were the most targeted species by all three land use groups (sheep, cattle and game), using all four stated control methods. Game farmers targeted jackal the most (58 %), followed by sheep/goat and then cattle farmers, this was the same pattern for caracal, and the English targeted the species to a greater extent than the Afrikaners. However, overall the Afrikaners targeted 50 % more species than the English, which included brown hyaena, cape fox, cheetah, hyaena (species unknown), leopard and spotted hyaena. Leopards were the third most targeted species (7 %) across 30 % of the total Provinces. Brown hyaenas were only targeted in the Limpopo and Western Cape Provinces. However, hyaena (unknown species) was also targeted in KZN and Free State. Cheetahs and spotted hyaenas were only targeted in the Limpopo Province. The methods of control used by respondents specifically for brown hyaena were hunting (shooting) with spot lights at night and traps (Table 3.13.). Although snares were listed twice as a method of control, the language of the respondent was not stated. Therefore, the method could not be added to Table 3.13. The species which the snares were aimed at catching were; wild dog, lion, leopard, jackal and caracal by a game farmer in Limpopo and a cattle farmer in the North West. The mean number of days that predator control was undertaken on a property was 139 days ± 162 (SD), with a variation in timeframes between 30 days (n = 25), 180 days (n = 5) and all year (365 days) (n = 15).

Table 3.12. The predator control methods (%) used across languages and provinces (*n* = 198).

		Land use types															
		Sheep/goats farming				Cattle farming				Game farming			Tourism	All land use			
Province	**Method of control / Language**	**Hd**	**Hs**	**T**	**P**	**Hd**	**Hs**	**T**	**P**	**Hs**	**T**	**P**	**Hd**	**Hd**	**Hs**	**T**	**P**
Eastern Cape	Afrikaans	50	50				100							33	67		
	English					33	33	33						33	33	33	
	Total	**50**	**50**			**25**	**50**	**25**						**33**	**50**	**17**	
Free State	Afrikaans		100					33	67						25	25	50
	English					100								100			
	Total		**100**			**25**		**25**	**50**					**20**	**20**	**20**	**40**
Gauteng	Afrikaans																
	English						100								100		
	Total						**100**								**100**		
KZN	Afrikaans						67	33							67	33	
	English						33	33	33						33	33	33
	Total						**50**	**33**	**17**						**50**	**33**	**17**
Limpopo	Afrikaans		67	33			67	33		73	20	7			71	24	5
	English																
	Total		**67**	**33**			**67**	**33**		**73**	**20**	**7**			**71**	**24**	**5**

Key: Hd: Hunting with dogs; Hs: Hunting by shooting; T: Trapping; P: Poison

Table 3.12. The predator control methods (%) used across languages and provinces (*n* = 198) (continued).

		Land use types															
		Sheep/goats farming				**Cattle farming**				**Game farming**			**Tourism**	**All land use**			
Province	**Method of control / Language**	**Hd**	**Hs**	**T**	**P**	**Hd**	**Hs**	**T**	**P**	**Hs**	**T**	**P**	**Hd**	**Hd**	**Hs**	**T**	**P**
Mpumalanga	Afrikaans	100												100			
	English																
	Total	**100**												**100**			
North West	Afrikaans						100								100		
	English							100								100	
	Total						**67**	**33**							**67**	**33**	
Northern Cape	Afrikaans		50	50			100								67	33	
	English																
	Total		**50**	**50**			**100**								**67**	**33**	
Western Cape	Afrikaans		33	50	17								100	14	29	43	14
	English																
	Total		**33**	**50**	**17**								**100**	**14**	**29**	**43**	**14**
Total	Afrikaans	13	47	33	7		62	23	15	73	20	7	100	7	59	25	9
	English					22	33	33	11					22	33	33	11
	Total	**13**	**47**	**33**	**7**	**9**	**50**	**27**	**14**	**73**	**20**	**7**	**100**	**9**	**55**	**26**	**9**

Key: Hd: Hunting with dogs; Hs: Hunting by shooting; T: Trapping; P: Poison

Table 3.13. The predator control methods used in relation in each targeted species across languages and provinces categories (*n* = 198) by land use type.

		Land use type																						
		Sheep/goats farming				**Cattle farming**							**Game farming**			**All land uses**								
Province	**Species / Language**	**Bh**	**Cf**	**Ca**	**Jc**	**Bh**	**Ca**	**Ct**	**H**	**Jc**	**Lp**	**Mg**	**Ca**	**Jc**	**Sh**	**Bh**	**Cf**	**Ca**	**Ct**	**H**	**Jc**	**Lp**	**Mg**	**Sh**
Eastern Cape	Afrikaans			50	50					100								33			67			
	English			50	50		33			67								40			60			
	Total			**50**	**50**		**25**			**75**								**38**			**63**			
Free State	Afrikaans			50	50		44		11	44								45		9	45			
	English				100																100			
	Total			**33**	**67**		**44**		**11**	**44**								**42**		**8**	**50**			
Gauteng	Afrikaans				100																100			
	English				100																100			
	Total				**100**																**100**			
KZN	Afrikaans						20		20	40	20							20		20	40	20		
	English						33			33		33						33			33		33	
	Total						**25**		**13**	**38**	**13**	**13**						**25**		**13**	**38**	**13**	**13**	
Limpopo	Afrikaans				100	6	19	13		38	25		37	58	5	3		28	6		50	11		3
	English																							
	Total				**100**	**6**	**19**	**13**		**38**	**25**		**37**	**58**	**5**	**3**		**28**	**6**		**50**	**11**		**3**

Key: Bh: Brown hyaena; Ca; Caracal; Ct: Cheetah; H: Hyaena (species unknown; Jc; Jackal; Lp: Leopard; Mg: Mongoose (species unknown); Sh: Spotted hyaena

Table 3.13. The predator control methods used in relation in each targeted species across languages and provinces categories (n = 198) by land use type (continued).

		Land use type																						
		Sheep/goats farming				**Cattle farming**							**Game farming**			**All land uses**								
Province	**Species / Language**	**Bh**	**Cf**	**Ca**	**Jc**	**Bh**	**Ca**	**Ct**	**H**	**Jc**	**Lp**	**Mg**	**Ca**	**Jc**	**Sh**	**Bh**	**Cf**	**Ca**	**Ct**	**H**	**Jc**	**Lp**	**Mg**	**Sh**
Mpumalanga	Afrikaans																							
	English																							
	Total																							
North West	Afrikaans									100											100			
	English										100											100		
	Total									**67**	**33**										**67**	**33**		
Northern Cape	Afrikaans		20	20	60					100							17	17			67			
	English																							
	Total		**20**	**20**	**60**					**100**							**17**	**17**			**67**			
Western Cape	Afrikaans	17		50	33											13		50			38			
	English																							
	Total	**17**		**50**	**33**											**13**		**50**			**38**			
Total	Afrikaans	6	6	35	53	3	24	6	6	47	15		37	58	5	3	1	31	3	3	51	7		1
	English			25	75		29			43	14	14						27			55	9	9	
	Total	**5**	**5**	**33**	**57**	**2**	**24**	**5**	**5**	**46**	**15**	**2**	**37**	**58**	**5**	**2**	**1**	**30**	**2**	**2**	**52**	**7**	**1**	**1**

Key: Bh: Brown hyaena; Ca; Caracal; Ct: Cheetah; H: Hyaena (species unknown; Jc; Jackal; Lp: Leopard; Mg: Mongoose (species unknown); Sh: Spotted hyaena

National killing rates (individuals/100 km^2) were substantially lower for jackal when compared to Thorn *et al*.,'s (2012) North West Province only killing rates; however, caracal killing rates were three times higher nationally (Table 3.14.). In the North West the number of individual jackals killed was reported as >1,000, whereas only 416 were reported nationally. Killing rates for the brown hyaena were also lower nationally but leopards were the same as the North West Province only. Cheetah could not be added to the analysis even though it was listed as a target species as the exact numbers killed per year were absent from the respondents input.

Table 3.14. National (South Africa) killing rate per 100 km^2, by species, of individual carnivores, based upon responses (n = 37), compared to the total killing rate per 100 km^2 of individual carnivores determined in the North West Province only (Thorn *et al.*, 2012).

Species	**Total number of individuals killed using all predator control methods/year (*n* = 36)**	**National killing rate (number of individuals killed /100 km²) (*n* = 36)**	**North West Province killing rate (no. individuals killed /100 km²) (*n* = 42)**
Jackal	416	6.54	29.4
Caracal	215	3.38	1.1
Leopard	7	0.1	0.1
Brown hyaena	6	0.09	0.4
Mongoose (species unknown)	2	0.03	unknown
Cheetah	0	0.00	0.3

The targeting of jackal also reflected in the responses of farmers to whether carnivore numbers are increasing, decreasing or remaining constant over the past five years on their property (Figure 3.12.). Jackals are the only species to show a majority increase (37.1 %) compared to caracal (21.9 %) and the other carnivores targeted for predator control.

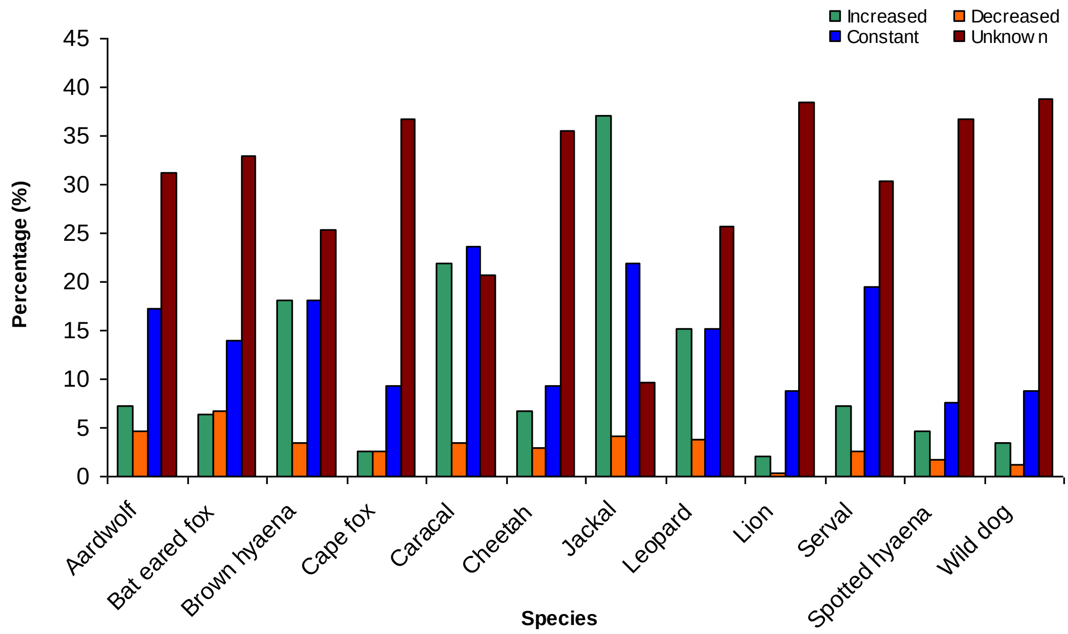

Figure 3.12. Responses to the question, 'Compared to approximately 5 years ago, do you think predator numbers have Increased, Decreased, Remained Constant, or Unknown on the property?' in relation to each carnivore species (*n* = 173).

Farmers' stock value, inclusive of game and livestock, was determined in relation to the size of each individual property. The mean value was £34,701 per km² ± 117,424 (SD) with a range of £287/km² to £1,491,464/km². Individual stock values were stacked into three groups: low (0-1,000 £/km²), medium (1,001-2,000 £/km²) and high (2,000+ £/km²) to determine whether the value of stock influenced the farmer's propensity to undertake predator control. However, there was no significant difference between the three stock value groups in relation to whether they would or would not undertake predator control on their properties (Chi-Square test, $\chi^2 = 0.437$, d.f. = 2, $P = 0.804$).

Farmers believe that their perimeter fences are not acting as a barrier to brown hyaena movement and therefore they are able to move between farms (yes = 93, *n* = 198). They are also regularly finding spoor (tracks) on their property with 84.8 % having a sighting of an individual brown hyaena within the last 12 months, of which 11.1 % see one every week and 49.1 % have a sighting once a month (Figure 3.13.).

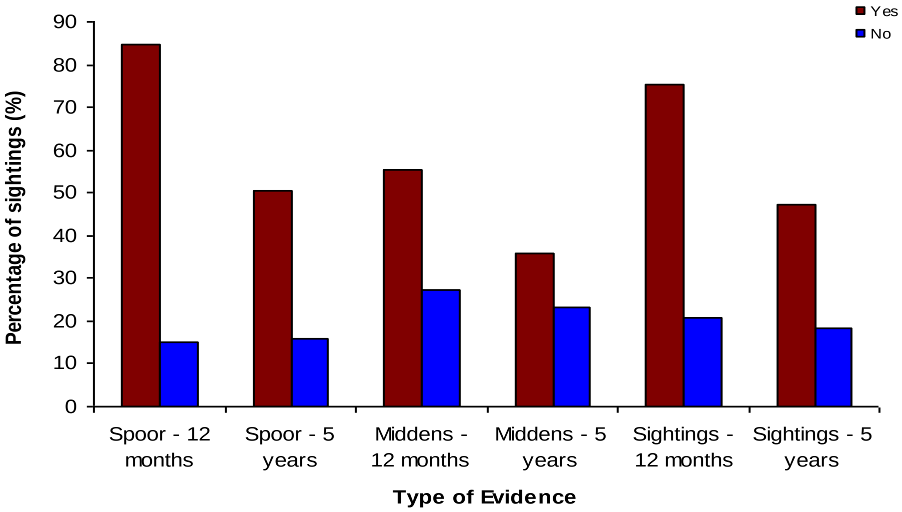

Figure 3.13. Farmers' responses to the question, 'Which evidence of the presence of brown hyena has been seen on the property in the last 12 months and 5 years' (*n* = 125), by type of evidence and percentage of sightings.

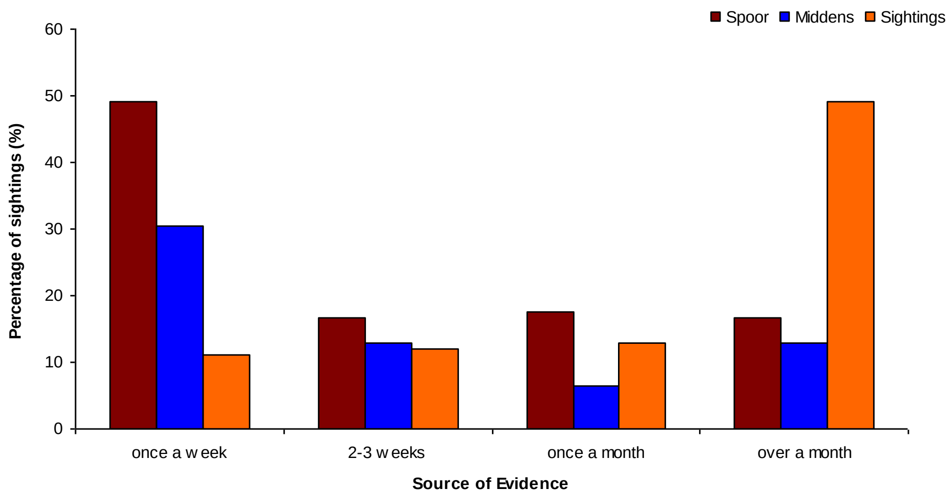

Figure 3.14. Farmers' responses to the question, 'If yes to seeing brown hyaena evidence in the last 12 months, how frequently is the evidence seen?' (*n* = 108), by type and frequency of evidence sightings.

Farmers recorded brown hyaena pups on 28 % and 29 % properties in the last twelve months and five years, respectively. Overall, the farmers viewed the brown hyaena as either just a scavenger (47 %) or both a scavenger and predator (44 %) with a minority stating the hyaena was just a predator (9 %). Farmers across different land use groups were found to have similar attitudes to the brown hyaena in relation to being perceived as a predator, scavenger or both (Chi-Square test, χ^2 = 1.34 d.f. = 2, P = 0.512). Overall, the attitude towards brown hyaenas was positive with 50 % of all respondents (n = 190) saying they would want them on their property compared to 32 % who did not want them on their property and 18 % whose views were unknown. However, when asked if they would want brown hyaena on their properties there was a significant association between land use (sheep, cattle, game, tourism) and attitude (Chi-Square test, χ^2 = 29.4, d.f. = 2, P < 0.001) a significantly greater number of game farmer and tourism respondents stated that they would want brown hyaenas on their property rather than not. There was a significant association between game farmers (tourism) and a disagreement with the statement that their fences were there to actively discourage brown hyaena from coming onto their property (Chi-Square test, χ^2 = 6.388, d.f. = 1, P = 0.041).

When asked whether farmers wanted hyaenas on their property or not they were asked for the reasons behind their decisions. The only reason for not wanting hyaenas on their property was related to their perceived impact on livestock (31 % of farmers, n = 124). The most common reason for wanting hyaenas on their property was 'their value for the natural ecosystem' (39 %), followed by tourism (6 %). This is reflected in 35 % of farmers stating that brown hyaenas are actively conserved on their properties (Table 3.15.). Other reasons for which an attitude was not assigned included 'don't understand the species' and 'not in my area' (24 %).

Farmers were asked to indicate whether they agreed or disagreed with a number of statements in relation to brown hyaenas (Table 3.15.). These responses were then analysed against the respective farming activities. There was no significant difference between livestock and game farmers for agreeing or disagreeing to the statement 'Brown hyaena regularly hunt and kill game' (Table 3.15.). Conversely, significant differences were found for all the remaining statements (Table 3.15.). The clear distinctions between the response of game and livestock farmers are in line with expected outcomes, given their differing economic drivers. However, the response to the statement 'Brown hyaena are a natural component of a healthy ecosystem' provided an unexpected result from the game farmers who, having demonstrated largely positive attitudes to and tolerance of brown hyaenas on their property, indicated that they did not regard brown hyaenas as a natural part of the ecosystem (Table 3.15.).

Table 3.15. Chi-squared results of questionnaire responses (agree/disagree) to a series of statements about brown hyaena in association with land use types

Statement	**Agree**	**Disagree**	**Unanswered**	**Chi-Square test ($\chi 2$)**	**d.f.**	***P***	Significant associated response group
Brown hyaena regularly hunt and kill game	52	104	46	2.764	2	0.251	no difference
Brown hyaena regularly hunt and kill livestock	60	106	36	8.010	2	0.018*	Game farmers disagree
Brown hyaena are a natural component of a healthy ecosystem	148	19	35	13.758	2	0.001***	Game farmers disagree
Brown hyaenas are a liability to a livestock farmer because they consume valuable livestock but provide no economic return	79	87	36	58.283	2	0.000***	Livestock farmers agree
Brown hyaenas are a liability to a game farmer because they consume valuable game but provide no economic return	47	114	41	9.793	2	0.007**	Game farmers agree
I would not mind having brown hyaena on my land	116	54	32	37.586	2	0.000***	Game farmers agree
I would not mind having brown hyaena on my land and denning on the property	107	61	34	30.455	2	0.000***	Game farmers agree
The fences are there to actively discourage brown hyaena from coming onto the property	23	145	34	6.388	2	0.041*	Game farmers disagree
Brown hyaenas are actively conserved on the property	81	81	40	35.684	2	0.000***	Game farmers agree

* significant to $P < 0.05$, ** significant to $P < 0.01$, *** significant to $P < 0.001$

3.8. Discussion

3.8.1. National Distribution Maps of Carnivores across South Africa deriving from the Questionnaire Survey

The questionnaire survey revealed the presence of aardwolf, brown hyaena, caracal, jackal and serval across all nine provinces of South Africa. Jackal and caracal were the most widely distributed species followed by brown hyaena. Lion were the least recorded species followed by wild dog, spotted hyaena and cheetah. The greatest proportions of presence for the twelve carnivore species were found across the provinces; Eastern Cape: cape fox, lion and bat-eared fox; Free State: jackal and aardwolf; KZN: spotted hyaena; Limpopo: wild dog and cheetah; Mpumalanga: brown hyaena and serval; Western Cape: caracal. The Province of Gauteng had the highest number of absent records, with half of the carnivore species not recorded, which may have been due to the province being the smallest of all the nine provinces and to the high level of urbanisation.

The results for aardwolf were consistent with previous studies as the aardwolf has been shown to cover most of Southern Africa (Anderson and Mills, 2008). The aardwolf is found in areas of open grassland and scrub and, specifically, is dependent on its niche food availability, *Trinervitermes* termites (Anderson and Mills, 2008). The results for bat-eared fox were also consistent with previous studies, as the species has recently expanded its range in Southern Africa due to changes in rainfall patterns (Nel and Maas, 2008). The species' habitat preferences of short-grass plains and bare ground fit the profile of the coastal cape regions and, hence, the study found the highest distribution levels in these areas (Nel and Maas, 2008). The results for cape fox were consistent with previous studies as the cape fox has been found to expand its range over recent decades particularly into the Eastern Cape region and is known to be distributed across South Africa (Stuart and Stuart, 2008). The study found that leopards had a patchy distribution but were wide ranging across South Africa, which is in line with previous studies (Henschel *et al.,* 2008). It has been reported that the leopard has suffered marked range loss in South Africa and other areas (Ray *et al.,* 2005). However, this study identified three strongholds of distribution across the Limpopo, KZN and Western Cape Provinces. This finding supports the consensus that the majority of leopard populations are found outside of protected areas (Henschel *et al.*, 2008).

The results for jackal and caracal are consistent with previous studies showing they are still common and widely abundant (Friedmann and Daly, 2004; Breitenmoser *et al.,* 2008; Thorn *et al.,* 2011a). However, serval were thought to be restricted to high rainfall areas and rarely found in arid areas (Nowell and Jackson, 1996). Nevertheless, in agreement with Hermann *et al.,* (2008) and Thorn *et al.,* (2012) this study found a presence in all nine provinces, with a dominance across the northeast of South Africa (Mpumalanga and KZN).

Similarly, large-bodied apex predators such as lion, spotted hyaena and wild dog are deemed to be locally extinct from the unprotected rangelands (Hayward *et al.,* 2006; 2007ab). However, this study captured records of presence outside the designated protected areas. A significant result was that the wild dog, listed as 'Endangered' by the IUCN Red List (Woodroffe and Sillero-Zubiri, 2012) and geographically restricted to Kruger National Park in South Africa, was recorded in two Provinces, Limpopo and KZN. This shows that, in agreement with Lindsey *et al.*, (2005), there is potential for conserving naturally occurring wild dogs *in situ* in unprotected rangelands.

The lion, whose status is still unknown over large parts of Africa (7.6 million/km²) (Bauer *et al.,* 2012), was recorded in two provinces, Limpopo and Eastern Cape, which had the highest distribution. Similarly, cheetahs are known to be present and have viable populations mainly outside of protected areas in, for example, the Limpopo Province (Marnewick *et al.,* 2006; Durant *et al.,* 2008). This study reflects this previous finding as the greatest cheetah distribution was found across this province and into the North West.

3.8.2. Brown Hyaena Distribution across South Africa deriving from the Questionnaire Survey

In South Africa the brown hyaena historically occurred from the southern cape throughout the south west arid zone to northern south west Africa (Eaton, 1976; Mills and Hofer, 1998). The brown hyaena distribution reports by IUCN (Mills and Hofer, 1998; Wiesel *et al.,* 2008) and others (Friedmann and Daly, 2004; Thorn *et al.,* 2009; Thorn *et al.,* 2011a) revealed that the brown hyaenas had the highest distribution across the North West and

Limpopo provinces and had the lowest distribution across large parts of the Eastern and Western Capes. The current national questionnaire survey revealed the presence of brown hyaena across all nine provinces of South Africa in line with the distribution patterns found in previous studies.

The survey revealed the presence of brown hyaena across Mpumalanga (78 %), Limpopo (77 %), North West (71 %) and Gauteng (50 %) to be the cluster of provinces with the greatest proportions. These findings are in line with the original distribution ranges of Mills and Hofer (1998). These four provinces were a stronghold for the brown hyaena in since the 1970s (Eaton, 1976) which, based on this study's findings, is still true today. The distribution of brown hyaena presence across the North West mirrors those results found in the recent study by Thorn *et al.,* (2011).

The presence of brown hyaena across the Western Cape (21 %), Eastern Cape (23 %) and Northern Cape (29 %) reveal this to be the cluster of provinces with the lowest proportions. These findings are in agreement with Mills and Hofer (1998), Friedmann and Daly (2004) and Wiesel *et al.,* (2008) showing that the cape region contains the lowest distribution of the brown hyaena with the exception of the Gemsbok National Park.

In 1998 the brown hyaena was deemed practically extinct in the Free State (Mills and Hofer, 1998); however, the findings of this national questionnaire survey are contradictory to that study since they showed presence on 40 % of farms. Mills and Hofer (1998) identified that the brown hyaena was mainly persecuted and killed by sheep farmers. However, the current provincial distribution of sheep identifies that the Eastern Cape Province has the highest density of sheep (7,294 million) followed by the Northern Cape Province (6,018 million) then the Free State Province (4,806 million) (Department of Agriculture, Forestry and Fisheries, South Africa, 2013). This study has seen widespread occurrence of brown hyaena throughout the Free State, even though the questionnaire outcomes have also shown that both cattle and sheep farmers have negative attitudes towards the majority of medium-large bodied carnivores but not the brown hyaena.

Mills and Hofer (1998) discovered no resident populations of brown hyaena in KZN due to the reported high levels of shooting and trapping. However, this questionnaire survey, in agreement with Friedmann and Daly (2004), identified the presence of brown hyaena on 42

% of farms, and a greater likelihood of presence in the northern half of the province compared with the south. In accordance with Friedmann and Daly's (2004) study, the findings also show a presence of brown hyaena on the boundary between KZN and the Eastern Cape.

Across South Africa there were 29 data points collected by the national questionnaire outside of the historically recognised extent recorded by Friedmann and Daly (2004), of which brown hyaena was present at 31 % of sites. Furthermore, in comparison to the IUCN Red List current known extent in 2013 (Wiesel *et al.,* 2008), a total of 44 data points were outside the range with brown hyaena being present at 34 % of sites. In combination with the historically recognised extent (2004) and the IUCN Red List current known extent (2013), 15 data points were outside both ranges with brown hyaena present at 25 % of sites. These new brown hyaena sightings mean that it is necessary to undertake further investigations to quantify whether these sightings are part of new viable populations or a few occasional sightings of lone individuals. These new data points highlight the importance of conducting this type of study. In agreement with Groves and Peterson (1992), the results give a clearer understanding of species distributions which can then be used to inform conservation management.

Unlike Eaton (1976), Mills and Hofer (1998) identified that brown hyaenas were found in many of the smaller game reserves. In South Africa, an area of 33,205 km^2 has been set aside for conservation or multiple use wildlife areas by private individuals or groups (Pinnear, 1991), which is potentially suitable habitat for brown hyaenas and other medium-large bodied carnivore species (Lindsey *et al.,* 2005).

Eaton (1976) determined that brown hyaenas prefer areas with low rainfall and predominately acacia, mopane scrub or woodland vegetation, a pattern supported by this study. The distribution of brown hyaena was significantly associated with woodland vegetation, which is in agreement with (Thorn *et al.,* 2009) who showed that hyaenas prefer dense vegetation. The greatest occurrence of brown hyaenas was found in areas within the high rainfall transitional zone, 300-2,000 mm annually, situated between the arid Kalahari and the moister eastern savannahs of southern Africa. This contradicts Mills (1990) who suggests the brown hyaena is designated as a semi-arid species, traditionally inhabiting areas that have 700 mm rainfall or less annually (Mills and Hofer, 1998).

Overall, the data from the questionnaire identified that farmers perceived brown hyaenas to be increasing (28 %), remaining constant (28 %) or they did not know (39 %) but only 5 % thought the species was declining. These findings are in line with Thorn *et al.*, (2011a) who stated that in the North West Province brown hyaenas had the greatest increase in extent and area of occupancy in comparison to the other medium-large resident carnivores post Friedmannn and Daly's (2004) study.

The results presented here generally agree with the historical distribution (Friedmann and Daly, 2004), Eaton's (1976) notes and the studies of Thorn *et al.*, (2009; 2011a) on distribution patterns of brown hyaena. In addition, the survey agrees with the re-classification of the brown hyaena distribution map by the IUCN Red list (Wiesel *et al.*, 2008). As the results of this study have shown, the distribution of brown hyaena from 1998 has substantially increased, due to further data collection, and it now covers the majority of South Africa, with exceptions still being found along the south and eastern coastlines.

Questionnaires were utilised to collect the data for all the earlier studies referred to with a varying sample size of respondents (Mills and Hofer, 1998; Friedmannn and Daly, 2004; Wiesel *et al.*, 2008; Thorn *et al.*, 2011a) and utilised experts who are experienced in species recognition (Lovell *et al.*, 1998; Carrier and Beebee, 2002; Thorn *et al.*, 2009). However, the distribution map produced for this study, using non-expert stakeholders, accurately represents carnivore, in particular brown hyaena, distributions in South Africa in accordance with the previous studies. This study has provided a baseline of distribution from which long term population monitoring of twelve carnivores, which range from 'Least Concern' to 'Critically Endangered' (IUCN, 2013), and occur on a national scale can be undertaken. As other studies have found, future data collection within a similar format will add substantial information on the distribution of the twelve carnivores and highlight any potential fluctuations (Berg *et al.*, 1983; Carrier and Beebee, 2002; Sathyakumar and Choudhury, 2007).

3.8.3. National Attitudes towards Carnivores in South Africa: Survey Findings

Brown hyaenas were sighted on 52 % of the properties, which is a positive sign that a viable population exists in the unprotected rangelands (Mills and Hofer, 1998; Burgener and Gusset, 2002; Maude and Mills 2005; Thorn *et al.,* 2009; 2011ab; 2012). The study highlighted the fact that, compared to other carnivores such as jackals and caracals, brown hyaenas are perceived by game farmers as a major threat towards livestock (Mills, 1990). When asked specifically about brown hyaenas the overriding negative attitude of livestock farmers was due to the perceived threat to their livestock, in particular their young calves, which is in line with the findings of Weisel *et al.*, (2008). The negative attitudes increased with body size as the three smallest carnivores (aardwolf, bat-eared fox, cape fox) were shown to be most liked whereas the large bodied apex predators such as the spotted hyaena, lion and wild dog were the least liked by both groups of livestock and game farmers.

Aardwolf were found by the study to be predominantly sighted on sheep and goat farms where 58 % of respondents displayed highly favourable views to having them on their property. This species was not cited as a predator-controlled species by respondents. These findings concur with Anderson and Mills (2008) who noted in their study that perceptions of aardwolf have changed recently in that they were regarded as livestock killers but are now recognised, through dietary evidence, as representing no threat to livestock. They further noted that aardwolf are being killed indirectly through poisoning of their sole food source (Anderson and Mills, 2008).

Sightings of bat-eared fox were also found by this study mainly on sheep and goat farms. They were regarded highly favourably by 60 % of respondents, with no significant difference between the attitudes of different types of land users. A previous study showed that bat-eared foxes are occasionally persecuted on farms and are hunted for their skins, as well as being perceived as a killer of small livestock (Nel and Maas, 2008). This study found no evidence of such persecution, since no respondent listed the bat-eared fox as a species subject to predator control.

Cape fox was also present predominantly on sheep and goat farms but was regarded highly favourably by only 30 % of respondents. However, more game farmers than expected displayed negative attitudes towards them although they did not go so far as to identify the species as a target of predator control. This contrasts with the findings of Stuart and Stuart (2008) which described the species as declining due to being the subject of predator control.

Cheetah were reported as being sighted primarily on farms that are tourism-based. 48 % of all respondents to the questionnaire regarded the presence of cheetah on their property highly unfavourably. Sheep and goat farmers regarded them particularly negatively. However, more game farmers than expected displayed positive attitudes towards them. Even so, the species was still identified as a target of predator control. These results fall in line with Durant *et al.,* (2008) and reinforce the fact that the main threat to cheetahs is the ongoing conflict with livestock farmers.

Serval, similarly, were most observed on tourism-based farms and regarded highly favourably by 32 % of respondents. More game farmers than expected regarded having them on their property highly unfavourably.

Leopard, mainly sighted by respondents on sheep and goat farms, were regarded highly unfavourably by 42 %. Ray *et al.,* (2005) found that intense persecution and real and perceived livestock losses were affecting the leopard population, the majority of which are resident outside the protected areas. Based on those previous findings, it is perhaps not surprising that this study found leopard to be a predator-controlled species.

Lion were regarded highly unfavourably by 34 % of respondents to this study, with cattle farmers taking a particularly negative view. However, this was largely a theoretical view since the vast majority of the species are confined to protected areas. The same applies to spotted hyaena, noted by Honer *et al.,* (2008) as having stable populations concentrated in protected areas.

Wild dog were regarded highly unfavourably by 63 % of respondents in this study, particularly sheep/goat and cattle farmers. However, the most positive attitudes came from tourism-based farms, which demonstrates potential for eco-tourism (Lindsey *et al.,* 2005). The findings concur with Woodroffe and Sillero (2012), who suggested that, outside protected areas, wild dogs may be unable to co-exist with increasing human populations unless conservation actions such as eco-tourism are implemented.

Sheep and goat farmers showed the greatest dislike of all carnivore species across all land use groups, followed by cattle, agriculture, game and tourism.

Previous studies have found that human-mediated changes, such as perimeter fences have resulted in the inability of species to disperse and/or colonise an area as they act as a barrier (Hayward, 2009; Davies-Mostert *et al.,* 2013). However, in this study game famers (tourism) stated that their fences were not there to actively discourage hyaenas and that the hyaenas could move freely through them. This is a positive result as it allows unrestricted movement of brown hyaenas across the unprotected areas and suggests much of the unprotected areas in South Africa are contiguous which will help to maintain genetic heterogeneity, thus reducing the risk of extirpation from localised stochastic events (Lindsey *et al.,* 2005; Hayward *et al.,* 2009).

Predator control was undertaken by a third of respondents. Western Cape, Free State and Northern Cape Provinces displayed the highest levels of use of predator control methods, while respondents from Mpumalanga Province used these methods least. Livestock farmers (75 %) were, primarily sheep and goats, followed by cattle farmers. Both groups were predominantly targeting jackals and caracals. This corresponds with the findings of Blaum *et al.,* (2009), Thorn *et al.,* (2009; 2012) and St John *et al.,* (2012). However, this finding contradicts Lindsey *et al.,* (2005) who found that attitudes towards jackals were very positive, although the study took place on conservancies, which support conservation activities. The evidence from chapter 4 demonstrated that in the unprotected areas the abundance of the mesopredators, in particular jackals, was higher and that the brown hyaenas are potentially filling the roles of apex predators (Roemer *et al.,* 2009). Jackals are seen as a common and widely abundant species, in conjunction with being the most targeted species in relation to predator control. Thus, it is a critical finding that brown hyaenas could potentially be acting as a suppressor of the mesopredators (particularly jackals) due to the dietary niche overlap found only in the unprotected areas (Merwe *et al.,* 2009; Yarnell *et al.,* 2013). Therefore, by maintaining brown hyaenas numbers across the unprotected areas jackal numbers may be being kept under control. This finding has implication on the wider human-wildlife conflict across South Africa as removal of brown hyaenas, who are acting as a suppressor, could cause jackal to go through further 'mesopredator release' which would lead to substantial higher conflict and killing rates than are currently found.

Nationally, caracal were targeted 32 % compared to a lower figure of 20 % across the North West Province (Thorn *et al.,* 2009; 2012; St John *et al.,* 2012). National brown hyaena killing rates were lower than those found in the North West Thorn *et al*., (2012), but leopard were found to be equal. However, St John *et al.,* (2012)'s study found that 19 % of farmers had killed leopards on their property in the past year; these figures were not reflected in the findings of this study.

Mills and Hofer's (1998) study found high levels of shooting and trapping of brown hyaena in KZN and low density of brown hyaena in the Free State (caused by the numerous sheep/goat farmers). In seeking to establish whether the results of that study were still current, it emerged from this survey's results that shooting and trapping, are still ongoing in KZN but that poisoning is now also used; in the Free State 100 % of Afrikaan sheep/goat farmer respondents stated that they undertake control through hunting. In both provinces the hyaena (species unstated), was listed as a target for predator control. Even though brown hyaenas were listed as a targeted species, the number killed was a very small proportion in relation to other carnivore species (St John *et al.,* 2012).

Overall, the amount of predator control being undertaken in the North West Province (Thorn *et al.,* 2012) was twice as high as that occurring at the national level. The national killing level for jackal in the North West was substantially higher in comparison to the national results from this study. However, this may be due to the land use configuration across all the Provinces varying in relation to just the North West Province, as the number of livestock farmers was higher in other Provinces. In agreement with Lindsey *et al.,* (2005) and Thorn *et al.,* (2012) cultural group, as determined using the primary language spoken, was found to be one of the most influential factors over predator control methods. The Afrikaners were the most likely to use lethal control. However, farming types, in particular livestock farmers, when combined with cultural groups, were the strongest predictors of the extent of predator control methods undertaken on individual farms. There was a significant association between livestock farmer respondents and an agreement with the statement 'brown hyaenas are a liability to a *livestock* farmer because they consume valuable livestock but provide no economic return'. However, when asked if 'brown hyaenas are a liability to a *game* farmer because they consume valuable game but provide no economic return' there was a significant association between game farmers and an agreement to the statement. This highlights that all farmers feel that overall the brown hyaena is a liability to both livestock and game farmers. This is a worrying trend as 88 % of the North West Province was Afrikaans speaking, as this group was most prone to indiscriminate predator killings. However, this may prove positive as there has been a steady decline of cattle and mixed farms in favour of game ranching with the conversion identified to be increasing by 3-5,000 km² per annum (Bothma, 2005; Thorn *et al.,* 2012), in conjunction with 27 % of game farmers contributing to nature conservation and tourism. In line with the study by Thorn *et al.*, (2012) the stock value per property was not shown to be a precursor to whether a farmer will or will not undertake predator control.

Brown hyaenas were controlled using shooting at night with spotlights and traps. The consideration of trapping, snaring and poisoning as methods of predator control is a cause for concern as these three methods are both indiscriminate and illegal (St John *et al.,* 2012). The levels of poison used nationally (9 %) was lower than those found for just the North West Province; 20 % (Thorn *et al.*, 2009; 2012) and 21 % (St John *et al.*, 2012). However, in the current study only two provinces listed the use of traps and poison (North West and Western Cape). Higher levels of persecution in the Limpopo Province may be due to a higher density, and hence encounter rate, of brown hyaena compared to the whole of South Africa.

In the survey, non-response was highest in the category of questions relating to predator control techniques, indicating reluctance by respondents to answer these potentially sensitive questions (Schumann *et al.*, 2008; St John *et al.*, 2012). With one respondent stating that "I will not incriminate myself". Therefore, these limitations need to be taken into consideration and further investigated using techniques to reduce the bias caused by the discussion of sensitive topics (St John *et al.,* 2012).

The current study has shown that overall the respondents significantly felt that brown hyaena numbers had either increased or remained constant over the past five years, which is encouraging for the future of the species in the unprotected areas. South African attitudes in 1979 were characterised by repugnance, indifference and ignorance with the majority, stating that the brown hyaenas were doomed in South Africa (Eaton, 1976). This is strengthened by Mills and Hofer's (1998) study, which concluded that in the two decades preceding their study there has not been a change in farmers' opinions towards brown hyaenas. This is a major step forward from comments received as part of Eaton's

(1976) study. The evidence from the respondents of this study demonstrates that there has been an overall shift towards a more positive attitude and understanding of the species.
As Mills and Hofer (1998) found in Namibia, the brown hyaena was treated with suspicion by farmers who were ignorant of its feeding habits. However, the current study only a minority of respondents stated that they did not know about brown hyaena feeding and habitat preferences, whereas the majority describe the hyaena as a species which balances the ecosystem by cleaning the veldt as they remove dead animals. This shows that there has been progress as some respondents even saw the hyaena as a potential tourism attraction which should be encouraged. Within the North West Province alone, just over a third of game farmers derived an income from ecotourism (Van Der Waal and Dekker, 2000). This shows a real potential for wildlife to be both intrinsically and economically valued to be maintained and conserved within the landscape, especially considering that a third of respondents stated that brown hyaenas were being actively conserved on their property. This follows as only a minority of farmers described the hyaena as just a predator, with most seeking to describe the species as either a scavenger or both a scavenger and predator. It can be concluded that respondents have a strong understanding of the brown hyaena's ecology but in livestock driven areas the hyaena is still thought of as a potential threat.

In agreement with Winter *et al.,* (2007) by undertaking this study and utilising tools of research outside those of the biological sciences a better understanding of the attitudes and lives of the private landholders has been achieved. Education and information in general can improve tolerance in another way if it reduces the perceived threat to more realistic levels (Sillero-Zubiri *et al.,* 2006). In this instance, the findings have evolved our preconceptions of how land owners perceive the brown hyaena and other carnivores. The stronger than average association noted between game farmers and favourable attitudes to large apex predators and mesopredators (jackal, caracal) provides a positive base line from which conservation education strategies can be developed.

However, the limitations of the study must also be recognised in relation to the required anonymous participation of respondents via a distant online questionnaire format as well as the spatial scale upon which the study was conducted. As with other studies aimed at farmers and landowners who utilised electronic questionnaires, this study recognises that it is impossible to quantify the percent of returns, as on numerous occasions the email was forwarded on by an interested party to others without the researcher's knowledge (Grey-Ross *et al.,* 2010). The more traditional method of postal questionnaire dispersal the study has the potential for sampling response/non response biases (Lovell *et al.*, 1998). However, the counter argument is that the electronic survey provides a randomly sampled data set (Lovell *et al.,* 1998). In seeking to reduce geographical bias (Groves and Peterson, 1992), every attempt was made to engage farmers from every province of South Africa by using both regional and national farming organisations and interest groups to distribute the email to their members. However, due to the differences in the sizes of the nine Provinces, the density of respondents overall was variable.

To reduce the number of errors when translating the terminology within the questionnaire text a native speaking Afrikaans person was used (Groves and Peterson, 1992) leading to both English and Afrikaans versions made available to the respondents (Van Der Waal and Dekker, 2000). The survey assumed that the respondent had a basic understanding of individual carnivore identification within their local area, which was then accurately translated into the questionnaire. The limitation of distant participation was that a baseline or cross-section of respondent's skills was not acquired, which means that observer bias may have occurred, but is not quantifiable (Carrier and Beebee, 2002; White *et al.,* 2005; Nunez-Quiros, 2009).

Brown *et al.,* (2009) determined that the people of South Africa held cost as an important factor when considering obtaining internet access, which reflects the overall high telecommunications costs across the country. Therefore, these costs present a major impediment to more equitable internet access across socio-economic groups (Brown *et al.,* 2009). In 2008, there were an estimated 4.6 million internet users in South Africa (approx. 10 % of the population), which was set to double by 2014 (WorldWideWorx, 2009). Therefore, the potential for undertaking a far reaching survey is constantly increasing in conjunction with the number of internet users that come online across South Africa. Due to the scope and scale of this study, using a web-based medium for the questionnaire was the only feasible option. By utilising the online groups and community of farming groups, farmers could be reached where traditional methods may have struggled (Wright, 2005). However, in agreement with Frazier and Rohmund (2007) one disadvantage of using online surveys was that it excluded people without internet access, which in turn has under-represent some sectors of the population. Consequently, the study did not capture the farmers on the communal lands and, due to the nature of the method, in turn this study was skewed towards affluent farmers with internet access. Therefore, there is a knowledge gap within this study that needs further investigation by utilising an alternative methodology suitable for the target participants. As with Thompson *et al.,* (2003) the use of a web-based medium did not appear to discourage participation. This study's costs would have been substantial if conducted using postal or face-to-face interviews. Therefore, using an online system was deemed to be the fast and effective solution (Sparrow, 2007). Another advantage was that response and completion rates could be monitored on a daily or weekly basis as well as the survey being left to run over the period of a year, maximising potential response rates.

Several key conclusions emerge from this element of the research:

The use of a web-based questionnaire to ascertain viable data on national attitudes and the distribution of twelve medium-large bodied mammalian carnivores does provide a usable baseline, with recognised limitations, from which long-term monitoring of carnivore distribution can occur. The correlation of the results with expert studies demonstrated sufficient accuracy to deliver confidence in the methodology.

The adoption of a multi-species approach enabled this study to acquire information on twelve small-large bodied carnivores. Of particular note was the reporting of large apex predators (wild dog, lion) present across some of the unprotected range lands and outside their 'traditional' distribution. As predicted, brown hyaenas were found to be widely distributed across all provinces of South Africa. Additionally, due to greater survey effort, new presence points were discovered outside the current IUCN (Wiesel *et al.,* 2008) known distribution. This has resulted in the presence data set being used as part of the IUCN Red List 2014 reassessment of the brown hyaena's threat category.

The hot-spot conservation action areas with high negative attitudes towards carnivores have been pinpointed. As predicted, brown hyaena were found to be actively targeted by predator control methods. However, this was not to the extent expected since, although livestock farmers were likely to hold overtly negative attitudes to carnivores on their property, other land users were more likely to hold positive attitudes.

In conclusion, conservationists may draw some positive encouragement from the findings of this study in respect to attitudes to carnivores. Since small to medium bodied carnivores were broadly regarded favourably across land use types, it would seem that the basis for future conservation strategies already exists if current approaches are modified and applied to medium to large carnivores. Sheep and goat farmers, who were most prone to negative attitudes to carnivores and who reported most sightings on their land, should perhaps be a particular focus of such strategies. However, as noted, it does appear that negative attitudes to wild dog are so entrenched that specifically targeted conservation strategies will need to be developed in known areas of occurrence. The particular example of the perception shift effected towards the aardwolf through scientific research provides a good example of how the conservation effort may be targeted.

The brown hyaena stands out as an exception to the more general conclusions. Although it is a medium to large bodied carnivore, respondents viewed it more positively and, again, this provides wider opportunities for its conservation. Since it was found that cattle farmers believe it to be only a predator, education programmes may be the most effective tool to create a shift in attitudes.

The hope is that this research, combined with future conservation programmes, will go some way to reducing the level of human-wildlife conflict, not only for brown hyaenas but for the wider carnivore guild.

Chapter 4: A comparison of carnivore relative abundance between protected and unprotected areas in North West and Limpopo Provinces, South Africa.

4.1. Introduction

Effective conservation management is of paramount importance to wide-ranging carnivores living in human-dominated landscapes outside of protected areas (Muntifering *et al*., 2005). Protected areas cover 6.2 % (84,495 km²) of South Africa's land area, leaving 93.8 % as unprotected rangelands (UNEP-WCMC, 2012). To conserve large carnivores it is necessary to understand their abundance in the human dominated landscapes, which is where the real conservation action is needed particularly in light of 31 % of carnivore species being listed as 'Threatened' or 'Data Deficient' (IUCN, 2013). Over the course of 56 years (1904-1960) the urban population of South Africa grew by 21.4 % (Wilson and Mafeje, 1963). Furthermore, since the 1950s the average farm size has been steadily increasing (Biggs and Scholes, 2002). In 1911 only 4 % of the area of privately owned farms was under cultivation, compared to 13 % in 1993 (Biggs and Scholes, 2002). This rapid development has led to conservation failures through extinctions of large predators outside protected areas, due to a deficiency in knowledge for individual predators across their geographical range (Hayward *et al.,* 2007ab). In order to conserve carnivores, baseline abundance data are required (Tobler *et al.,* 2008; Marnewick *et al.,* 2008; Pettorelli *et al.,* 2010).

Large bodied carnivores often have large home ranges (Gusset *et al.,* 2008). Consequently, many protected areas are too small to hold large viable populations (particularly in South Africa), which makes human dominated landscapes key to future carnivore population persistence (Woodroffe and Ginsburg, 1998; Inskip and Zimmermann, 2009). Hence there is a need to establish the density and the status of the remaining carnivores in South African rangelands so that targeted conservation management can take place in these areas.

Factors such as prey availability (Macdonald, 1983; Kaunda and Skinner, 2003; Hayward *et al.,* 2007; Burton *et al.,* 2012) and inter-species competition (Linnell and Strand, 2000;

Rich *et al.,* 2012) have already been shown to have a significant influence on carnivore density, including the brown hyaena (Owens & Owens, 1978; Mills, 1982). Some evidence for competition between brown and spotted hyaena has been found in the Kalahari by Mills (1990) but the impact of introduced spotted hyaena to protected areas on local brown hyaena populations is unknown. In addition, other large predators in the ecosystem may be both beneficial and detrimental to brown hyaena populations. On the one hand, brown hyaena may benefit from the presence of other large carnivores as they will have more scavenging opportunities in terms of prey remains which may positively influence density (Yarnell *et al.,* 2013). If this is true, then brown hyaena populations that exist without lions and spotted hyaena in their range might be limited by the number of scavenging opportunities available to them. In contrast, brown hyaena could be negatively affected by the presence of other large predators that compete for scavenging opportunities (Mills, 1990). Brown hyaena might also be killed directly by either spotted hyaena or lions which may also reduce their density in protected areas with a full compliment of apex predators (Mills, 1990).

"*Changes in the relative abundance of sympatric carnivores can have far-reaching ecological consequences, including the precipitation of trophic cascades and species declines*" (Trewby *et al.,* 2008 p.170). The removal of apex predators from the system may result in unknown fluctuations of other mesopredator and prey species, altering the dynamics of the ecosystem, termed 'mesopredator release' (Treves and Karanth, 2003; Blaum *et al.,* 2009). Apex predators may control smaller mesopredators through intraguild interactions, by removing apex predators changes may occur creating an increase of mesopredators leading to a rise in predation on smaller prey (Prugh *et al.,* 2009; Richie and Johnson, 2009). As apex predator numbers decline and become locally extinct in some areas, previously suppressed populations are undergoing 'mesopredator release'. For example, apex predators have been removed from South African rangelands and are only present inside protected areas leading to a potential mesopredator release and a suppression of mesopredators in the protected areas (Merwe *et al.,* 2009; Thorn *et al.,* 2011b, 2012, 2013; Yarnell *et al.,* 2013).

In order to understand and quantify changes such as mesopredator release a multi-species survey is required. Wildlife surveys have been greatly enhanced by the development of remote camera traps (O'Connell *et al.,* 2011). Camera traps were first deployed by researchers such as Gysel and Davis (1956) in the form of a simple mechanical shutter-release unit as a method to determine which animals were utilising various seeds on the ground. Remote cameras have been used in multiple fields including relative index of abundance (RIA) and distribution (Carbone *et al.,* 2001, Moruzzi *et al.,* 2002; Janelle *et al.,* 2002; Silver *at al.,* 2004; Kauffman *et al.,* 2007; Gerber *et al.,* 2010; Kinnaird and O'Brien, 2012), species richness (Tobler *et al.,* 2008), direct observations of bird nests (Hernandez *et al.,* 1997), activity patterns of animals (Culter and Swann, 1999) occupancy density estimates based upon presence absence data (Mackenzie and Royle, 2006; Bailey *et al.,* 2007; Thorn *et al.,* 2009, 2011a) and density estimates through mark capture-recapture based on identification of individuals (Karanth, 1995; Wallace *et al.,* 2003; Karanth *et al.,* 2004; Trolle and Kery, 2005; Cuellar *et al.,* 2006; Kelly *et al.,* 2008; Sharma *et al.,* 2010).

The benefits of using remote cameras are numerous; a key factor is the capture, confirmation and monitoring of rare and elusive species (Karanth, 1995; Karanth and Nichols, 1998; Cuttler and Swann, 1999; Carbone *et al.,* 2001; Swann *et al.,* 2004) particularly when the species is located across large remote areas (Culter and Swann, 1999; Parker *et al.,* 2008) for example, Pettorelli *et al.,* (2010) conducted a study across multiple protected areas in Tanzania. Another advantage of remote camera trapping studies is the ability to immediately identify individual animals (Karanth *et al.,* 2004; Long *et al.,* 2007). Behavioural data based upon visitation rates and group sizes can be captured and monitored (Long *et al.,* 2007). The method is noninvasive and produces little disturbance to the survey area or individual target animals (Maffei *et al*., 2004). The by-product of camera traps is that they not only capture the target species but non-target species as well, providing valuable information on species richness with no extra surveying. A comparison between standard ecological survey methods by Silveira *et al.,* (2003) identified that using remote cameras was the most effective method to estimate species abundance. Cameras can quickly determine the presence and absence of species (Pettorelli *et al.,* 2010) and in some cases discover; new species (giant sengi, *genus Rhynchocyon*); species thought to be locally extinct or outside their known geographical range (Rovero *et al.,* 2008; Starr *et al.,* 2010).

New discoveries utilising camera traps have been used to strengthen the arguments of conservationists in a range of environments. For example, an area in the Dermakot Forest

Reserve, Malaysia which was under pressure to be cleared for industrial plantations, has now been protected (Yasuda *et al.,* 2007). In this forest the camera traps captured the very first film footage of the recently described Sundaland clouded leopard (*Neofelis diardi*) as well as two other rare cats the flat-headed cat (*Prionailurus planiceps*) and the Borneo bay cat (*Pardofelis badia*) (Yasuda *et al.,* 2007). Based on this study's results the IUCN red list criteria for the flat-headed cat was raised from 'Vulnerable' to 'Threatened' (Wilting *et al.,* 2008). Camera trap surveys are also valuable for determining the presence of rare species. For example, a World Wildlife Fund (WWF) survey conducted in 2011 using camera traps discovered five out of a possible seven wild cat species that are known on the Indonesian island of Sumatra to be present in a single forest area (World Wildlife Fund, 2011).

Conversely, the disadvantages include the initial cost to purchase the camera units, which can range between $300-1000 (Srbek-Araujo and Chiarello, 2005; Parker *et al.,* 2008; Kelly and Holub, 2008) and the long survey duration (Tobler *et al.*, 2008), which creates time and logistic costs, especially when surveying in difficult terrain (York *et al.*, 2001). Other issues include setup time of a camera trap survey which Moruzzi *et al.*, (2002) found to be extensive as well as technical and mechanical difficulties as experienced by Rice (1995) and Swann *et al.,* (2004). There is always the possibility that the camera can be either be stolen or damaged by an animal, although protective metal cases reduce this risk. Despite these shortcomings Silveira *et al.*, (2003) showed that remote cameras were the most effective method for estimating species abundance, especially species that are elusive, found at low density and nocturnal which encompasses many carnivore species (Wilson and Delahay, 2001).

The use of lures or baits to improve detection of species has been used in many monitoring studies (Kucera and Barrett, 1993; Rice, 1995; Moruzzi *et al.*, 2002). Baits reduce survey effort and improved accuracy of density estimates (Long *et al.*, 2007). Baits and lures have been used to increase species detection in a number of related survey techniques as such sand traps (Copeland, 1993) or snow tracking stations (Mortelliti and Boitani, 2007). Baits can help to artificially extend the time the animal is present at the station (Yasuda, 2004), which helps to keep the target animal in view to improve identification. Studies that do not use baits require extensive survey periods, which increase the costs of the survey. For example, Pettorelli *et al.,* (2010) used 430 non-baited stations over 11,355 camera trap nights to measure carnivore diversity and distribution in Tanzania. This resulted in a capture success of 23 out of the 35 known carnivore species. Tobler *et al.,* (2008) also carried an unbaited camera trapping project over two years totalling 3,780 trap nights concluding that their study required substantial survey effort to register certain species. In some circumstances several species were only represented by one photograph taken over 4,815 camera days (Tobler *et al.,* 2008).

One possible problem with using bait as a lure, is that if the bait is edible, then the bait is likely to be removed by the first few animals that encounter it, thereby reducing the subsequent detection of target species on subsequent trap nights. In some instances this effect may be mitigated by the scent permeating into the substrate where it was originally located even after the bait has been taken, so that other animals may still come to investigate (Mortelliti and Boitani, 2007). To reduce the impact of bait removal on detection indices, regular rebaiting should be employed (Thorn *et al.*, 2009). Therefore there is a trade off between bait replenishment and length of time required to gather data from non-baited surveys in terms of logistics and survey duration.

Seasonal variation in the availability of alternative foods may also influence detection rates by altering the bait consumption rate (Koerth and Kroll, 2000; Yasuda, 2004). As bait consumption is likely to be higher during periods of low natural food availability, studies must either account for the bias or survey across several seasons to create a balanced survey design. For example, urban foxes removed significantly more bait during summer than at other times of the year (Hegglin *et al.*, 2004). Therefore when comparing camera trap studies using baits, the effectiveness of the lure across seasons requires consideration. Another consideration when designing camera trap studies is the target animal's behaviour. Copeland (1993) when assessing wolverine (*Gulo gulo*) abundance used road-killed deer and fish lure as an attractant but the attractant was found to favour the capture of two non target species the pine marten (*Martes americana*) and red fox rather than the wolverine (*Gulo gulo*). Due to the biases that using baits and lures could cause, the majority of camera trapping studies chose not to utilise baits to avoid further complications within their studies (Srbek-Araujo and Chiarello, 2005; Tobler *et al.*, 2008; Pettorelli *et al.*, 2010). It is important therefore that careful consideration of camera type and the use of baits is required during the experimental design phase of any remote camera trap study.

In some circumstances pilot studies have been carried out to pre-test baits and lures on captive animals from which the information can be transferred to a field situation (Long *et al.,* 2003; Thorn *et al.,* 2009). Both Thorn *et al.,* (2009) and Long *et al.,* (2003) used a pre-tested scent lure at camera trap stations to estimate wild population densities. The results were mixed with Long *et al.,* (2003) capturing zero images of mountain lions (*Puma concolor*) but many non target species. Thorn *et al.,* (2009) tested various lures on a range of captive carnivores and found that fish, offal, fermented eggs and blood were effective lures for the captive carnivores, which was then used on wild populations (Thorn *et al.,* 2009). The main problem with testing lures on captive animals for application into wild conditions is that captive animals are likely to be sensory deprived unlike free roaming individuals, which may not be similarly interested in the same scent (Long *et al.,* 2003). However in the case of Thorn's *et al.,* (2009) camera trapping study the use of the pre-tested fish lure produced a 100 % increase in wild brown hyaena detection probability, highlighting the benefits of using a lure to increase detection rates.

Over the past ten years there has been a proliferation of remote cameras available to wildlife researchers, which has introduced problems of standardisation within and between studies using different camera makes. For example, different makes of camera may produce differences in capture rate, sensitivity and photographic quality, which can often produce different species detection histories (O'Connell *et al.,* 2011). This makes comparisons between sites or between the outputs from different camera types difficult (Parker *et al.,* 2008; Sollmann *et al.,* 2013).

Remote cameras are a widely used tool in carnivore ecology aimed at assessing three ecological objectives; detecting presence of a species (Foresman and Pearson, 1998); estimating animal abundance (Karanth, 1995; Karanth and Nichols, 1998) and recording animal behaviour (Sanz, 2004). Using relative index of abundance (Tobler *et al.,* 2008; Gerber *et al.,* 2010; Kinnaird and O'Brien, 2012) or occupancy approaches (Mackenzie *et al.,* 2002; Royle and Nichols, 2003; Mackenzie and Nichols, 2004; Mackenzie *et al.,* 2006; Linkie *et al.,* 2007; Thorn *et al.,* 2009, 2011a; Pettorelli *et al.,* 2010) enables differences across and within landscapes to be detected and quantified. Relative differences in abundance can be utilised for species that cannot be identified from photographs i.e. they have no discernable individual patterns or markings (Sollmann *et al.,* 2013). Relative abundance indexes are frequently found as part of camera trapping studies, wildlife monitoring reports and biodiversity assessments (Sollmann *et al.,* 2013). The relative abundance indexes is based upon the number of photographs acquired per night, the index will increase as the density increases, making it an easily interpreted index (Carbone *et al.*, 2001; O' Brien *et al.,* 2003). The relative abundance index has been utilised for both single species and multiple species studies from Harvey's duiker (*Cephalophus harveyi*) (Rovero and Marshall, 2009) to the woodland wildlife of western Uganda (Treves *et al.,* 2010). The relative abundance index can be used to monitor long-term changes in the population, for example in Khao Yai National Park, Thailand a decline was detected for key mammal species that were then linked to increased human activity in the park (Jenks *et al.,* 2011).

Determining the relative abundance in comparison to the absolute abundance requires lower survey effort and is cost effective both in time and funds. Solitary medium to large bodied carnivores that occur at low densities are difficult species to study through conventional survey techniques (Carbone *et al.,* 2001; Trolle and Kery, 2005; Jackson *et al.,* 2006; Wang and Macdonald, 2008), therefore new techniques such as camera trapping were required, a rapidly growing number of camera traps surveys produce data on multiple species (rare, common) which are not fully utilised (Burton *et al.,* 2012). However a multi-species hierarchical framework to understand detection probabilities across focal communities is ideally suited for camera trap surveys as the cameras not only capture the target species but also non-target species (Burton *et al.,* 2012). Camera trapping is seen as a cost-effective alternative for multi-species monitoring (O'Brien *et al.,* 2010). This study is therefore ideally situated to undertake a multi-species survey using remote camera traps to detect variations in abundance between protected and unprotected rangelands.

There is a deficit of data on the status and abundance of brown hyaena across much of its range (Friedmann and Daly, 2004). With a quarter of the global brown hyaena population being estimated to exist in South Africa and its connection to human wildlife conflict, the brown hyaena in this study is acting as the focal species. The brown hyaena, as discussed above, like another medium-large bodied carnivores is influenced by many factors in particular; protection levels, abundance of apex and mesopredators. Therefore the aim of this study was to determine whether there was an overall difference in relative abundance of carnivores between protected and unprotected treatment areas.

4.2. Objective

This study objective was to use remote camera traps to: i. determine whether there was an overall difference of relative abundance of carnivores between protected and unprotected treatment areas in the North West and Limpopo Provinces of South Africa.

The objective was to significantly enhance our knowledge base of the differences in species richness and relative abundance of individual carnivore species, including the focal species, the elusive brown hyaena, between areas that are protected and unprotected. By obtaining species richness and relative abundance of individual carnivore species across both protected and unprotected areas a comprehensive picture can be created of how the level of protection and varying apex predator density influence the relative abundance of the carnivore community. The working hypothesis was that carnivore abundance would be higher in the protected areas as a consequence of the active protection afforded there compared to the unprotected areas. The application of camera trapping was considered to be the most appropriate means of testing this hypothesis.

4.3. Method

The study took place in North West and Limpopo Provinces of South Africa across 27 camera stations. Seventeen camera stations were set up in protected areas (7 at PNP and 10 at MGR) (Figure 4.1.)

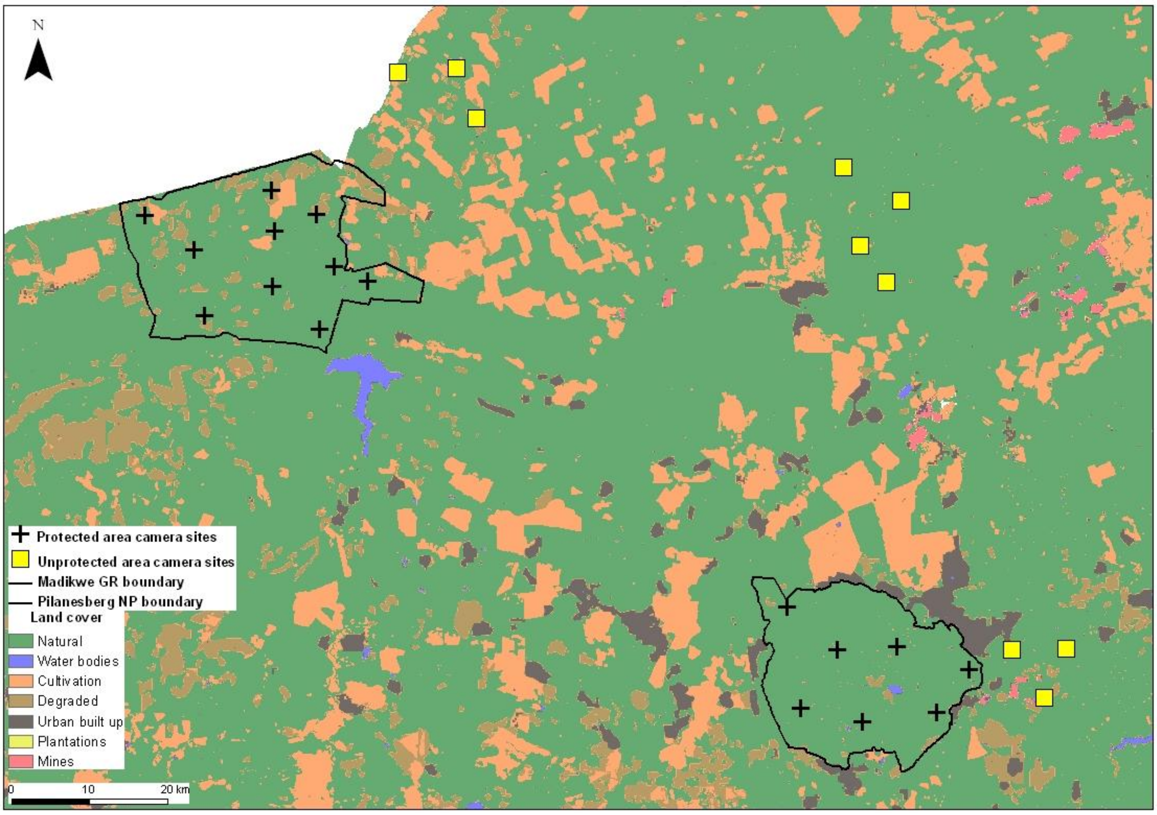

Figure 4.1. Locations of the camera trapping sites in the protected (*n* = 17) and unprotected areas (*n* = 10) situated in the Northwest and Limpopo Provinces of South Africa.

None of the 27 camera locations were situated directly at a watering hole to ensure no bias was incurred and the detection probability for each species therefore remained the same during the sampling periods as each species interacts differently with natural features within the landscape (Gotelli and Colwell, 2011; Sollmann *et al.*, 2013). The camera stations in the protected areas were all located within mixed bushveldt habitat (Marnewick *et al.*, 2008). The camera stations were placed at locations with similar habitat structure to ensure that the probability of detection of each site by the animals was standardised. The other 10 camera stations were located in unprotected farmland across six game farms. The farmland locations were based upon firstly access, logistics and obtaining the landowner's permission. Secondly the farms were standardised by their features as all six farms' major source of income was from live game sales and hunting with a minor proportion from cattle. This was representative of the land use for the area as a whole (Marnewick *et al.*, 2008). The farms and protected areas both had fixed water points distributed across the study sites allowing for access to water all year round. Each camera station was spaced ≥5km apart to standardise the distribution and ensure all stations were considered independent (Gompper *et al.,* 2006). The spacing was determined by the average distance moved per night by nine hyaenas (5 km²) across both protected and unprotected areas. The spacing used ensured that the study area was covered evenly and each hyaena had an equal probability of capture (Dillon and Kelly, 2006). The study site locations were chosen using a random stratified design within a 5 km x 5 km grid which was laid over each study area. A point was chosen at the centre of the grid to ensure the spacing between cameras was maintained. As the combined surveyed area for the protected areas was greater (1,130 km²) compared to in the unprotected areas (682.44 km²) it was therefore necessary to utilising 17 camera sites in the protected areas compared to 10 in the unprotected areas to ensure that the density of cameras across the two survey areas were similar. The total buffer area was determined by combining the total area covered by the camera locations based on the outlying location and adding a 5 km radius (Dillon and Kelly, 2008). As the protected areas have fixed boundaries due to the predator proof fencing these buffers could not be added as it would take the buffer area outside the reserves therefore the absolute area was used. The camera density was quantified in the protected areas as 66.47 km² / camera which was similar to the unprotected areas, 68.24 km² / camera, which enables a direct comparison between the two treatments.

The digital cameras used were HCO Scoutguard SG550™ (HCO Outdoor Products, 6050 Peachtree Pkwy Suite 240-353, Norcross, GA, 30092, U.S.A. www.hcodealer.com). Cameras were operational 24hr per day with a trigger delay of 5 seconds (i.e. the time that the cameras would be ready to take another image should another animal pass by). All cameras were set to take three photos per capture to maximise the opportunity to identify the species. All the cameras used throughout the study were set to the same specifications to ensure the rate of capture was standardised. The camera sensitivity was set to medium to reduce the number of false triggers. As a consequence of the bait station the time the animal was in front of the camera increased and distance from the camera was controlled. Camera covers were used to protect them not only from the weather conditions but also from animal damage.

The study operated within a limited budget which dictated that 5 remote cameras were purchased due to their high cost per unit. The experimental design had to not only take into consideration the necessary rotation of camera stations but the logistical difficulties presented by the physical distances between survey areas and camera stations.

Compounding this was the fact that certain camera stations became inaccessible during heavy rain. Taking into account these limitations the survey was designed to provide a comparison between repeated data points across the protected and unprotected areas between seasons, winter/dry (April – September) and summer/wet (October – March) and years (2010, 2011). Approximately two months were required to complete one full surveying period (protected/unprotected). Therefore each treatment area was surveyed twice in 2010 and twice in 2011 creating four temporal repeats for each treatment area totalling approximately eight months.

Once the general location had been identified the actual camera station was determined by the observation of field signs such as fresh pasting or an active brown hyaena latrine in order to maximise the photographic capture rate (Karanth and Nichols, 2002). All camera stations were placed at a road junction or on the side of a road on average 12 meters (±10 SD) into the vegetation (Treves *et al.*, 2010), as it has been identified that brown hyaena's activity patterns are significantly related to the road network as they are used as territorial boundaries (Mills, 1990). Cameras were not set on roads to reduce the disturbance from tourist and farm vehicles and minimise the risk of the camera being stolen. All cameras were attached to a tree 0.5 m up (approximate height of a hyaenas shoulder). The vegetation was cleared to reduce the number of false triggers and to optimise the quality of the image captured for identification purposes (Rice, 1995; Swann *et al.*, 2004). The cameras were also placed in a north south direction to reduce false triggers from shadowing (Rice, 1995).

A pilot study was conducted to investigate the influence of bait and drag on carnivore detection rates using camera traps. Two different baiting treatments were tested and compared to a control treatment to determine which gave greatest detection rates of carnivores in North West and Limpopo Provinces, South Africa. There was a significant difference in detection rates between baited and drag sites compared to the control sites (Wilcoxon Signed Rank Test, $W = 1$, $n = 9$, $P = 0.027$). Carnivore species were captured 25 times at baited/dragged sites, compared to five for the control sites, which consisted of 8 and 4 individual carnivore species respectively. Therefore, it was determined that the camera trapping methodology used throughout this study would be to use sites that were baited and dragged to improve the detection of the focal and other carnivore species.

At each camera station a meat bait was used as an attractant as it was shown to significantly increase the rate of capture for brown hyaenas in the pilot study (Kucera and Barrett, 1993; Rice, 1995; Moruzzi *et al.,* 2002, Thorn *et al.,* 2009). Impala bait was utilised 60 % of the time, followed by; cow 11 % (n = 16), zebra 8 % (n = 12), blesbok 8 % (n = 12), wildebeest 5 % (n = 7), hartebeest 4 % (n = 6) (*Alcelaphus buselaphus*), and kudu 3 % (n = 5) depending on availability. The bait was either purchased using the study's funds or donated to the project by local farmers in the study area. Each piece of bait weighed between 1-2 kg and was staked into the ground using metal pins, at a distance of three metres the camera. This distance was determined by the optimal effective autofocus distance (Copeland, 1993; Moruzzi *et al.,* 2002; Swann *et al.,* 2004; Hegglin *et al.,* 2004). Gloves and boots were worn and every effort was made to reduce the level human scent left at the stations.

At each site the cameras were left out for eight consecutive nights and after four nights the bait was replenished (Hegglin *et al.,* 2004). The timing of the bait replacement was consistent with the rate set by Thorn *et al.,* (2009). At each station a 1 km drag was created by dragging 1 km directly away from the station to the nearest road and along both directions of the road. This created transects of 2 km running past the camera station that had been treated using the scent lure/drag. Brown hyaenas have an acute sense of smell with the ability to detect carrion from up to 4 km away and therefore using a distance of 1 km maintained camera station independence (Mills and Gorman, 1987).

Each image produced by the camera traps had a date and time stamp allowing images to be categorised as either a dependent or independent event according to the assumptions set out in O'Brien *et al.,* (2003). Using the independent events as a measurement allowed for the standardisation of images across all sampling occasions. For this study an independent event was counted as consecutive photos of different individuals of the same or different species and consecutive photos of the same species taken ≥30 minutes apart (O'Brien *et al.,* 2003; Yasuda, 2004; Thorn *et al.,* 2009; Hulsman *et al.,* 2010; Treves *et al.,* 2010). This method allows for the relative index of abundance (RIA) for non individually identifiable species to be calculated where as with alternative methods such as capture mark re-capture individuals have to be identifiable (Carbone *et al.,* 2002; O'Brien *et al.,* 2003).

The mean number of carnivore species or species richness and the RIA for all of the carnivore species captured were analysed from the largest apex predator, the lion, to the smallest, the slender mongoose (*Galerella sanguinea*) (157.5 kg to 0.5 kg (Estes ,1991)).

4.4. Data Analysis

Images were subdivided into the following categories: empty (false trigger no animal); error (incorrect colour saturation, images were blank once downloaded); unknown (contained an animal but was unidentifiable due to quality of image i.e. out of focus, or the location of the animal in the image preventing identification i.e. too close or too far); carnivores; herbivores; human (people, vehicles); insects (contained only flies, butterflies etc); livestock (cattle, sheep, goats); and camera set up (images of the person setting the camera). The independent events per trap night were analysed using SPSS version 19.0. All treatment variables were tested for normality using Kolmogorov-Smirnov tests and where appropriate parametric tests. When the data were found to be not normal, equivalent non-parametric tests were used. Nine carnivore species had an insufficient number of data points to conduct robust statistical analysis between the two treatment areas due to either a lack of capture (caracal, serval, aardwolf, bat eared fox and banded mongoose (*Mungos mungo*)), or the species was not present in the unprotected areas (lion, spotted hyaena, wild dog).

4.5. Results

A total of 800 camera trap nights undertaken between February 2010 and June 2011 across the North West and Limpopo Provinces of South Africa yielded 34,679 images. A total of 64 trap nights were lost due to faulty and/or broken equipment following either environmental or animal interactions. In addition weather conditions prevented certain trap sites being accessed during the survey due to the combination of unseasonal heavy rainfall and clay soils. The total image count of 34,679 included all images taken of domestic livestock in the farmland, vehicles and people passing camera stations as well as extreme weather such as a hail storm that triggered the camera. Due to the sensitivity of the camera the movement of insects on the meat was also recorded and included in the total image count. The consistent clarity of the image produced by the digital cameras meant that only 0.6 % (n = 196) of all images were classified as errors and 0.2 % (n = 53) were deemed as unknown images (Table 4.1.). However 18.9 % (*n* = 6,552) of images were classified as empty due to false triggers (Table 4.1.). For the unprotected areas the majority of the empty images (2,368) were derived from one camera at one camera station caused by high winds leading to a large amount of vegetation movement picked up by the camera. As the total number of empty images for that one camera station prior to that event was 14. The range of species captured across both treatment areas can be found in Appendix 4.

Table 4.1. Outcomes of all the camera trapping surveys conducted in the protected and unprotected areas from February 2010 to June 2011

	Survey Dates		**Number of nights**	**Total no. images**	**% empty (*n*)**		**% error (n)**		**% unknown (n)**		**Total % carnivore images (n)**	
Protected area	29.3.10	20.11.10	240	10,468	14.34	(1,501)	0.2	(18)	0.1	(14)	31.7	(3,316)
	4.2.11	10.6.11	216	8,251	13.93	(1,149)	1.9	(160)	0.0	(4)	34.2	(2,818)
Unprotected area	16.2.10	21.11.10	184	7,485	11.93	(893)	0.1	(6)	0.0	(1)	36.9	(2,763)
	5.2.11	11.6.11	160	8,475	35.50	(3,009)	0.1	(12)	0.4	(34)	16.8	(1,426)
Total protected area			**456**	**18,719**	**14.2**	**(2,650)**	**1.0**	**(178)**	**0.1**	**(18)**	**32.8**	**(6,134)**
Total unprotected area			**344**	**15,960**	**24.4**	**(3,902)**	**0.1**	**(18)**	**0.2**	**(35)**	**26.2**	**(4,189)**
Mean protected area			**228**	**9,360**	**14.2**	**(1,325)**	**1.1**	**(89)**	**0.1**	**(9)**	**32.8**	**(3,067)**
Mean unprotected area			**172**	**7,980**	**24.4**	**(1,951)**	**1.0**	**(9)**	**0.2**	**(18)**	**26.2**	**(2,095)**
Total			**800**	**34,679**	**18.9**	**6,552**	**0.6**	**196**	**0.2**	**53**	**39.8**	**10,323**

Of the 34,679 images, 30 % (10,323) of images were made up of carnivores consisting of 44.7 % jackal (4,614), 21 % brown hyaena (2,169), 16.9 % civet (1,743), 5 % honey badger (519), 4.4 % lion (459), 3.8 % spotted hyaena (393), 2.4 % slender mongoose (244), 0.7 % leopard (72), 0.7 % common genet (68), 0.13 % serval (13), 0.08 % caracal (8), 0.06 % banded mongoose (6), 0.06 % African wild cat (6), 0.04 % wild dog (4), 0.04 % bat eared fox (4) and 0.01 % aardwolf (1).

For protected areas 456 camera trap nights created a total of 18,719 images, of which 32.8 % (6,134) of images were carnivore species, made up of 39.9 % jackal (2,453), 33.2 % brown hyaena (2,035), 7.7 % honey badger (471), 7.5 % lion (459), 6.4 % spotted hyaena (393), 3.7 % slender mongoose (226), 0.7 % leopard (44), 0.5 % civet (30), 0.2 % common genet (13), 0.08 % caracal (5), 0.07 % wild dog (4), 0.02 % African wild cat (1). Bat eared fox, banded mongoose, serval and aardwolf were not recorded in this area.

In unprotected areas 344 camera trap nights produced 15,960 images, of which 26.6 % (4,189) of images were carnivores consisting of 50.9 % jackal (2,161), 40.3 % civet (1,713), 3.2 % brown hyaena (134), 1.3 % common genet (55), 1.2 % honey badger (48), 0.7 % leopard (28), 0.4 % slender mongoose (18), 0.3 % serval (13), 0.14 % banded mongoose (6), 0.12 % African wild cat (5), 0.1 % bat eared fox (4), 0.07 % caracal (3) and 0.02 % aardwolf (1). Lion, spotted hyaena and wild dog were not recorded in this area.

4.5.1. Relative Index of Abundance

The relative index of abundance (RIA) (±SD) for total independent events per trap night for all carnivore species was marginally higher in the unprotected areas, 2.49 ± 0.9 compared to the protected areas 2.29 ± 1.03 (Table 4.2.), with an average of 2.39 ± 0.14 individual carnivore species being captured across all survey areas. As expected the protected areas captured lion, spotted hyaena and wild dogs which are all in residence throughout the national parks. Zero captures of these three species in the unprotected area was as predicted as these species are designated as locally extinct in the unprotected area (Hayward *et al.,* 2007). The relative abundance for leopard and slender mongoose were similar across both areas (Table 4.2.). However the relative abundance for civet, honey badger, jackal, African wild cat and common genet were higher in the unprotected areas (Table 4.2.). Brown hyaena and caracal were the only two species that showed a higher relative abundance in the protected areas (Table 4.2.). Four species: serval, aardwolf, bat eared fox and banded mongoose were only captured in the unprotected areas and therefore show a larger relative abundance compared to the protected areas (Table 4.2.). When spotted hyaena and brown hyaena relative abundance was compared within the same protected area the brown hyaena had the higher relative abundance index (0.5 ± 0.31) compared to the spotted hyaena (0.12 ± 0.2) within the same protected area.

Table 4.2. Summary of species richness (mean number of carnivore species), the mean relative index of abundance (RIA) for the total independent events per trap night (±SD) and an indicator of the highest RIA per species captured in the protected and unprotected survey (February 2010 and June 2011).

Species	Protected area RIA (±SD)	Unprotected area RIA (±SD)	Area with highest RIA
Aardwolf	0	0.003 (±0.01)	UPA
African wild cat	0.002 (±0.01)	0.02 (±0.03)	UPA
Banded mongoose	0	0.003 (±0.01)	UPA
Bat eared fox	0	0.003 (±0.01)	UPA
Brown hyaena	0.49 (±0.03)	0.11 (±0.1)	PA*
Caracal	0.004 (±0.02)	0.002 (±0.007)	PA
Civet	0.02 (±0.04)	0.43 (±0.5)	UPA*
Common genet	0.01 (±0.03)	0.02 (±0.07)	UPA
Honey badger	0.02 (±0.06)	0.05 (±0.1)	UPA
Jackal	0.23 (±0.37)	0.46 (±0.64)	UPA
Leopard	0.02 (±0.03)	0.02 (±0.03)	S
Lion	0.004 (±0.06)	0	PA
Serval	0	0.007 (±0.02)	UPA
Slender mongoose	0.11 (±0.21)	0.11 (±0.23)	S
Species richness	2.29 (±1.03)	2.49 (±0.9)	UPA
Spotted hyaena	0.12 (±0.2)	0	PA
Wild dog	0.002 (±0.01)	0	PA

Key: PA: Protected area, UPA: Unprotected area, S: Same, * highest RIA

4.5.2. Species Richness

There was no effect of site on the Relative Index of Abundance for protected (One-way ANOVA: $F_{16,48}$ = 1.51, P = 0.158) or unprotected areas ($F_{9,38}$ = 1.21, P = 0.329). When treatment, year, season and site (nested within treatment) were incorporated into a General Linear Model, there was not a significant effect of treatment on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 0.34, P = 0.561) (Table 4.3.). The significant effect of site nested within treatment was due to the inclusion of sites at Mankwe Wildlife Reserve where the farmland was atypical as it was protected to some extent. There was not a significant effect of year on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 2.67, P = 0.106). There was a significant effect of season on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 8.41, P = 0.005) with winter having significantly greater species richness than summer.

Table 4.3. Results of a General Linear Model to examine species richness in relation to 4 factors. Treatment = protected, unprotected; Season = summer, winter; Year = 2010, 2011; Site = 1-17(protected), 18-25(unprotected). Interactions between factors were not significant.

Factor	***F***	**d.f.**	***P***
Season	14.85	1,87	**<0.001**
Year	7.74	1,87	**0.007**
Site(Treatment)	1.78	25,87	**0.036**
Treatment	0.09	1,87	0.762

4.5.3. Brown Hyaena

There was no effect of site on the Relative Index of Abundance for protected (One-way ANOVA: $F_{16,48}$ = 1.82, P = 0.073) or unprotected areas ($F_{9,38}$ = 1.14, P = 0.371). Therefore, data from all sites were pooled. When treatment, year, season and site (nested within treatment) were incorporated into a General Linear Model, there was a significant effect of treatment on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 26.27, P < 0.001) (Table 4.4.) where there was a higher index of abundance of brown hyaena in protected areas (Figure 4.2.).

Table 4.4. Results of a General Linear Model to examine the relative index of abundance of brown hyaena in relation to 4 factors. Treatment = protected, unprotected; Season = summer, winter; Year = 2010, 2011; Site = 1-17(protected), 18-25(unprotected). Interactions between factors were not significant.

Factor	***F***	**d.f.**	***P***
Treatment	26.27	1,87	**<0.001**
Site(Treatment)	1.35	25,87	0.175
Season	0.78	1,87	0.533
Year	0.54	1,87	0.543

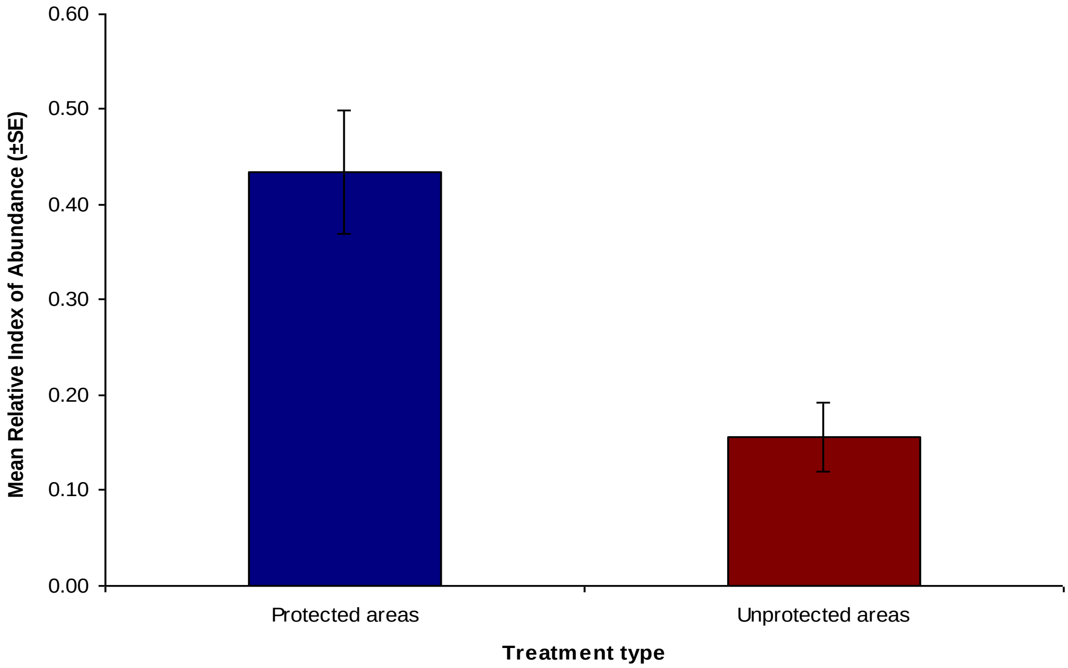

Figure 4.2. Mean Relative Index of Abundance ± SE of brown hyaena in protected and unprotected areas ($F_{1,87}$ = 24.40, P < 0.001).

4.5.4. Civet

When treatment, year, season and site (nested within treatment) were incorporated into a General Linear Model, there was a significant effect of treatment on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 22.48, P < 0.001) (Table 4.5.) where there was a higher index of abundance of civet in unprotected areas (Figure 4.3.).

Table 4.5. Results of a General Linear Model to examine the relative index of abundance of civet in relation to 4 factors. Treatment = protected, unprotected; Season = summer, winter; Year = 2010, 2011; Site = 1-17(protected), 18-25(unprotected). Interactions between factors were not significant.

Factor	*F*	d.f.	*P*
Treatment	22.48	1,87	**<0.001**
Season	1.95	1,87	0.168
Site(Treatment)	1.89	25,87	0.023
Year	0.78	1,87	0.382

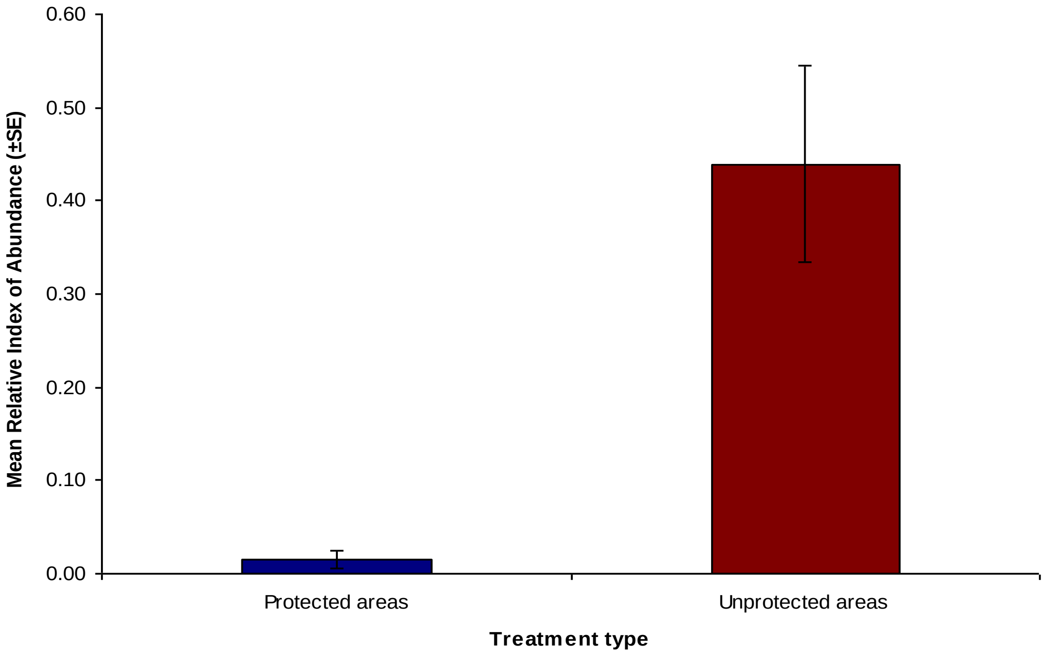

Figure 4.3. Mean Relative Index of Abundance ± SE of civet in protected and unprotected areas ($F_{1,87} = 22.48$, $P < 0.001$).

4.5.5. Honey Badger

When treatment, year, season and site (nested within treatment) were incorporated into a General Linear Model, there was no significant effect of treatment on the Relative Index of Abundance (Table 4.6.). There was a significant effect of year on the Relative Index of Abundance (One-way ANOVA: $F_{1,87} = 4.75$, $P = 0.033$) with greater levels of honey badger relative abundance in 2010 compared to 2011.

Table 4.6. Results of a General Linear Model to examine the relative index of abundance of honey badger in relation to 4 factors. Treatment = protected, unprotected; Season = summer, winter; Year = 2010, 2011; Site = 1-17(protected), 18-25(unprotected). Interactions between factors were not significant.

Factor	*F*	d.f.	*P*
Year	4.75	1,87	**0.033**
Season	2.07	1,87	0.155
Treatment	2.0	1,87	0.162
Site(Treatment)	1.53	25,87	0.093

4.5.6. Jackal

There was no effect of site on the Relative Index of Abundance for protected (One-way ANOVA: $F_{16,48}$ = 1.61, P = 0.123) or unprotected areas with site 27 ($F_{9,38}$ = 4.34, P = 0.001), without site 27 ($F_{9,38}$ = 1.30, P = 0.285). Therefore, data from all sites were pooled. When treatment, year, season and site (nested within treatment) were incorporated into a General Linear Model, there was no significant effect of treatment on the Relative Index of Abundance (Table 4.7.). The significant effect of site nested within treatment (One-way ANOVA: $F_{1,87}$ = 1.83, P < 0.032) was due to the inclusion of sites at Mankwe Wildlife Reserve where the farmland was atypical as it was protected to some extent.

Table 4.7. Results of a General Linear Model to examine the relative index of abundance of jackal in relation to 4 factors. Treatment = protected, unprotected; Season = summer, winter; Year = 2010, 2011; Site = 1-17(protected), 18-25(unprotected). Interactions between factors were not significant.

Factor	*F*	d.f.	*P*
Site(Treatment)	1.83	24,84	**0.032**
Season	0.71	1,84	0.403
Treatment	0.14	1,84	0.711
Year	0.01	1,84	0.935

4.5.7. Leopard

When treatment, year, season and site (nested within treatment) were incorporated into a General Linear Model, there was no significant effect of treatment on the Relative Index of Abundance (Table 4.8.).

Table 4.8. Results of a General Linear Model to examine the relative index of abundance of leopard in relation to 4 factors. Treatment = protected, unprotected; Season = summer, winter; Year = 2010, 2011; Site = 1-17(protected), 18-25(unprotected). Interactions between factors were not significant.

Factor	***F***	**d.f.**	***P***
Season	1.87	1,87	0.177
Site(Treatment)	1.21	25,87	0.268
Year	0.14	1,87	0.706
Treatment	0.08	1,87	0.775

4.5.8. Slender Mongoose

When treatment, year, season and site (nested within treatment) were incorporated into a General Linear Model, there was not a significant effect of treatment on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 0.02, P = 0.879) (Table 4.9.). The significant effect of site nested within treatment was due to the inclusion of site 18 in the farmland which had a higher mean abundance (0.75 ± 0.67 SD) compared to the mean of the remaining sites (0.05 ± 0.07 SD, n = 8). There was a significant effect of year on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 5.78, P = 0.018) with 2010 having significantly higher relative abundance than 2011. There was not a significant effect of season on the Relative Index of Abundance (One-way ANOVA: $F_{1,87}$ = 2.83, P = 0.096).

Table 4.9. Results of a General Linear Model to examine the relative index of abundance of slender mongoose in relation to 4 factors. Treatment = protected, unprotected; Season = summer, winter; Year = 2010, 2011; Site = 1-17(protected), 18-25(unprotected). Interactions between factors were not significant.

Factor	***F***	**d.f.**	***P***
Season	6.44	1,87	**0.014**
Site(Treatment)	1.89	25,87	**0.024**
Year	12.21	1,87	**0.001**
Treatment	0.48	1,87	0.492

There was insufficient number of data points for Africa wild cat and common genet to undertake any robust statistical analysis.

4.6. Discussion

Remote cameras are a widely used tool targeted to assess three main objectives: detecting presence of a species (Foresman and Pearson, 1998); estimating animal abundance (Karanth, 1995; Karanth and Nichols, 1998) and recording animal behaviour (Sanz, 2004).

This study, in agreement with O'Brien *et al.,* (2010), has proved that the utilisation of remote cameras as a research tool for multi-species approach including the brown hyaena is highly effective and efficient. As with other large carnivores, the brown hyaena is an elusive, solitary animal that occurs at low densities making it a difficult species to study through conventional survey techniques (Carbone *et al.,* 2001; Trolle and Kery, 2005; Jackson *et al.,* 2006; Wang and Macdonald, 2008). This study has been able to ascertain the relative abundance indices for sixteen medium-large bodied carnivores including the focal species, brown hyaena. The remote cameras allowed for continuous surveying over a period of nearly two years/seasons across two different landscape variables, protected and unprotected areas. This study as with others (Rice 1995; Swann *et al.,* 2004) experienced technical and mechanical difficulties with the camera traps leading to a loss of survey nights. However the rate of empty and error images was similar to that found in other studies (Rice 1995; Swann *et al.,* 2004).

Anthropogenic factors are as much of an influence on carnivore density outside protected areas as prey abundance and habitat requirement (Woodroffe, 2000; Johnson *et al.,* 2006). The findings of this study reflect the needs for protected areas for the brown hyaena as the abundance of the species was found to be significantly higher in the protected areas. Understanding the drivers behind the lower abundance in the unprotected areas is critical if conservation management is going to be effective (Muntifering *et al.,* 2005; Marker and Dickman, 2005; Marker *et al.,* 2008).

Apex predators, large bodied and specialised hunters, often have strong effects on the tropic dynamics and diversity of the systems in which they occur (Ritchie and Johnson, 2009). Such carnivores are important components of the ecosystem as they control prey numbers (Treves and Karanth, 2003) and a large volume of evidence has shown that the presence/absence of apex predators within an ecosystem leads to either mesopredator suppression or release (Treves and Karanth, 2003; Ritchie and Johnson, 2009). This has been found to be the case in this study, as species richness within the unprotected areas for carnivores was marginally higher but not significantly different compared to the protected areas. Changes in the abundance of apex predators has been associated with larger changes in mesopredator abundance, as apex predators increase in abundance the likelihood will be a fourfold negative effect on mesopredator abundance (Ritchie and Johnson, 2009). Apex predators have been removed from the rangelands in South Africa and are only present inside protected areas (Hayward *et al.,* 2007ab) leading to a potential mesopredator release in the rangelands and a suppression of mesopredators in the protected areas (Merwe *et al.,* 2009; Yarnell *et al.,* 2013). The brown hyaena has the potential to be acting as a suppressor of the mesopredators particularly jackals due to the dietary niche overlap found only in the unprotected areas (Yarnell *et al.,* 2013). The results demonstrated that in the unprotected areas as the abundance of the mesopredators was higher the brown hyaenas may be filing the roles of apex predators (Roemer *et al.,* 2009) filling the open niche created by the absence of large apex predators. Other large predators in the ecosystem may be beneficial and at the same time detrimental to carnivores populations including the brown hyaena. On the one hand, brown hyaena can benefit from the presence of other large carnivores, such as lion, as they will have more scavenging opportunities in terms of prey remains which may positively influence density (Yarnell *et al.,* 2013).

This study has shown this to be true as the brown hyaena populations that exist without lions and spotted hyaena in the unprotected areas are being limited by the number of scavenging opportunities available to them as their abundance is lower. In this study it does not appear to be the case that the brown hyaena are negatively affected by the presence of other large predators that scavenge and reduce the potential available resources or directly impact the species by killing it (Mills, 1990). Therefore this study is broadly in agreement with Ray *et al.,* (2005) as it suggests that the relationship of the brown hyaena with other large carnivores is having implications for their persistence in both protected and unprotected areas (Yarnell *et al.,* 2013). Further quantitative evidence would be required to verify this relationship.

In relation to the individual carnivore species the study determined that five out of the sixteen; civet, honey badger, jackal, African wild cat and common genet, relative abundance was higher in the unprotected areas. This provides evidence that mesopredator release is occurring within the unprotected areas, especially as the relative abundance of civet, a medium bodied carnivore was found to be at significantly higher abundances in the unprotected areas, compared to that found in the protected areas. Jackals were found to be at a higher abundance levels across the unprotected area compared to the protected areas but there was no significant difference. Jackal had the highest relative index of abundance of all species captured in the unprotected area and was second highest after brown hyaena in the protected areas. Therefore this study reflects the current view that jackals are the most common of the larger carnivores in Sub-Saharan Africa (Kaunda and Skinner, 2003). The jackal like the brown hyaena is an opportunistic predator and scavenger with the propensity to utilise numerous sources of prey depending on its availability (Klare *et al.*, 2010; Yarnell *et al.,* 2013). The jackal's diet, as with the brown hyaena, fluctuates in relation to temporal, spatial and seasonal changes which in turn affects the availability of prey. The civet and brown hyaena share similar traits as they are both omnivorous and not deemed to be excellent hunters detecting prey through both smell and sound (Mills, 1990; Ray, 1995). Four species, serval, aardwolf, bat eared fox and banded mongoose were only captured in the unprotected areas and therefore indicates a larger relative abundance compared to the protected areas, which continues the pattern of mesopredator suppression due to the resident apex predators in the protected area.

Kinnaird and O'Brien's (2012) study determined that the relative abundance of most carnivores was highest or second highest in sanctuaries and conservancies, which given the conserve and protect premises under which the areas were set up, this is as expected. The research findings showed that the relative abundance of brown hyaena was significantly higher in protected areas compared to unprotected areas, which are in agreement with Thorn *et al.,* (2009, 2011a) and Yarnell *et al.,* (2013).

Brown hyaena occur within a restricted distribution range in the South West Arid Zone of Southern Africa and the estimated global population equates to <10,000 mature individuals (Wiesel *et al.,* 2008). Outside protected areas, brown hyaena numbers are thought to be declining as the species is experiencing a measure of deliberate and incidental persecution (Mills, 1990; Wiesel *et al.,* 2008). A 10 % population decline over three generations would cause brown hyaena to be re-classified from its current status of 'Near Threatened' to 'Vulnerable' (Wiesel *et al.,* 2008). The main driver of persecution is that brown hyaena are perceived livestock killers by farmers, a concept that has largely been found to be untrue with very few cases of reported livestock predation (Skinner 1976; St John *et al.,* 2012). Where livestock has been taken by brown hyaena it has been found to be a few problem individuals that have been responsible (Skinner 1976). Therefore, the landowner perception that brown hyaena are a threat to livestock and cause a major economic loss is not based on hard evidence and could have led to the indiscriminate and unjustified persecution of this species (St John *et al.,* 2012). Of all Africa's large carnivores, the brown hyaena is least likely to cause livestock losses and is consequently a carnivore that has the ecological attributes to allow co-existence with humans in livestock areas (Mills and Hofer, 1998).

Eaton (1975) stated that brown hyaena numbers were being held at low densities due to interspecific competition rather than habitat alterations, loss of prey and control measures. This study's findings showed that outside of protected areas it is not the interspecific competition but the control methods and persecution that is keeping brown hyaenas at lower densities which is in disagreement with the Eaton (1975) study. The findings show that inside the protected areas where persecution is not occurring the densities were significantly higher. These finding are in line with other studies which have shown that large carnivore population numbers are lower in areas where human populations and the associated disturbances are greatest (Johnson *et al.,* 2006). Human disturbances can also lead to behavioural changes and adaptations, as Schuette *et al.,* (2012) found with lions becoming more cryptic and nocturnal.

In South Africa, terrestrial protected areas only cover 6.2 % of the total land cover. This has led to carnivores' home ranges spreading across both protected and unprotected areas (Woodroffe and Ginsburg, 1998; Inskip and Zimmermann, 2009; UNEP-WCMC, 2012). Effective conservation management is of paramount importance to wide-ranging carnivores living in human-dominated landscapes outside of protected areas, especially in light of 31 % of carnivore species being listed as 'Threatened' or 'Data Deficient' (Muntifering *et al*., 2005; IUCN, 2013). As stated previously acquiring a baseline of knowledge on the density and distribution of a species is required to enable planning and execution of conservation strategies (Tobler *et al.,* 2008; Marnewick *et al.,* 2008; Pettorelli *et al.,* 2010). Many protected areas are too small to hold large viable populations (particularly in South Africa), which makes human dominated landscapes key to future carnivore population persistence (Woodroffe and Ginsburg, 1998; Inskip and Zimmermann, 2009). Development of South Africa has led to conservation failures through extinctions of large predators outside protected areas due to a deficiency in knowledge on carrying capacity for individual predators across their geographical range (Hayward *et al.,* 2007ab). These findings are reflected in the study which found that the largest apex predators (lion, wild dog, spotted hyaena) were locally extinct across the unprotected areas. However, utilising an alternative source such as the national questionnaire records of presence of these species were recorded outside protected areas but in very small proportions (see Chapter 3 section 3.8.1.).

This study has shown that medium-large bodied carnivores are found across the landscape matrix, which includes the human dominated areas and the protected areas, although at varying levels of abundance. Even though the brown hyaena was found at high density inside the protected areas, it was the discovery of the species persisting at low densities within the human dominated landscape, outside the protected areas boundaries that is cause for optimism (Thorn *et al.,* 2012). The fate of the brown hyaena has been improved since 1975 when it was the expert opinion that brown hyaenas were endangered due to the probability of extinction outside of protected areas (Eaton, 1975). 39 years on, this study and others (Mills and Hofmer, 1998) have shown that the brown hyaena is far from doomed in South Africa and is surviving and maintaining a healthy population in the unprotected rangelands. However, the large variation between the brown hyaena abundances in the unprotected and protected areas is cause for concern as species found at low levels of abundance are most susceptible to environmental and stochastic events, which can lead to local extinctions (Karanth and Chellam, 2009; Pettorelli *et al.,* 2009). This study has established the abundances of key carnivore species and therefore added to the knowledge of their status in South African rangelands, which in turn can lead to targeted conservation management plans across these areas. As summarised by Margules and Pressey (2000) “reserves alone are not adequate for nature conservation,” which is a direct reflection of the findings of this study. Prior to this study there was a recognised lack of data on the abundance of brown hyaena across much of its range (Friedmann and Daly, 2004).

As a quarter of the global brown hyaena population is estimated to exist in South Africa, conducting this study was extremely important. Through achieving the study’s objectives and acquiring a well rounded understanding of the abundance and distribution of the target populations across the dynamic landscape of South Africa has contributed further to the fundamental ecological understanding of these areas. Specifically, the research confirmed that, as anticipated, brown hyaena are at a higher abundance inside the protected areas. However, and contrary to the initial hypothesis, the majority of small-medium bodied carnivores were at higher abundances in the human dominated rangelands. The results suggest that the removal of apex predators has led to a mesopredator release, potentially leading to the brown hyaena fulfilling the role of an apex predator.

Chapter 5: Determining the drivers of brown hyaena home range size inside and outside protected areas, across the North West and Limpopo Provinces of South Africa.

5.1. Introduction

Carnivores are highly susceptible to human wildlife conflict as they are wide ranging and compete with humans for protein (Treves and Karanth, 2003; Baker *et al.,* 2008; Inskip and Zimmermann, 2009; Winterbach *et al.,* 2012). To understand the pressures that endangered carnivores face in an increasingly human dominated landscape, baseline knowledge of spatial habitat use, distribution and behaviour is required to help conservationists develop informed conservation strategies (Tobler *et al.,* 2008; Marnewick *et al.,* 2008; Pettorelli *et al.,* 2009). Therefore there is a fundamental need to understand the spatial ecology of animals across their range and to understand the drivers behind their habitat preferences (Seaman and Powell, 1996; Anderson and Lindzey, 2003; Carbone *et al.,* 2011; Edwards *et al.,* 2013).

Gaining insights into habitat preferences and spatial ecology of carnivores that are often nocturnal and secretive can be problematic, and often requires intensive telemetry studies to provide the necessary insights required for conservation management (McConnell *et al.,* 1999; Hulbert and French, 2001). Acquiring the knowledge of a species' ranging behaviour is deemed to be fundamental to understanding its behavioural ecology and is also a prerequisite to planning its management (Muntifering *et al.,* 2005; Marker *et al.,* 2008).

Carnivore home-range size is influenced by a range of factors including: resource dispersion (Mills, 1982; Macdonald, 1983; Kruuk and Macdonald, 1985); density (Mattisson *et al.,* 2013); inter and intra-specific competition (Owens and Owens, 1978; Mills, 1982; Dyk and Slotow, 2003); persecution (Muntifering *et al.,* 2005); body size (Gehring and Swihart, 2002); energy requirements (Dahle and Swenson, 2003); and gender

(Rautio *et al.,* 2013), followed by interspecific competition (Creel, 2001; Hayward *et al.*, 2009b; Winterbach *et al.,* 2012).

The resource dispersion hypothesis (RDH) predicts that territory size is determined by the dispersion pattern of food patches (Macdonald, 1983; Kruuk and Macdonald (1985) and is considered the primary factor that determines the ranging behaviour of large carnivores. The definition of territory used in this study is as described by Davies (1978) "Individual animals or groups are spaced out more than would be expected from a random occupation of suitable habitats." Therefore the larger the spread of food patches the greater the size of the territory, and *vice versa*. One group will have to work harder to acquire the same amount of resource in a patch of low dispersion thus making their home range larger to compensate (Macdonald, 1983; Kruuk and Macdonald, 1985; Owens and Owens, 1978; Mills, 1982; Dyk and Slotow, 2003). For example, brown hyaenas had smaller home ranges in unprotected areas where food was more closely distributed than in the protected areas of Botswana (Maude 2005). Further support of the RDH has been found in Pilanesberg National Park, where wild dogs have relatively small home ranges due to high prey abundance and the need to move to avoid lions (Van Dyk and Slotow, 2003).

Human demography and land use are also important factors in carnivore distributions, especially where protected areas are small and fragmented (Karanth *et al.,* 2009). The majority of mortalities occur when carnivores range beyond reserve boundaries and are killed, accidentally and deliberately, by humans (Castley *et al.,* 2002; Schwartz *et al.*, 2006; Loveridge *et al.,* 2007). Many carnivores are often forced into unsuitable habitats due to competition and persecution from humans, which increases home range size (Mizutani and Jewell, 1998; Muntifering *et al.,* 2005; Marker *et al.,* 2008). For example, red wolves (*Canis rufus*) have been found to avoid areas with high human density (Dellinger *et al.,* 2013). In Southern Africa leopards' survival probability is proportionally related to the time spent outside protected areas (Balme *et al.*, 2009). Unprotected areas are also likely to subject brown hyaena to increased mortality rates as they are frequently persecuted by livestock farmers who perceive them as a threat to their stock. However, very few cases of reported livestock predation by brown hyaena have been reported (Skinner 1976; Mills and Hofer, 1998; Maude and Mills, 2005; Thorn *et al.,* 2009; 2011b; 2012).

Large carnivores have been shown to use roads as travel corridors (Kerley *et al.,* 2002; Hines *et al.,* 2010). Red wolves' (*Canis rufus*) avoidance of natural land-cover types decreased when they were near secondary roads (Dellinger *et al.,* 2013). The brown hyaena is no exception as it has a strong preference towards the utilisation of the road network within home range areas (Thorn *et al.,* 2009). Mills (1990) established that brown hyaenas used roads as territorial boundaries which they continuously scent marked and patrolled. As with the red wolves, the brown hyaena will use human-associated landscapes, but modify their habitat selection patterns with increased human presence (Thorn *et al.,* 2009; Dellinger *et al.,* 2013).

Game fences also have the potential to cause indiscriminate mortality, due to game and livestock colliding with the fences that seek to keep them in. Furthermore, large bodied animals may be hindered in their movement across the landscape (Cozzi *et al.,* 2013). However in Botswana, aardvark (*Orycteropus afer*), black-backed jackal (*Canis mesomelas*) and brown hyaena have been found to dig and move through holes in just one night, thus easily moving through the human-dominated landscape (Kesch *et al.,* 2013). Whether this is true in South Africa is currently unknown.

Brown hyaena spatial ecology is well documented in Botswana and Namibia with home ranges varying from a maximum of 1,250 km² in land away from the coastline in Namibia to 192 km² in Botswana (Mills, 1978; Mills, 1982; Mills, 1990; Owens and Owens, 1978; 1996; Maude, 2005; Wiesel, 2006). Nomadic males make up to 33 % of the overall population and have been shown to have the largest home ranges (Mills, 1990; Wiesel, 2006). In addition to gender and movement patterns, home ranges are also affected by the locations of any breeding dens as females and other clan members are drawn to the location which is the focal point of society (Mills, 1990). The resource dispersion hypothesis can account for the majority of variability in relation to group and clan size, as clan size is affected by food patch richness and clan size is influenced by distance to food, which in turn all influence home range size (Mills, 1990). Unlike spotted hyaenas, browns hyaenas have a wide and varied diet, which means they are able to travel and forage over smaller areas to acquire the necessary quantity of food (Mills, 1990).

It is critical for the continued conservation of brown hyaena to ascertain and understand all the factors that maybe influencing home range size. This need is further emphasised by the fact that 25 % of the global brown hyaena population is resident in South Africa. As a country, South Africa has the smallest and most fragmented terrestrial protected areas across the entire brown hyaena geographical range. In recent years the brown hyaena has demonstrated resilience within the unprotected areas even though occupancy is low in the extensive croplands (Thorn *et al.*, 2011a). However, the species is not showing trends of fragmentation associated with the edge of species ranges (Thorn *et al.*, 2011a). Of all Africa’s large carnivores, the brown hyaena is least likely to cause livestock losses and consequently the carnivore that has the ecological attributes to allow co-existence with humans in livestock areas (Skinner 1976; Mills and Hofer, 1998; Maude and Mills, 2005; Thorn *et al.*, 2009; 2011b; 2012). Therefore the unprotected rangelands are essential for the future persistence of brown hyaena and detailed ecological studies are urgently required in these habitats to facilitate their persistence

Inter-species competition may have a significant influence on brown hyaena home range size, density and distribution (Owens and Owens, 1978; Mills, 1982). Africa’s large predator guild, of which the lion and spotted hyaena are the largest, with overlapping dietary preferences, competes for a limited food resource base (Hayward and Hayward 2006). Both lions and spotted hyaena are regarded as competitors of the brown hyaena (Mills, 1990), but they also may facilitate the provision of food resources via their kills (Yarnell *et al.*, 2013). The influence of lion and spotted hyaena on brown hyaena populations and ranging behavior is, however, unknown. As the density of apex predators is typically higher inside the protected areas, this factor may mean that the home ranges of brown hyaenas inside the protected areas are larger, due to the inter-species competition driving the hyaenas to traverse over larger areas to reduce competition (Owens and Owens, 1978; Mills, 1982). However, the presence of apex predators is double edged as they may benefit the brown hyaena by providing a constant and predictable source of carrion to scavenge and creating a higher quantity of available food inside the protected areas (Mills, 1990). The differing ecological constraints that exist in South Africa’s protected and unprotected areas provide an ideal natural experiment to investigate how the presence or absence of apex predators will influence the ranging behaviour and density of brown hyaena in the region.

5.2. Objectives

This study's objectives were to use GPS/GSM collars to: i. compare home range estimates and movement patterns of free living brown hyaena inside and outside protected areas in the North West and Limpopo Provinces of South Africa; and ii. determine what ecological and environmental variables influence brown hyaena home range size in the North West and Limpopo Provinces of South Africa.

According to the current home range and resource dispersion theories, the prediction is that home range sizes will be larger for brown hyaena located outside protected areas compared to those inside.

5.3. Material and Methods

Between 17th April 2007 and 18th May 2011 ten brown hyaenas were either caught in steel cage traps (Figure 5.1.) or free darted under veterinary supervision and collared with a cellular collar (GPS/GSM) (Africa Wildlife Tracking, Pretoria, South Africa). Five of these hyaenas were captured in two protected areas (Madikwe Game Reserve and Pilanesberg National Park) and the remaining five in neighbouring unprotected mixed cattle and game farms in North West and Limpopo Provinces of South Africa. The protected areas were chosen on the basis that they were both impenetrably fenced and contained the same resident apex predators (lion, leopard, wild dogs), with the one exception of the spotted hyaena, which was resident in only one of the areas. The park area, climate, vegetation structure, management authority, herbivore species are as similar as possible across both areas. Therefore, variables were standardised across both protected areas. The unprotected farms on which the hyaenas were captured were within a similar climatic region and vegetation structure to the protected areas. Other than the brown hyaena, leopards were the only large transient carnivore found in the unprotected area. All farm livelihoods were derived from a mixture of cattle, and game ranching. These farms were chosen as they were representative of the overall land use structure of the district (Marnewick *et al.*, 2008). Landowner permission was sought before any trapping activity took place in the unprotected areas and permission was granted by Northwest Parks and Tourism Board

(NWPTB) under TOPS permit number CPM-002-00005 to capture brown hyaena in Pilanesberg National Park and Madikwe Game Reserve.

5.3.1. Capture Locations

One hyaena (BHP1 'Alfred') was captured in Madikwe Game Reserve (-24.719526°, 26.390424°) and four (BHP2, 3, 4, 5) were captured in Pilanesberg National Park, further details can be found in chapter 2 (Table 2.2. and 2.3.). The unprotected farmland area was the location for five hyaena (BHUP6, 7, 8, 9, 10) capture sites: 1. BHUP7, Ben Alberts Nature Reserve (-24.688714°, 27.354296°); 2. BHUP6, Tweeldstrum Farm (-24.460649°, 27.766437°); 3. BHUP8, Bullsprait Farm (-24.549540°, 26.560315°); 4/5. BHUP9/10 Ingala Farm (-24.698268°, 26.626765°) (see Table 2.2. and 2.3.). All are mosaics of privately owned blocks divided by game fencing, which is electrified and utilises a mixture of electric strands and wire mesh (Lindsey *et al.,* 2005; Hayward *et al.,* 2009a).

5.3.2. Immobilisation of Hyaenas

Cage traps were used to live-trap the study animals. Two traps types were used, one with a single door entrance with a release pin at the back of the cage (1m x 2m), and one with two doors with a trigger plate in the middle (1m x 3m) (Figure 5.1.).

Figure 5.1. Example of a two door metal cage trap used to capture brown hyaena

Cage traps were baited with game meat and placed at strategic locations, such as junctions of roads that were likely to intercept brown hyaena. The cages were always situated under trees to act as shade and camouflage and were checked between 6 am and 8 am on a daily basis. Any non-target species captured in the cage were released and the cage re-set. Three out of the four brown hyaenas in Pilanesberg National Park were captured using free darting at a carcass. All trapped and free darted brown hyaenas were immobilised by a qualified veterinarian via an air-pump dart gun, using intramuscular injection of 2.5 mg/kg of Zolitol. Once immobilised the body condition of the brown hyaena was assessed by checking the fur, teeth, muscle and fat layer and any wounds were noted (Mills, 1982; Spoor 1985). The following morphometrics were recorded: age based on tooth wear (following method described by Mills, 1982); gender based on visual assessment; and weight using portable spring scales. Throughout the procedure the veterinarian monitored the hyaena's breathing and heart rate to ensure the animal's safety. Each hyaena was allowed to recover in the cage trap, and then released at point of capture. Trapping attempts were made on a continuous basis throughout the year, as capture rates were highly variable between individuals and study areas, and ranged from two days after the trap was set to three months.

5.3.3. The GPS-GSM Collar and Home Range Analysis

All the collars used were a combination collar that contained both GPS-GSM (Global System for Mobile Communication) and VHF units. These collars were used to track individuals (Africa Wildlife Tracking, Pretoria, South Africa, www.awt.co.za). The combination of the two units enabled animals to be tracked either by GPS coordinates or manually using VHF. The GPS data was transmitted via the GSM network as a text message to a secure server from which the data was downloaded and viewed via Google Earth. In areas where cellular signal fluctuated in strength, the collar, using its inbuilt data logger, could store up to 20,000 coordinate points. Once the animal had returned into an area of adequate signal strength the data was uploaded to the GSM network. The location of the animal at the point of upload greatly influenced the success of the data capture as described by Hulbert (2001), Di Orio (2003) and Hansen (2008).

The collars fitted to all ten hyaenas had different positioning schedules to maximise the life of the battery. As brown hyaenas are predominately active between 6pm and 6am (Mills,

1982) the collar schedules were initially set between these hours at two hourly intervals. A point at midday was also taken as a way of attempting to identify the individual's daily resting place. Once a hundred fixes had been logged the number of fixes recorded per night was reduced to two fixes a night to maximise collar battery life.

All recorded GPS positions were used to calculate individual home range size, movement patterns and habitat use. Adaptive Kernel (AK) density and Minimum Convex Polygon (MCP) for each individual were calculated using ArcView GIS (version 9.3, ESRI, Redlands, CA, USA) and Home Range Tools extension for ArcGIS (version 1.1) (Rodgers *et al.,* 2007). These are standard methods of measuring animal home ranges (Jackson, 2006; Leggett, 2006; Dillion & Kelly, 2008). The MCP home range analysis is solely based on peripheral data points, taking into account outliers, which can lead to over estimates of home range size (Harris *et al.*, 1990; Leggett, 2006). The kernel method refers to the probability of density of locations calculated from the standard bivariate normal (Gaussian) kernel probability density estimator (i.e. utilization distribution) (Rodgers and Kie, 2011). Therefore the home range estimation is derived from the greatest number of points and the assigned smoothing parameters (Leggett, 2006).

For methods such as the adaptive kernel (AK) there is currently no analytical method to determine adequate sample size for non-parametric home range estimators, as they do not have an associated variance estimator (Seaman *et al.*, 1999). The MCP method requires a minimum sample size of between 100 and 300 locations, since fewer than 50 observations can greatly overestimate the home range area (Seaman *et al.*, 1999). However, undertaking home range analysis using kernel probability density estimations, a sample size of greater than, or equal to, 60 fixes, based upon the assumption of using the LSV smoothing parameters, is required. Due to the level of autocorrelation of the fixes for all individuals in this study, the use of LSV or Biased Cross Validation smoothing parameters was not suitable and individual smoothing parameters were assigned to each individual home range analysis (Kernohan *et al.,* 2001; Rodgers and Kie, 2011). The AK probability density method was used to determine the adequate sample size to ensure that an accurate home range size was acquired. Random points were taken from each individual brown hyaena and accumulation of the home range quantified from 10 to 100 fixes. It was determined that from 40 fixes (One way ANOVA, Dunnett t (2-sided), $F = 0.063$, $n = 9$, $P = 0.806$) onwards there were no significant differences between the groups. Therefore 40 +

observations provided an accurate home range estimation across all individuals. To ensure that individual brown hyaena could be effectively compared across treatment groups, the influence between the number of nights collared and the overall adaptive kernel home range size was analysed. The analysis showed that the number of collared nights had no influence on the home range size (One way ANOVA, F = 1.914, n = 9, 81, P = 0.068). Therefore there was no need to standardise the number of nights used for the home range analysis, which in turn would reduce the biological relevance of the data (Kernohan *et al.,* 2001). Home range sizes determined by the adaptive kernel at 95 % volume when tested against 100 % of observations and 95 % of fixes were significantly affected by the 5 % of outliers (Paired sample t-test t = -2.577, d.f. = 8, P = 0.033) and would lead to an overestimation of home range sizes. Thus, the exclusion of the outer 5 % of observations was justified and followed other studies' recommendations (Kernohan *et al.,* 2001; Girard *et al.,* 2002). All home range results were therefore based upon adaptive kernel analysis, utilising 95% of the total fixes collected.

It is widely acknowledged that MCP estimates produce over-estimates of home range (Leggett 2006), but are still widely used as a standard measure in many studies (Kernohan *et al.,* 2001; van Dyk and Slotow, 2003; Lent and Fike, 2003; Marker and Dickman, 2005). The advantage of the AK method is that it utilises information derived from the placement and density of the interior data points (Lent and Fike, 2003) and areas with low densities of observations receive more smoothing as the parameters can be varied in accordance with the data (Worton, 1989) unlike the fixed kernel density. The disadvantage of the AK method is that it has the potential to re-adjust the bandwidth value in the course of the calculation leading to overestimations (Girard *et al.,* 2002). Therefore the brown hyaena GPS data was analysed using both the AK density estimation and MCP method in order to calculate home range sizes as well as to determine the possible output discrepancies between the two methods.

It is understood that independence of successive animal locations is a basic assumption of many statistical methods of home range analysis (Rodgers and Kie, 2011). Temporal autocorrelation of GPS data can lead to an underestimation of the true home range size (Swihart and Slade, 1985) and therefore the level of autocorrelation for ten hyaenas was tested and identified as being highly auto correlated. However, to achieve statistical independence, the data needed to be resampled multiple times resulting in major reductions in the observation sample size which in turn could lead to a significant underestimation of the brown hyaena's home range size and movement patterns (McNay *et al.,* 1994; Solla *et al.,* 1999; Katajisto and Moilanen, 2006). By excluding the auto correlated observations not only will the sample size be reduced but the biological significance of the analysis diminished (Solla *et al.,* 1999). Further to this some studies found that the accuracy of home range analysis improved at shorter time intervals even though this increased the autocorrelation between observations (McNay *et al.,* 1994; Solla *et al.,* 1999). Therefore, following the recommendations of Solla *et al.,* (1999) and Katajisto and Moilaned (2006), all further analysis was undertaken on the entire sample size for all ten hyaenas.

5.3.4. Apex Predator Interactions

The apex predator numbers in protected areas were provided by the NWPTB (Knoop *et al.,* 2010) as part of their overall management strategy to monitor predator levels, particularly lion and wild dog numbers. The spotted hyaena estimation was based upon work carried out by Ball (2007).

5.3.5. Available Biomass

The annual herbivore stocking density, which ranged from steenbok (8.5 kg) and duiker (15.5 kg) to white rhino (1125 kg) and elephants (1980 kg) was calculated for all study areas using aerial game census count data divided by study area (km^2). For the purposes of this analysis ostriches were included, but warthog and bush pig were excluded as accurate counts could not be acquired. The available annual live biomass for each of the six areas was calculated based on the average biomass calculated from 3/4 mean adult female body mass (Coe, 1976), which assumes equal sex ratio and size distribution.

The natural mortality rates for the main ungulate species (zebra (*Equus quagga burchellii*), wildebeest (*Connochaetes taurinus*), impala (*Aepyceros melampus*) giraffe (*Giraffa camelopardalis*), greater kudu (*Tragelaphus strepsiceros*), waterbuck (*Kobus ellipsiprymnus*), sable (*Hippotragus niger*) and tsessebe (*Damaliscus lunatus*)) were calculated only for the unprotected areas and were based on the survival rates outlined by Owen-Smith and Mason (2005) from the Kruger National Park between 1978 and 1996. The unknown survival rates for the remaining ungulates species (excluding elephant, rhino) were taken as the mean survival rate of prime aged females based on results from Gaillard *et al.,* (2000) and Owen-Smith and Mason (2005) using the original aerial count data. The natural mortality rates in the protected areas were not calculated based on the findings of Owen-Smith and Mills (2008), who stated that almost all mortality determined from ungulate carcasses was due to predation, and only megaherbiovres, substantially exceeding 1000 kg, were exempt. As the three largest apex predators (lion, spotted hyaena, wild dog) are absent in the unprotected areas natural mortality was occurring in the ungulate population.

5.3.6. Brown hyaena relationship and utilisation of road networks across home range

The use of roads by brown hyaenas has been shown to have a strong influence on movement patterns as the roads are utilised as both territorial boundaries and a path of least resistance through the habitat (Mills, 1982). The aim of the study was to investigate whether there was any difference in i) the overall preferential use of roads by brown hyaenas within the core and peripheral home range areas and ii) differences in road usage between protected and unprotected treatment areas (core and peripheral areas). All roads located in each study area, irrespective of type (dirt, tarmac etc), were treated the same. A buffer of 50m was placed around all the roads found within the hyaena's 95 % AK home range area. The number of GPS observations found completely within the 50 m buffer and the remainder outside the buffer were summed for each hyaena. The total area (km^2) of the buffer zone was calculated and the area for each 95 % home range (minus the 50 m buffer zone) was used to determine the density of GPS observations (locations/km^2). The density of locations was then compared between all the core and peripheral areas and then between treatment areas to ascertain whether hyaena preferentially used roads as opposed to natural terrain.

5.3.7. Fences and Brown Hyaena Movement

As fences have the potential to act as barriers to movement for medium-large bodied carnivores it was essential to ascertain if this was the case for the brown hyaena. The make up of the unprotected area was one of multiple independent farms that utilised both a perimeter game fence (2-3 m fencing with 17-25 wire strands of 1-2 m with four strands for cattle fencing) along their farm boundaries and internal three strand barb wire cattle fences (0.5 m) within the boundary. The fence boundaries data were collected by travelling the routes with a manual GPS unit where possible and digitisation of known farm boundaries from paper maps when access to farmland was not possible. The fence boundaries were then overlaid on top of the GPS point collar data in ArcView ver. 9.3 for all the unprotected area hyaenas.

5.3.8. Species Ecology; influence of gender and dens on home range sizes

The gender of each hyaena was taken during immobilisation and collaring. Any potential dens or daily resting places for all ten brown hyaenas were determined by ground truthing clusters of GPS collar points, downloaded onto a manual GPS unit, in areas where access was viable. On the ground, observations were used to determine the key areas frequented by individual animals.

The data was analysed using the software package SPSS, version 19.0 (IBM Company, 2010). All the home range variables were tested for normality using the Kolmogorov-Smirnov test and were all found not to be significantly different to the normal. Therefore parametric tests were used for comparisons between protected and unprotected areas. The home range analyses (Kernel and MCP) were undertaken using HRT: Home Range Tools for ArcGIS®, Version 1.1, Compiled September 19, 2007 (Rogers *et al.*, 2007) in combination with ERSI® ArcMap ver. 9.3.

5.4. Results

5.4.1. Trapping Effort

A total of ten brown hyaena (five males and five females) were captured and collared between 2007 and 2011 (Table 5.1.). Five of these were captured in protected areas and the remaining five in neighbouring unprotected mixed cattle and game farms. Five (50 %) collars stopped sending signals one, two, three, four and 11 months respectively after deployment (Table 5.1.). The causes of these stoppages are unknown. Two (20 %) animals were known to have died during the study. One was shot on farmland four days after collaring, reducing effective sample sizes in the data analysis below to nine, and a male died of suspected natural causes, three months after collaring in a protected area (PNP). All animals recovered from anaesthesia and collars were successfully removed from 50 % (*n* = 5) of animals. The project was unable to re-capture 50 % (*n* = 5) despite considerable effort, as animals whose collars were not transmitting could not be detected for capture and collar removal.

Table 5.1. The information collected on all ten GPS collared brown hyaenas.

Hyaena ID	Time period collared	Number of nights collared	Treatment type	Sex	Age	Body mass (kg)	Capture method	Days to capture	Capture location	Collar removed
BHP1	30.9.09 12.5.10	224	Protected	Male	Adult	45	Cage trap	2	Madikwe Game Reserve	No
BHP2	4.8.08 16.9.08	43	Protected	Female	Adult	33	Free dart	1	Pilanesberg National Park	Yes
BHP3	21.4.07 9.6.07	49	Protected	Male	Adult	43.5	Free dart	1	Pilanesberg National Park	Yes
BHP4	10.4.08 23.7.08	104	Protected	Female	Adult	40	Free dart	1	Pilanesberg National Park	Yes
BHP5	24.11.09 22.4.11	453	Protected	Female	Adult	35	Cage trap	115	Pilanesberg National Park	No
BHUP6	9.2.10 17.3.10	36	Unprotected	Male	Adult	45	Cage trap	54	Tweeldstrum Farm	No
BHUP7	24.9.09 27.7.10	306	Unprotected	Male	Sub-adult	32	Cage trap	21	Ben Alberts Nature Reserve	No
BHUP8	13.4.10 26.10.10	196	Unprotected	Female	Sub-adult	27	Cage trap	44	Bullsptriait Farm	No
BHUP9	9.3.11 4.4.11	26	Unprotected	Male	Sub-adult	30	Cage trap	30	Ingala Farm	Yes
BHUP10	18.5.11 23.5.11	5	Unprotected	Female	Adult	37	Cage trap	70	Ingala Farm	Yes
Total		**1,442**				**367.5**		**339**		
Mean		**144.2**				**36.75**		**33.9**		
Mean Protected areas		**174.6**				**39.3**		**24**		
Mean Unprotected areas		**113.8**				**34.2**		**43.8**		

5.4.2. Brown hyaena home range size in relation to protection levels

Nine individuals had sufficient data to calculate home range sizes (Figure 5.2.), Figure 5.3. is an example of a male brown hyaena home range in the protected area, the remaining eight hyaena home range maps can be found in Appendix 5. The overall mean (±SE) brown hyaena 95 % MCP was 104.66 km² ± 31.89 km² (Table 5.2.). The mean 95 % MCP in the protected areas area was 156 km² ± 45.57 km² (SE) and higher, but not significantly different to the unprotected area, which was 40.48 km² ± 13.09 km² (SE) (Two sample t-test, t = 2.182, d.f. = 7, n = 4, 5, P = 0.065). The overall mean (±SE) brown hyaena 95 % AK home range was 71.3 km² ± 18.4 km² (Table 5.2.). The mean 95 % AK in the protected areas was 103.8 km² ± 17.9 km² which was significantly larger than the unprotected area, which was 30.63 km² ± 9.02 km² (Two sample t-test, t = 2.849, d.f. = 7, n = 4, 5, P = 0.035). The overall mean (±SE) brown hyaena 50-95 % AK peripheral areas were 63.4 km² ± 16.8 km². The mean 50-95 % AK peripheral areas in the protected areas was 91.7 km² ± 17.1 km² and was significantly larger compared to the unprotected area of 28 km² ± 8.3 km² (Two sample t-test, t = 2.607, d.f. = 7, n = 4, 5, P = 0.048). The overall mean (±SE) brown hyaena 50% AK core home range was 7.7 km² ± 1.9 km². The mean 50 % AK core range in the protected areas was 11.7 km² ± 1.5 km² and was also significantly larger than the unprotected area, which was 2.6 km² ± 0.8 km² (Two sample t-test, t = 4.249, d.f. = 7, n = 4, 5, P = 0.007).

Table 5.2. Summary of GPS collared brown hyaena home range data.

Hyaena ID	Treatment type	Number of nights acquired	Number of fixes	MCP, km² (95%)	Core area, km² (AK 50%)	Peripheral area, km ² (AK 50%-95%)	Total home range area, km² (AK 95%)
BHP1	Protected	224	923	190.7	10.9	110	120.9
BHP2	Protected	43	251	308.5	14.5	162.8	177.3
BHP3	Protected	49	247	128.8	17.53	75.75	95.25
BHP4	Protected	104	85	118	9.8	88.1	97.9
BHP5	Protected	453	629	34	5.9	21.8	27.8
BHUP6	Unprotected	36	180	51	3.7	34.8	38.4
BHUP7	Unprotected	306	718	36.9	2.8	24.4	27.2
BHUP8	Unprotected	196	896	67.9	3.6	46	49.6
BHUP9	Unprotected	26	83	6.1	0.3	7	7.3
Total		**1,437**	**3,929**	**942**	**69**	**570.7**	**641.7**
Mean (±SE)		**159.7 ± 49.3**	**437 ± 118.7**	**105 ± 31.9**	**7.7 ± 1.9**	**63.4 ± 16.8**	**71.3 ± 18.4**
Total Protected area		**873**	**2135**	**780**	**58.6**	**458.5**	**519.2**
Total Unprotected area		**564**	**1794**	**162**	**10**	**112**	**123**
Mean Protected area (±SE)		**174.6 ± 57.3**	**427 ± 152.8**	**156 ± 45.6**	**11.7 ± 1.5**	**91.7 ± 17.1**	**103.8 ± 17.9**
Mean Unprotected area (±SE)		**141 ± 44.9**	**449 ± 213.3**	**40.5 ± 13.1**	**2.6 ± 0.8**	**28 ± 8.3**	**30.6 ± 9.0**

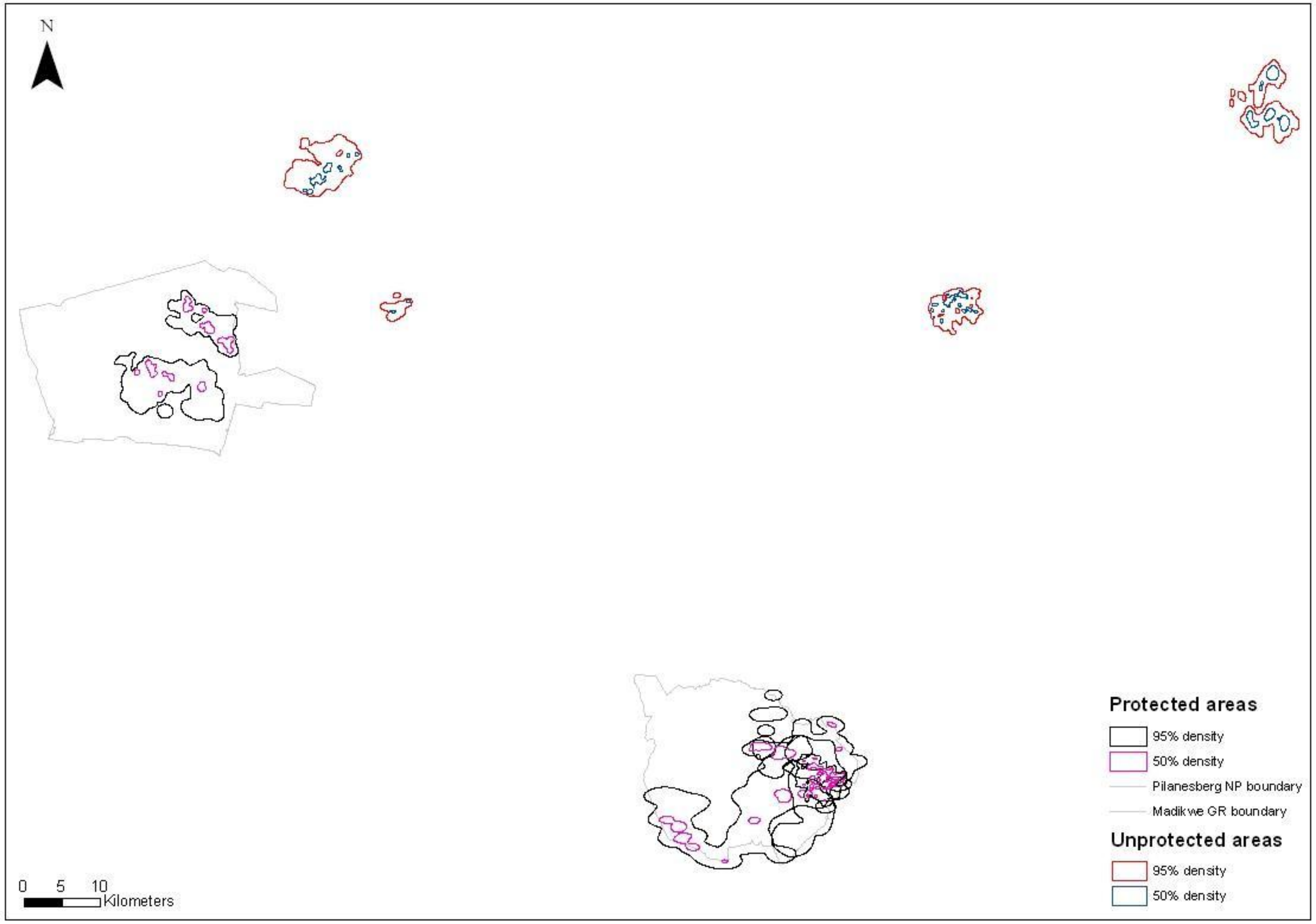

Figure 5.2. Overview of home range sizes using the 95 % AK density for all nine brown hyaenas collared across the protected and unprotected areas in the North West and Limpopo Provinces of South Africa (17th April 2007 - 4th April 2011).

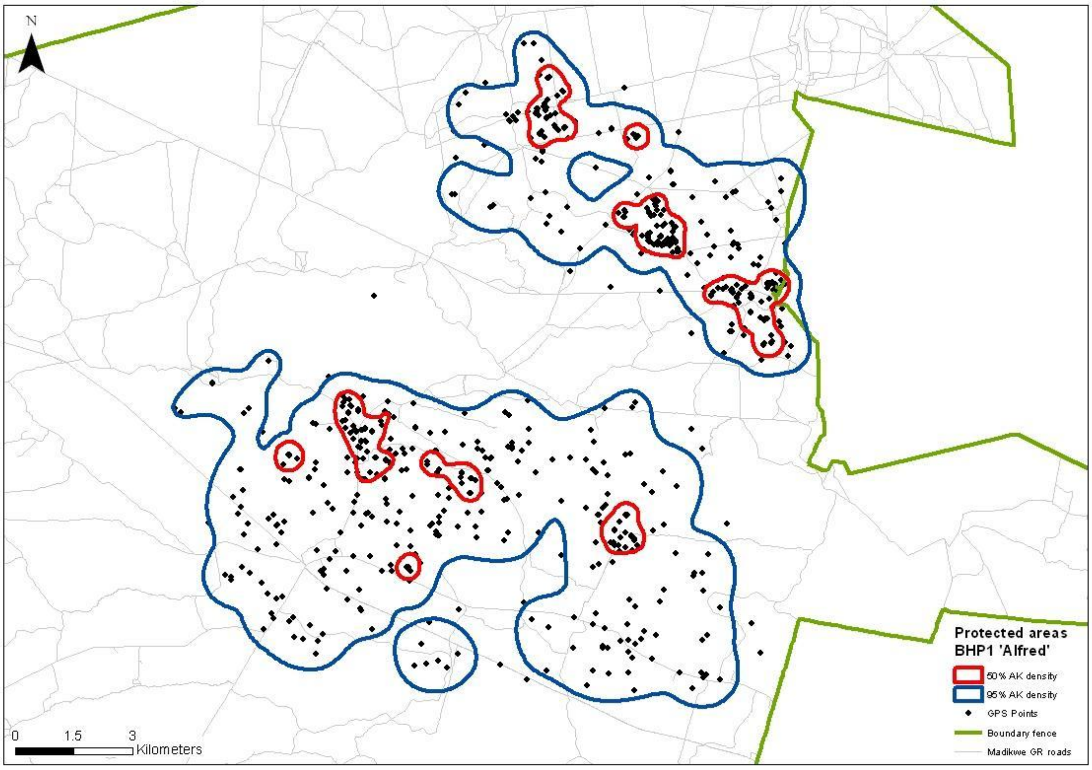

Figure 5.3. Home range size using the 95 % and 50 % AK density for the brown hyaena BHP1 'Alfred' collared in Madikwe Game Reserve in the North West Province of South Africa (30th September 2009 - 12th May 2010).

5.4.3. The influence of food resources on brown hyaena home range sizes

The mean quantity of live biomass was greater per unit area (km²) in the unprotected areas 4,735 kg/km² ± 2,988.2 kg/km² (SD) compared to that found in the protected areas 3,609 kg/km² ± 740.34 kg/km² (SD) (Figure 5.4.).

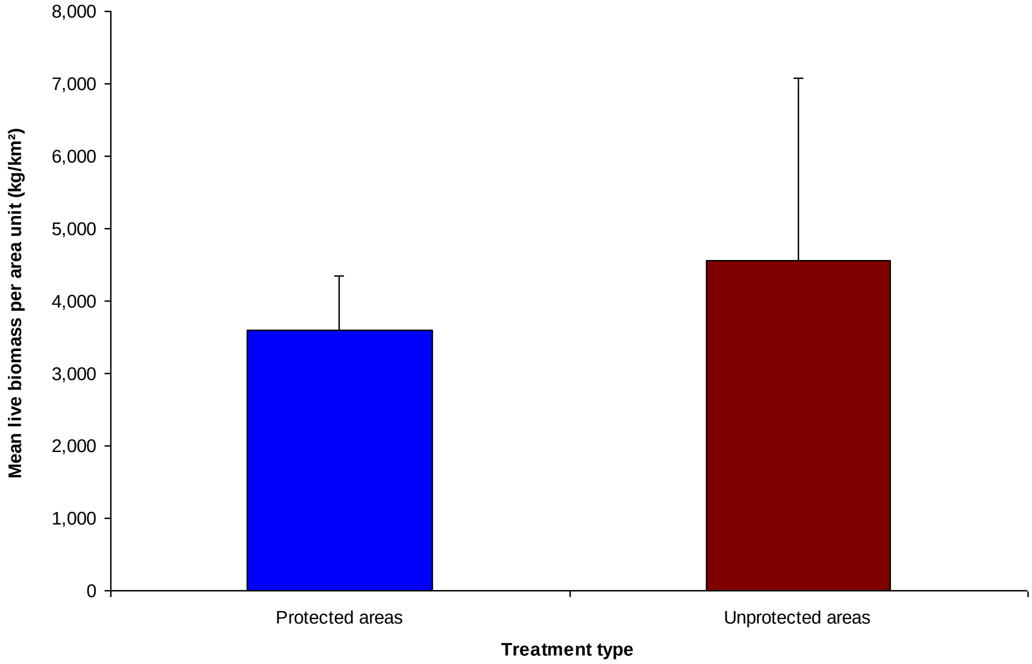

Figure 5.4. Comparison of mean density (±SD) of available live biomass (kg) in 2010 between protected and unprotected areas.

The variation in available live biomass between protected and unprotected areas could not be tested for significance due to low sample size associated with the protected areas (n = 2). The protected areas have a greater range of herbivore species, with an average of 21 ± 2.83 (SD) species compared to 8.1 ± 3.2 (SD) in the unprotected areas (Table 5.3.).

Table 5.3. Density of live biomass (kg) calculated at each site in 2010 and the number of herbivore species found across the protected (*n* = 2) and unprotected areas (*n* = 10).

Hyaena ID	Treatment type	Site	Area (km²)	Live biomass (kg/km²)	Number of herbivore species
BHP1	Protected	Madikwe Game Reserve	580	4,124	22
BHP2 BHP3 BHP4 BHP5	Protected	Pilanesberg National Park	550	3,074	20
BHUP6	Unprotected	Tweeldstrum Farm (capture farm)	45	7,952	12
BHUP7	Unprotected	Ben Alberts Nature Reserve (capture farm)	11	1,518	12
BHUP8	Unprotected	Bullsprait Farm (capture farm)	13	2,508	6
	Unprotected	Farm 2	18	2,499	10
	Unprotected	Farm 3	5.05	5,234	7
	Unprotected	Farm 4	6.38	1,406	8
	Unprotected	Farm 5	58	4,042	8
	Unprotected	Farm 6	18	4,295	1
BHUP9	Unprotected	Ingala Farm (capture farm)	18.5	7,905	8
	Unprotected	Farm 2	12	9,994	9
Total			**1,335**	**54,551**	**123**
Mean (SD)			**111 ± 221**	**4546 ± 2251**	**10 ± 6.1**
Total protected areas			**1,130**	**7,198**	**42**
Total unprotected areas			**205**	**47,353**	**81**
Mean protected areas (SD)			**565 ± 21**	**3599 ± 743**	**21 ± 1.4**
Mean unprotected areas (SD)			**20.5 ± 17**	**4735 ± 2988**	**8 ± 3.2**

There was a non-significant weak negative relationship between total home range (95 % AK), core home range (50 % AK) and the density of live biomass found across the different areas (Spearman's rank, *rho* = -0.148, *n* = 9, *P* = 0.704) (Figure 5.5.) and (Spearman's rank, *rho* = -0.296, *n* = 9, *P* = 0.439) respectively.

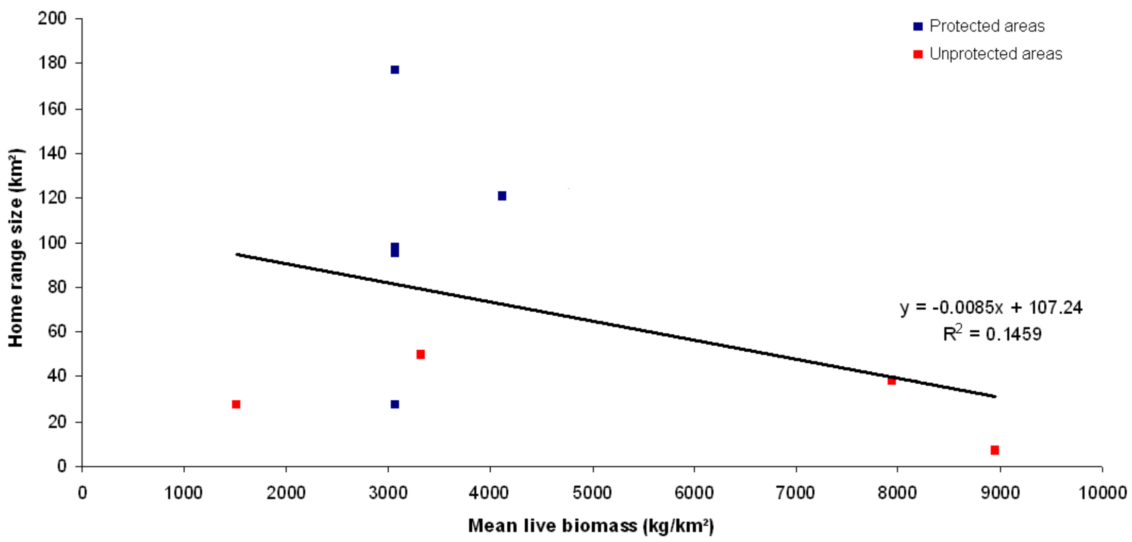

Figure 5.5. The relationship between the density of live biomass (kg) available at the time of collaring and the home range size 95 % AK (km²) for all nine brown hyaenas across both protected and unprotected areas.

The mean density of dead biomass (natural mortality only) for all ungulate herbivores (excluding elephant, black, white rhino) made available in 2010 across the protected areas was zero compared to 379.1 kg/km² ± 336.1 kg/km² (SD) in the unprotected areas (Table 5.4.). The dead biomass made up of human hunting and additional natural mortality was only present in the unprotected areas totalling 275.8 km² in 2010 with a mean value across the total area of 27.6 kg/km² ± 41.1 kg/km² (SD) (Table 5.4.). Overall the average dead biomass inclusive of all groups was found to be higher in the unprotected areas 406.7 kg/km² ± 336.8 kg/km² (SD) as predation was the main cause of mortality rather than natural processes (Owen-Smith and Mills, 2008). Natural mortality provided the hyaenas in the unprotected areas with a higher density of dead biomass throughout the year than off cuts from human hunting. The production of dead biomass by human hunting is seasonal and was only available for four months of the year (May-August). Therefore during the human hunting season there was a 14.2 % increase of dead biomass made available for the unprotected hyaenas only to scavenge for relatively little extra effort. In relation to dead biomass created from naturally mortality only, the amount available to the unprotected area hyaenas was over two times greater than the quantity available to the protected area hyaenas.

Table 5.4. Available density of dead biomass per km², caused by natural mortality in the protected areas (*n* = 2) and human hunting and additional natural mortality in the unprotected areas (*n* = 10) in 2010.

Hyaena ID	Treatment type	Site	Total dead biomass kg/km² (natural mortality)	Total dead biomass kg/km² (human hunting and additional natural mortality)	Total
BHP1	Protected	Madikwe Game Reserve	0	0	0
BHP2		Pilanesberg National Park	0	0	0
BHP3			0	0	0
BHP4			0	0	0
BHP5			0	0	0
BHUP6	Unprotected	Tweeldstrum Farm	510.6	122.1	632.7
BHUP7		Ben Alberts Nature Reserve	217.5	48.4	265.9
BHUP8		Bullsprait Farm (including farms 2-6)	1,555.8	54.2	1,610
BHUP9		Ingala Farm (including farm 2)	1,506.9	51.2	1,558
Total protected areas			**0**	**0**	**0**
Total unprotected areas			**3,790.8**	**275.8**	**4,066.5**
Mean protected areas (±SD)			**0**	**0**	**0**
Mean unprotected areas (±SD)			**379.1 ± 336.1**	**68.9 ± 35.5**	**1,016.6 ± 672.4**

5.4.4. Brown hyaena relationship and utilisation of road networks across home range

The farmlands had a greater density of roads than protected areas (Table 5.5.). However, the mean road length was higher inside the protected areas. This was because the 95 % AK contours were larger for the individual hyaenas. This meant that longer stretches of road were incorporated into the home range. Therefore road preference was standardised by GPS locations per km². The 50 m road buffer area covered 19 ± 14.3 % of the 95 % AK contour areas of all nine brown hyaenas but contained 26 ± 17 % of the GPS locations recorded by each collar unit. The density of GPS locations within the 50 m road buffer in the 95 % AK contours (median = 10.69 locations/km^2) was significantly higher than the density in the overall 95% AK contours (median = 5.09 locations/km^2; Z = -2.310, P = 0.021).

The 50 m road buffer covered significantly more of the 50% AK contours (median = 23 %) than the 95 % AK contours (median = 12 %; Z = -2.66, P = 0.008), and the density of GPS locations within the 50 m road buffer in the 50 % AK contours (median = 40.5 locations/km^2) was not significantly different compared to the overall 50 % AK contours (median = 54.8 locations/km^2; Z = 0.533, P = 0.594).

In the protected areas the density of GPS locations within the 50 m road buffer in the 95 % AK contours (median = 2.04 locations/km^2) showed no significant variation to the unprotected areas (median = 24.88 locations/km^2, Independent t-test, t = 0.759, d.f. = 7, n = 4, 5, P = 0.473). In the protected areas the density of GPS locations within the 50 m road buffer in the 50% AK contours (median = 12.5 locations/km^2) also showed no significant differences compared to the unprotected areas (median = 91.8 locations/km^2, Independent t-test, t = 1.690, d.f. = 7, n = 4, 5, P = 0.175).

Table 5.5. Utilisation of road networks by Brown hyaena based on 95% Adaptive Kernel home range.

Site name	Hyaena ID	Road Buffer (km^2)	HR Kernel 95% (km^2)	Total road buffer GPS points	Density of GPS points in road buffer (points/km^2)
Madikwe Game Reserve	BHP1	13	120.86	139	10.7
Pilanesberg National Park	BHP2	15.18	177.3	31	2.0
	BHP3	8.73	95.25	10	1.1
	BHP4	9.07	97.9	10	1.1
	BHP5	2.67	27.8	142	53.2
Tweeldstrum Farm	BHUP6	1.45	7.34	53	36.6
Ben Alberts Nature Reserve	BHUP7	9.04	27.2	308	34.1
Bullsprait Farm (including farms 2-6)	BHUP8	12.69	49.6	199	15.7
Ingala Farm (including farm 2)	BHUP9	4.32	38.4	26	6.0
Median (all)					**10.7**
Median (protected)					**2.0**
Median (unprotected)					**24.9**

Table 5.5. Utilisation of road networks by Brown hyaena based on 95% Adaptive Kernel home range (continued).

Site name	**Hyaena ID**	**Buffer (km)**	**HR Kernel 50% (km)**	**Total buffer GPS points**	**Density of GPS points in buffer**
Madikwe Game Reserve	BHP1	2	10.9	79	39.1
	BHP2	1	14.5	13	12.5
Pilanesberg National Park	BHP3	1.8	17.5	6	3.3
	BHP4	1.5	9.8	5	3.3
	BHP5	1.1	5.9	103	91.2
Tweeldstrum Farm	BHUP6	0.1	0.3	34	283.3
Ben Alberts Nature Reserve	BHUP7	1.4	2.8	172	122
BullspRait Farm (including farms 2-6)	BHUP8	0.9	3.6	58	61.7
Ingala Farm (including farm 2)	BHUP9	0.4	3.7	15	40.5
Median (all)					**40.5**
Median (protected)					**12.5**
Median (unprotected)					**91.8**

5.4.5. Fences and Brown Hyaena Movement

Throughout the unprotected areas there was no evidence found to support the supposition that the perimeter game fencing was acting as a barrier to the movement (Hayward *et al.*, 2009a) of the brown hyaenas. All the unprotected hyaenas moved through boundary game fencing during their collaring periods. The hyaenas crossed a total of 35 fences on average 194 ± 163.9 times (n = 4). In the protected areas the density of GPS locations recorded within the 50 m boundary fence buffer in the 95 % AK contours (median = 5.64 locations/km^2) was not significantly different compared to the unprotected areas (median =

12.03 locations/km^2, Independent t-test, t = 0.563, d.f. = 7, n = 4, 5, P = 0.592). In the protected areas the density of GPS locations recorded within the 50 m boundary fence buffer in the 50 % AK contours (median = 36.9 locations/km^2) was significantly different compared to the unprotected areas (median = 36.9 locations/km^2, Mann-Whitney U Test, W = 15.0, n = 4, 5, P = 0.016). The unprotected hyaenas occupied, on average, 8.8 ± 3.8 different parcels of privately owned game farms (Figure 5.7.). In the protected areas the one predator proof boundary fence was a barrier to movement as no individual was recorded moving beyond the boundary fence.

The movement of the brown hyaenas through the unprotected areas was facilitated by holes dug by other large bodied mammals such as the warthog. Evidence of these holes underneath perimeter fences was found across the home range areas in which the collared hyaenas resided. Brown hyaenas were known to utilise these holes by the spoor tracks that were observed in and around the holes (Figure 5.6.).

Figure 5.6. Illustrative examples of mammalian-dug holes underneath multiple perimeter game fences.

5.4.6. Species Ecology; influence of gender and dens on home range size

The largest home range was that of a protected area female covering 177.3 km² followed by a protected area male hyaena at 120.9 km². Overall the mean male home range size was 65.88 km² compared to the female which was 75.96 km². In protected areas the male hyaenas mean home range size was 108.9 km² (n = 2) compared to the female 101 km² (n = 3). In the unprotected areas the mean males home range size was 22.85 km² (n = 2) compared to the females 38.4 km² (n = 3). Across both areas there was no significant difference found between the male and female home range sizes (One way ANOVA, F = 0.65, n = 9, P = 0.806).

The dens or daily resting places were determined for two hyaenas both in the unprotected (n = 1) and protected (n = 1) areas. Both den areas were distinctively the focal points within the core home range areas and therefore can be shown to have influenced not only home range sizes but movement patterns as well (Figure 5.7.).

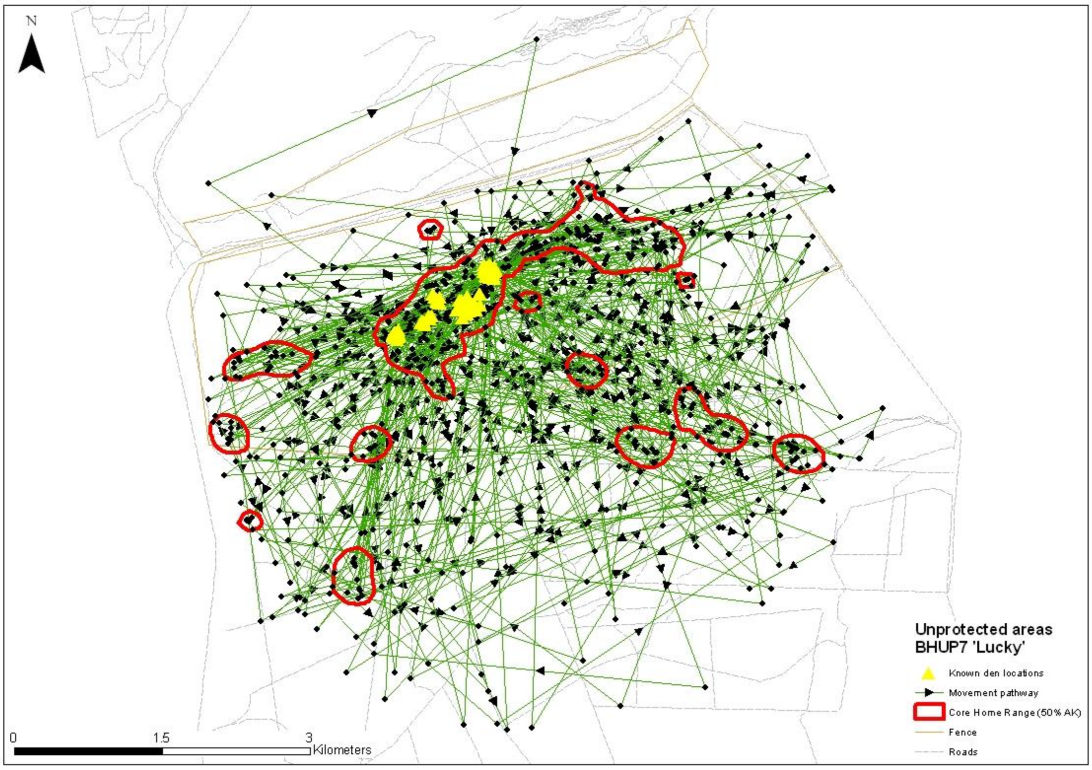

Figure 5.7. The known daily resting places, the total straight line movement pathway during the hours of 6pm-6am and the core home range contours (50 % AK density) of the brown hyaena BHUP7 ‘Lucky’, collared in the unprotected area in the North West Province of South Africa (24th September 2009 – 27th July 2010).

5.5. Discussion

This study has demonstrated that brown hyaena home ranges in the North West and Limpopo Provinces of South Africa are on average 2.5 times smaller than those recorded elsewhere across their distribution. For example, those reported in the Southern Kalahari were 481 km^2 (Mills, 1984); Central Kalahari, 170 km^2 (Owens and Owens, 1978, 1979); Makgadikgadi area in Botswana, 447 km^2 inside a protected area and 192 km^2 in unprotected areas (Maude, 2005). Indeed these are the smallest home range estimates recorded for brown hyaena in areas away from the coastal areas of the Namib desert (31.9 to 220 km^2 Skinner *et al.,* 1995) where food is greatly abundant in a localised area – namely seal breeding colonies. The findings of this study illustrate that home ranges sizes not only differ between individual hyaenas but also in areas with different levels of protection and are highly variable both between individuals and throughout their range. Despite this, the research has demonstrated that brown hyaena in protected areas, have on average, larger total and core home ranges than those in neighbouring unprotected areas (Fig 5.2.).

It was expected that the protected home range sizes would be smaller compared to the unprotected areas. However, this study found that the opposite was true. Higher levels of persecution in the unprotected areas (Thorn *et al.,* 2011a) could be one reason for the smaller home ranges in the unprotected areas. It seems that the mechanism for these differences is that increased persecution has led to lower abundance (see Chapter 4) which in turn leads to lower competition and a reduced need to travel widely to meet their energy requirements. The opposite is likely to be true in the protected areas which have larger home ranges.

Paradoxically, the lower abundance found the in the unprotected areas (see Chapter 4) should have produced larger home range sizes. However, this study demonstrated the opposite to be true. The suggested reason for these differences is that persecution in the unprotected areas influences clan sizes and, in turn, home range sizes. Further research into clan structure and size, particularly in the unprotected areas, may provide further information on this subject.

Even with the level of persecution, a greater availability of food resources (RDH, Macdonald, 1983) has been shown to influence clan and group sizes (Mills, 1990) and in turn home range sizes of the unprotected areas. Therefore this study's results are in direct contrast with the findings of Mizutani and Jewell (1998), Muntifering *et al.*, (2005) and Marker *et al.*, (2008), which showed that home range sizes increase due to avoidance of human activities and certain land use types. However, persecution in the unprotected areas is a concern for brown hyaena, as evidenced by the shooting of one collared hyaena (BHUP10) after four days on a road. A similar incident happened to one of the brown hyaena Skinner and van Aarde (1981) were studying.

The significant variation between the core home range areas suggests that, in the protected areas, brown hyaenas have to forage over a larger area in order to acquire the necessary resources for survival. This then caused the expansion of the peripheral area between the core and outer home range contour. These results are in line with those found in the Makgadikgadi area as home range sizes in the unprotected cattle areas were half the size of those of the hyaenas inside the protected area where prey resources were more widely spread (Maude, 2005). This result shows that the necessary core space for the unprotected areas is smaller than those in the protected areas in the North West and Limpopo geographical region of South Africa and therefore is directly influenced by other variables. In agreement with Mortelliti and Boitani (2008) by modifying the relative amount of resources as the farmers have done by manipulating the prey density in the unprotected areas it has been possible to increase suitability in smaller patches for the brown hyaena.

One possible reason for the smaller home ranges in unprotected areas is the high levels of ungulate abundance (Schwalbach *et al.*, 2001; Marnewick and Cilliers, 2006). This study's findings are in line with the IUCN Hyaena Specialist Group action plan (Mills and Hofer, 1998), which concluded that more carrion was available in the unprotected areas. The core home ranges in the unprotected areas showed a negative correlation to the biomass created by natural ungulate mortality, additional natural mortality and the thrown out off cuts produced by human hunting. The overall density of biomass in the unprotected areas was significantly greater since these resources are not present in the protected areas. The combination of increased scavenging material with reduced competition provides strong evidence for the smaller home ranges found in the unprotected areas, which is inline with the resource dispersion hypothesis (Macdonald, 1985). The study recognises the limitations of the carcass availability calculations as they were based upon averaged estimates rather than absolute numbers. Across the unprotected areas natural mortality provided brown hyaena with a higher density of dead biomass throughout the year than the additional natural mortality and remains created from human hunting. The production of dead biomass from human hunting is seasonal and is only available for four months of the year (May-August).

Home range of brown hyaena may be influenced by the presence or absence of fences. Actual fences act as barrier and are utilised in a variety of forms such as electrified predator proof to keep in large carnivores in protected areas. Fences have been found by some studies to have an ecological impact by potentially blocking daily or wider migration movements, restricting the range use of biodiversity which may have consequences such as; overabundance, inbreeding and isolation and restriction of evolutionary potential (Hayward *et al.*, 2009a; Hayward and Kerley, 2009). Fences are heavily utilised in South Africa as a management tool, from marking individual farms to national park boundaries and keep economically valuable game in and predators out (Kesch *et al.*, 2013).

This study is in agreement with Hayward *et al.,* (2009a) that the fencing in either the protected and unprotected areas was not inhibiting movement patterns and in turn home range sizes. This is demonstrated by hyaenas in the unprotected area covering an average of eight land parcels, which could only be reached by going through game fencing. Furthermore the study found that the hyaenas on average moved across the game fence line an average of 194 times over the study duration. The study's findings are in line with Kesch *et al.,* (2013)'s who confirmed that brown hyaenas were utilising old holes or creating their own holes to dig underneath the game fences both in Botswana and South Africa. The hyaenas in the protected areas did not utilise the entire area that was potentially available to them inside the impenetrable fencing. Therefore as with other carnivores (lion, leopard, spotted hyaena) the indicators to predict home ranges sizes was the amount of available and dispersion of preferred prey biomass (Hayward *et al.*, 2009a) rather than the fencing structures that surrounds them.

Fences also have a more immediate impact by causing indiscriminate mortality. The electrified predator proof fences that surround each privately owned farm can potentially kill animals as large as a 240 kg adult male greater kudu as they get caught between the electric strands and wire mesh (Hayward *et al.*, 2009a). However, based on the land owners reports from the study area on average one to two impala a month were found dead on fence patrols. As the density of these fences is high in the unprotected areas the potential repercussions are an increase in dead biomass that is easily scavenged. The excess biomass produced from human hunting on farmsteads is easily found and scavenge and therefore is a resource that requires minimal time and energy expenditure by the hyaenas (Skinner, 1976; Skinner and van Aarde, 1981). This suggests the home range areas increase in size as the amount of available of total large herbivore biomass declines, which is an expected relationship according to the resource dispersion hypothesis (Macdonald, 1985).

This study highlighted that the brown hyaenas from both treatment areas had a strong preference towards the utilisation of the road network within their respective home range areas. Mills (1990) established that brown hyaenas use roads as territorial boundaries which involved continuous scent marking and patrols. Therefore the results of this study are in line with the current thinking and shows that South Africa's brown hyaena behaviour is consistent with the wider population. The results also emphasise that hyaenas in the unprotected areas are not actively avoiding the road networks which are heavily utilised by farmers and therefore have a strong human presence. This may have significance on the levels of human-wildlife conflict in that the chances of them being detected and persecuted are increased.

It is important to recognise that in the unprotected areas three out of the four individuals captured were sub-adults. Sub-adults weighing approximately 30 kg require 2 kg of food per day where as an adult of 50 kg requires 3.5 kg/day. Therefore the adult foraging activity will be greater to acquire the necessary resources, creating a larger home range size (Mills, 1990). However, the capture of these sub-adults in the unprotected areas shows that there are breeding adults female present and that the cubs are surviving the first 30 months, which for the long-term conservation of the species shows there is a viable population of brown hyaena in the North West and Limpopo Provinces of South Africa.

In conclusion, these differences between protected and unprotected areas in the brown hyaena's home range size have direct conservation implications. The findings highlight that, in the unprotected areas, the smaller home ranges will influence the number of brown hyaena that can utilise a given area as their resource use and space allocation is lower. In turn this could mean that a closed protected area can only maintain a given number of brown hyaena as their utilisation of space is greater. The findings show that the conservation of the species overall does not just lie within protected areas but outside as well. In the unprotected areas hyaenas ranged over a number of individually owned farms, the average being eight privately owned land parcels. This has direct implication for hyaena conservation as efforts to promote positive management needs to be targeted not only on the farm where signs of hyaenas are recorded but on the surrounding farms as well. With the large (and increasing) numbers of game ranches that occur across the Limpopo and North West Provinces, it may be concluded that prey will be permanently available for the brown hyaena within a relatively small area. The study is in agreement with Maude and Mills (2005) that brown hyaenas are one of the few large bodied carnivores that can survive alongside farmers and still maintain a viable population.

Chapter 6: Final Discussion

As the human population continues to expand, its associated growth in the rate of resource use and, in turn, habitat loss, inevitably brings people into close proximity to wildlife, leading to a rise in human-wildlife conflict (Inskip and Zimmermann, 2009; IUCN, 2013). Consequently, 31 % of all carnivore species are either 'Threatened' or 'Data Deficient' (IUCN, 2013). To conserve large carnivores it is necessary to understand their abundance in the human-dominated landscapes, which is where the real conservation action is needed through an interdisciplinary and adaptive approach (Winterbach *et al.,* 2012).

The primary aim of this research was to understand the fundamentals of conflict dynamics at work in the human-dominated rangelands compared to the protected areas of South Africa. The brown hyaena was used as a focal species for the wider carnivore guild. Specifically, the study aimed to establish the distribution and abundance of brown hyaena and the importance of the protected areas for maintaining a viable population.

In Chapter 3, distribution maps for twelve medium-large carnivores were created based upon the presence/absence data derived from the national web-based questionnaire across South Africa. As hypothesised, brown hyaenas were found to be widely distributed across South Africa, with the greatest distribution in the North East region. A key outcome of the research was that non-expert stakeholders accurately represented carnivore species spatial distribution across South Africa. The majority of these distributions are in line with current known occurrences (IUCN) of the species. This suggests that the species distributions are accurate across the study. Of particular note was the fact that brown hyaena were detected by the survey, beyond the distribution as suggested by IUCN 2008 (Wiesel *et al.,* 2008). This is fundamentally important since IUCN use distribution as one of the assessment criteria for determining species threat categories (Wiesel *et al.,* 2008). The study recognises that these may not be new sub-populations but rather existing populations identified as a consequence of increased survey effort. This is not to imply that the study suggests a re-categorisation of the brown hyaena by IUCN Red List at this stage. Rather, it draws attention to the requirement for further investigation of the brown hyaena and other under-studied species categorised as 'Data Deficient'.

A further finding of the survey was the detection of what have been assumed to be locally extinct species outside the protected areas (Hayward *et al.*, 2006; 2007ab). For example, wild dog, which are listed as 'Endangered' by the IUCN Red List (Woodroffe and Sillero-Zubiri, 2012) and geographically restricted to Kruger National Park in South Africa, were found to be present in two Provinces, KZN and Limpopo. Lion, listed as 'Vulnerable' and still of unknown status over large parts of Africa (Bauer *et al.,* 2012) were recorded in two provinces, Limpopo and Eastern Cape. Similarly, cheetahs are known to be present and have viable populations, mainly outside of protected areas, for example in the Limpopo Province (Marnewick *et al.*, 2006; Durant *et al.,* 2008). This study reflects this previous finding as most records of cheetah were found across this province and into the North West. The results do highlight the impact of this low cost, wide reaching methodology and suggest the potential benefit of its application on a broader scale to increase the knowledge base for establishing distributions of species in unprotected areas. Clearly, the method has greatest application in unprotected areas where human presence and local knowledge can be harnessed to obtain large data sets.

Chapter 3 further addressed the factors that influenced farmers' attitudes towards carnivores across South Africa as the attitudes of landowners in these areas are little understood (Lindsey *et al.*, 2009; Balme *et al.,* 2013). Previous research across the geographical range of the brown hyaena had identified that brown hyaena were still actively being targeted by predator control methods (Mills and Hofer, 1998; Thorn *et al.*, 2012). Of all land users, livestock farmers were presumed to hold overtly negative attitudes towards carnivores on their property (Treves and Karanth, 2003; Inskip and Zimmermann, 2009; Balm *et al.,* 2009; St John *et al.,* 2012; Thorn *et al.,* 2013). In fact, the findings of this research demonstrated that a more subtle range of attitudes existed amongst farmers, as indicated by the generally positive view of questionnaire respondents towards brown hyaenas. Further to this was the identification of a growing understanding among landowners of the ecology of the brown hyaena. A specific contribution of this study was the finding that approximately a third of respondents actively conserve brown hyaenas on their land and recognise the eco-tourism potential of the species. However, the presence of brown hyaena on the species target list of some land owners undertaking predator control methods is cause for concern as are the methods stated for control. Trapping and poisoning were utilised for predator control in two provinces (North West and Western Cape) of South Africa, despite being illegal and indiscriminate methods (St John *et al.,* 2012).

In common with previous studies, the research found that jackal (Klare *et al.*, 2010) and caracal (Breitenmoser-Wursten *et al.,* 2008) were firstly, commonplace and widely distributed across South Africa and secondly, the most frequently targeted species for predator control methods. It emerged that there was a relationship between perceived threat and increasing carnivore body size. In addition, a connection between financial loss (calves/lambs) and carnivores was revealed as a key basis for the livestock farmers' negative attitudes towards carnivores (Lindsey *et al.*, 2005; Thorn *et al.*, 2012; 2013). However, limitations exist to the study due to the absence of respondents in communal lands, who were not proportionally represented across the respondents surveyed. The limitations of the approach adopted are discussed in further detail in chapter 3.

Chapter 4 considered the differences between multiple carnivore species abundance in protected and unprotected areas. Since the protected areas are the focus for conserving biodiversity, the working hypothesis was that the abundance of carnivore species would be higher in the protected areas and that the unprotected areas would be centres of human-wildlife conflict, leading to lower abundance. Commercial game ranches comprise a significant proportion of suitable habitat for several carnivore species in South Africa, including brown hyaena (Lindsey *et al.,* 2009). Recently, studies have been initiated and important data has been collected on occupancy (Thorn *et al.*, 2009; 2011a) and threat levels (Thorn *et al.*, 2011b; 2012: 2013). However, home range data has not previously been collected and no study of attitudes or distribution has been conducted at a national level. This research therefore sought to add to the database of knowledge on these themes.

This study demonstrated that the preliminary hypothesis that abundances would be higher in the protected areas, while correct for brown hyaena, caracal and apex predators (in protected areas only), was not true for small-medium bodied carnivores, which showed higher abundances in the unprotected areas. In line with previous studies, brown hyaena abundance was shown to be significantly higher in the protected areas (Maude, 2005; Thorn *et al.,* 2009). There is a general consensus that this is due to higher persecution levels across the human-dominated landscape in comparison to the protection levels found within the protected areas (Wiesel *et al.,* 2008). The evidence demonstrated that, in the unprotected areas, the abundance of mesopredators was higher. As apex predators are locally extinct within the unprotected areas jackal and brown hyaena may act as the apex predators (Roemer *et al.,* 2009; Merwe *et al.,* 2009; Yarnell *et al.,* 2013). Mesopredator release of smaller carnivores could induce, exacerbate or alter the scope of local human-wildlife conflict. This links clearly to the issues discussed in Chapter 4.

The evidence showed that hyaenas were more numerous in protected areas. This may be due to either more scavenging or less persecution. However, due to high herbivore biomass in unprotected areas it is likely that high persecution is a reason for lower abundance. Resource availability is further discussed in chapter 5. Thorn *et al.,*'s (2011b) study found that positive land user attitudes led to greater occupancy. Thus, it may be concluded that the negative attitudes identified in this study have the potential to lead to lower abundances. These findings illustrate the advantages of the multi-species approach adopted in this study as it was possible to detect the variation in carnivore abundances. However, a limitation of the study was that the dynamic relationships between the various carnivore species within the ecosystem were not investigated and therefore require further research.

Chapter 5 investigated the potential differences between home range estimates for brown hyaena across protected and unprotected area. The hypothesised difference, that the protected area home range sizes would be smaller compared to the unprotected areas, was based upon the assumptions laid out by the resource dispersion hypothesis.

In this area of South Africa no previous studies of brown hyaena home range have been undertaken to inform future management of the species. The research tested the assumption that protected areas would contain smaller home ranges and that unprotected areas would have larger home ranges due to a combination of habitat use and avoidance of human activity (Maude, 2005). Contrary to expectations, the core and peripheral home ranges of brown hyaena were found to be significantly smaller in the unprotected areas. This finding possibly reflects the higher level of food availability in the unprotected areas, arising from: lack of competition from apex predators; higher stock densities; greater natural mortalities of herbivores from fence collisions and additional off-cuts being discarded during the human hunting season. These findings fall clearly within the parameters of the research dispersion hypothesis (Macdonald, 1983; Kruuk and Macdonald, 1985) as the larger home ranges observed in the protected areas were found to be a consequence of the greater density of apex predators and the resulting interspecific competition for resources. Therefore, the brown hyaena has to range further to acquire the necessary food resources from the carrion created by apex predator hunting. The findings described in chapter 4 suggest that the lower abundances of the brown hyaena should have led to larger home ranges in the unprotected areas due to the levels of persecution found there. A combination of persecution and greater availability of food resources (RDH, Macdonald, 1983) has been shown to influence clan and group sizes. In this instance therefore, it is probable that these factors have led to smaller home range sizes in the unprotected areas.

In addition, chapter 5 addressed the ecological constraints and environmental variables that potentially influence home range sizes across the protected and unprotected areas in South Africa, in order to secure further evidence of the effects of human presence and manipulation on each area and the carnivores within it. Questionnaire (Chapter 3) evidence showed consistency with the hypothesis that brown hyaenas and other carnivores are able to move through perimeter game fences. Therefore, it was concluded that the carnivores in the unprotected areas are effectively acting as an open population, whereas the predator-proof fences of the protected areas create closed populations. Due to the nature of a closed population, the brown hyaenas and other carnivores of the protected areas have a greater risk of problems associated with inbreeding (Hayward *et al.,* 2009a) as well as being at greater risk from stochastic environmental and catastrophic events (Desbiez *et al.,* 2012). In contrast to the enclosed populations in the protected areas, the brown hyaena, with unrestricted movements in the unprotected areas, may be assumed to be more capable of adaptation to habitat alterations and changes created by anthropogenic climate change. Furthermore, home range analysis demonstrated an even distribution of the road network across all brown hyaena home ranges. The findings showed that the brown hyaenas in the unprotected areas were not avoiding roads, providing further, encouraging evidence of their ability to maintain a viable population in the presence of humans.

6.1. Limitations of this Study

The main limitations of the research include: the range of cultural groups and communal land users found within the national questionnaire; non-respondent rates for predator control questions; the restricted sample sizes of the collared hyaena group and paucity of available covariate supporting data.

The benefits of using a web-based questionnaire were clear (Rushton *et al.*, 2004; Jacobson *et al.*, 2013) and felt to outweigh any disadvantages (Groves and Peterson 1992; Nunez-Quiros 2009), not least because any under-representation of sub-groups was easily identifiable and therefore could be remedied by future studies. Nevertheless, it is important to recognise the absence of some groups and land users. The particular lack of response to questions on predator control methods, whilst predictable given the illegal nature of some practices, must also be acknowledged and might in the future be remedied by face to face interviews (Lindsey *et al.*, 2005; Thorn *et al.*, 2012). Hyaena conservation in South Africa would be advanced by the development of interview techniques which provide respondents with a 'safe' environment in which to express their full views.

The camera trapping research determined relative abundance of multiple carnivore species. However, the data set also has the potential to determine occupancy for all individually identifiable and non-identifiable carnivore species captured within the study. The analysis could be taken further by combining the presence/absence data collected in both the camera trapping and national questionnaire to model brown hyaena and other carnivore species occurrence in relation to associated ecological and social covariates found across South Africa (Karanth *et al.*, 2009). From this, precise identification and management of key conservation areas may be achieved at a regional level (Karanth *et al.*, 2009).

A particularly exciting development, which was unavailable to this study but which could be used in the field of camera trapping in the future, is the Zoological Society of London's InstantWild app. This enables users to receive live shots from biodiversity hot spots in real time and can be downloaded on to mobile devices (Andrews, 2013). The particular applicability of the app. to future studies is its ability to involve non-expert observers in conservation studies, allowing them to obtain and verify data and, in the process, become engaged in conservation activities.

As the majority of studies undertaken using GPS collars utilise similar sample sizes or less (Leggett, 2006; Volampeno *et al.*, 2010), it was determined that the sample size in this research was adequate. However, the study recognises the possible limitations of inference from a small sample size to the wider population. The sample size was limited by the low brown hyaena capture rates, particularly in the unprotected areas, financial costs of the purchasing and running of the GPS collars, veterinarian fees and logistical constraints (e.g.

number of cage traps). Similarly, while the limited nature of pre-existing data on genetics was a complicating factor, enough ecological base line evidence was available to provide a source of structured evidence on home range sizes (Mills, 1978; Mills, 1982; Mills, 1990; Owens and Owens, 1978, 1996; Maude, 2005; Wiesel, 2006; 2010). Importantly, since no prior study of home range size of brown hyaena in this area had taken place previously, it was considered that this research had the potential to contribute significantly to the collective knowledge base.

6.2. Management Recommendations

The findings of this study have highlighted a series of target areas where management intervention and conservation planning could substantially assist in reducing the ongoing human-wildlife conflict as it relates to the focal species and other carnivores. The approaches outlined may be of considerable utility to conservation practitioners in regions of the world where carnivores are threatened or imperilled by as yet unknown anthropogenic threats.

The use of web-based questionnaires has proved to be a rapid means of establishing areas of high human-wildlife conflict and, providing national carnivore distribution data simultaneously. The ability to acquire both types of information is invaluable and, it is suggested, could be used to re-assess the brown hyaena's IUCN Red List threat category, and currently listed as 'Near Threatened' (Wiesel *et al.*, 2008). Similarly, having identified key provinces that undertake greater proportions of predator control (often illegal), a further management action plan should be developed to mitigate the ongoing human-wildlife conflict in these areas. A possible strategy may be the release of questionnaire results to the stakeholder groups to filter these down to their wider membership and to initiate debate and change. A further benefit of the cost effective web-based method is the ability to use it as a long term monitoring tool since it can be easily repeated and tied into the four year IUCN re-assessment time frames (IUCN, 2013).

Further, as a model management tool, the methodology can be applied on a range of scales and would equally lend itself to use at sub-provincial conservation management level. A specific suggested group to be targeted would be Afrikaaner livestock (cattle, sheep/goat) farmers who were shown to hold received views on threats posed by brown hyaenas, to be most prone to indiscriminate predator killings and to be least likely to exhibit a broader understanding of effective methods of co-existence. Clearly, there remains much work to do in context where a TOPS[1] hunting permit for a brown hyaena costs only £14.54 (*pers comm.,* North West Province, Department of Environmental Affairs and Tourism). As a metaphor for the value placed upon the brown hyaena, this is strong evidence that the perceived value of the hyaena is very low, despite its protected species status within the South Africa Biodiversity Act 10, 2004.

The findings of the study showed, encouragingly, that a proportion of the respondents viewed the brown hyaena as a potential species for eco-tourism on their properties and that active conservation of the species on properties was occurring. With the double trend of cattle farmers turning to game farming and game farmers including tourism activity on their property (Lindsey *et al.,* 2009), there is a clear potential for positive management strategies to be undertaken across these properties. The growth of small, privately fenced reserves can only assist in the expansion of brown hyaenas as eco-tourism species. This could be led by promotion of the species by the protected areas in the North West and Limpopo Provinces where the highest density of brown hyaenas within sub-Saharan Africa is found.

Protected areas are the fundamental building blocks of virtually all national and international conservation strategies; they provide the core efforts to protect the world's threatened species (Dudley, 2008). The success of protected areas as a tool for conservation is based around the assumption that they are managed to protect the values that they contain (Hockings, 2003; Hockings *et al.,* 2006; Dudley, 2008). To be effective, management should be tailored to the particular demands of the site, given that each protected area has a variety of biological and social characteristics, pressures and uses (Hockings *et al.,* 2006; Dudley, 2008).

Protected areas should strive to be areas in which scientific research is conducted at both a species and landscape level. The aim of the research should be to identify critical knowledge and data gaps, and in turn to develop a focused research programme to fill

[1] Listed threatened or protected species (TOPS) based on the National Environmental Management: Biodiversity Act 10, 2004

those gaps (Ervin, 2003; Hockings, 2003). The reasons for long-term monitoring with consistency are so that the effectiveness of the protected area management can be evaluated. The advantages of continuous evaluation of a management strategy are that as environments and climates change so can the management focus. This will lead to; effective resource allocation; promote accountability and transparency; help to improve the community involvement and links; build and promote protected area values (Hockings, 2003; Wells and McShane, 2004; Hockings *et al.,* 2006). Conducting assessments has great benefits such as building cooperative teams of people and encouraging the sharing of knowledge and reflection (Hockings, 2003; Hockings *et al.,* 2006).

In relation to specific protected area management, the flagship charismatic species such as lion and wild dog are actively prioritised by protected area management (Bauer *et al.,* 2012; Woodroffe and Sillero-Zubiri, 2012). However, the study has highlighted the fact that, within closed brown hyaena populations, there is limited to zero ongoing long term monitoring. Animal population biology ultimately must be understood in a broader context of the habitats and communities of which the populations are a part of as every animal is influenced by both biotic and abiotic pressures (Williams *et al.,* 2002). Therefore, to ensure the long term survival of the highly threaten and endangered species it is critical to understand how each of the elements within system are interconnected especially if they are working within a closed population. As this study has showed the brown hyaena within the protected area and the farmland are influenced by different pressure resulting in a variation in density and distribution. Therefore, within a closed system it is critical to firstly understand and subsequently manage these pressures that may be occurring on a micro scale.

It is suggested that conservation managers have a key role to play in promoting the brown hyaena to flagship status and, thus, potentially altering the perceptions of the broader community. A caveat must be that management within the farming community should not take place on isolated land parcels but, based on the findings of this study, should cover a minimum of eight land parcels (which equates to a home range territory).

6.3. Further Research

Several issues emerged from this study that warrant further investigation and research:

i. Determination of attitudes to carnivores in communal lands

A recognised limitation of this study, due to the use of a web-based questionnaire, was the absence of perspectives from the communal land users. A potential solution would be to access these groups through workshops and face to face interviews to deliver greater confidence in the attitudinal data. Results thus obtained have the potential to clarify whether there are significant distinctions between the attitudes of communal land users and the farming population already accessed by this study and would thus inform the development of targeted conservation and education efforts appropriate to their perspectives. Since, for example, 10 % of the North West Province (Thorn *et al.*, 2011a) is designated as communal land and has a differing socio-economic profile it is clearly an area where research effort should be concentrated.

ii. Behavioural differences between carnivore and prey in protected and unprotected areas.

Although outside the scope of this study, the camera trapping data has provided opportunities for further behavioural analysis to determine whether human presence and activity have altered carnivore and prey base behavioural patterns as a survival mechanism.

iii. Prey availability in the unprotected areas.

There is a need for a comprehensive study that fully quantifies the food resources in the unprotected areas. Although food is being created by disposing of off cuts into the veldt during and outside the human hunting season, information on this topic is currently severely limited and, hence, new data is required to establish the relative impact of human activities on brown hyaena and other carnivore distributions and densities. A fence line impact survey is also required to determine the scale of mortality on both herbivore and carnivore species. A comprehensive understanding of the total natural mortality across the unprotected areas is also required and may be achieved through a carcass count transect survey.

iv. Climate change: impact on national distributions

The presence/absence data obtained from the national questionnaire for the twelve carnivore species has the potential to be inputted into various spatial modelling programmes e.g. Maxent (Phillips *et al.,* 2006), with a specific emphasis on modelling changes in distribution in relation to climate change. Clearly, this is a long-term project and thus beyond the scope of this study. However, it has significant future relevance in terms of predicting any range contractions and/or expansions that may influence the long-term viability of some carnivore sub-populations and could be used to mitigate against putting the entire population under increased stress and threat.

v. Genetics of Brown Hyaenas

Genetic information on the brown hyaena is currently non-existent but critically important (Ray *et al.*, 2005). Determining the extent of inbreeding within the closed protected area populations is necessary to (a) identify long term management strategies for that population and (b) quantify the desirable extent of re-introductions to ensure long-term survival of the protected area populations, as discussed in chapter 5.

6.4. Conclusion

All research should be regarded as part of a continuum since, as noted by Hayward (2009 p.773) "*Ecosystems are dynamic things that are rarely at equilibrium but are rather in a constant state of flux*." It is expected that this study will contribute to this continuum and provide additional new knowledge on the status, distribution and threats that are currently affecting brown hyaenas and other carnivores across South Africa and globally.

The study has shown that brown hyaenas are widely distributed across South Africa, and indicates they are expanding the current range. One of the possible explanations for this is that attitudes towards brown hyaena were more positive than expected, especially in comparison to other carnivores in the region. However, some predator control methods, including illegal methods, were still found to be used. Therefore, the threat to the population from persecution is still ongoing and current, and as such we recommend ongoing monitoring of South Africa's carnivore populations to better inform future conservation management. The utilisation of web-based citizen science projects is one methodology which could be deployed, as in this study, to do this.

The presence of brown hyanea across South Africa's unprotected areas was corroborated by the camera trap and home range study. However, the camera trapping study identified that the brown hyaena are persisting at lower densities within the unprotected, human dominated landscape compared to protected areas. Although it is encouraging that brown hyaena still persist in these areas, further research is required to determine why densities appear lower in unprotected areas. Continued illegal persecution by a minority of landowners may be the key factor here, but other ecological factors cannot be ruled out.

Despite the lower densities associated with unprotected rangelands, home ranges across the unprotected area were significantly smaller than those found in the protected areas. This indicated that individuals do not have to travel as far to meet their biological requirements. However, one of the critical aspects discovered was that multiple private farms were utilised across a single brown hyaena home range. Using this study as a baseline further research is required to determine the plasticity of brown hyaenas in response to environmental change which will feed directly into their long-term conservation strategy plan. Overall these combinations of factors lead to the conclusion that the brown hyaena, of all Africa's large carnivores, has the ecological and behavioural attributes to allow for co-existence with humans within the unprotected rangelands and their survival is not reliant on protected areas alone.

Large carnivore research is ultimately required outside of protected areas where, as this study has highlighted, carnivores are involved in high levels of conflict and are at the greatest risk. The study has identified key areas for future research that will continue the expansion of our understanding of the cryptic and elusive brown hyaena species.

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Appendices

Appendix 1: A copy of the national questionnaire.

Dear Sir/Madam,

This questionnaire survey is being conducted by Louisa Richmond-Coggan a Ph.D. student from the University of Pretoria as part of a wider study that aims to determine the presence and absence of carnivores across a range of land uses, with specific emphasis on the brown hyena. Specifically, the project objective is to establish the density and distribution of brown hyena across South Africa. This survey aims to determine whether the species is present or absent on your property and the attitudes of you as a landowner, national and provinicial government reserve managers and private reserve owners towards this species and the reasons behind these attitudes. Your assistance in completing this questionnaire survey would be greatly appreciated. Your answers will remain anonymous and entirely confidential.

Section 1. Property Details

1a. What is your position on the property?

□ Land owner
□ Lease holder
□ Manager
□ Other, please specify………………………..

1b. What is your first language?

□ Afrikaans □ English □ Ndebele □ Sepedi
□ Sesotho □ Setswana □ Swati □ Tshivenda
□ Xhosa □ Xitsonga □ Zulu
□ Other, please specify……………………..

2. Please provide the following property details

Property name…………………………..

Province…………………………………

District…………………………………..

Nearest town…………………………….

Distance to nearest town………………..

3a. What is the size of the property in hectares?

3b. What are the activities that take place on your property?

Activity	% of the Property
Tourism	
Mining	
Cattle farming	
Sheep/goats farming	
Game farming	
Hunting	
Agriculture	
Other (please specify)	

4a. What are the number of permanent water sources (such as pans, rivers, dams or lakes) on your property?

□ 1-5 □ 6-10 □ Greater than 10

4b What is the estimated average rainfall per year on your property over the past five years (mm)

□ 0 – 100 □ 101 – 200 □ 201 – 300 □ 301 – 400

□ 401 - 500 □ 501 – 600 □ 601 – 700 □ above 700

5. What habitat types are found on your property? Please indicate the area of the site they cover.

Habitat types	Hectares
Grassland	
Woodland	
Scrub	
Crop (monoculture)	
Other, please specify ………………………	

6a. Please provide the following details concerning the perimeter fencing on the property.
Type of fencing (please select more than one as necessary):
□ None
□ Mesh fence
□ Strand fence
□ Electrified fence
□ Bonox fence
□ Other (please specify) ……………………………

Purpose of fencing…………………………………………………………………...

6b. Please indicate whether you think its possible for brown hyena to get in or out of the perimeter fence?
□ Yes □ No

7. Please give approximate game numbers or livestock on the property – not including inside predator proof camps, if applicable.

Game	Number
Black wildebeest	
Blesbok	
Blue wildebeest	
Buffalo	
Bushbuck	
Duiker	
Eland	
Gemsbok	
Giraffe	
Klipspringer	
Kudu	
Impala	
Ostrich	
Reedbuck	
Red hartebeest	
Roan	
Sable	
Springbok	
Tsessebe	
Warthog	
Zebra	
Other, please	

specify	
Livestock	
Cattle	
Sheep	
Poultry	
Goat	

Section 2. Predators

7. Indicate with a tick any of the predators that have been seen or found evidence of (spoor, midden) on the property during the last 12 months but are NOT permanently resident on the property.

□ Wild dog
□ Cheetah
□ Jackals
□ Lion
□ Leopard
□ Brown hyena
□ Spotted hyena
□ Caracal
□ Serval
□ Cape fox
□ Bat eared fox
□ Aardwolf
□ Feral dog
□ Others, please specify………………………………….

8. Indicate how you feel about having (or how you would feel about having) each of the following species on your property by giving each species a score of 1-5 (1=Strongly unfavourable; 2=Unfavourable; 3=Neutral; 4=Favourable; 5=Highly Favourable).

Species	Score	Reason
Wild dog		
Cheetah		
Jackal		
Lion		
Leopard		
Brown hyena		
Spotted hyena		
Caracal		
Serval		
Cape fox		
Bat eared fox		
Aardwolf		

9a. Do you undertake predator control on the property?

□ Yes □ No

If 'No', go to question 11

9b. If yes, please indicate A. What methods are used B. Which predators they are aimed at C. How many days a year you use them D. How many predators have been killed/removed by each method in the last year:

A. Method	B. Predator(s) targeted	C. Days used/year	D. No. predators killed

10. Using the scale below, please indicate the severity of poaching on the property

0=no poaching, 5=serious poaching problem

0 □ 1 □ 2 □ 3 □ 4 □ 5 □

11. If poaching occurs on the property, by what means does it occur and how many times has it occurred in the last 12 months?

Poaching method	Num of times occurred
Snaring	
Hunting with dogs	
Shooting	
Other, please specify……………………………. ….	

12. Compared to approx 5 years ago, do you think predator numbers have Increased (I), Decreased (D), Remained Constant (C), or Unknown (U) on the property?

Wild dog	I □	D □	C □	U □
Cheetah	I □	D □	C □	U □
Jackal	I □	D □	C □	U □
Lion	I □	D □	C □	U □
Leopard	I □	D □	C □	U □
Brown hyena	I □	D □	C □	U □
Spotted hyena	I □	D □	C □	U □
Caracal	I □	D □	C □	U □
Serval	I □	D □	C □	U □
Cape fox	I □	D □	C □	U □
Bat eared fox	I □	D □	C □	U □
Aardwolf	I □	D □	C □	U □

Section 3. Brown hyena

13a. Which evidence of the presence of brown hyena has been seen on the property in the last 12 months?

Spoor □ Yes □ No
Middens □ Yes □ No
Sightings □ Yes □ No

If 'No' to all, go to question 17

13b. If yes to the above, how frequently is the evidence seen, please tick a box?

Evidence	Once a week	2-3 weeks	Once a month	Over a month
Spoor				
Middens				
Sightings				

14a. If brown hyenas occur on the property, how many brown hyenas have you seen in the last 12 months?

14b. In the last 5 years?

15a. Have brown hyenas had pups on the property in the last 12 months?
□ Yes □ No

15b. In the last 5 years?
□ Yes □ No

16. Do you think that brown hyenas are principally scavengers or predators on the property?
□ Scavengers
□ Predators
□ Both

17a. Given the choice between having brown hyenas on the property, or not having them at all, which would you choose?

□ I want brown hyenas present in the area
□ I don’t want brown hyenas present in the area
□ Don’t Know
17b. Why?

18. Please indicate whether you agree or disagree with the following statements and any comments that you may have are welcomed.

Statement	Yes	No	Comments
A. Brown hyena regularly hunt and kill game.			
B. Brown hyena regularly hunt and kill livestock.			
C. Brown hyena are a natural component of a healthy ecosystem.			
D. Brown hyenas are a liability to a livestock farmer because they consume valuable livestock but provide no economic return.			
E. Brown hyenas are a liability to a game farmer because they consume valuable game but provide no economic return.			
F. I would not mind having brown hyena on the property.			
G. I would not mind having brown hyena on my land and denning on the property.			
H. The fences are there to actively discourage brown hyena from coming onto the property			
I. Brown hyenas are actively conserved on the property			

Thank you for taking the time to complete this questionnaire, your assistance with the project is greatly appreciated

Appendix 2: A copy of the email sent out to respondents, organisations and specialist groups.

Dear Sir, Madam

My name is Louisa Richmond-Coggan, I am PhD student at Nottingham Trent University, this questionnaire survey is part of a wider study that aims to determine the presence and absence of carnivores across a range of land uses, with specific emphasis on the brown hyaena. Specifically, the project objective is to establish the density and distribution of brown hyaena across South Africa. This survey aims to determine whether the species is present or absent on your property and the attitudes of you as a landowner, national and provincial government reserve managers and private reserve owners towards this species and the reasons behind these attitudes. Your assistance in completing this questionnaire survey would be greatly appreciated. Your answers will remain anonymous and entirely confidential. The information you provide is vital to the project. I would greatly appreciate if you could take a few minutes to fill out this short survey by clicking on one of the links below in either English or Afrikaans.

http://www.surveymonkey.com/s/National_Brown_Hyena_Survey

http://www.surveymonkey.com/s/National_Brown_Hyena_Survey_Afrikaans

Please pass the link on to anyone who you know would like to participate.

If you have any further questions about the project please feel free to email me on brownhyena@hotmail.co.uk.

Many thanks

Louisa Richmond-Coggan

PhD Researcher

Nottingham Trent University, Nottingham, England

Appendix 3: The proportion of distribution of the individual species across South Africa based upon the percentages of farms reporting presence (%) across all nine provinces recorded by respondents to the national questionnaire (*n* = 190) between 2010 and 2011.

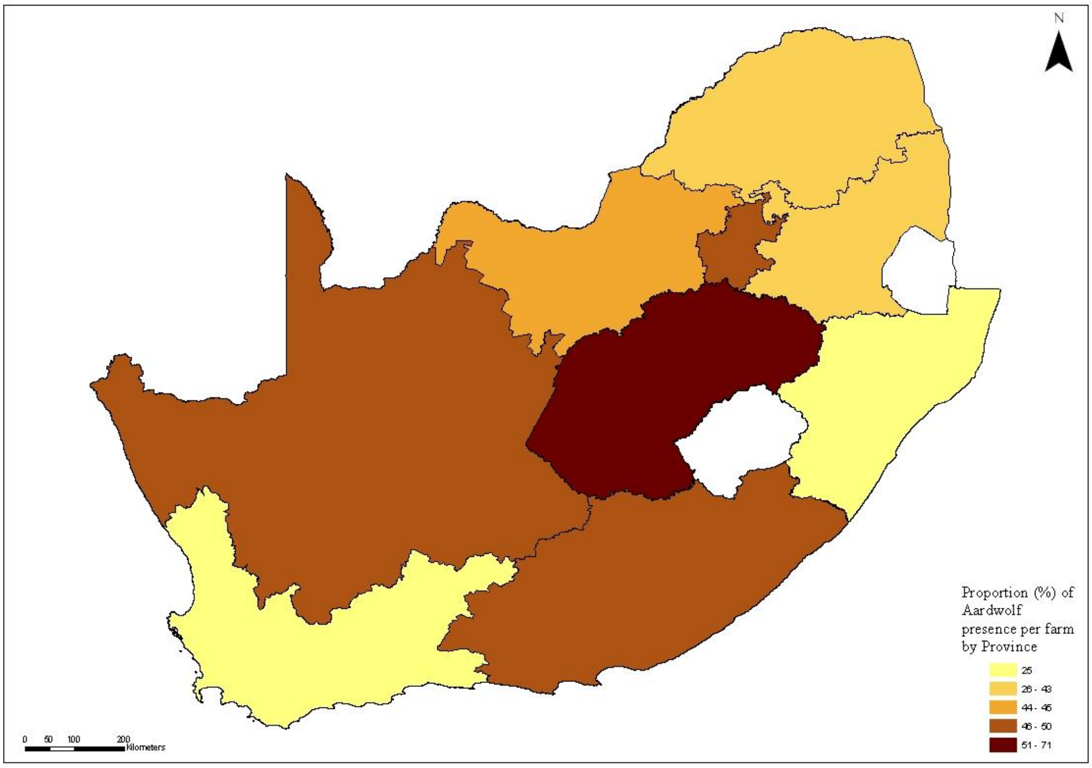

Figure 8.1. Distribution of the aardwolf across South Africa based upon the percentages of farms reporting presence (%)

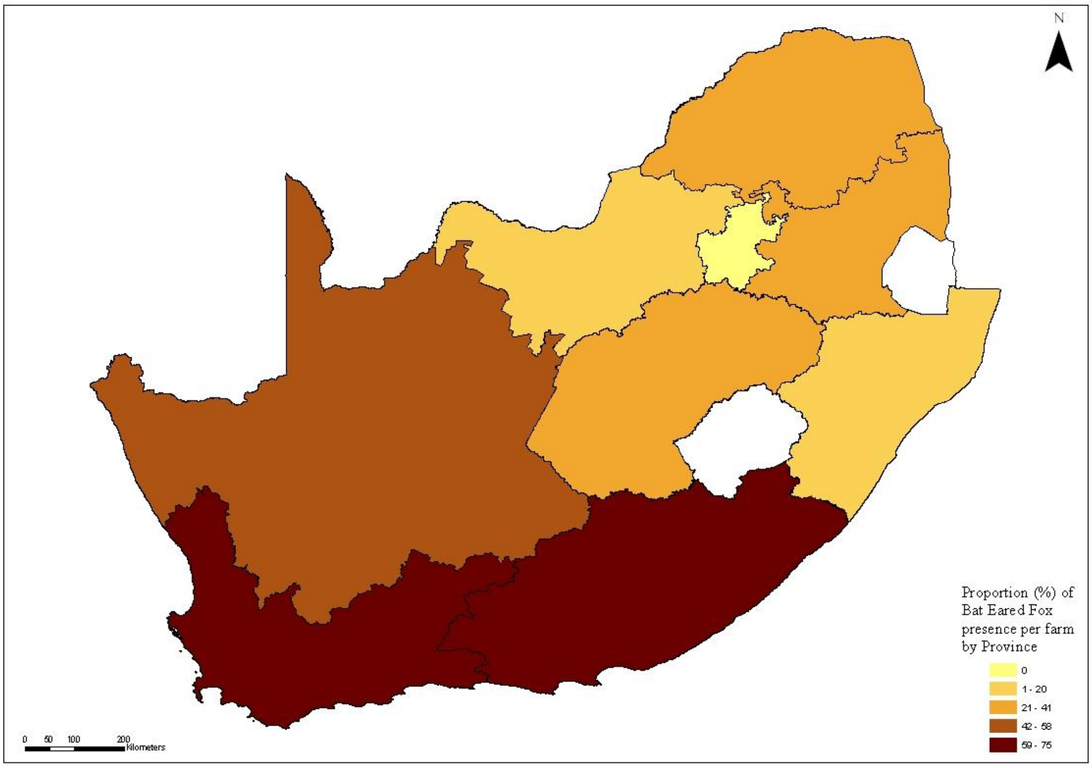

Figure 8.2. The distribution of the bat-eared fox across South Africa based upon the percentages of farms reporting presence (%) .

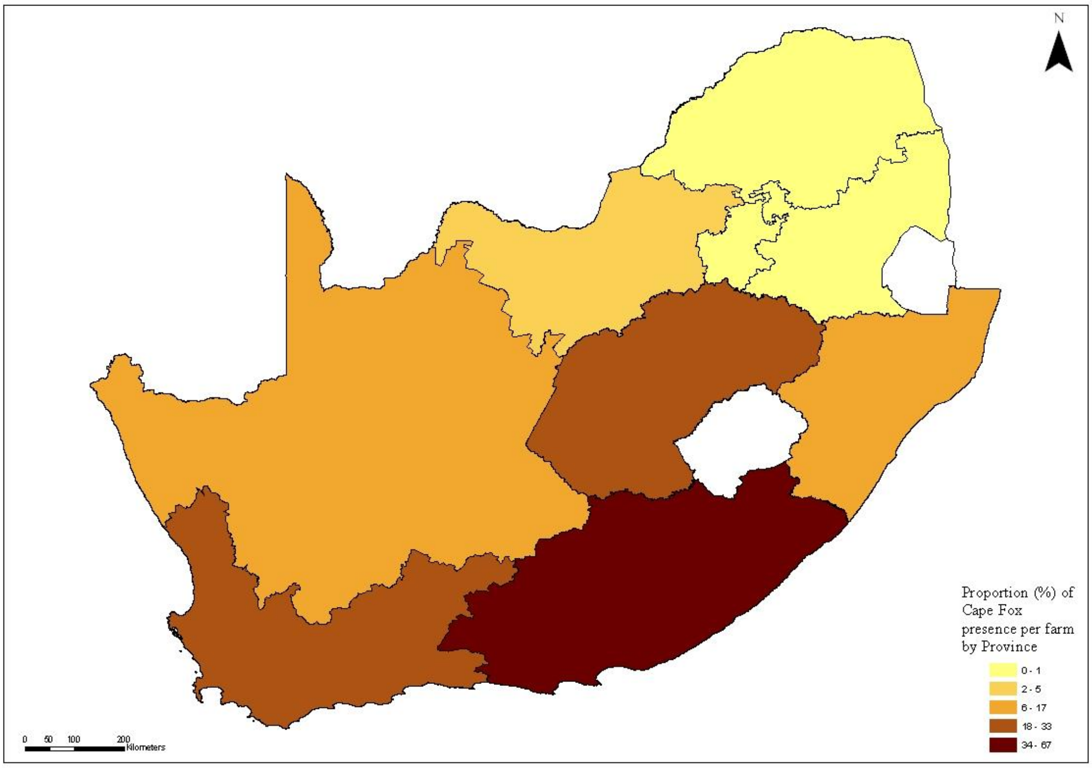

Figure 8.3. The distribution of the cape fox across South Africa based upon the percentages of farms reporting presence (%) .

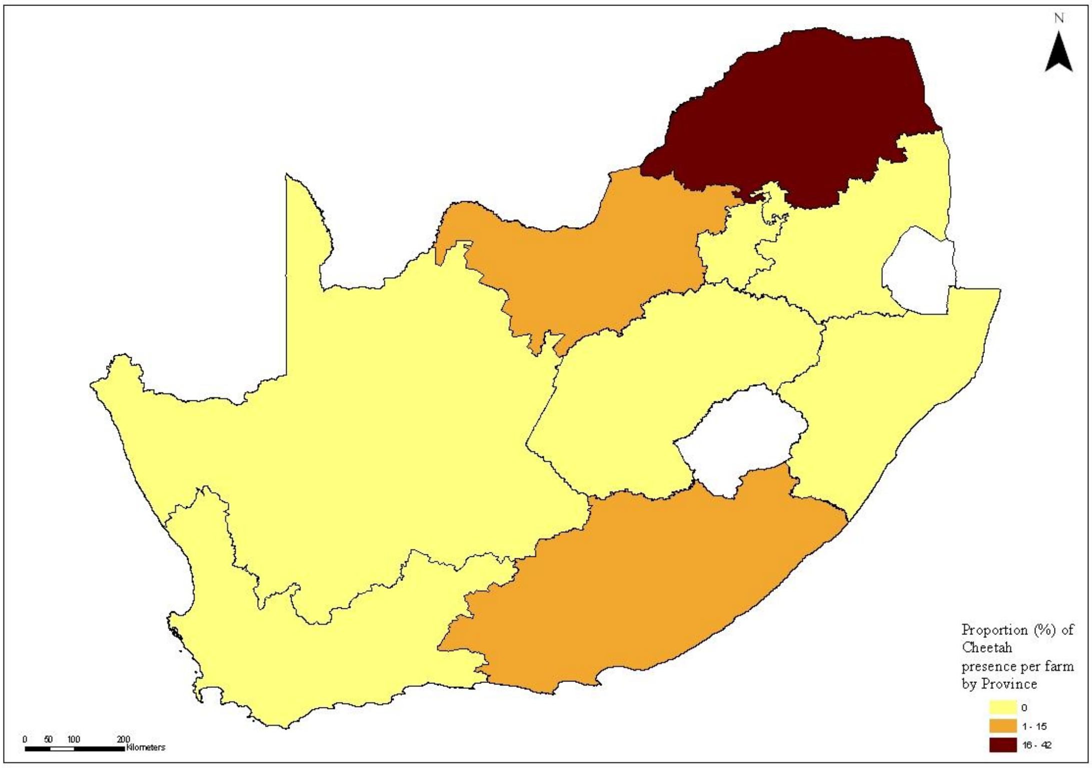

Figure 8.4. The distribution of the cheetah across South Africa based upon the percentages of farms reporting presence (%) .

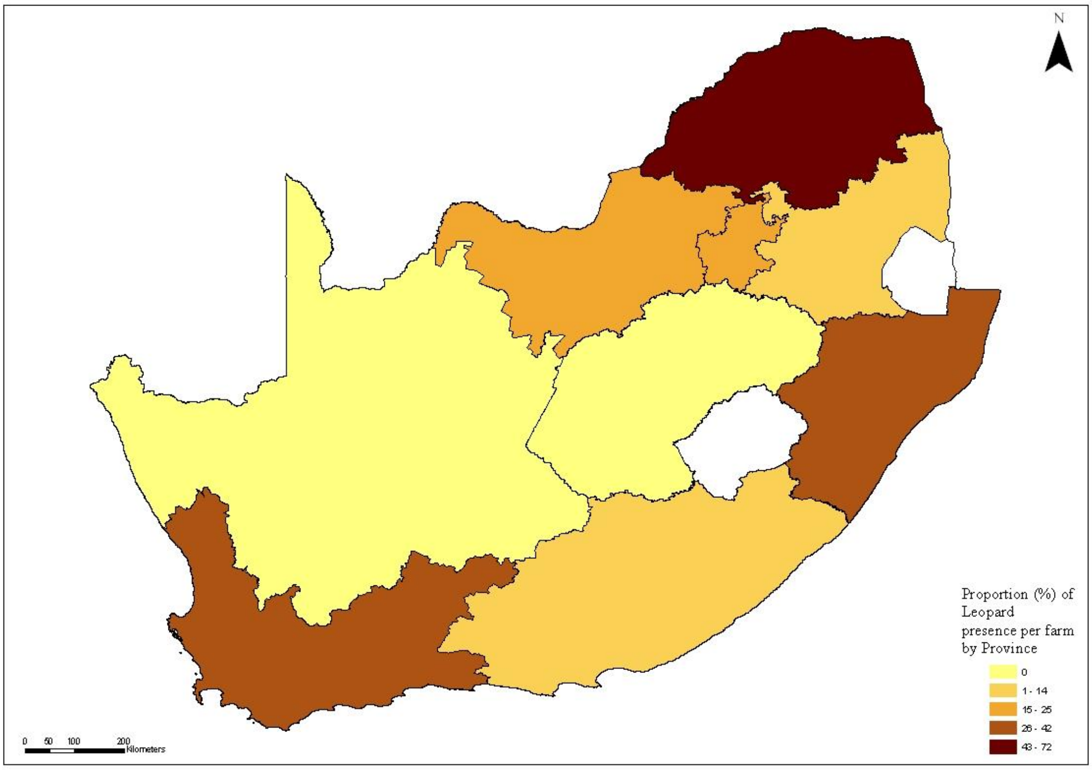

Figure 8.5. The distribution of the leopard across South Africa based upon the percentages of farms reporting presence (%) .

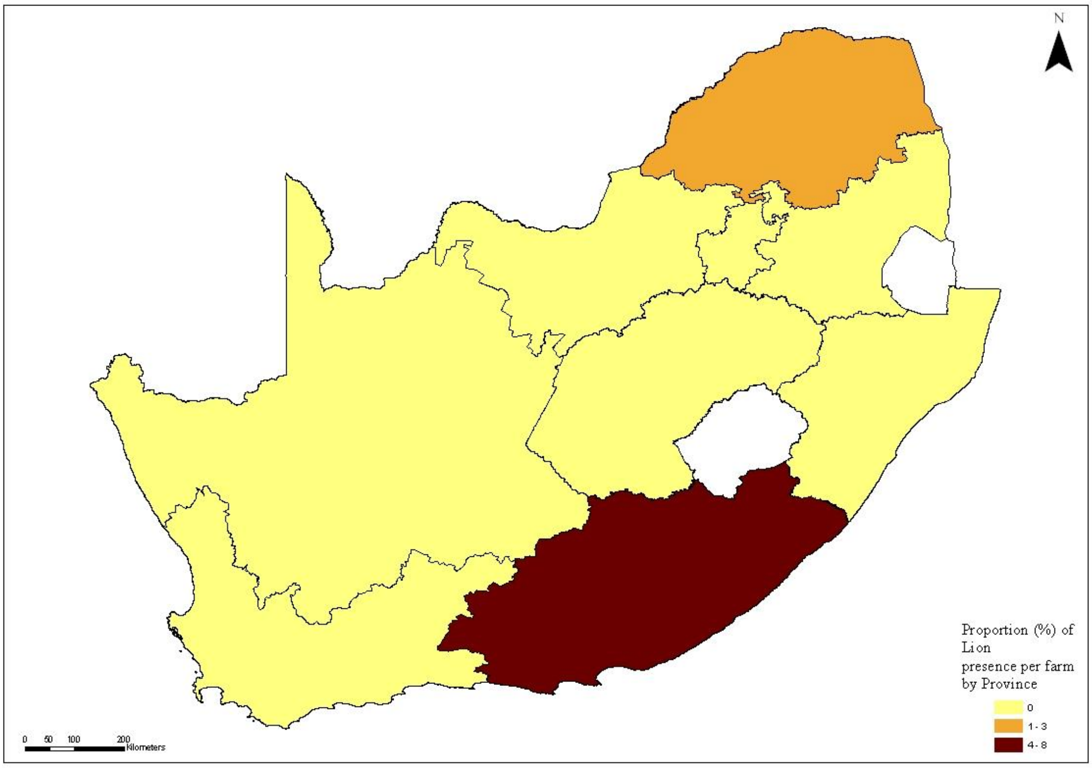

Figure 8.6. The distribution of the lion across South Africa based upon the percentages of farms reporting presence (%).

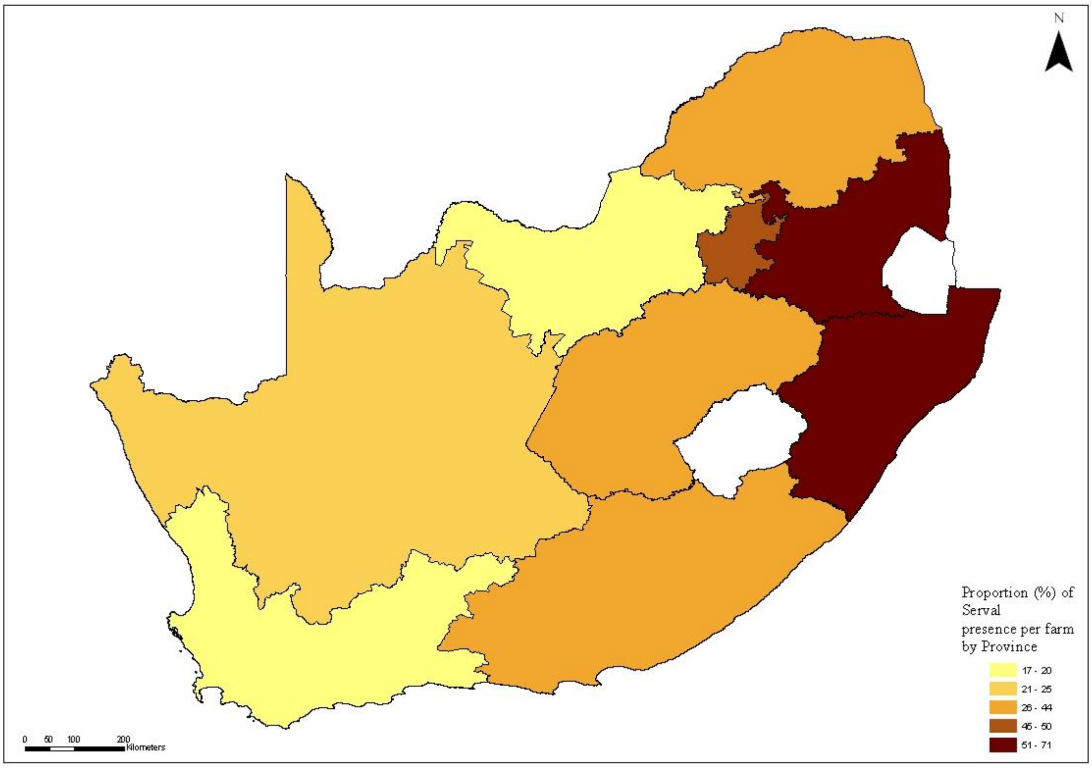

Figure 8.7. The distribution of the serval across South Africa based upon the percentages of farms reporting presence (%)

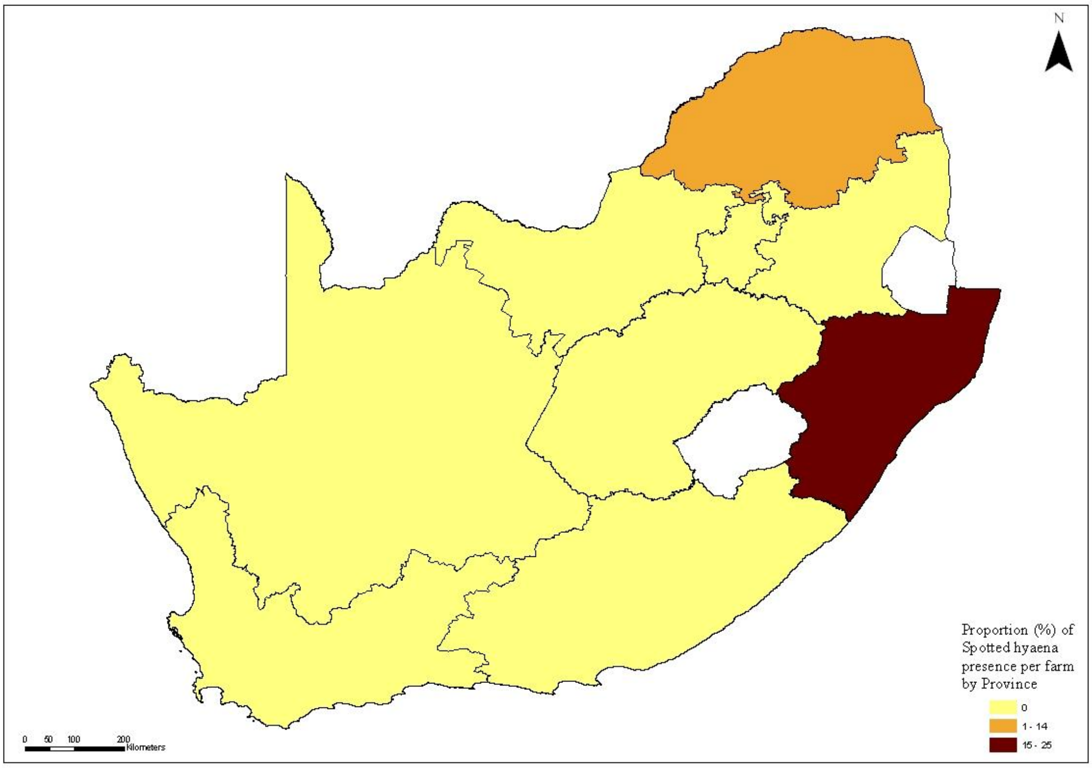

Figure 8.8. The distribution of the spotted hyaena across South Africa based upon the percentages of farms reporting presence (%).

Appendix 4: Table 8.1. Non-target species of interest captured throughout the remote camera trapping study in the protected and unprotected areas across the North West and Limpopo Provinces, South Africa (February 2010 to June 2011).

Key: Captured = one or more photographs were taken of an individual species, blank = no photographs taken.

Species/Treatment	**Protected area**	**Unprotected area**
Aardvark (*Orycteropus afer*)	Captured	Captured
Aardwolf (*Proteles cristatus*)		Captured
African buffalo (*Syncerus caffer*)	Captured	
African civet (*Civettictis civetta*)	Captured	Captured
African Elephant (*Loxodonta Africana*)	Captured	
African wild cat (*Felis Lybica*)		Captured
African wild dog (*Lycaon pictus*)	Captured	
Black Rhino (*Diceros bicornis*)	Captured	
Black-backed Jackal (*Canis mesomelas*)	Captured	Captured
Brahman cattle (Bos indicus)		Captured
Brown hyaena (*Parahyaena brunnea*)	Captured	Captured
Common Zebra (*Equus burchellii*)	Captured	Captured
Helmeted Guineafowl (*Numida meleagris*)	Captured	
Honey Badger (*Mellivora capensis*)	Captured	

Appendix 4: Table 8.1.Non-target species of interest captured throughout the remote camera trapping study in the protected and unprotected areas across the North West and Limpopo Provinces in South Africa from February 2010 to June 2011 (continued).

Key: Captured = one or more photographs were taken of an individual species, blank = no photographs taken.

Species/Treatment	Protected area	Unprotected area
Impala (*Aepyceros melampus*)	Captured	Captured
Large-spotted genet (*Genetta tigrina*)	Captured	Captured
Leopard (*Panthera pardus*)	Captured	Captured
Lion (*Leo Panthera*)	Captured	
Porcupine (*Hystrix cristata*)		Captured
Slender mongoose (*Galerella sanguinea*)	Captured	
Southern Giraffe (*Giraffa camelopardalis*)	Captured	Captured
Spotted hyaena (*Crocuta crocuta*)	Captured	
Warthog (*Phacochoerus aethiopicus*)	Captured	Captured
White Rhino (*Ceratotherium simum*)	Captured	
Wildebeest (*Connochaetes taurinus*)		Captured

Appendix 5: The home range size using the 95% and 50% AK density for the remaining eight brown hyaena collared in Pilanesberg National Park and in the unprotected area in the North West and Limpopo Provinces of South Africa, between 17th April 2007 – 22nd April 2011.

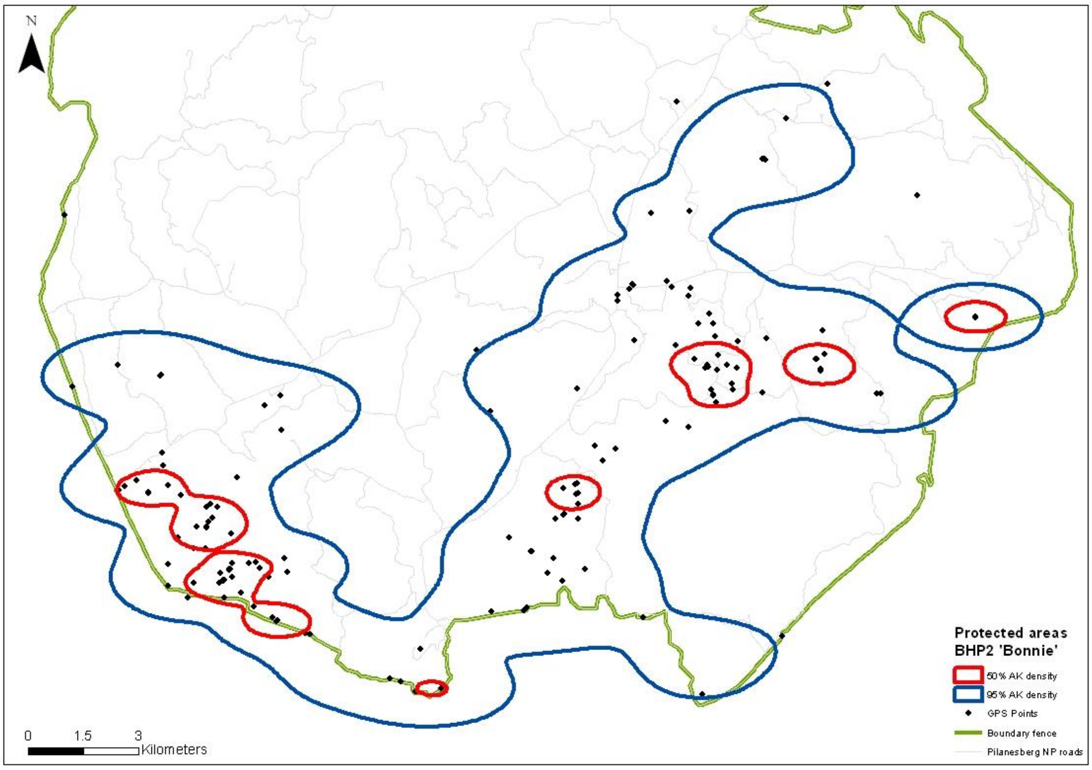

Figure 8.9. Home range size using the 95% and 50% AK density for the brown hyaena BHP2 'Bonnie' collared in Pilanesberg National Park in the North West Province of South Africa 4th August 2008 – 16th September 2009).

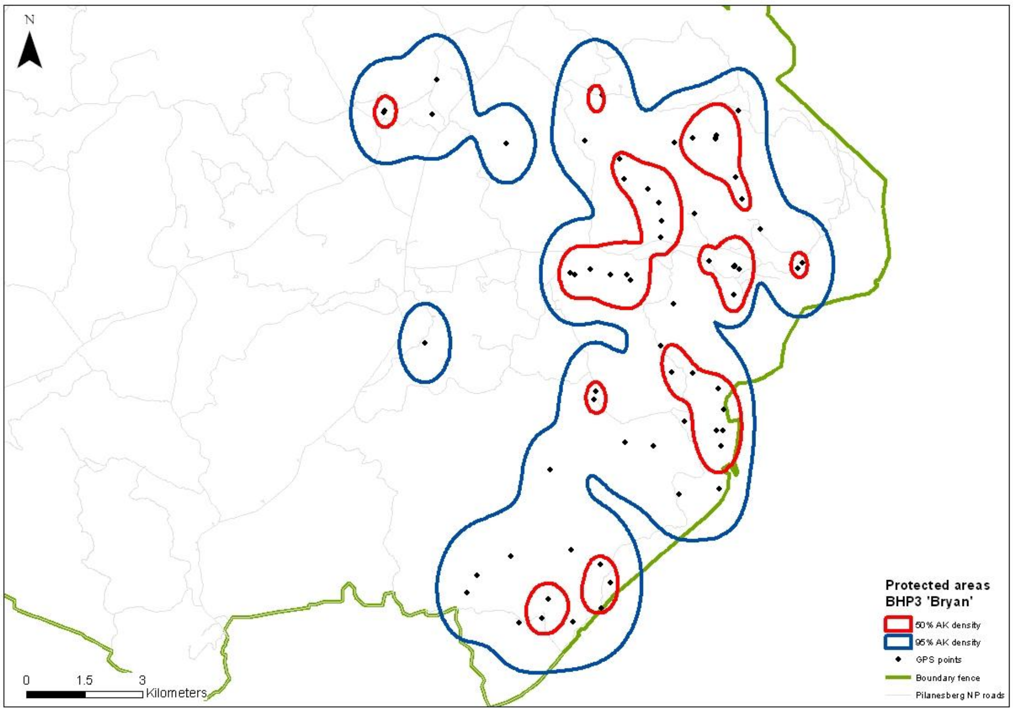

Figure 8.10. Home range size using the 95% and 50% AK density for the brown hyaena BHP3 'Bryan' collared in Pilanesberg National Park in the North West Province of South Africa (17th April 2007 – 4th July 2007).

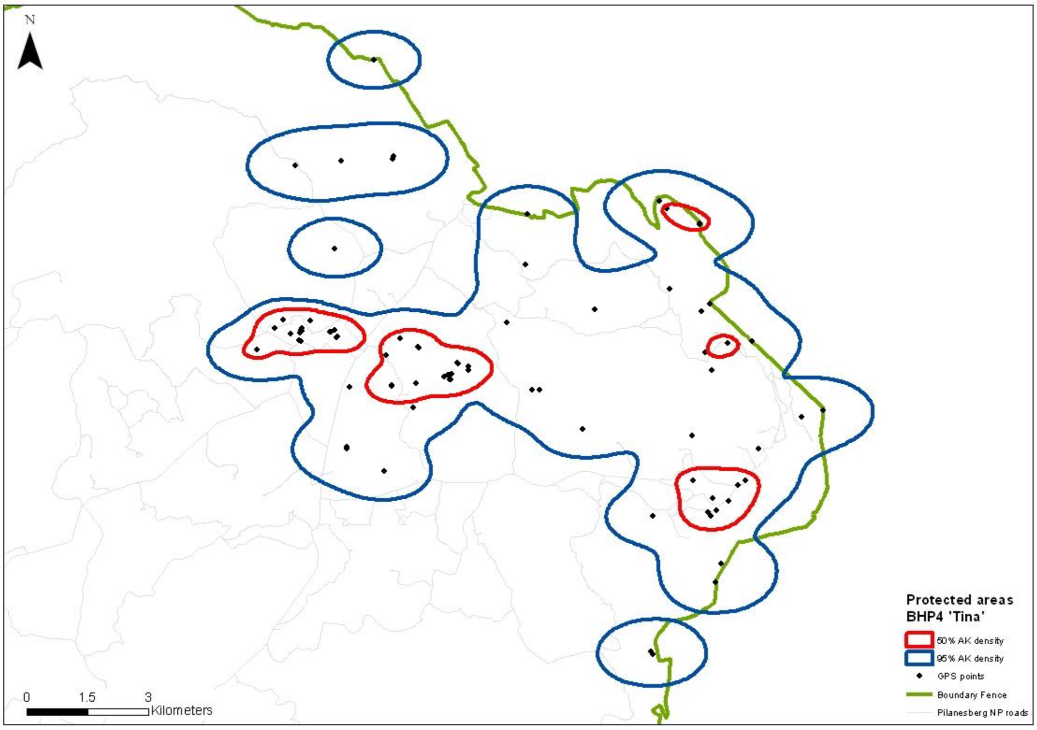

Figure 8.11. Home range size using the 95% and 50% AK density for the brown hyaena BHP4 'Tina' collared in Pilanesberg National Park in the North West Province of South Africa (10th April 2008 – 23rd July 2008).

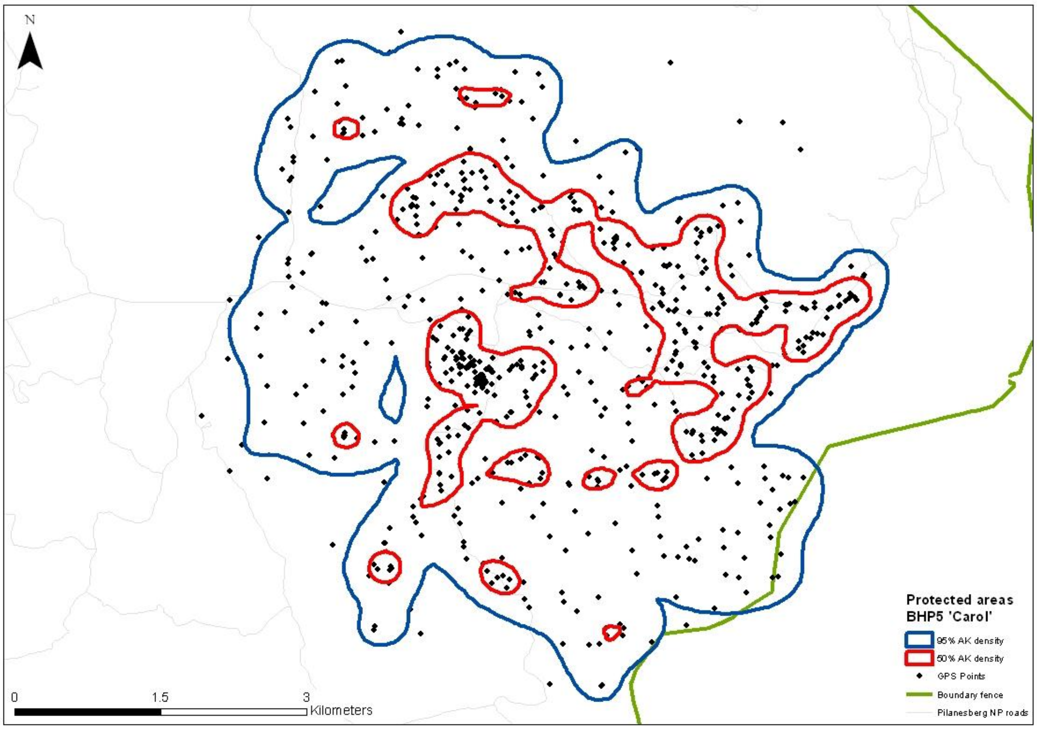

Figure 8.12. Home range size using the 95% and 50% AK density for the brown hyaena BHP5 'Carol' collared in Pilanesberg National Park in the North West Province of South Africa (24th November 2009 – 22nd April 2011).

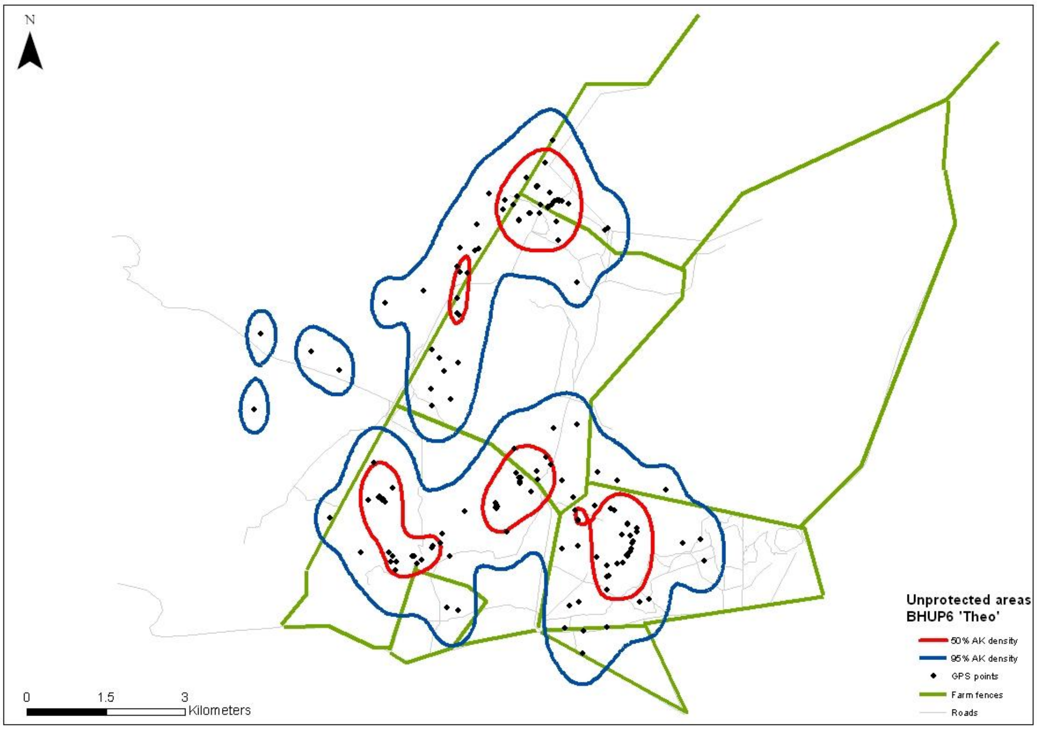

Figure 8.13. Home range size using the 95% and 50% AK density for the brown hyaena BHUP6 'Theo' collared in the unprotected area in the Limpopo Province of South Africa (9th February 2010 – 17th March 2010).

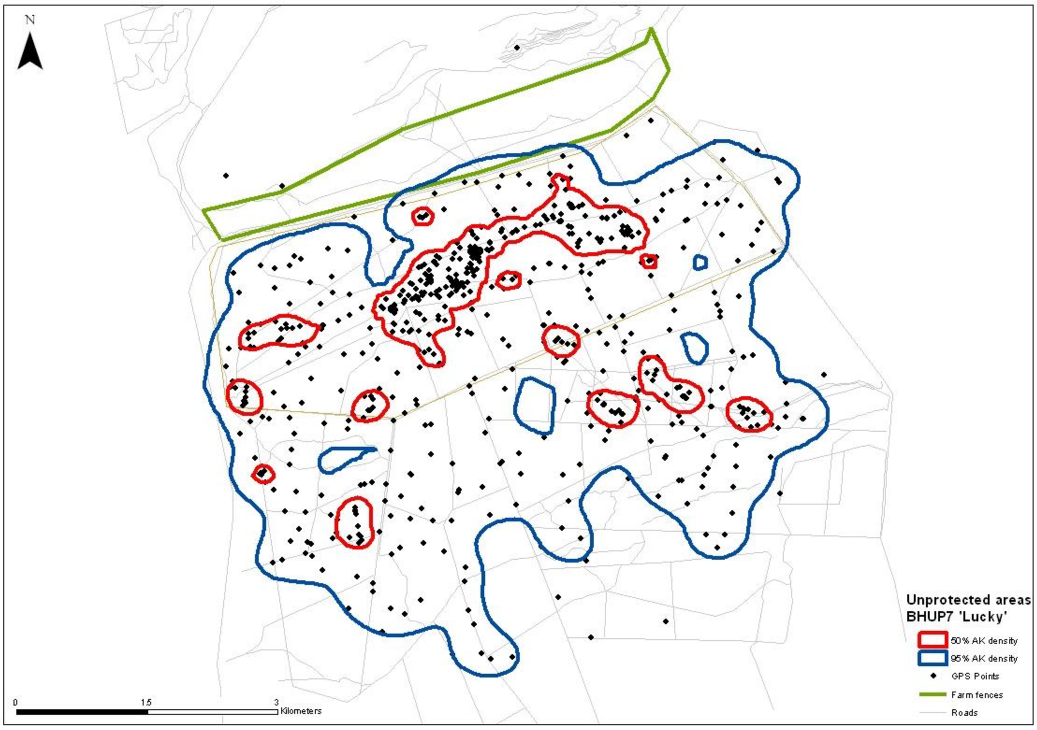

Figure 8.14. Home range size using the 95% and 50% AK density for the brown hyaena BHUP7 'Lucky' collared in the unprotected area in the North West Province of South Africa (September 2009 – 27th July 2010).

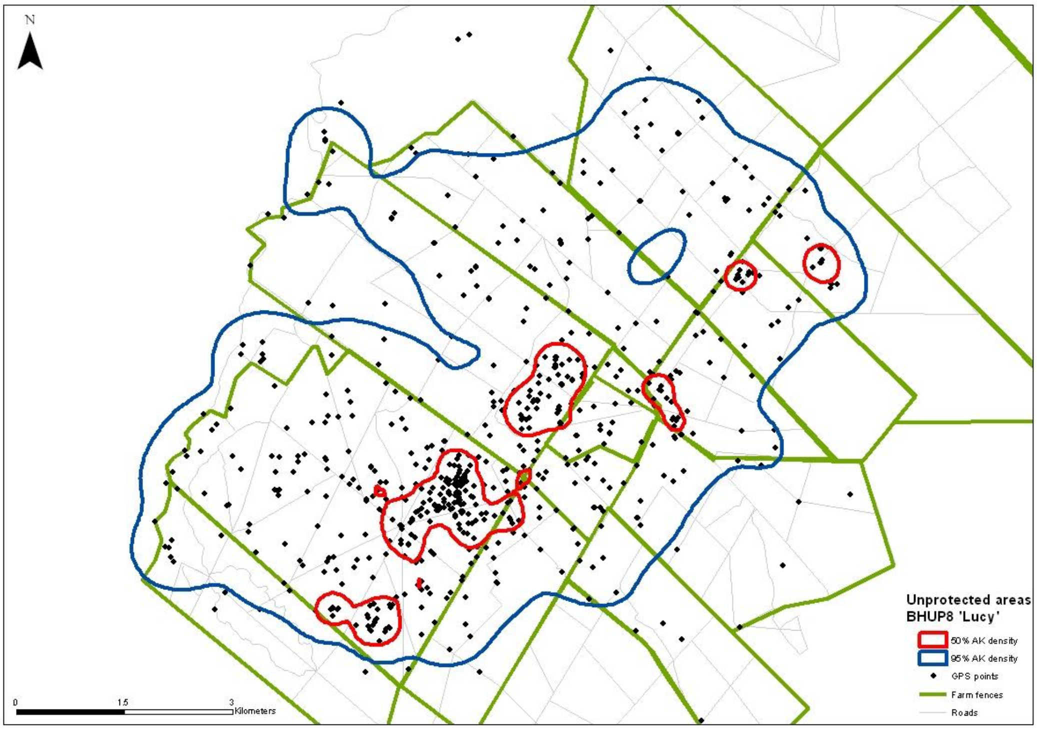

Figure 8.15. Home range size using the 95% and 50% AK density for the brown hyaena BHUP8 'Lucy' collared in the unprotected area in the Limpopo Province of South Africa (13th April 2010 – 26th October 2010).

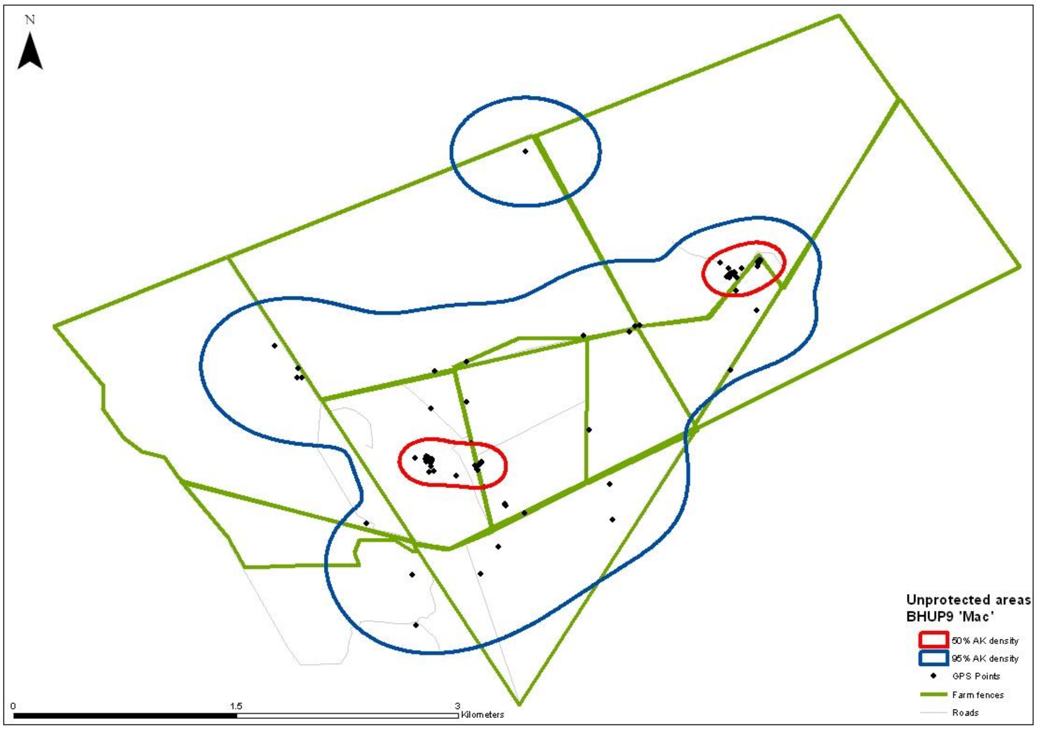

Figure 8.16. Home range size using the 95% and 50% AK density for the brown hyaena BHUP9 'Mac' collared in the unprotected area in the Limpopo Province of South Africa (9th March 2011 – 4th April 2011).