# Translocation and ecology of the brown hyaena (*Hyaena brunnea*) in the Lowveld bushveld, Limpopo, South Africa

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# Abstract

Large carnivores fulfil intricate roles in their ecosystems yet populations are declining globally. Increasing human encroachment into natural areas reduces habitat quality for wild species. In agricultural areas, increased encounters with humans lead to inevitable conflict when brown hyaenas are blamed for livestock deaths. Subsequent poisoning, trapping and killing of brown hyaenas cause a local threat to populations. To conserve the species effectively we must consider options for reducing conflict. In this thesis I investigated translocation as a possible tool for mitigating conflict and answered a range of questions on the response of hyaenas to translocation, range use and general ecology in the Lowveld bushveld of South Africa. I achieved this by analysing data obtained from GPS collars. I carried out analysis of the habitats used by hyaenas, calculated ungulate densities, monitored other large carnivores and opportunistically collected data on brown hyaena feeding behaviour.

Four monitored brown hyaenas survived translocation and established home ranges in the Lowveld bushveld, forming two social groups. Home range size for individuals ranged between 15.0 and 50.4 $km^2$ ($\dot{x}$=32.5 $km^2$). Mean distances and speeds travelled per night were 10.2 km and 0.83 km/hr respectively. One of the brown hyaena groups successfully reproduced and reared three cubs. The other group established themselves in an area with lions and spotted hyaenas but reproduction could not be confirmed. Hyaenas showed a preference for riverine and drainage line habitats as well as eroded soils; significant use of roads was recorded. Habitat use was not found to be associated with ungulate density but brown hyaena home range size was considerably smaller in the area of the reserve where ungulate densities were highest. The presence of lions and spotted hyaenas may influence home range size as brown hyaenas living amongst these carnivores used larger home ranges.

My study suggests that brown hyaena ecology may be correlated with rainfall as home range size varies between studies in the Lowveld bushveld and more arid regions such as the Kalahari and Namib deserts. Brown hyaenas respond well to movement and translocation should be considered in the future as a tool for mitigating conflict with farmers and reducing further loss to brown hyaena populations in southern Africa.

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# Dedication

*For Ruby Penney*

*Who helped make my dream in Africa come true*

## Declaration

I declare that the work in this dissertation was carried out in accordance with the requirements of the University's Regulations and Code of Practice for Research Degree Programmes and that it has not been submitted for any other academic award. Except where indicated by specific reference in the text, the work is my own. Work done in collaboration with, or with the assistance of others, is indicated as such. The views expressed in this dissertation are my own and do not represent those of the University of Bristol.

Signed…… Date……...

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# Introduction

## 1.1 Preface

For millennia humans have intentionally moved animals or populations of animals from one place to another. The motives behind these moves are varied and have been driven by a variety of factors. Conservationists move animals as a strategy to prevent species extinction, assist species recovery or restore ecosystems. Human and wildlife conflict has also driven animal translocations (Seddon *et al.* 2007). There have been both successes and failures from movement attempts on both small and large scales and animal movement is now frequently used in conservation (Fischer & Lindenmayer 2000; Hunter *et al*. 2007). The Eurasian lynx (*Lynx lynx*), for instance, has been successfully reintroduced into parts of Europe following translocation (Hayward & Somers 2009). However, translocation is not always successful and there may be a variety of negative outcomes. Translocated animals may die (Woodroffe & Frank 2005), species at the release site may be displaced, and an increase in human deaths has resulted where animals moved to reduce conflict reacted poorly to translocation (Athreya *et al*. 2010). In this study my aim was to assess the ease and outcome of moving brown hyaenas (*Hyaena brunnea*) and to increase our general knowledge of the species in an area of its range where little is known. Brown hyaenas were removed from two areas where they were in conflict with livestock and wildlife farmers and released on a conservation reserve. By simultaneously monitoring the hyaenas with GPS collars, my main aim was to monitor the response of the hyaenas to translocation. I aimed to study the spatial relationships and home range of individuals and therefore determine whether translocation could be a successful tool in mitigating the conflict between brown hyaenas and farmers. I also aimed to learn more about the ecology of brown hyaenas in the Lowveld area of South Africa, particularly their patterns of habitat use and interactions with other large carnivores in the bushveld habitat.

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## 1.2 The movement of animals

For endangered species, movement can be considered an important conservation tool and used as a technique to reduce the damage caused by carnivores on livestock (Bradley *et al*. 2005; Molony *et al*. 2006). Animal movement allows the restoration of viable populations of native species within their former range (Seddon *et al*. 2007) and can be used to increase the number of individuals in a population. Movement can increase the dispersal capacity of endangered species when natural dispersal is prevented by natural and human-created barriers. This is particularly relevant to those species affected by anthropogenic climate change that can be moved to a broadly similar geographic region to prevent extinction within their isolated native range (Thomas 2011). Reducing inter-specific competition and even conflict with humans can also be achieved by the movement of animals. To date, black bears (*Ursus americanus*) in North America are the most frequently translocated carnivores due to their conflict behaviours with humans (Linnell *et al.* 1997).

### *1.2.1 Terminology*

Terms used to describe the movement of animals are introduced in Table 1.1. For the purposes of this review I will assume that all of these terms refer to the same main goal: to move animals from one place to another, irrespective of the motive or whether a genetically similar or identical species has previously existed there in the past.

### *1.2.2 Carnivore translocation*

Translocation has been used for a wide variety of species, including carnivores such as gray wolves (*Canis lupus*) and African wild dogs (*Lycaon pictus*) which have been successfully reintroduced in North America and South Africa respectively (Hayward & Somers 2009). The first true translocation is thought to have been in 1907 which involved the movement of 15 American bison (*Bison bison*) (Kleiman 1989). Large carnivores can be a good indicator of wilderness and wilderness quality (Miller *et al*. 1999; Hunter *et al*. 2007), yet their populations are declining globally (Hunter *et al*.

2007). Their translocation has been used as a means of restoring the ecological integrity of large predators and carnivores and conserving threatened species around the world (Hayward *et al*. 2007).

**Table 1.1** Definitions of terms describing anthropogenic [or human-mediated] movement of animals.

| Term | Definition |
|---|---|
| Translocation | The deliberate and mediated movement of wild individuals or populations from one part of their historic geographical range to another (Fischer & Lindenmayer 2000; Molony *et al*. 2006). Often associated with the movement of animals which have come into conflict with human interests (Wemmer & Sunquist 1988) and where conservation of the target species is the primary objective (Seddon *et al*. 2012). |
| Reintroduction | The release of animals of any origin (captive or wild) into an area within their original geographical range but from which it has been extirpated (Kleiman 1989; Seddon *et al*. 2012). |
| Transplantation | Relocation of a plant or animal species into areas where it does not occur and most probably did not occur in the past (Wemmer & Sunquist 1988). |
| Augmentation, Supplementation or Restocking | The release of animals, regardless of their origin, into an area already containing conspecifics (Kleiman 1989; Fischer & Lindenmayer 2000). Normally an effort to increase population size and reduce risks of genetic or demographic collapse (Seddon *et al.* 2012). |
| Introduction | The release of either captive-born or free-ranging wild-born animals into an area outside their original range (Kleiman 1989). |

Carnivores play a key role within their ecosystem: being at the top of the food chain, they are vulnerable to any changes in the many trophic levels below them (Kleiman 1989; Miller *et al*. 1999). They are also

disproportionately extirpated from ecosystems around the world due to destruction and fragmentation of habitats, pressure and even persecution from humans (Wemmer & Sunquist 1988; Kleiman 1989; Miller *et al*. 1999; Hunter *et al*. 2007). Habitat fragmentation in particular inhibits easy recolonisation (Miller *et al*. 1999) and translocation is now viewed as a potential way to assist populations. Carnivores are known to be harder to re-establish through translocation than herbivores and omnivores (Griffith *et al*. 1989; Miller *et al*. 1999; Seddon *et al*. 2005) and many translocation attempts have failed (Wemmer & Sunquist 1988; Mills 1991; Hunter 1998; Miller *et al*. 1999). Identifying the reasons behind successes and failures is therefore crucial to future conservation management efforts and overall conservation success (Hayward *et al*. 2007).

## 1.3 Aspects of translocation and the associated problems

Over the years many of the factors influencing translocation success have been identified; these are discussed below.

### *1.3.1 Definition of success*

To categorise a translocation as a success or failure, we need to be clear what characterises 'success'. Survival is generally used as the primary measure of success but this may be misleading by itself as the ability to reproduce is also important (Miller *et al*. 1999). Therefore, most translocation and release programmes use both survival and reproduction as the main measures of success and the International Union for Conservation of Nature (IUCN) suggests the focus of all translocations should be to establish a self-sustaining population that requires minimal long-term management (Griffith *et al.* 1989).

### *1.3.2 The release site*

The characteristics of the release site are thought to be the most important determinant of translocation success and factors such as the availability of prey, the type of habitat available (particularly for denning), water availability and presence of competitors must be considered

(Wemmer & Sunquist 1988). Habitat is thought to be the most important of these at a release site but prey availability may be more important to large carnivores than vegetation characteristics (Hayward *et al*. 2007). Local environmental conditions such as food supply and potential competitors may influence the success of a translocation attempt (Engelhardt *et al*. 2000). Additionally, the cause for the species' initial decline in the habitat must be recognised and eliminated before a translocation is attempted (Kleiman 1989; Mills 1991; Miller *et al*. 1999; IUCN 2012). Releasing a species into the core of its historical range is likely to be more successful than release on the edge (Griffiths *et al*. 1996). The most likely reason for this is that the core area has the most suitable habitat and characteristics for which the species is best adapted. An exception to this may be where climate change is moving the zone of suitability. Translocation into an area without competitors is also likely to be beneficial (Griffiths *et al*. 1996).

### *1.3.3 Which animals to translocate?*

As far as possible, only wild-caught mammals should be translocated as they fare better than those that have been captive-bred (Mills 1991; Griffiths *et al*. 1996; Fischer & Lindenmayer 2000) which may not adapt well to natural systems (Mills 1991; Hayward *et al*. 2007). Past translocation studies have attempted to identify an optimum age for translocation and also look at the factors affecting how males and females respond post-release (Miller *et al*. 1999). Generally, although it may be species specific, male mammals have a stronger homing instinct than females, which are likely to stay closer to the release site. Older animals are also more likely to move further from a release site and have a greater tendency to show homing instinct than juveniles. Male carnivores often wander larger areas looking for females but these movements are related more to reproduction and social status than habitat quality (Ewer 1997 in Miller *et al*. 1999). A translocated adult female therefore best represents the habitat needs of a species.

*1.3.4 Pre-release conditioning and soft versus hard release techniques*

Time in captivity prior to release at a new site is advantageous for a variety of animal species undergoing translocation and use of a "soft release" technique has improved translocation success in a number of cases (Hunter 1998; Hayward *et al*. 2007). Habituating animals at the release site prior to release appears to help reduce dispersal following translocation (Linnell *et al*. 1997; Fischer & Lindenmayer 2000). It familiarises animals with their release area, breaks homing tendencies (Linnell *et al*. 1997; Miller *et al*. 1999), allows animals to build up fat reserves and reduces manipulation stress suffered on release (Molony *et al*. 2006). For a soft release to be effective, appropriate fencing must be maintained which also enables translocated individuals to become familiar with fencing (Hunter 1998). For a variety of species from European hedgehogs (*Erinaceus europaeus*) to gray wolves, a 'soft release' has been found to reduce the incidence of 'homing' and increase post-release survival chances (Bradley *et al*. 2005; Molony *et al*. 2006).

*1.3.5 Post-release monitoring*

Any translocation should be monitored closely but post-release monitoring of large carnivores is rare (Mills 1991; Linnell *et al*. 1997; Hunter 1998; Hunter *et al*. 2007). Even when monitoring has taken place, the reasons for failure are poorly understood: these include erratic behaviour immediately following release, poor foraging success, homing back to the original capture site and the inability of a species to navigate within its new environment (Breitenmoser *et al*. 2001). Black bears have returned to their capture site up to 400 km away (Linnell *et al*. 1997). With carnivore translocations becoming more common, it is important to identify the successes and failures so future conservation efforts can be improved. Benefits of post release monitoring include an opportunity to gain biological data on a species, particularly its homing ability, spatial behaviour and movements, settlement behaviour following release and the potential causes of mortality post release (Linnell *et al*. 1997). Since monitoring also provides data to guide future releases (Mills 1991), peer review and publishing translocation results is widely recommended (Breitenmoser *et al*.

2001; Hunter *et al*. 2007). For monitoring, it is believed the period immediately following release is most critical and also the period with the highest mortality due to exploratory movements (Hunter 1998). Post-release movements may be very large at first due to the animals orientating themselves and assessing local conditions such as food resources, mate distribution, other competitors, refuge positions and suitable denning areas that are important for survival (Hunter 1998).

## 1.4 Moving conflict animals

Translocation is increasingly being used to reduce or eliminate conflict caused by predators. Undesirable behaviours may involve predation on livestock, foraging close to human habitation and even attacks on humans (Linnell *et al*. 1997; Woodroffe *et al*. 2005). Human-wildlife conflict is increasing due to loss of natural habitats, habitat fragmentation, reduced food availability and encroachment of human habitation into wild areas. In many cases, the wide ranging habits of large carnivores enhance conflict and encounters with humans can lead to their persecution (Mills 1991; Winterbach *et al*. 2012). Globally, livestock depredation by large carnivores is probably the most common cause of wildlife-human conflict, and retaliatory killing is believed to be the most serious threat to carnivore survival (Woodroffe *et al*. 2005). In many areas carnivore-livestock conflicts present a significant barrier to carnivore conservation (Linnell *et al.* 2012). As conflict incidences increase, translocation is a popular non-lethal technique for dealing with problem animals, and has high public support (Linnell *et al.* 1997). Individual killers of livestock are said to have been identified in lion (*Panthera leo*), leopard (*Panthera pardus*) and cheetah (*Acionyx jubatus*) populations (Winterbach *et al*. 2012). The movement of conflict leopards has been attempted in India, and in at least one attempt the results were disastrous. Not only did the translocated leopards not remain at the release site, but there were increased attacks on people. Heightened aggression in the leopards was thought to be induced by the stress of translocation (Athreya *et al*. 2010). Few studies follow up on whether a translocation attempt leads to reduced conflict at the removal site

(Linnell *et al.* 1997). Furthermore, removing one problem animal may create a different problem. For example, removing dingoes (*Canis lupus dingo*) in Australia allowed feral cats (*Felis catus*) and red foxes (*Vulpes vulpes*), less desirable predators, to dominate ecosystems instead (Hayward & Somers 2009). On South African farmlands, after the extirpation of large carnivores such as leopards, populations of black-backed jackals (*Canis mesomelas*) and caracals (*Caracal caracal*) increased to the extent that they became a threat to livestock themselves (Beinart 1998).

## 1.5 Brown hyaenas in Southern Africa

The Hyaenidae fulfil intricate roles in most African ecosystems and are an essential component of a natural and functioning system. The brown hyaena is classified as 'Near threatened' (lower risk) by the IUCN and population estimates suggest there are between 5000 and 8000 individuals remaining in southern Africa (Mills & Hofer 1998). They are believed to be in decline due to persecution by humans and habitat fragmentation (Mills & Hofer 1998). Brown hyaenas occur in stable, low density, yet viable populations but distribution and abundance data are hard to obtain due to their nocturnal, secretive and wide ranging habits (Mills & Hofer 1998; Maude & Mills 2005). They also rarely vocalise, making them difficult to find (Winterbach *et al*. 2012). Brown hyaenas are sparsely distributed throughout the Limpopo, North West, Mpumalanga and Gauteng provinces of South Africa. They are absent as a breeding species from the Kruger National Park and its surrounding reserves, where breeding has not been recorded in the past 40 years (Mills 1991). They are mostly associated with the Nama Karoo and Succulent Karoo biomes and the drier parts of the Grassland and Savanna biomes (Skinner & Chimimba 2005). In central Botswana they occur in semi-desert scrub, while in the Gauteng and Limpopo provinces they favour mountainous rocky areas with bush cover (Skinner 1976). Brown hyaenas are predominantly scavengers with a wide-ranging diet and spend very little time on hunting (Mills 1978). Although they forage solitarily, most live in a group which varies in size throughout the year (Owens & Owens 1996; Mills & Hofer 1998). In the southern Kalahari,

territory size for 6 groups averaged 330 km$^2$ (Mills 1982b) and for one group in the central Kalahari ranged from 170 km$^2$ to 400 km$^2$ dependent on rainfall (Owens & Owens 1996). In the Namib desert the territory size of a clan with nine individuals was 220 km$^2$ (Skinner *et al*. 1995). Cover in which to rest during the day is an essential resource; this may be holes in the ground, tall grass or thick bush (Skinner 1976). Lie-up sites may be near a food source (Mills 1978) and are often dug out hollows (Skinner 1976). Reproduction appears to be aseasonal and mean litter size in the wild is three (n=12). Cubs are born in dens and, although brown hyaenas are capable of excavating their own dens, they often take over disused aardvark burrows (Skinner 1976). Dens may have multiple entrances which narrow down to allow only cubs to enter. Mothers carry cubs to a new den up to the age of about two months and at around six months cubs can initiate the move themselves (Skinner & Chimimba 2005).

### *1.5.1 Brown hyaenas, farmers and conflict*

Brown hyaenas are often the victims of both deliberate and incidental persecution throughout their range, although they generally seem to benefit, to some extent, from living in proximity with people (Maude & Mills 2005). In agricultural areas, a reliable and abundant food source is provided by the carcasses of domestic animals which have died of natural causes such as starvation, disease and accidents (Mills 1991). By scavenging on dead livestock, brown hyaenas are often blamed for the death and the true reason why the animal died is rarely established (Linnell *et al*. 2012). This leads to inevitable clashes with humans and intolerance and although persecution by people is believed to have little effect on their overall population (Mills 1990), brown hyaenas are particularly at risk in agricultural areas. Poisoning, trapping and hunting have had detrimental effects and are locally a threat (Mills & Hofer 1998). While there are some records of individual hyaenas killing livestock (Skinner 1976), farmers in Namibia, South Africa and Zimbabwe also kill many non-harmful individuals (Mills & Hofer 1998). It is important to educate farmers about hyaena foraging behaviour to change perceptions of the threat that brown hyaenas cause to their livestock and minimise conflict (Winterbach *et al*. 2012).

*1.5.2 Remaining habitat for brown hyaenas*

Viable populations of brown hyaenas are found in bush and agricultural land, as well as private reserves and conservation areas (Mills & Hofer 1998), with Botswana thought to have the largest population of brown hyaenas. However, their distribution has shrunk dramatically since the end of the 18$^{th}$ century and brown hyaenas are now confined to the southern African sub-region (Skinner & Chimimba 2005). Encroachment from an increasing human population contributes to the deterioration of habitat quality and is probably one of the key factors causing brown hyaena populations to decline (Mills & Hofer 1998).

*1.5.3 The study animals*

The hyaenas used in this study were trapped by farmers on two farms in the Limpopo province of South Africa. The farms were 100 km apart; one was a livestock farm, while the other bred rare antelope such as nyala (*Tragelaphus angasi*) and sable (*Hippotragus niger*) in an enclosed area. The hyaenas were translocated between 250 and 350 km to the 250 km$^2$ Greater Pidwa and Makalali nature reserve. Previous intensive farming practices in the area are believed to have caused the decline of brown hyaenas in this particular habitat. These farming practices ceased following reclamation of the land for conservation purposes, and so the original cause for the species' decline had been removed.

## 1.6 Aims of the study

*1.6.1 Assess the viability of brown hyaena translocation*

There are few data on the translocation of brown hyaenas with just one study published to date. Thirty brown hyaenas were translocated to conservation areas between 1976 and 1985. Four were fitted with radio collars but moved out of the reserve where they were released within 14 days. Home range size was calculated for three; the fate of the other 26 hyaenas was unknown (Skinner & van Aarde 1987). My aim was to provide more data on the behaviour of translocated brown hyaenas, establish

whether they can be moved, and assess the subsequent response of the species to a new environment. Although the hyaenas originating farms were also in the savanna biome, they bordered the Kalahari desert and were more arid, with hotter summers and colder winters than the bushveld environment at the release site (Smallie & O'Connor 2000).

My study also provided an opportunity to learn more about the general biology of the brown hyaenas, particularly in an area on the edge of their range. Incidental sightings of brown hyaenas at the release site within the past five years are believed to have been transient individuals. Camera trapping and the lack of latrines and scent markings (anal pastings) suggested the absence of resident individuals at the release site. So a second aim of my study was to determine whether brown hyaenas can survive in this area, and in doing so better understand their ecology in this habitat.

Brown hyaenas are sensitive to the activities of other carnivores in their area (Mills 1991). They are believed to avoid their dominant competitors by ranging widely and inhabiting areas where few spotted hyaenas (*Crocuta crocuta*) and lions occur (Mills & Gorman 1997; Durant 2000; Creel *et al*. 2001). I aimed to test this hypothesis and quantify the extent to which the translocated brown hyaenas avoided or interacted with spotted hyaenas and lions resident on the reserve.

Finally, studying the effect of translocation on brown hyaena survival has the potential to improve the conservation of this near threatened species. If successful, translocation could be used as a potential tool for the removal of brown hyaenas from areas where they are in conflict with farmers.

## 1.7 The study area

The study was conducted on Pidwa Wilderness Reserve, a 13 000 ha privately owned wilderness area in South Africa. Through an agreement between neighbouring land owners, Pidwa Wilderness is joined to Makalali private game reserve to form the larger, 25 000 ha Greater Pidwa and Makalali nature reserve. The agreement eliminates internal fencing between

the two properties to create a larger natural area for wildlife. The Greater Pidwa and Makalali nature reserve formed the entire release site available for the study. The release site supports lions, leopards, white rhinos (*Ceratotherium simum*), cheetahs, spotted hyaenas and elephants (*Loxodonta africana*), but buffaloes (*Syncerus caffer*) are in a separate 400 ha breeding camp. Most species of general game and nocturnal mammals indigenous to the area are also present. The release site is situated in the Lowveld area of South Africa's Limpopo province (see Figure 1.1).

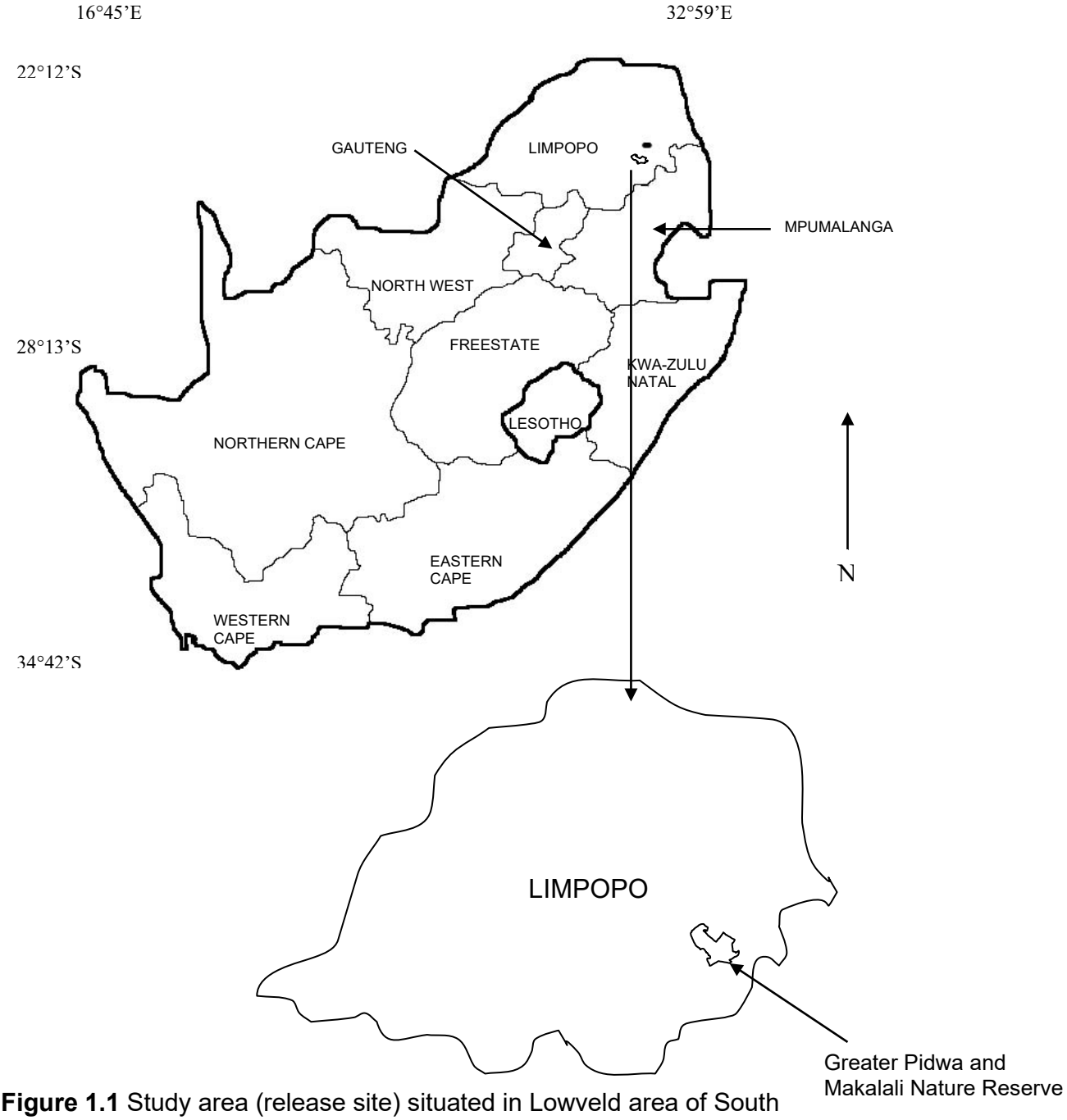



**Figure 1.1** Study area (release site) situated in Lowveld area of South Africa's Limpopo province.

There are two river systems, the Selati River in the north and the Makutsi River in the south (see Figure 1.2).

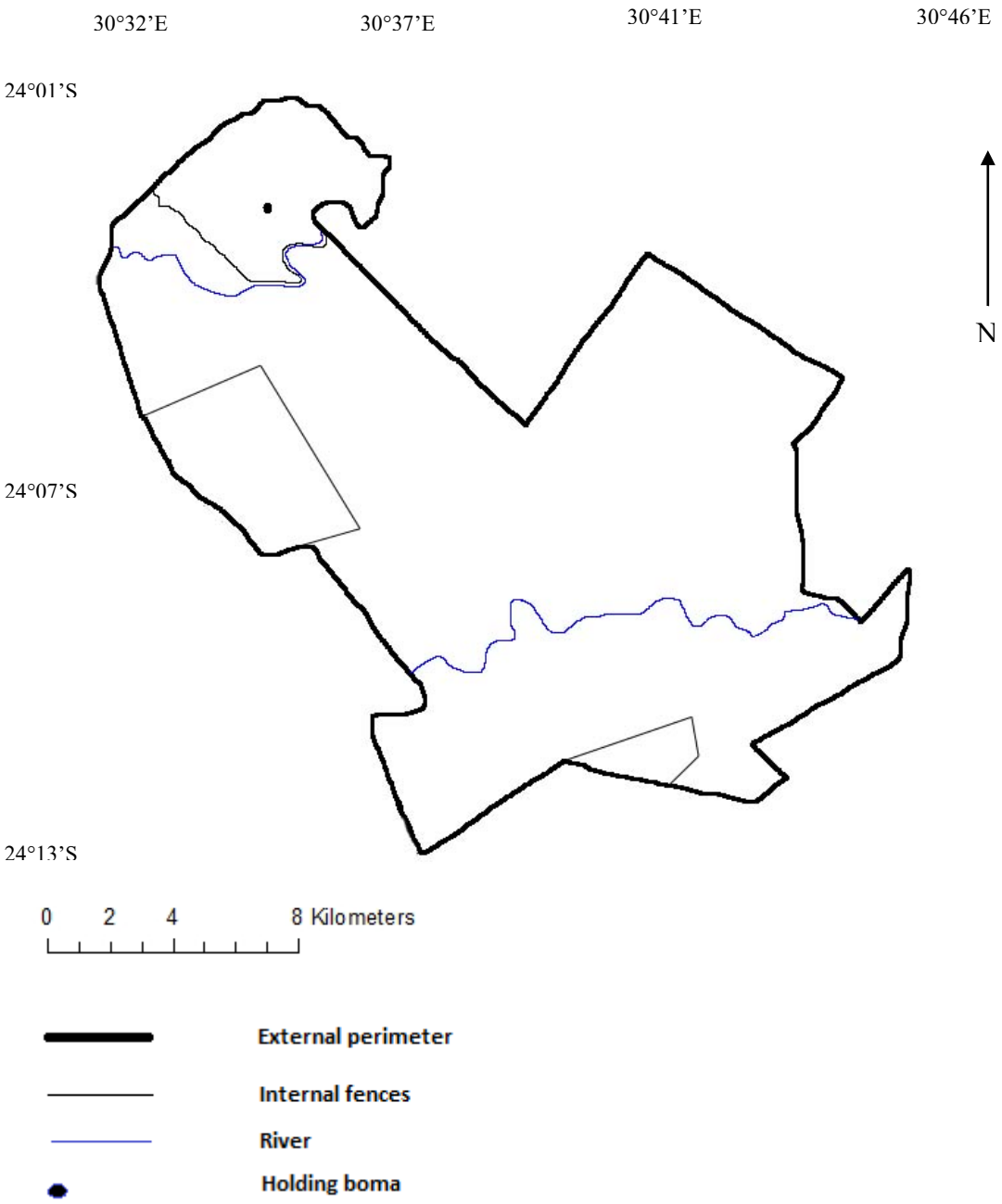



**Figure 1.2** Pidwa and Makalali nature reserve showing the study area, external and internal fences, rivers and holding boma.

Both are perennial rivers but illegal upstream damming affects natural water flow, although annual flood waters cause the rivers to flow for at least a small period each year. The rivers support varied vegetation including large jackalberry (*Diospyros mespiliformis*) and leadwood (*Combretum imberbe*)

trees, tamboti (*Spirostachys africana*) and ankle thorn (*Acacia robusta*). The typical habitat across the reserve is mixed bushveld, dominated by knobthorn (*Acacia nigrescens*) and red bushwillow (*Combretum apiculatum*), interspersed with mopane (*Colophospermum mopane*) belts and *Acacia* thickets. Rocky outcrops and small koppies, predominantly granite, are scattered across the landscape, with soils supporting broad-leaved species such as marula (*Sclerocarya birrea caffra*), cluster (*Terminalia*) leaf species and raisin (*Grewia*) species. Areas of erosion, a result of past cattle farming practices, support little vegetation except pioneer species such as flakythorn (*Acacia exuvialis*) and sicklebush (*Dichrostacyhs cinerea*) thickets. The reserve is surrounded by a 2.3 metre high electric, predator-proof fence (trip wires fitted) carrying a minimum of 4000 volts (see Figure 1.3).

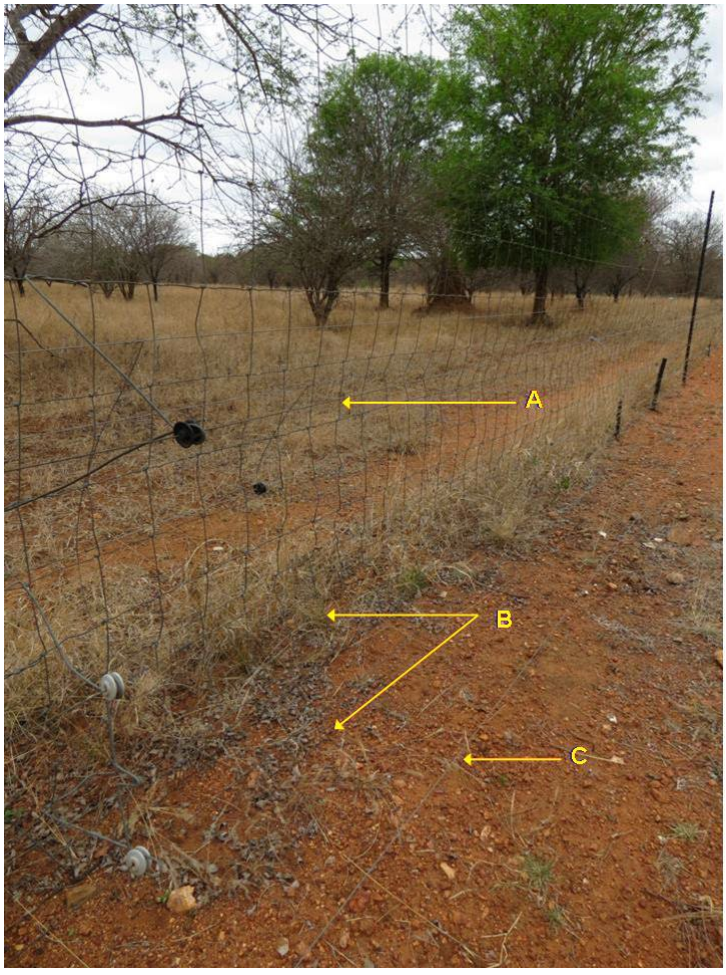



**Figure 1.3** Electric, predator-proof fence

A: Top electric wire
B: First & second middle electric strand
C: Electric trip wire

Within the reserve there are three smaller sections, each surrounded by an electric fence separating it from the open system (see Figure 1.2). These three sections are all free from elephants, cheetahs, lions and spotted hyaenas; two are also free from white rhinos. The boma (100x100 metre holding area with electric fencing to keep animals in a closed environment) where the hyaenas were held prior to release is within one of these areas, the 2000 ha area in the most northern section of the reserve (see Figure 1.2).

Summers are hot (mean daytime temperature 30°c) and wet, winters warm (mean daytime temperature 23.6°c) with occasional frost. The annual average rainfall is 540 mm which falls between October and April, peaking in January and February (see Figure 1.4). Annual floods occur during these peak summer months. Spring is signalled by the flowering of the knobthorn trees, which generally occurs in late September or early October. Increased day length is associated with birth of the first impala (*Aepyceros melampus*) young around mid to late November which indicates the start of summer. Reduced rainfall and the departure of migratory birds signal the beginning of autumn around the end of March. Lower morning and evening temperatures in June mark the start of winter.

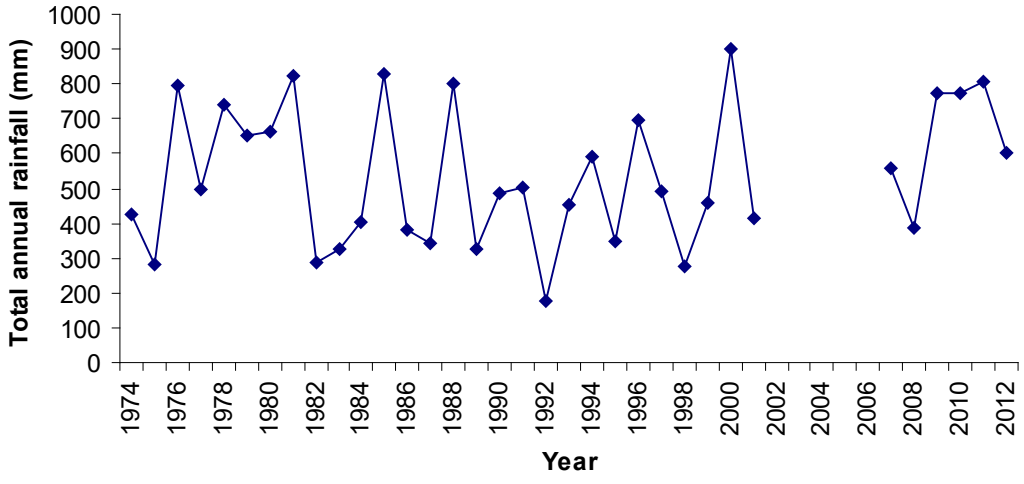



**Figure 1.4** Annual rainfall figures for Pidwa Wilderness Reserve from 1974-2012*

* Data not available for 2002-2006

## 1.8 General hypotheses and predictions

I predicted bushveld to be a suitable release site for brown hyaena translocation because of the available habitat and food resources. Additionally, the area forms part of their known historical range. Assessing the results of past translocation studies, I believed the use of a soft release technique would be successful in preventing large homing movements post-release. I predicted that the hyaenas would cover the majority of the reserve in their home range as previously recorded ranges are generally more than 200 $km^2$ (Mills 1982b; Maude 2005; Wiesel 2006). I will cover these aspects specific to translocation in chapter 2. I predicted that the brown hyaenas would use habitats with the highest ungulate densities but avoid those with the highest numbers of lions and spotted hyaenas. Based on previous feeding studies, I also predicted that the hyaenas would feed on a large variety of mammal species along with birds, insect and fruits. These factors will be considered in chapter 3 along with the effect that large carnivores may have on patterns of activity and habitat selection.

# Translocation, acclimatisation and survival

## 2.1 Summary

Translocation is a common tool used for the conservation of species and can be used to remove animals from conflict situations. Five brown hyaenas were removed from areas where they were in conflict with farmers and translocated to a conservation reserve in the bushveld habitat of the Lowveld, South Africa. After an initial holding period in a boma, hyaenas were fitted with GPS enabled collars, released and monitored. Data were collected on their patterns of activity, home range use and reproductive success. Following the early malfunction of one collar, four hyaenas were monitored for a period of one year. All survived and established two social groups in the conservation area where they were released. Their 90% home range isopleths ranged from 15-50.4 km$^2$ ($\dot{x}$=32.5 km$^2$, n=4). Mean distances and speeds travelled per night were 10.2 km and 0.83 km/hr respectively. One group successfully reared three cubs and data relating to den use is presented. Translocation was successful in removing at least four brown hyaenas from conflict and establishing them in a new area where some reproduced.

## 2.2 Introduction and Aims

The translocation of carnivores has been used for many decades as a standard management tool in southern Africa (Linnell *et al.* 1997). As a response to livestock predation, it is believed that the removal and translocation of one or a few 'problem individuals' can eliminate the conflict problem (Linnell *et al.* 1997; Winterbach *et al*. 2012). Translocation also has the potential to establish new populations. For example eight new packs were formed from 88 gray wolves translocated to reduce livestock conflict in North America (Bradley *et al*. 2005). The release site is the most important determinant of translocation success (Linnell *et al*. 1997). It must be large, with low conflict potential and be between 100 and 300 km away from the capture site (Linnell *et al*. 1997). Although translocation generally carries a low success rate as a means of managing problem animals (Mills 1991),

there has been very little follow up of translocated individuals (Linnell *et al.* 1997). Adequate follow up observations should be made where possible following the translocation of carnivores to collect information on successful strategies (Mills 1991). The suitability of the release site and the ability to use a soft release procedure for this study provided the opportunity to monitor the settlement behaviour of translocated brown hyaenas accurately for the first time. It also provided the opportunity to measure individual home range sizes, shapes and patterns of utilisation. A home range consists of a more or less restricted area within which an animal moves when performing its normal activities (Harris *et al*. 1990). Home range analysis methods can therefore be used to answer important biological and ecological questions (Harris *et al*. 1990). Although brown hyaena home ranges have been calculated in other areas of southern Africa (see Table 2.1), no data were available for the area covered by this study, the Lowveld of South Africa. Data were also severely lacking on the reaction of this species to translocation and their ability to adapt and survive following movement. The only previous study by Skinner & van Aarde (1987) is now more than 20 years old and our knowledge about the practicalities of translocating this species has not increased in this time. The earlier translocation study was also limited by its use of radio-telemetry devices which carry limitations such as the need to triangulate the position of the animal and the risk of disturbing it. I had the advantage of using GPS collars which collect precise spatial data, and so I was able to look at the spatial orientation of the released individuals, how these patterns changed over time, the areas used by the hyaenas, speeds and distances travelled, and patterns of home range use. I also monitored changes in denning behaviour over time to assess how the hyaenas settled into their new area and how quickly they adapted.

**Table 2.1** Individual brown hyaena home ranges calculated in different regions of southern Africa and the techniques used to estimate them.

| Location | Range of home-range size ($km^2$) | Estimation method | Data collection technique | Number of hyaenas used to estimate home ranges | Author |
|---|---|---|---|---|---|
| Transvaal, South Africa | 5.5 - 48.9 | MCP* | Observations & VHF radio-tracking | 3 individuals | Skinner & van Aarde 1987 |
| Namib desert, Namibia | 31.9 – 220 | MCP | Observations & VHF radio-tracking | 5 individuals | Skinner *et al*. 1995 |
| Makgadikgadi region, Botswana | 135 – 447 | MCP | Observations, VHF radio-tracking and GPS collars | 8 individuals | Maude 2005 |
| Namib desert, Namibia | 500 – 1530 | Kernel (95%) | GPS collars | 3 individuals | Wiesel 2006 |

*Minimum Convex Polygon

## 2.3 Hypotheses and Predictions

Hypothesis 1: The release site provides suitable habitat for foraging, sheltering and denning.

Prediction: The hyaenas will utilise home ranges within the protected area of the release site and be able to establish a home range.

Hypothesis 2: Movements will be larger at first due to the hyaenas orientating themselves and assessing local conditions such as food resources, mate distribution, resting sites and suitable denning areas.

Prediction: The hyaenas will travel greater distances immediately following release, which will decrease over time.

Hypothesis 3: Individuals will need to utilise most areas of the release site to find the resources needed to survive, establish and reproduce.

Prediction: Hyaenas will utilise most of the 250 $km^2$ protected area available to them.

## 2.4 Methods

The subjects of this study were five brown hyaenas; two adult males (both of breeding age) and three females (one estimated to be of breeding age at four years and two at approximately 18 months when released). The relevant permit to do scientific research on mammals was obtained from the Department of Economic Development, Environment & Tourism of the Limpopo provincial government, Republic of South Africa (Permit No. 001-CPM403-00011). Before the start of the study, the hyaenas were trapped on the two farms in metal cages. These are considered a humane way of capturing wild brown hyaenas. The five hyaenas were moved in transport crates from the capture sites and released into a predator boma (with live trip wires to prevent digging and escape) over a period of three weeks. The boma was situated within the 2000 ha internally fenced area in the north of the reserve (see Figure 1.2). Due to the young age (estimated six months) of two individuals (“Spot” and “Gismo”) at capture, the hyaenas were held in the boma for 12 months, during which time they were fed an impala carcass

every fifth day. The carcass was cut into five pieces (the body and head and four legs) and observed for a period of 30 minutes as the hyaenas fed. The aim was to habituate the hyaenas to the presence of humans and vehicles and therefore facilitate the darting procedure when the time arrived for collaring. The hyaenas excavated a den in the boma which all but one individual ("No. 5") was confirmed to use. A metal cage trap was placed in the holding boma but left open and not set until the hyaenas were ready to collar. On occasion, part of the carcass was placed inside the cage to habituate the hyaenas to entering without fear.

*2.4.1 Darting, anaesthesia and collar fitting*

The hyaenas were darted by qualified South African veterinary surgeon, Doctor Peter Rogers. Darting and handling techniques were approved by the University of Bristol's Ethics Committee (Investigation No. UB/11/039). The initial darting and collaring took place at dusk and throughout the evening. A second darting session took place at the same time of day 10 days later. For each darting attempt, an impala carcass was used to attract the hyaenas. Three hyaenas (No.5, "Jaggedy" and Gismo) were collared in the first session and two hyaenas ("Smoothy" and Spot) in the second. During the first session, Gismo was darted as she fed on the carcass and No. 5 and Jaggedy were caught in the cage trap and then darted. Smoothy was caught in the cage but broke out before being darted. Zoletil was used to anaesthetise the hyaenas, which was topped up with an intravenous injection if required. A combination of other drugs was administered during handling to reduce infection risk at the dart site (see Table 2.2). During the second session, the two remaining hyaenas (Smoothy and Spot) were darted while they fed at the carcass. Gismo, whose collar had previously been fitted, was darted while feeding to allow repairs to be made to her damaged collar.

**Table 2.2** Anaesthesia and drug administration for five brown hyaenas during darting and collaring procedure.

| Hyaena | Sex | Mass (kg) | Initial dose of Zoletil (mg) | Top up dose of Zoletil (mg) | Time (mins) elapsed from darting to full recovery | Other drugs administered |
|---|---|---|---|---|---|---|
| No. 5 | M | 47 | 140 | n/a | 82 | Atropine, Penicillin |
| Smoothy | M | 46 | 140 | n/a | 87 | Atropine, Penicillin |
| Jaggedy | F | 53 | 140 | n/a | 95 | Atropine, Penicillin, Baytril |
| Spot | F | 40 | 120 | 50 | 75 | Atropine, Penicillin, Baytril |
| Gismo | F | 37 | 140 | 30 | 82 | Atropine, Penicillin |

Once sedated, each hyaena was individually identified, weighed, measured and sexed (see Table 2.3), their teeth photographed for aging, and blood samples taken to test for pregnancy and relatedness. General and specific identification features were noted such as ear notches, leg stripe patterns and other markings. Body condition was graded by visual inspection and classified as poor, average or good, and teeth were classified as white or brown, clean or dirty, and sharp or worn (see Table 2.3). Age was estimated by the condition of the teeth for each individual (Mills 1982c). An identification microchip (LifeChip®, Destron Fearing) was injected between the shoulder blades of each individual. GPS collars (see section 2.4.2 and Figure 2.1) were fitted around the neck so the width of two fingers could fit between the collar and neck. The fit of the collar was then tested by attempting to pull it over the head of the hyaena. After collaring, hyaenas were returned to the boma and left for the anaesthetic to wear off. Hyaenas were observed and the time taken to the first sign of recovery and full recovery recorded: full recovery was defined as the hyaena standing up and moving away a distance of at least 30 metres out of our view without falling over.

The five hyaenas remained in the boma for two full nights following the fitting of the last two collars. At dusk the following evening, an impala carcass was provided and the gate to the boma was opened and secured to allow the hyaenas free access to the study area (day 1). On day 5, after the gate was opened, the collar of Gismo was found broken at the bottom of the dam inside the boma (see Figure 2.2). The boma gate was closed to trap Gismo inside as she had not yet left. The collar was repaired using a piece of aluminium metal to replace the broken connection piece. Gismo was darted as she fed on an impala carcass and the collar re-fitted. The boma gate was opened again on the morning of day 6. An impala carcass was provided on day 10, 16 and 23. On day 25, the collar of Smoothy was found broken in the bush near the boma. That evening an impala carcass was provided in the boma and observed for six hours until Smoothy entered the boma to feed. While he was feeding the boma gate was closed and Smoothy trapped inside. The collar was repaired by the same replacement of the broken connection piece and on day 32 Smoothy was darted as he fed on an impala carcass and the collar re-fitted. The boma gate was opened for the last time in the morning on day 33. An impala carcass was provided on days 42 and 51; the hyaenas did not feed on the last carcass and feeding was discontinued. Blood samples were sent to the Veterinary Hormone Laboratory at the University of Pretoria. They were analysed by Professor Bertschinger to establish whether female hyaenas showed signs of pregnancy.

307 days after the collar malfunction of Jaggedy, the hyaena was anaesthetised and the collar removed. An impala bait was placed inside the original holding boma and watched for four nights between the hours of 19:00 and midnight. On the fourth night, Jaggedy came to feed at 19:45 and was shut inside the boma. The following day she was darted using the same procedure as previously detailed. The collar was removed and she was placed back in the boma to recover. Less than one hour after recovery she escaped from the boma taking the impala bait with her.

*2.4.2 GPS Collar*

All five hyaenas were fitted with GPS-enabled tracking collars (see Figure 2.1) made from reinforced predator belting material (Tellus, remote UHF, VHF and GSM-enabled collars, Followit, Sweden). Tellus 1D collars weighing 600g were fitted to the two sub-adult hyaenas (Spot and Gismo); they were approximately 1.5% of the animals' body mass. Adult hyaenas (No. 5, Smoothy and Jaggedy) were fitted with Tellus 2D collars weighing 800g, 1.5-1.7% of their body mass. GPS collars were programmed to take an hourly position at half past the hour, every night from 17:30 to 6:30 local time (GMT+2) during the winter months (April-September) and 18:30 to 5:30 during the summer months (October-March). Positional data were not recorded during the day because brown hyaenas are predominantly nocturnal. Parameters recorded by the collars were the date, time, GPS position, time (seconds) to fix, number of satellites (2D/3D), movement in the x and y axis (only during the time the position was being acquired), altitude and temperature. Collars included an activity sensor and had a mortality function. All collars featured a drop-off device which was pre-programmed to activate 386 days after fitting. Collars were set to send their data via the GSM network when they came into coverage.



**Figure 2.1** GPS enabled collar for adult brown hyaena



**Figure 2.2** Broken connection piece on collar of “Gismo”

*2.4.3 GPS and activity data*

GPS data were received through a combination of the GSM network and remote downloading. When not in GSM coverage, positions were stored in the unit and transferred to the server in Sweden as soon as the collar returned to GSM coverage. Positioning data and other scheduled parameters were then sent to me by email from Sweden. Emails were received between one and 44 days apart, depending on when individual hyaenas came into GSM coverage. Data in the emails were converted to Excel format using Notepad. To download the data remotely, hyaenas were located from the ground in a Land Rover using VHF tracking. Once a signal was found, I travelled on foot to within a distance of 100 metres of the hyaena. A UHF receiver (Followit RCD-04 with built in antenna) was then used with a Samsung netbook computer to download GPS data.

The collar fitted to female Spot ran out of battery before expected on day 243. The hyaena was located using the VHF function and the drop off remotely activated on foot within 100 metres of the hyaena. This was done using the UHF receiver with built in antennae, individual collar drop off code and Samsung netbook computer.

*2.4.4 Locating of den and confirmation of reproduction*

GPS data were scanned regularly to check for location and time out records made by the collar. When a position was consistently recorded by

the collar, the point was visited in the field to look for an active den. If a potential den was found, a trail camera (Moultrie D55-IR Manual) was then set on a nearby tree to record activity. GPS data were used to determine when Jaggedy moved den each time as the position of each new den (or nearby resting site) was repeatedly recorded by her collar. When each den was no longer in use, data were collected on the number and sizes of entrances to the den. A camera trap (Ranger 2MP mini trail camera) was set up full time at the fifth and final den and photos collected monthly to monitor the progress of cubs and collect further information on feeding behaviour and interactions where possible.

*2.4.5 Patterns of activity and their change over time*

All 2D fixes and those with an HDOP (Horizontal Dilution of Precision) higher than 10 were removed from the data, as were time-outs. Collars were tested at known GPS positions and found to be accurate to within 0.8 metres. Following these eliminations, data were only used in calculations if all attempted fixes in the night were successful or a maximum of one was missing. For the breeding female Jaggedy, more time-outs were recorded as a result of her spending time at the den with the cubs. During the denning period, it was assumed she was at the den if the previous or subsequent fix to a time out was within 100 metres of the den location. If the previous or subsequent fix was further from the den, it was assumed the time-out was a result of the collar not being able to fix a position. Data were used in calculations if no more than one fix per night was missing as a result of the collar being unable to fix a position as opposed to the female being at the den. In Excel the minimum distance travelled between two positions (cumulative straight line distance between each hourly fix) was calculated using the following equation.

$$\text{Distance} = \text{SQRT}\left[(lat_2-lat_1)^2+((long_2-long_1)*\cos(lat))^2\right] \times 1852 \times 60$$

The equation is based on Pythagoras theorem where 1º of latitude is equal to 60 nautical miles. 1852 and 60 are factors that convert nautical miles (Nm) to kilometres. Due to converging meridians at the poles, 1º of

longitude is not always equal to 60 Nm; it is only 60 Nm at the equator. To account for this the cosine function is used. The total minimum distance travelled per night was calculated as the sum of all these pair-wise distances per night.

The mean speed of travel per night was also calculated (minimum distance travelled in a night divided by the time period over which the collar attempted fixes). For each hyaena the mean minimum distance travelled per night and mean speed were calculated. Means were produced for the first 5 weeks post release, next 10 weeks and final weeks (range 24 to 39 weeks). A one-way Anova was used for each hyaena to test for significant differences in the mean distances travelled between the different periods post-release. ArcMap (Esri® ArcMap™ 10.0) was used to show the changes in hyaena activity patterns within their range at different stages following release. Positional data were plotted for the first five weeks, next 10 weeks and remaining weeks (range 24 to 39 weeks) in different colours.

*2.4.6 Calculation of home range size*

Shape files containing the UTM (the Universal Transverse Mercator geographic coordinate system) coordinates for all points were created in ArcMap. I made data area curves to investigate the minimum number of points required to estimate the home range for each hyaena. Curves were based on 100% minimum convex polygon (MCP) (Hayne 1949) and created using Biotas™ 2.0a Version 3.8 (Ecological Software Solutions LLC Hegymagas, Hungary). I used a 100% MCP and fixed kernel utilisation distributions (KER) (Worton 1989) method for estimating home range areas and core area using Geospatial Modelling Environment Version 0.7.2.0 (Beyer 2012).The least-squares cross validation method was used to select optimal bandwidth for KER home range estimates with a 70 x 70 metre grid. This cell size is consistent with many other studies used to estimate hyaena home range size (see Table 2.1). Individual home ranges were defined as the area within the 90% volume contour, with core area defined as the area within the 50% volume contour. MCPs were created for the different time periods following release and the total time period in weeks (n) for each hyaena (No.5 n=53, Smoothy n=54, Jaggedy n=51, Spot n=39). For the

90% and 50% KER home-ranges, I left out the first 7 weeks of data when the hyaenas were seen to make their biggest movements (see Figures 2.7 to 2.22). This was to eliminate locations affected by translocation and present only the area the animals used during routine activities for estimation of home range size. Isopleths were made for the remaining time period (weeks) within the study (No.5 n=46, Smoothy n=47, Jaggedy n=44, Spot n=32). The MCP method is considered a less accurate method for estimating home range area but is included here to facilitate comparisons between previous studies and this study. MCP and KER shape files were imported into ArcMap to calculate the respective areas in square kilometres.

## 2.5 Results

### *2.5.1 Darting and collar fitting*

Blood tests showed that the adult female hyaena Jaggedy had an elevated level of progesterone (15.88 nmol/l) in her blood compared to the two sub-adult females Spot and Gismo who had 1.14 nmol/l and 0.54 nmol/l respectively. No data were available for brown hyaenas relating to the serum concentrations of progesterone in the blood at different stages of pregnancy. Comparisons were therefore made with spotted hyaenas which were assumed to be similar, although serum concentrations appeared to be much higher in spotted hyaenas in two publications (Licht *et al.* 1995; Steinetz *et al.* 1997) than any recorded for the brown hyaenas in this study. From the serum concentrations, Professor Bertschinger concluded that sub-adult females Spot and Gismo were not pregnant, whereas Jaggedy may have ovulated and it could not be ruled out that she was in the early stages of pregnancy. However, her higher levels of progesterone could have been due to stress during immobilisation. Due to the relevant genetic markers not being available for brown hyaenas, it was not possible to test for relatedness between the five translocated hyaenas. Table 2.3 shows measurements taken for each individual during the darting procedure.

*2.5.2 GPS and activity data*

Table 2.4 shows the data collected from each collar including the number of fixes and time-outs recorded. On day 22, the collar of female hyaena Gismo ceased to make any more GPS fixes and was not included in any activity pattern and home range analysis. On day 309, the collar of female hyaena Jaggedy stopped working; it ceased sending fixes and the VHF function also malfunctioned. The collar of male Smoothy was retrieved using VHF tracking after the pre-programmed drop off activated. No signal was available for Jaggedy following malfunction on day 309 and the collar did not drop off; it was successfully removed at a later date by anaesthetising the animal. For No.5, the drop off activated (shown by a different paced signal emitted by the collar) but the collar did not fall off. Attempts will be made to remove the collar from No.5 in the future.

**Table 2.3** Sex, age (estimated by teeth condition), measurements and condition data collected during darting and collaring of 5 brown hyaenas.

| Hyaena | Capture method | Sex | Mass (kg) | Estimated age* | Body condition | Teeth | | | Measurements (cm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Colour | Cleanliness | Wear | Chest | Neck | Head | Tail | Body |
| No. 5 | Cage | M | 47 | 10 years | Average | Brown | Dirty | Worn | 80 | 58 | 60 | 23 | 79 |
| Smoothy | Direct | M | 46 | 4 years | Average | White | Clean | Sharp | 85 | 74 | 61 | 22 | 74 |
| Jaggedy | Cage | F | 53 | 6 years | Average | White | Clean | Worn | 80 | 58 | 60 | 23 | 79 |
| Spot | Direct | F | 40 | 1.5 years | Average | White | Clean | Sharp | 78 | 54 | 55 | 26 | 78 |
| Gismo | Direct | F | 37 | 1.5 years | Average | White | Clean | Sharp | 76 | 53 | 60 | 21 | 76 |

*Age estimated using teeth – specifically eruption and sharpness (Mills 1982c)

**Table 2.4** GPS data collected from each brown hyaena.

| Hyaena | Number of attempted fixes | Percentage of time outs | Percentage of 2D fixes | Percentage of HDOP>10 |
|---|---|---|---|---|
| No. 5 | 4830 | 3.6 | 1.0 | 0.1 |
| Smoothy | 4707 | 1.4 | 2.3 | 1.0 |
| Jaggedy | 4696 | 5.1 | 2.0 | 0.6 |
| Spot | 3514 | 3.2 | 3.4 | 1.1 |
| Gismo | 231 | 41.0 | 3.9 | 0.9 |

*2.5.3 Locating of den and confirmation of reproduction*

Based on the 'time-out' frequencies recorded by her collar, Jaggedy gave birth to an unknown number of cubs between the 27th and 29th February 2012. The trail camera was secured on a nearby tree facing the den entrance but no photos were taken. Jaggedy moved to a second den where the camera was positioned again. Here the first photographic record of the cubs was on 29th March 2012, 13:10.
Three cubs were photographed and estimated to be 4 weeks old (see Figure 2.3).



**Figure 2.3** First photo of three brown hyaena cubs with mother Jaggedy at second den on 29th March 2012.

On the same day at dusk (17:34) Jaggedy moved each cub in her mouth to a new den (see Figure 2.4). The trail camera recorded a lapse of 12 and 11 minutes between leaving and coming back to collect cubs two and three respectively. Jaggedy was recorded to use five different dens during the course of her cubs' development. All dens were within the initial release site, where there were no spotted hyaenas and lions, and located in mixed tall habitat where more than 50% of the surrounding vegetation was taller than five metres. Dens were all in old termite mounds and had between one and two active entrances (see Table 2.5).



**Figure 2.4** Jaggedy carrying the first cub to a new den.

**Table 2.5** Measurements and characteristics of five breeding dens used by Jaggedy over a period of nine months.

| Den | Distance to nearest road (m) | Number of active entrances | Outer entrance diameter (mm) | Outer entrance height (mm) | Actual entrance diameter (mm) | Actual entrance height (mm) |
|---|---|---|---|---|---|---|
| 1[a] | 227 | 1 | 570 | n/a | 500 | 370 |
| 2[b] | 180 | 1 | 680 | n/a | 400 | 300 |
| 3 | 50 | 1 | 880 | 600 | 330 | 250 |
| 4 | 328 | 1 | 730 | 730 | 450 | 370 |
| 5 | 458 | 2 | n/a | n/a | n/a | n/a |

[a] Den where the cubs were born; [b] First confirmed photo of cubs

Distance between successive dens, the proximity of resting sites and length of use can be seen in Table 2.6. After the clan left the final den, a new one was not found because Jaggedy's collar was no longer functioning. Twelve days later a porcupine moved into den five.

**Table 2.6** Time spent at each den and distance to next den for five dens known to be used by Jaggedy over a period of nine months; the cubs were born in den 1 and first photographed at den 2.

| Den | Distance to next den (km) | Distance to nearest resting site (km) | Number of days used |
|---|---|---|---|
| 1[a] | 0.42 | n/a | 6 |
| 2[b] | 0.14 | n/a | 10 |
| 3 | 1.31 | 0.1 | 25 |
| 4 | 0.22 | n/a | 25 |
| 5 | unknown | 0.09 | 310 |

[a] Den where the cubs were born; [b] First confirmed photo of cubs

All three of the cubs were still alive when den five was vacated and both the mother (Jaggedy) and the adult male Smoothy were still visiting regularly. Photos showed the cubs to use the area outside the den, even when no adults were present, with a higher frequency at night than during the day. Adults were observed at the den but also known to use resting sites within 100 metres of the den during daylight hours.

One suspected den was located (using VHF tracking of female Spot) in the main, open system of the study area. It was situated on the edge of a drainage line and tracks and scat were present at the entrance. A camera trap was secured on a nearby tree but no photos of activity were recorded. The collar of Spot then reported a low battery and remote drop off was activated.

*2.5.4 Patterns of activity and their change over time*

Minimum distances covered during a night of foraging ranged from 1.1 to 33.4 km ($\dot{x}$=11.1 ± 5.4; n=317) for male No. 5, 0.3 to 18.4 km ($\dot{x}$=10.9 ± 3.6; n=322) for male Smoothy, 0.06 to 22.3 km ($\dot{x}$=7.7 ± 4.7; n=334) for female Jaggedy and 0.1 to 30.2 km ($\dot{x}$=11.1 ± 5.5; n=219) for female Spot.

The mean distances travelled by male No.5 were significantly different over the three different periods post-release (one-way Anova, F=8.28, p=0.0003). There was no significant difference in the distances

travelled by the other three hyaenas for the different time periods post-release (Smoothy: one-way Anova, F=1.69, p=0.1860; Jaggedy: one-way Anova, F=1.71, p=0.1825; Spot: one-way Anova, F=1.59, p=0.2059).

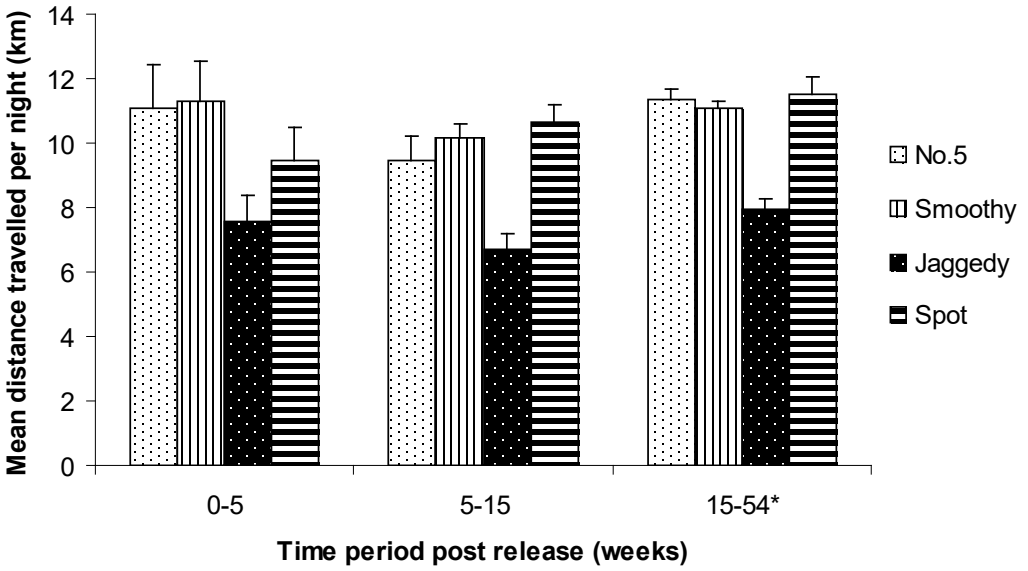



**Figure 2.5** Mean distance (km) travelled per night by individual brown hyaenas following release: error bars show 95% confidence interval for mean.

*Final time periods varied: No.5 15-53 weeks: Smoothy 15-54 weeks: Jaggedy 15-51 weeks: Spot 15-39 weeks

Minimum speeds travelled during a night ranged from 0.02 to 2.79 km/hr ($\dot{x}$=0.9 ± 0.4; n=317) for male No. 5, 0.03 to 1.52 km/hr ($\dot{x}$=0.9 ± 0.28; n=322) for male Smoothy, 0.01 to 1.65 km/hr ($\dot{x}$=0.6 ± 0.37; n=334) for female Jaggedy and 0.12 to 2.96 km/hr ($\dot{x}$=0.9 ± 0.4; n=219) for female Spot.

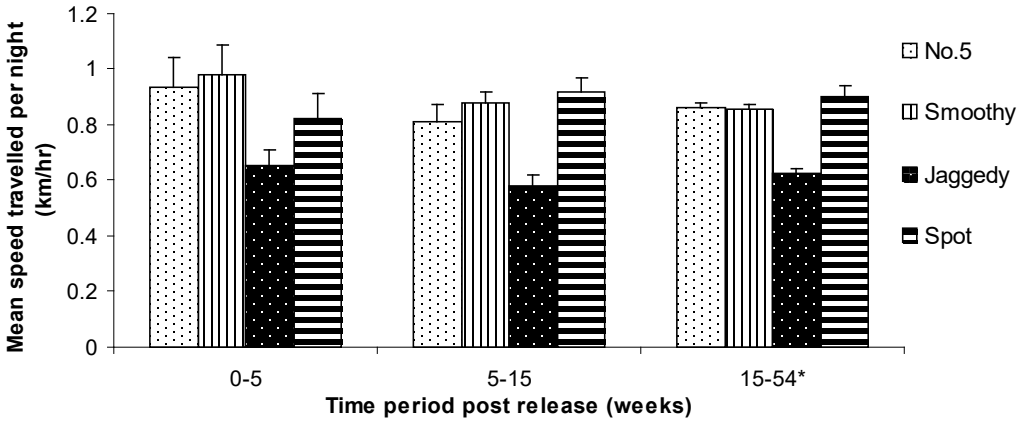



**Figure 2.6** Mean speed (km/hr) travelled per night by individual brown hyaenas following release: error bars show 95% confidence interval for mean.

*Final time periods varied: No.5 15-53 weeks: Smoothy 15-54 weeks: Jaggedy 15-51 weeks: Spot 15-39 weeks

Individual locations recorded following release are mapped in figures 2.7 to 2.22. Following release, all hyaenas remained within the external fence boundary of the study area for the full period of data collection. The hyaenas appeared to separate into two different pairs, one that moved to the open main system of the study area and one that remained within the internally fenced initial release area. Only one hyaena (male Smoothy) stayed within the internally fenced initial release area in the north for the entire period of data collection. Female Jaggedy left this area for a short period (three weeks after release) but returned to the initial release area a week later. She also recorded two positions in the main open system nine months after release; this occurred when a large carcass was left in the Selati River by lions. Male No.5 and female Spot left the internally fenced initial release area but remained within the external boundaries of the study area. The largest areas were covered in the first five weeks post release (green dots). Blue dots show movements in the following 10 weeks and red dots show the locations where hyaenas were recorded in the final (n) weeks following release (No. 5 n=38; Smoothy n=39; Jaggedy n=36; Spot n=24).

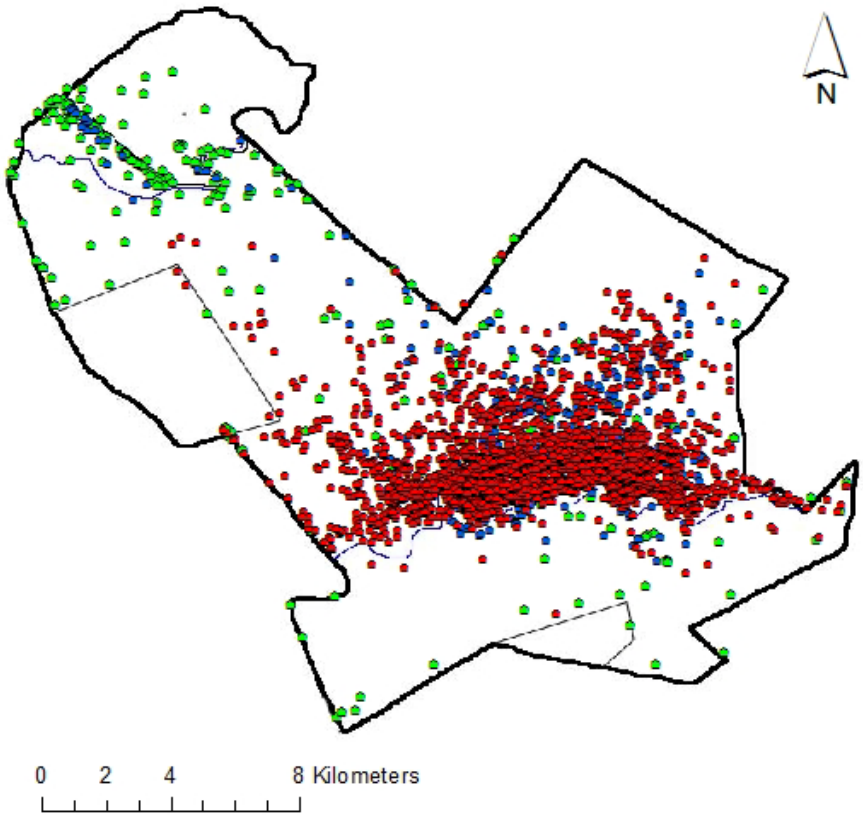



**Figure 2.7** Movements of male brown hyaena No. 5 at different periods following release. First 5 weeks green, next 10 weeks blue, last 38 weeks red.

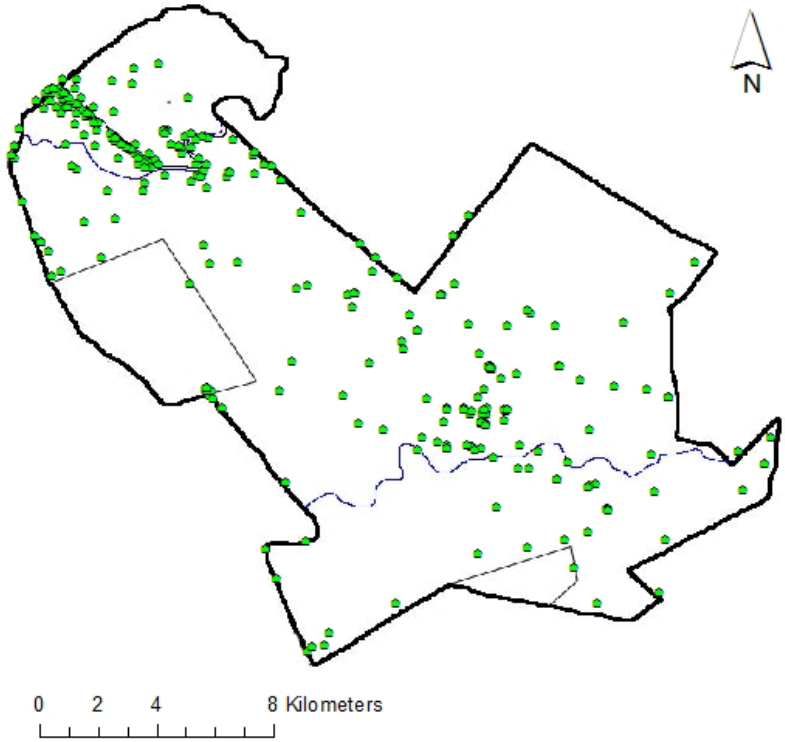



**Figure 2.8** Movements of male brown hyaena No. 5 in the first 5 weeks post release

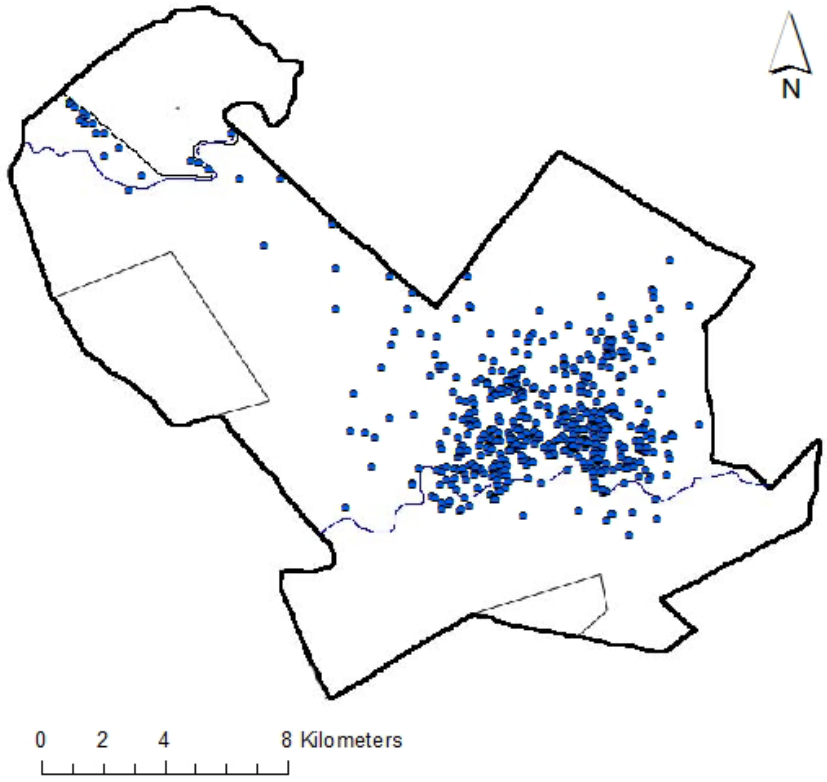



**Figure 2.9** Movements of male brown hyaena No. 5 in the next 10 weeks post release

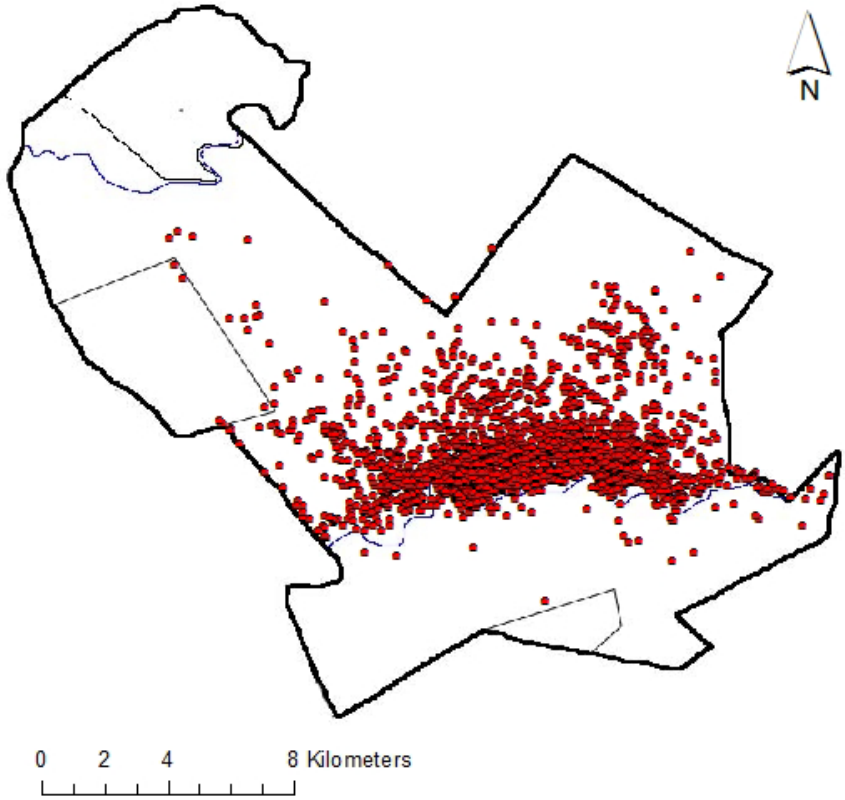



**Figure 2.10** Movements of male brown hyaena No. 5 in the last 38 weeks post release

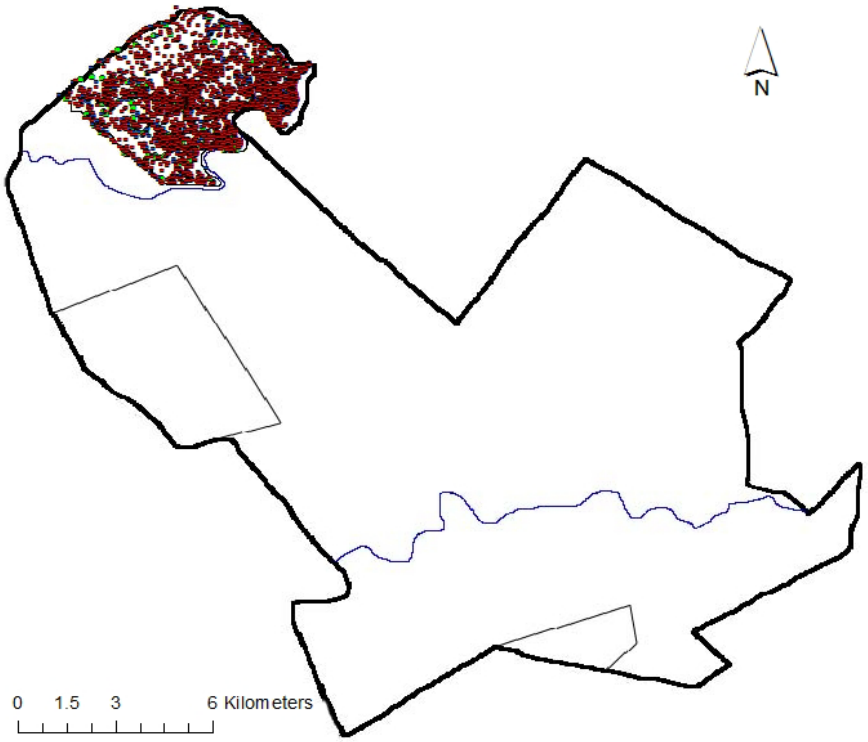



**Figure 2.11** Movements of male brown hyaena Smoothy at different periods following release. First 5 weeks green, next 10 weeks blue, last 39 weeks red.

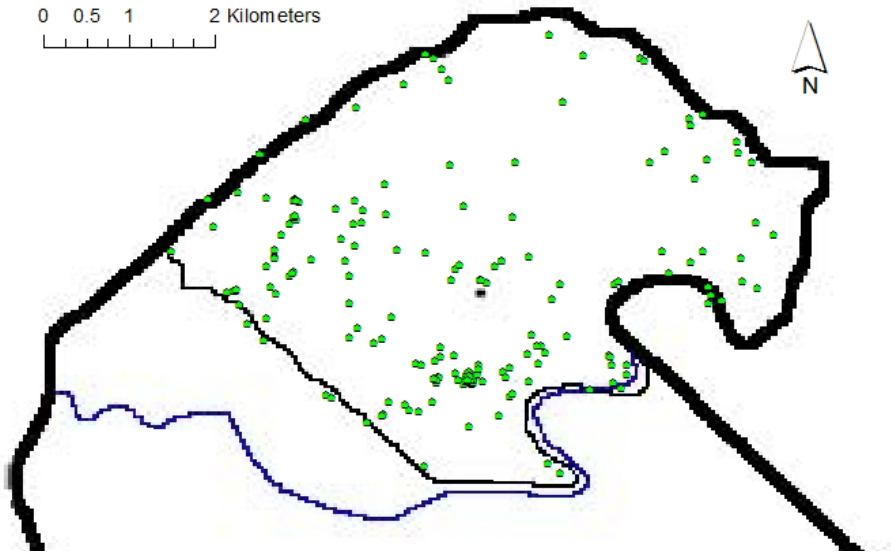



**Figure 2.12** Movements of male brown hyaena Smoothy in the first 5 weeks post release. Only the utilised portion of the study area is shown.

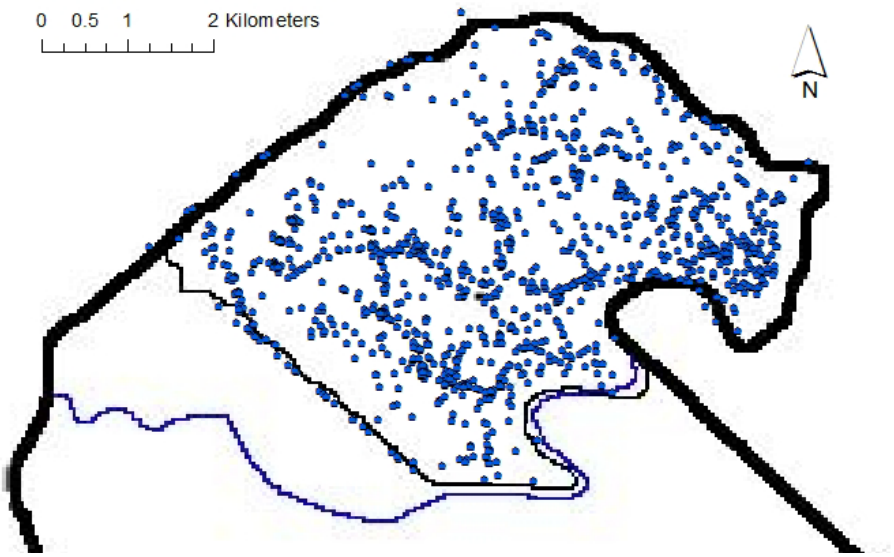



**Figure 2.13** Movements of male brown hyaena Smoothy in the next 10 weeks post release. Only the utilised portion of the study area is shown.

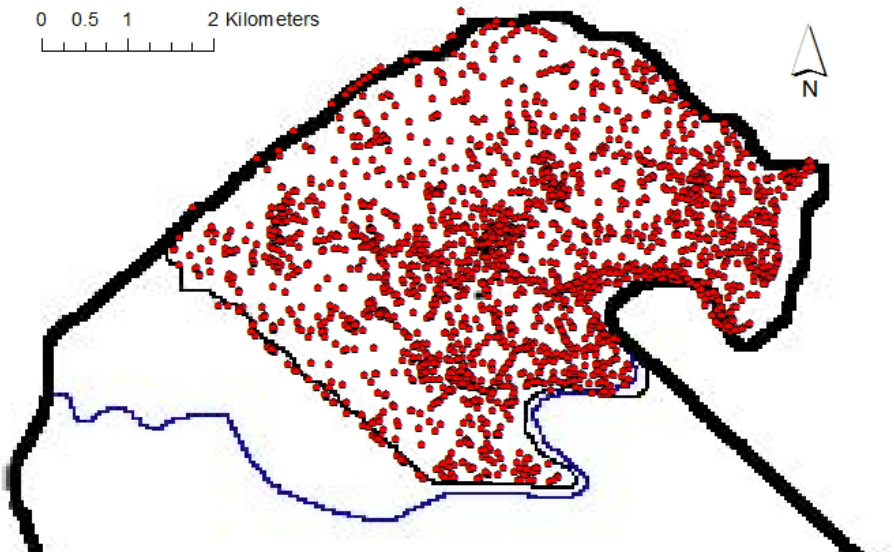



**Figure 2.14** Movements of male brown hyaena Smoothy in the last 39 weeks post release. Only the utilised portion of the study area is shown.

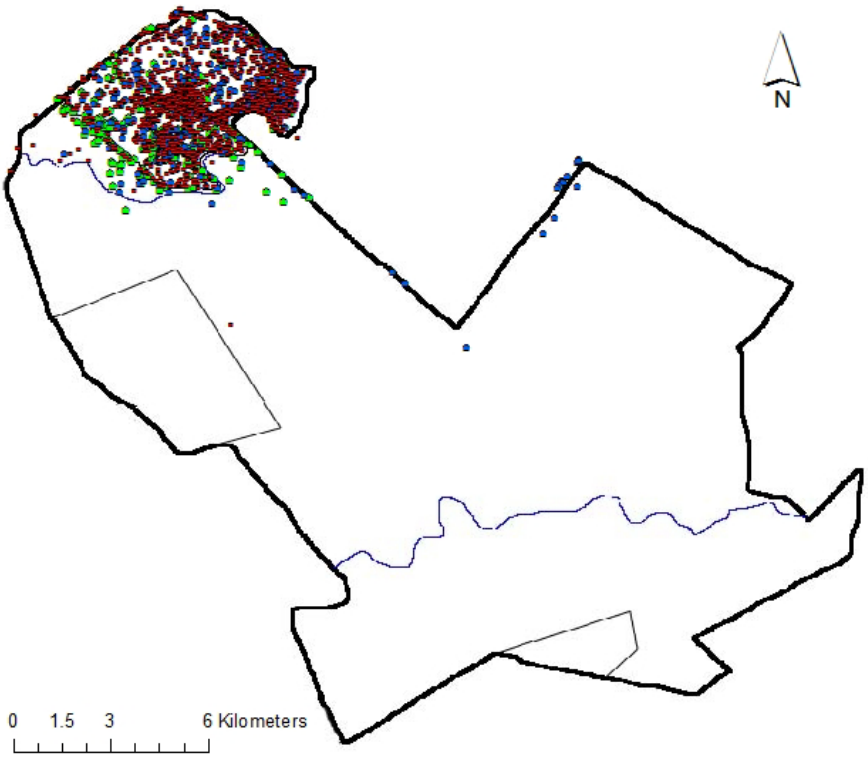



**Figure 2.15** Movements of female brown hyaena Jaggedy at different periods following release. First 5 weeks green, next 10 weeks blue, last 38 weeks red.




**Figure 2.16** Movements of female brown hyaena Jaggedy in the first 5 weeks post release.

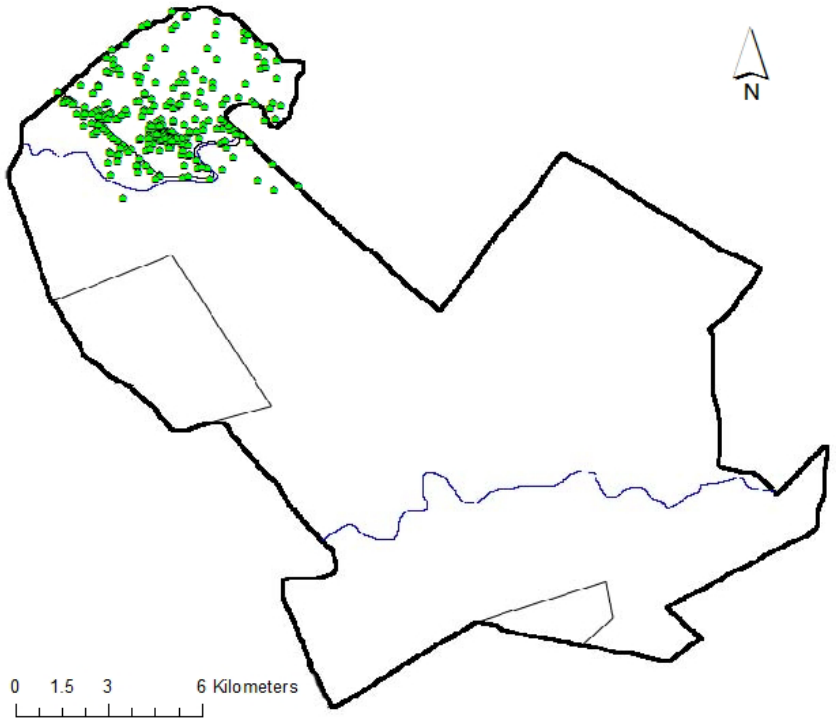



**Figure 2.17** Movements of female brown hyaena Jaggedy in the next 10 weeks post release.

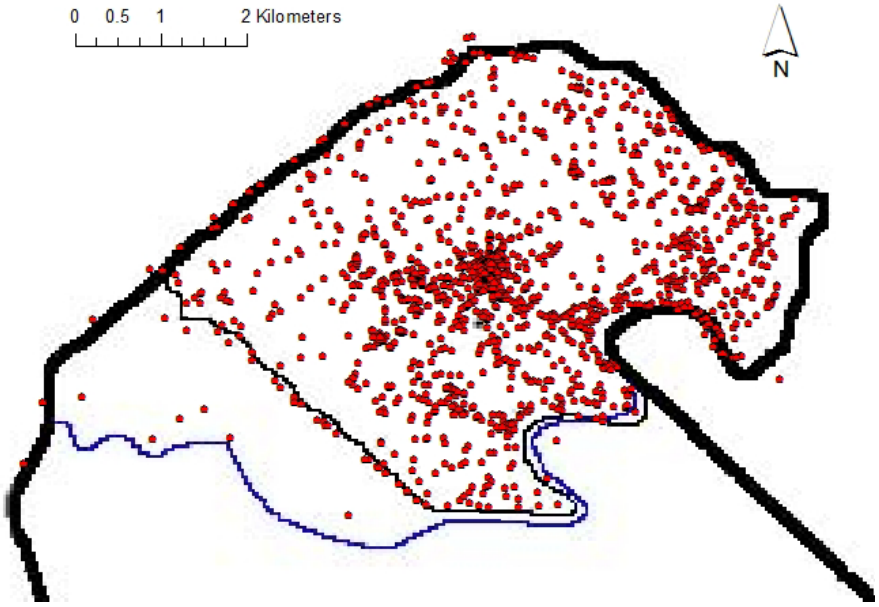



**Figure 2.18** Movements of female brown hyaena Jaggedy in the last 38 weeks post release. Only the main utilised portion of the study area is shown.

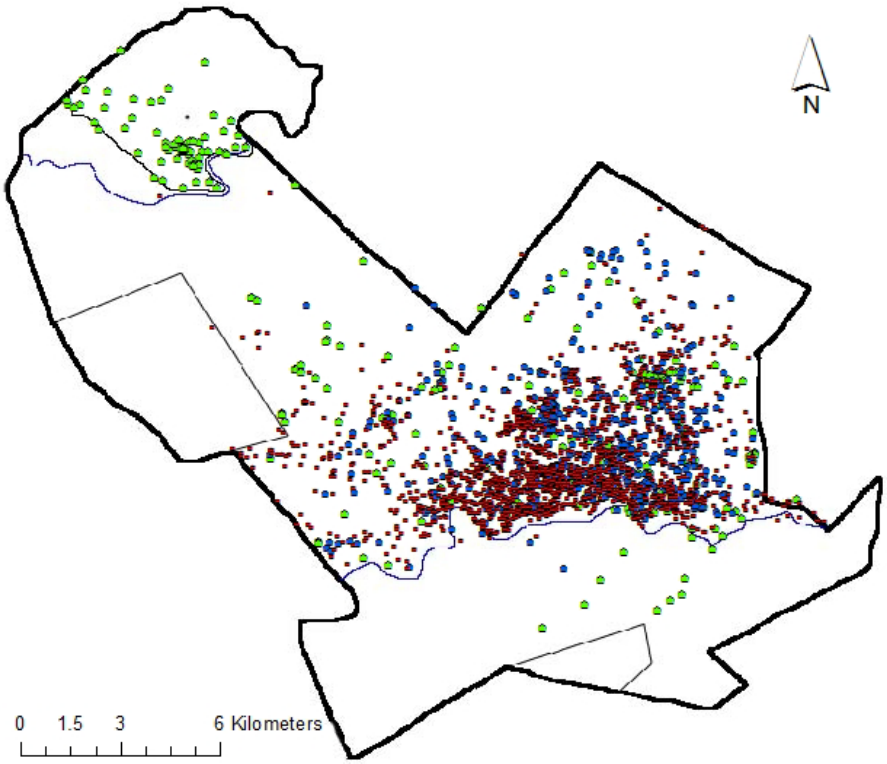



**Figure 2.19** Movements of female brown hyaena Spot at different periods following release. First 5 weeks green, next 10 weeks blue, last 24 weeks red.

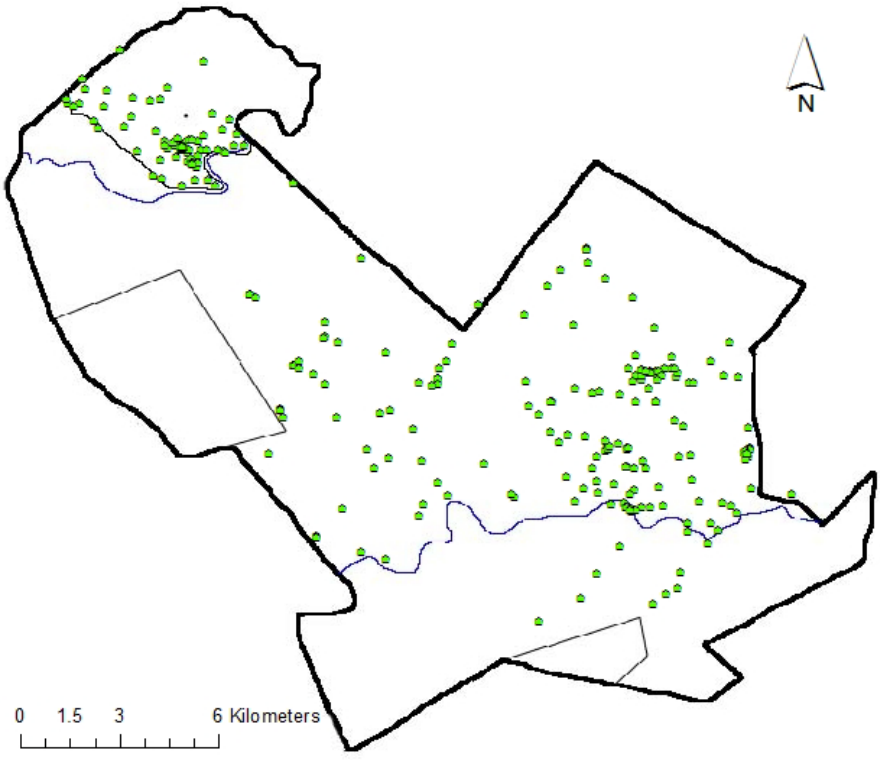



**Figure 2.20** Movements of female brown hyaena Spot in the first 5 weeks post release

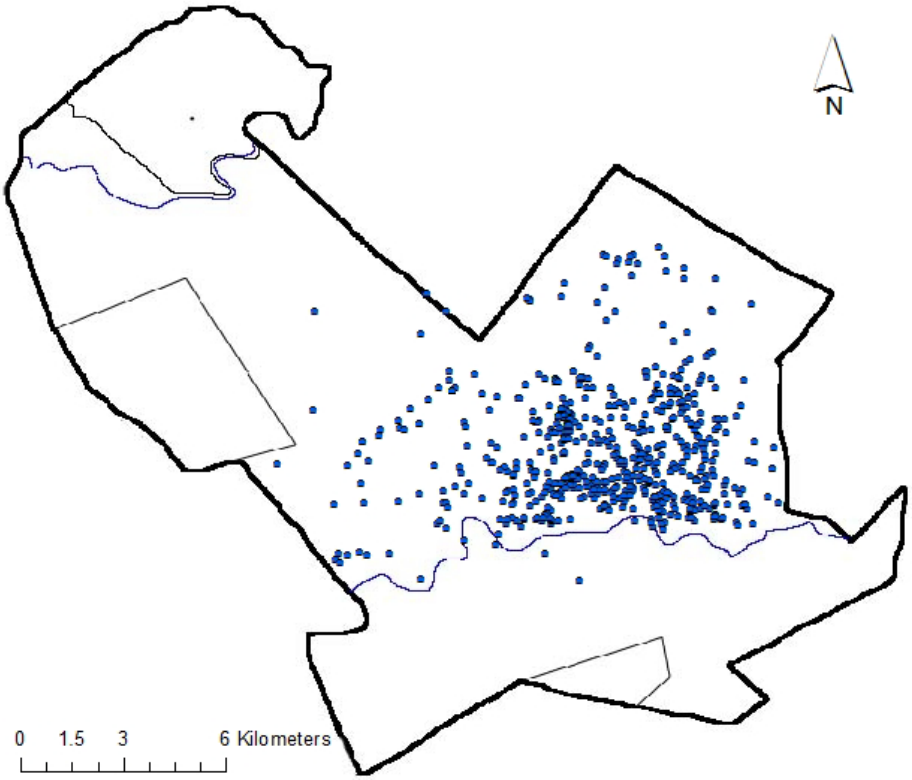



**Figure 2.21** Movements of female brown hyaena Spot in the next 10 weeks post release

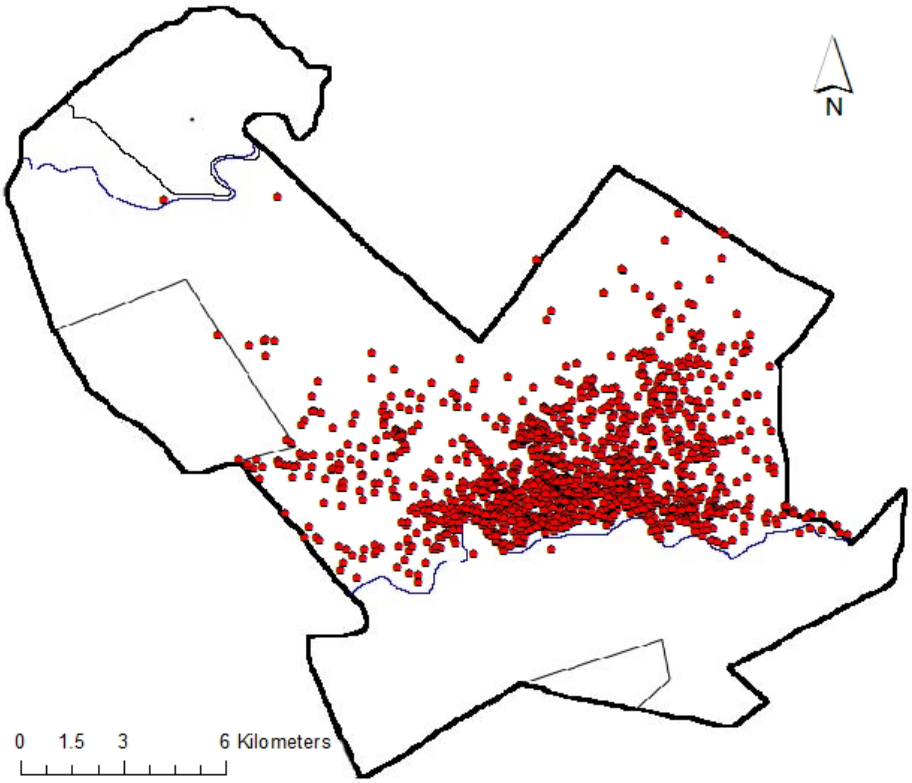



**Figure 2.22** Movements of female brown hyaena Spot in the last 24 weeks post release

*2.5.5 Calculation of home range size*

The number of fixes (locations) required before the home ranges of individuals reached an asymptote varied greatly from 40 for breeding female Jaggedy to 100 for the old male No. 5 (see Table 2.7).

**Table 2.7** Minimum and actual number of fixes necessary to accurately estimate home range sizes for brown hyaenas calculated with data area curves.

| Hyaena | Minimum number of fixes needed | Actual number of fixes used |
|---|---|---|
| No.5 | 100 | 4055 |
| Smoothy | 75 | 4108 |
| Jaggedy | 40 | 3796 |
| Spot | 50 | 2752 |

The estimated MCP home-range sizes varied considerably between the four individuals and also across the different time periods following release (see Table 2.8). For the two hyaenas (No.5 and Spot) that left the initial release site and crossed to the main, open system of the reserve, the area covered by their MCP was much larger in the first 5 weeks following release than during the other time periods. For the breeding female Jaggedy, the biggest area was covered between weeks 5 and 15 following release.

**Table 2.8** Home ranges ($km^2$) of four brown hyaenas calculated using minimum convex polygon (MCP) estimator at different stages following release.

| Hyaena | 0-5 weeks MCP ($km^2$) | 5-15 weeks MCP ($km^2$) | 15-54 weeks ($km^2$) | All weeks ($km^2$) |
|---|---|---|---|---|
| No.5 | 296.5 | 147.1 | 161.6 | 299.1 |
| Smoothy | 21.7 | 23.5 | 23.7 | 23.9 |
| Jaggedy | 30.5 | 80.5 | 46.9 | 102.1 |
| Spot | 182.4 | 103.9 | 155.2 | 214.6 |

*Final time periods varied: No.5 15-53 weeks; Smoothy 15-54 weeks; Jaggedy 15-51 weeks; Spot 15-39 weeks)

The 90% and 50% isopleths for each hyaena varied considerably between the different individuals (see Figures 2.23 to 2.26). Home ranges were larger for the two hyaenas (No.5 and Spot) that left the initial release site and crossed to the main, open system of the reserve (see Figures 2.23 to 2.26).

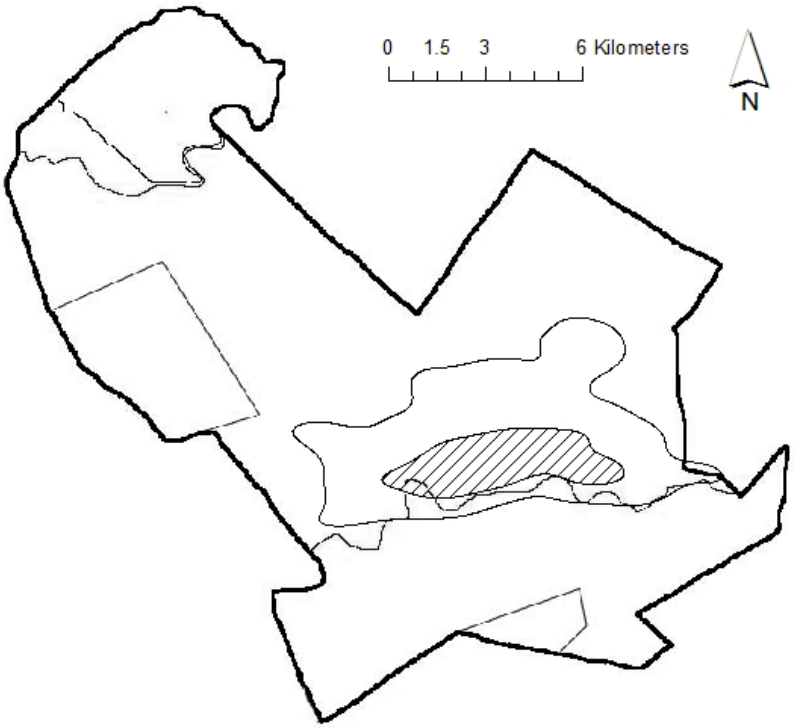



**Figure 2.23** Home range plots for adult male brown hyaena No.5 over a period of 46 weeks. The hollow contour is a 90% isopleth (area 45.3 km$^2$) and the shaded contour is a 50% isopleth (area 10.2 km$^2$).

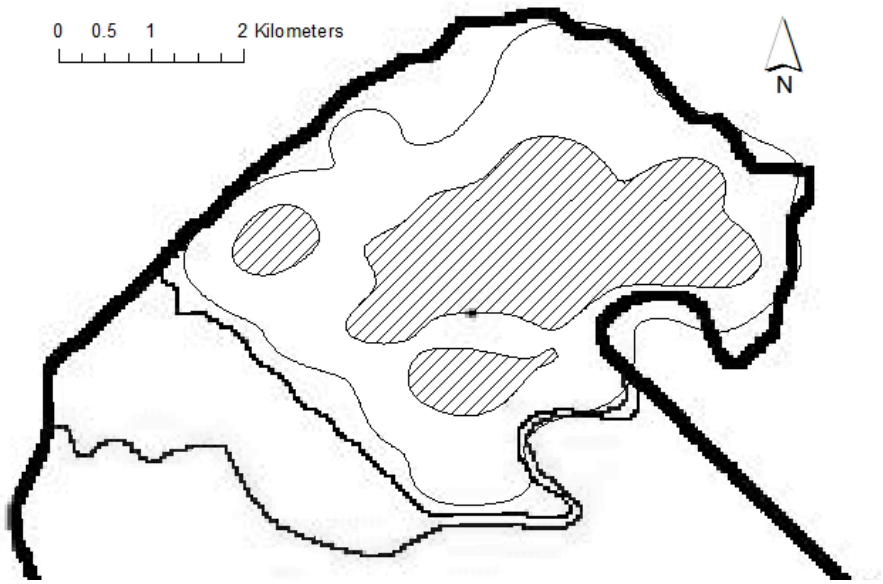



**Figure 2.24** Home range plots for adult male brown hyaena Smoothy over a period of 47 weeks. The hollow contour is a 90% isopleth (area 19.1 km$^2$) and the shaded contour is a 50% isopleth (area 7.2 km$^2$). Only the utilised portion of the study area is shown.

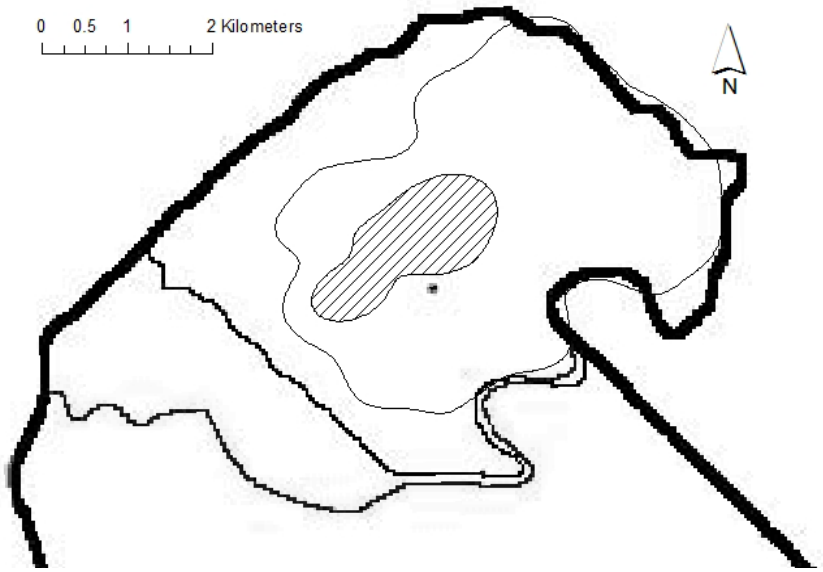



**Figure 2.25** Home range plots for breeding adult female brown hyaena Jaggedy over a period of 44 weeks. The hollow contour is a 90% isopleth (area 15.0 km$^2$) and the shaded contour is a 50% isopleth (area 2.0 km$^2$). Only the utilised portion of the study area is shown.

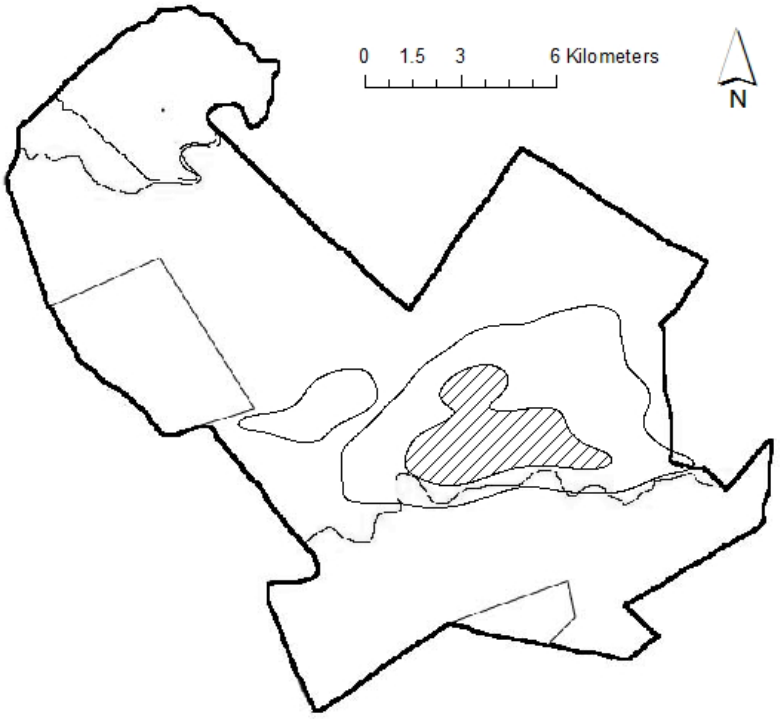



**Figure 2.26** Home range plots for adult female brown hyaena Spot over a period of 32 weeks. The hollow contour is a 90% isopleth (area 50.4 km$^2$) and the shaded contour is a 50% isopleth (area 12.8 km$^2$).

The method of home range estimation (minimum convex polygon or fixed kernel) also caused considerable variation in the estimated home range sizes for individuals (see Table 2.9).

**Table 2.9** Home range areas of four brown hyenas calculated using fixed kernel (90% and 50% isopleths) and MCP methods following release; the first 7 weeks were excluded.

| Hyaena | 90% isopleth home-range area (km$^2$) | 50% isopleth home-range area (km$^2$) | MCP home-range area (km$^2$) |
|---|---|---|---|
| No. 5[a] | 45.3 | 10.2 | 197.7 |
| Smoothy[b] | 19.1 | 7.2 | 23.7 |
| Jaggedy[c] | 15.0 | 2.0 | 46.9 |
| Spot[d] | 50.4 | 12.8 | 155.2 |

Data collection lasted for different periods: [a] 46 weeks; [b] 47 weeks; [c] 44 weeks; [d] 32 weeks

## 2.6 Discussion

My observations suggest that brown hyaenas can be translocated into a new environment and survive, establish and reproduce when conditions at the release site are suitable. I predicted the release site (part of the brown hyaenas native range) would provide suitable habitat for the hyaenas requirements and that translocated individuals would settle within the boundaries of the release site. The prediction was correct and although one pair (male No.5 and female Spot) crossed an internal fence to leave the initial release site, they established on the main open system, still within the protected area of the release site. The hyaenas successfully crossed internal fences on more than one occasion. In the case of adult female Jaggedy she chose to return to the original release area even after crossing onto the main, open system of the release site. There was no structural difference between the internal and external fences at the release site. The successful crossing of internal fences therefore suggests that the external boundary fence could also have been crossed if the hyaenas wished to do so. It can be concluded that neither internal nor external fencing appears to have an impact on the spatial ecology of hyaenas following translocation. The observation that fences do not restrict brown hyaena movements is further supported by the fact that the hyaenas' home ranges were smaller than the space available to them.

### Reproduction

The mean litter size of brown hyaenas in southern Africa is three (Skinner 1976; Skinner & Chimimba 2005) but in the central Kalahari a mean of 1.25 cubs has been recorded (Owens & Owens 1979). The number of cubs first photographed is consistent with Skinner (1976), although it is not known whether this was the number actually born or the number that survived to emergence. My results are consistent with the findings in the southern Kalahari where 90% of dens (n=37) had only one entrance (Mills 1983). The dimensions of the den entrances here are similar to those given by Mills (1983) in the Kalahari Gemsbok, where an entrance of 50x32 cm was recorded and in other studies of brown hyaena den use (Skinner 1976;

Owens & Owens 1979). Both female Jaggedy and male Smoothy brought food to the den and both used diurnal resting sites away from the den.

**Patterns of activity**

The minimum distance travelled per night by individual hyaenas in this study showed a large range (0.06 km to 33.4 km). Distances presented here are comparable to those found in other parts of the brown hyaena's range. The previous translocation study shows a range of 8.4 km to 22.6 km travelled per night in the Transvaal (Skinner & van Aarde 1987). Brown hyaenas in the southern Kalahari were found to travel between 10 and 20 km per night in the dry season and 20 and 30 km in the wet season (up to 30.3 km in 12 hours) (Owens & Owens 1978). Another study in the same area showed individuals covered a mean of 32 km per night; this was considered to be a slight under estimation due to small diversions and circling while foraging (Mills 1978). Brown hyaenas in the Namib desert covered distances ranging from 12.9 to 19.85 km per night (Skinner *et al*. 1995). However, all these studies used data from direct observation and VHF tracking, whereas I used GPS collars. Mine were some of the smallest distances travelled in a night for brown hyaenas but calculated distances may be skewed in the case of the breeding adult female Jaggedy. There is a dramatic reduction in maternal home range size immediately following the birth of cubs (Wemmer & Sunquist 1988) and she appeared to travel smaller distances during the period she spent at the den with the cubs. Omitting her data still gives shorter distances per night for my hyaenas (0.1 km one night by female Spot), suggesting that brown hyaenas in the Lowveld may cover smaller distances on average per night than in other areas of their range. Using GPS data rather than direct observations will under-estimate the distance travelled because it is assumed that hyaenas travelled in a straight line between locations. In the central Kalahari hyaenas were rarely observed to move in a straight line while foraging and generally use a zigzag mode of progression to maximise the possibility of encountering food items (Owens & Owens 1978).

The speed travelled per hour by the released hyaenas ranged from 0.01 km/hr to 2.96 km/hr. This suggests brown hyaenas move at a slower

rate when foraging in the Lowveld part of their range. In the previous translocation study average travel speed ranged from 0.3 km/hr to 5.6 km/hr (Skinner & van Aarde 1987), while in the central Kalahari they moved at between 3.2 and 6.4 km/hr (Owens & Owens 1978). Both these published studies were based on visual observations of the hyaenas, so this may in part account for the higher estimates.

**Home range size and use**

The four hyaenas in this study exhibited a large degree of variability in home range sizes (15.0-50.4 $km^2$) and core range areas (2.0-12.8 $km^2$). For initial discussion I will use home range areas calculated by the kernel distribution method due to the increased accuracy of this technique. The two hyaenas (Smoothy and Jaggedy) that remained predominantly within the initial release site used similar sized home ranges although the 90% and 50% isopleth range sizes were slightly larger for male Smoothy (see Table 2.9). Both of their home ranges were much smaller than those of No.5 and Spot who lived in the main, open system of the reserve. No.5 and Spot also utilised a similar sized home range to each other but the home range (90% isopleth) and core area (50%) used by Spot was slightly larger than No.5 (see Table 2.9). Intraspecific variation in home range size may be influenced by sex and social dominance hierarchy (Hoffer & East 1993 in Hayward *et al*. 2009). In sexually dimorphic species, the larger body massed sex should have a larger home range to fulfil their larger metabolic requirements (Packer *et al*. 2005 in Hayward *et al*. 2009). Dominant males may have a wider range than a subordinate one but alternatively, nomads may wonder large distances in search of territory and hence therefore cover a wider range (Hayward *et al*. 2009). In the present study there did not appear to be a correlation between sex and home range size, which may reflect the absence of large sexual dimorphism in brown hyaenas. Variation in home range size is also attributable to the resources (biomass of prey) available to individuals (Nilsen & Linnell 2006 in Hayward *et al*. 2009). This suggests more food resources may have been available to Smoothy and Jaggedy at the initial release site.

To compare home range use over time I will refer to the areas calculated using the MCP method. I predicted that hyaenas would make the biggest movements and travel the largest distances immediately after release. In swift foxes (*Vulpes velox*) smaller dispersal distances have been correlated with higher chances of survival (Moehrenschlager & Macdonald 2003) but this was not the case for the hyaenas as they covered different distances immediately following release but all survived. Male No. 5 supported my prediction and covered a much larger area during the five weeks immediately following release than later in the study. Erratic movements following release are not unusual as animals try to distance themselves from the release site (Moehrenschlager & Macdonald 2003). This was the oldest of the released hyaenas (see Table 2.3) and older animals travel further from the release site (Miller *et al.* 1999; Moehrenschlager & Macdonald 2003). Spot also ranged further immediately following release but not to such a great extent. The prediction was not supported by the other two hyaenas. Jaggedy showed a large increase in the home range area (MCP) used between weeks five and 15 following release rather than at the beginning (see Table 2.8). This was the ten week period immediately preceding giving birth, in week 16 following release. The increase in home range size may reflect Jaggedy's need to find a suitable and safe den site before giving birth. The male Smoothy also did not travel larger distances immediately following release than at any other time during the study period.

Comparing home range sizes with other publications is difficult due to a number of variables including technique used to estimate home range size and number of hyaenas used in analysis (see Table 2.1). Some studies present home range size for clans (235-480 $km^2$) and not individuals (Mills 1982b) and studies take place in different areas of the brown hyaena's range. To make comparisons with other studies I will use home range sizes (excluding the first 7 weeks) calculated using the MCP method because the majority of publications use this technique to estimate home range sizes. Based on previous studies I predicted the hyaenas home ranges would cover most of the 250 $km^2$ at the release site. No translocated individuals used a home range as large as predicted. Previous studies were carried out

in desert habitats such as the southern Makgadikgadi region and Namib desert (see Table 2.1), very different to the habitat available to hyaenas in this study. It is likely that habitat type and the prey densities supported vary widely between these study areas and influence brown hyaena home range size.

Although used for comparison here, the MCP method is limited and may calculate inflated areas for home ranges due to the inclusion of outlying points. Outliers may have only been visited once and not represent the true area the animal utilises (Harris *et al*. 1990). The initial exploration of the reserve boundaries by No.5 demonstrates this; although using these areas initially, they did not form part of his established home range (see Figure 2.7). This study gives the first home range sizes (using the kernel distribution method) for brown hyaenas in the Lowveld part of their range which can be used for more accurate comparisons in the future.

**Home-range overlap**

Using the kernel distribution method (see Table 2.9) and MCP method (see Table 2.8), the two hyaenas in the main open system of the study site had considerably larger home range sizes than the pair who remained on the internally fenced release site. Overlap can be seen between the home range (90% isopleth) and core areas (50% isopleth) utilised by these two individuals (No. 5 and Spot) (see Figures 2.23 and 2.26). For the pair that remained within the internally-fenced release area the pair also exhibited overlap in both the home range (90% isopleth) and core area (50% isopleth) they used (see Figures 2.24 and 2.25). No overlap was observed in either the home range (90% isopleths) or core areas (50% isopleths) used by the two different pairs (see Figures 2.23 to 2.26).

## 2.7 Conclusion

Preliminary results suggest this translocation was a success (Griffith *et al*. 1989; Miller *et al*. 1999). Although the fate of one hyaena (Gismo) cannot be confirmed because of collar failure, all other translocated individuals established a home range within the release site and

reproduction was confirmed for at least one group. The female hyaena in the other group (Spot) was likely still too young to breed during the study period. The environment and conditions at the release site were suitable and bushveld habitat can support brown hyaenas.

None of the four hyaenas recorded positions outside the release site (conservation reserve) to which they were translocated during the period of data collection. No further conflict with farmers took place and translocation can be used as a suitable tool for the removal of brown hyaenas from areas where they are in conflict with farmers. This translocation used wild-caught individuals and a soft release procedure with appropriate fencing. The release site also formed part of the hyaenas native range.

It is not known whether the hyaenas had knowledge of each other prior to translocation. While hyaenas caught on the same farm may have been related or socially bonded; it is unlikely that all translocated individuals had prior knowledge of each other due to the distance between the farms on which they were caught. Therefore, prior bonding does not appear to be a pre-requisite for holding brown hyaenas in a boma together. Extent of relatedness between hyaenas was not confirmed thus it is unknown whether the splitting of the two social groups was due to hyaenas being bonded or related prior to translocation. Further translocation efforts should look at how brown hyaenas adapt if moved to habitats with herbivore densities and predator composition different to those at the release site in this study.

The conclusions presented here are based on data from four individuals. Therefore some caution must be used as data are not necessarily representative of the whole population and are not likely to capture the full range of individual variation possible. At the conclusion of the study, some collars had ceased operating and others were nearing the end of their predicted lifespan. The required data were obtained and successful translocation had occurred. Re-collaring of the hyaenas was therefore not deemed to be necessary. Information relating to specific factors (habitats and resources) that enabled survival, establishment and reproduction of translocated hyaenas are presented in chapter 3.

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# Brown hyaena ecology in Lowveld bushveld habitat

## 3.1 Summary

General ecology was studied for four brown hyaenas fitted with GPS collars in the Lowveld bushveld habitat of South Africa's Limpopo province. Data were collected on habitat use and the factors affecting selection including food dispersion and the presence of other large carnivores. Feeding data were opportunistically collected. Data were compared between brown hyaenas living amongst lions and spotted hyaenas with those where these carnivores were absent. Two brown hyaenas showed a preference for riverine and drainage line habitats as well as mixed eroded habitat. Habitat preference was not associated with ungulate density. Brown hyaenas can coexist with lions and spotted hyaenas but the presence of these carnivores may affect home range size and the vegetation cover utilised. Brown hyaenas living in the absence of lions and spotted hyaenas used open habitats more often than those living amongst these carnivores. Brown hyaenas used roads when travelling in this habitat but less often where lions and spotted hyaenas were present. Food dispersion and the distance between feeding sites may also influence brown hyaena home range in this biome. Brown hyaenas feed on a range of vertebrate species in this habitat, predominantly mammals as well as reptiles and birds. The extent to which food is hunted or scavenged is unknown.

## 3.2 Introduction and Aims

The primary reason for fitting GPS collars was to monitor the reaction of brown hyaenas to translocation; to assess their survival and the ability to establish and reproduce in a new area. Additionally the GPS collars presented an ideal experimental opportunity to learn more about the ecology of brown hyaenas in this biome. No published information is available for brown hyaenas here so little is known about how they utilise habitats on the fringe of their current range. Fundamental questions such as which habitats they prefer, how they select them, what they feed on and

how they fit within a complex guild of other predators have not been addressed.

Brown hyaenas are unusual amongst large carnivores in that they do not cooperate in foraging for food (Mills 1982b). In the southern Kalahari individuals use different parts of their home range to varying extents depending on habitat, which in turn is reflected by food availability (Mills 1978). In this chapter I look at the food dispersion in different habitat types and whether this influences habitat selection by the released hyaenas.

The study provided a chance to investigate the effect of other large carnivores on brown hyaena behaviour. At the initial release site (home range of Smoothy and Jaggedy) there were no lions due to the predator proof (fitted with live trip wires) fence which kept them out. Spotted hyaenas also appeared to be absent from this area. In a five year period, no spotted hyaenas had been seen but there had been multiple sightings of the more elusive leopard which is generally difficult to see in this area and sightings are much less common than spotted hyaenas. In the main, open system (home range for No. 5 and Spot) both spotted hyaenas and lions were present and seen regularly. Brown hyaenas are sensitive to the activities of other carnivores in their area (Mills 1991). They are believed to avoid their dominant competitors by ranging widely and inhabiting areas with few spotted hyaenas and lions (Mills & Gorman 1997; Durant 2000; Creel *et al*. 2001). I will investigate the effects of large predator presence on brown hyaena patterns of activity and habitat use by comparing activity and habitat data from No.5 and Spot with Smoothy and Jaggedy. By mapping the spatial movements of No.5 and Spot with large carnivore locations I will determine if the presence of spotted hyaenas and lions influences brown hyaena movements. I will calculate the vegetation cover in areas used by the brown hyaenas and assess whether they preferentially use or avoid roads for travel. Roads are generally more open habitats and regularly used for travel by lions and spotted hyaenas (Stander 1998). It may therefore be expected that brown hyaenas would avoid the use of roads to avoid contact with these larger predators.

Detailed, quantitative data on brown hyaena diet is hard to obtain due to the nocturnal and secretive habits of the species as well as the low

densities in which they occur (Mills & Mills 1978). They most frequently scavenge the remains of fresh kills left by other predators, supplemented by hunting small mammals, birds, insects and reptiles (Owens & Owens 1978). Smaller mammals are hunted with a relatively low success rate (5.7% in the southern Kalahari), so the contribution to an individual's diet from hunting is relatively small (Mills 1978). The remains of other predator's kills are therefore the single most important food item in brown hyaena diet in the central Kalahari (Owens & Owens 1978). Vegetation, including fruits, is an important source of moisture during dry months in the central Kalahari (Owens & Owens 1978) and in the Namib desert Cape fur seals (*Arctocephalus pusillus*) are the dominant food source for brown hyaenas (Skinner *et al*. 1995). I took the opportunity to collect the first feeding data for brown hyaenas in the bushveld habitat of the Lowveld.

## 3.3 Hypotheses and Predictions

Hypothesis 1: Habitat use will be selective and concentrate in the mopane scrub, tree savanna and sandstone rocky ridges with which brown hyaenas are associated in nearby areas of South Africa.
Prediction: The hyaenas will show preference for habitats that increase their chances of finding mates and safe, suitable denning areas.

Hypothesis 2: Brown hyaenas will select habitats based on where they find the necessary food resources.
Prediction: Hyaenas will forage in habitats with the highest biomass of live ungulates, representing greater food availability and an increased chance of finding a carcass.

Hypothesis 3: Brown hyaenas are sensitive to the activities of other carnivores in their area and avoid dominant competitors such as spotted hyaenas and lions.
Prediction: Brown hyaenas will select home range locations with low lion and spotted hyaena activity. In areas where large predator activity is higher,

brown hyaenas will travel larger distances, range over larger areas, use denser habitat and avoid roads to minimise encounters.

Hypothesis 4: Brown hyaenas predominantly scavenge the remains of large vertebrates but also hunt small vertebrates and include insects and fruit in their diet.
Prediction: The hyaenas will feed on a wide range of species. Due to the absence of large predators on the initial release site, fewer large vertebrate remains will be available so the hyaenas will consume more small vertebrate species that they hunt themselves.

## 3.4 Methods

For general methods relating to capture, procedures during boma holding, darting, collar fitting and release, see Chapter 2.

### *3.4.1 Habitat selection by brown hyaenas*

Used (points visited by hyaenas) and available (random points) GPS locations were visited to assess brown hyaena habitat selection within their home range area. Analysis of habitat type and vegetation cover at sites began two months after release of the brown hyaenas to eliminate initial random movements. A random number table was used to select which hyaena points to visit; no more than one point per night was visited for each hyaena. Only 3D satellite locations were used for analysis and sites were visited within 36 hours of the hyaena being present. Random location GPS positions were created using a random number table.

A handheld GPS (Garmin eTrex® 10) was used to navigate from the nearest road to the GPS location. At the site the distance to the nearest road was recorded and the main habitat type categorised (see Table 3.1). I noted whether the habitat type was uniform within 50 $m^2$ of the point and whether a boundary to a different habitat type was present within 10 $m^2$. The presence of a road was included as a boundary and for analysis, any point actually on the road or 10 metres either side was considered as ‘road use’. A compass and stick with a 5 cm diameter white disk were used to assess

**Table 3.1** Categories and definitions for habitat analysis at nocturnal positions recorded by hyaenas and random points.

| Category | Definition |
|---|---|
| Mixed bushveld tall | More than 50% of tree species at the point were taller than 5 metres |
| Mixed bushveld shrub | More than 50% of tree species at the point were shorter than 5 metres |
| Mixed bushveld eroded | More than 50% of the ground cover at the point was eroded due to past farming practices |
| Riverine | Habitat in the river bed itself or within 50 metres either side of the river bank |
| Drainage line | Habitat in a drainage line (natural dip with rocks and sand present) itself or within 50 metres either side |
| *Mopane*/*Combretum* mix | *Combretum* and *Mopane* bushes and/or trees made up more than 50% of the tree species present |
| *Mopane* dominated | *Mopane* trees formed more than 50% of the tree species |
| Open grassland | Mostly open grassed area only sparsely covered with any wooded species |

vegetation cover at each site. One observer crouched at the point to simulate being at brown hyaena eye level. Another person walked with the white disk, holding it at the bend of their knee, in the four cardinal directions of the compass. The first time the disk completely disappeared from view the walker was told to stop and a digital range finder (Bushnell yardage Pro Sport 450 Laser Rangefinder) used to determine the distance at which the disk disappeared. Where the bush prevented a clear view for the range finder I used pacing to measure the distance.

The area around each point was searched for signs of brown hyaena presence. Signs included spoor, scent marking (anal pasting), scat, a den site, resting place or evidence of feeding. Data were analysed for each hyaena separately. Although it would be technically possible to make population inferences based on a sample size of four, the power would be

very low (not just because of the sample size; the sample is also heterogeneous with respect to sex and age) and any tests which happened to be significant would have questionable authority. Instead, robust, well-powered statistics were applied to each individual's data, and these are presented as four case studies, the generality of which will be determined by future investigations of brown hyaena behaviour and ecology. A chi-squared test was used to determine whether the habitats used by the hyaenas were representative of what was available to them or whether some habitat types were over or under utilised. A chi-squared test was also used to test whether individual brown hyaenas specifically used roads while travelling. For statistical analyses, points recorded in riverine and drainage line habitats were combined so that at least 80% of the expected values for chi-squared tests exceeded five. The two *Mopane*-associated habitats (*Mopane* dominated and *Mopane/Combretum* mix) were also combined. Any habitat categories which recorded a count of zero for both used and available points were removed from the analyses. These were open grassland on the initial release site and *Mopane*-associated habitats and mixed eroded habitat on the main, open system.

### *3.4.2 Food dispersion*

Food dispersion was assessed by counting ungulates in the study area. Ungulate biomass was calculated by repeatedly driving four set line transects: 69 transects (Route 1 n=18 transects, Route 2 n=18, Route 3 n=16, Route 4 n=17) covering 1521.7km ($\dot{x}$=22.1 km ± 0.5) during every month of the study period. Transects covered areas in and around those utilised by the hyaenas in their home range and included all eight habitat categories listed in Table 3.1. Transects started between 06.30 and 7.00 or 15.00 and 15.30 and lasted for between two hours 45 minutes and four hours 38 minutes. The vehicle was driven at a speed of 25 km/hr and stopped when an ungulate was seen. The time was recorded, species identified and the total number of individuals counted. When possible, ancillary data were recorded on the sex and age class of all individuals seen. The perpendicular distances between the transect line (road) and initial location of the ungulate(s) were measured with a digital rangefinder.

For a herd, distance was measured to the animal in the centre of the cluster. The position was recorded with a handheld GPS and the habitat type recorded using the categories in Table 3.1. A maximum of 5 minutes was spent at each sighting to prevent duplicate counting.

Transects were chosen to be representative of the sampled area. For each transect, the distance (km) of each habitat category was measured on both the right and left hand sides of the vehicle. Distances were combined to calculate the total transect length and percentage composition of habitat categories in the transect (see Table 3.2).

**Table 3.2** Habitat composition of transect lines driven to estimate ungulate biomass.

| Habitat category | Percentage composition of transect on initial release site | Percentage composition of transects on main, open system | Mean percentage covered in all transects |
|---|---|---|---|
| Mixed bushveld tall | 83.5 | 83.4 | 83.2 |
| Mixed bushveld shrub | 1.2 | 4.0 | 3.4 |
| Mixed bushveld eroded | 1.0 | 1.8 | 1.6 |
| Riverine | 0 | 6.2 | 4.8 |
| Drainage line | 1.4 | 1.7 | 1.7 |
| *Mopane*/*Combretum* mix | 6.2 | 1.2 | 2.4 |
| *Mopane* dominated | 6.7 | 0.8 | 2.2 |
| Open grassland | 0 | 0.9 | 0.7 |

The transect width for each habitat category was calculated using a visibility survey. For this I stopped at ten random points within each habitat category. At each point, I walked into the bush at a right angle to the vehicle. A second person, sat in the middle row of the vehicle, watched me until I disappeared from sight completely then shouted for me to stop. A range finder was used to measure the distance I had travelled from the road. This was repeated on both sides of the vehicle at each point giving 20

transect widths for each habitat category. The mean transect width was calculated and used as the maximum distance at which ungulates could be reliably viewed for each habitat category. During analysis, only ungulates recorded within the transect width for that habitat category were included. For calculations, mean biomass figures were taken from Skinner (2005) for each ungulate species. The mean mass for males and females was used and when the recorded ungulate was of unknown sex, a mean of the male and female mass was used. The total biomass (kg/km$^2$) of ungulates seen on each transect line was calculated for each different habitat category using the following equation:-

$$\text{Biomass} = \frac{\text{Total mass of all individuals encountered (kg)}}{\text{Transect width (km)} \times \text{Distance of habitat category covered (km)}}$$

*3.4.3 Other large carnivore demography*

Mean minimum distance (km) travelled per night and home range size (km$^2$) was calculated for individual hyaenas as described in chapter 2. The data for Jaggedy and Smoothy were then compared with data for Spot and No.5. Habitat composition in each area of the reserve (the initial release site and main, open system) was estimated using representative transects (see Table 3.2).

Trail cameras were used to collect positional data for spotted hyaenas and lions. Two trail cameras (Moultrie Gamespy I 40 and Ranger 2MP mini trail camera) were positioned randomly along roads within and outside the home range areas of Spot and No.5 (for each camera, 13 locations, 315 camera trap days, January-October 2012) (see Figure 3.1). GPS coordinates were recorded for incidental sightings of lions and spotted hyaenas using a handheld GPS. Positional data were converted to UTM format in ArcGIS and mapped to show lion and spotted hyaena locations in relation to brown hyaena home ranges and locations over two month periods throughout the study.

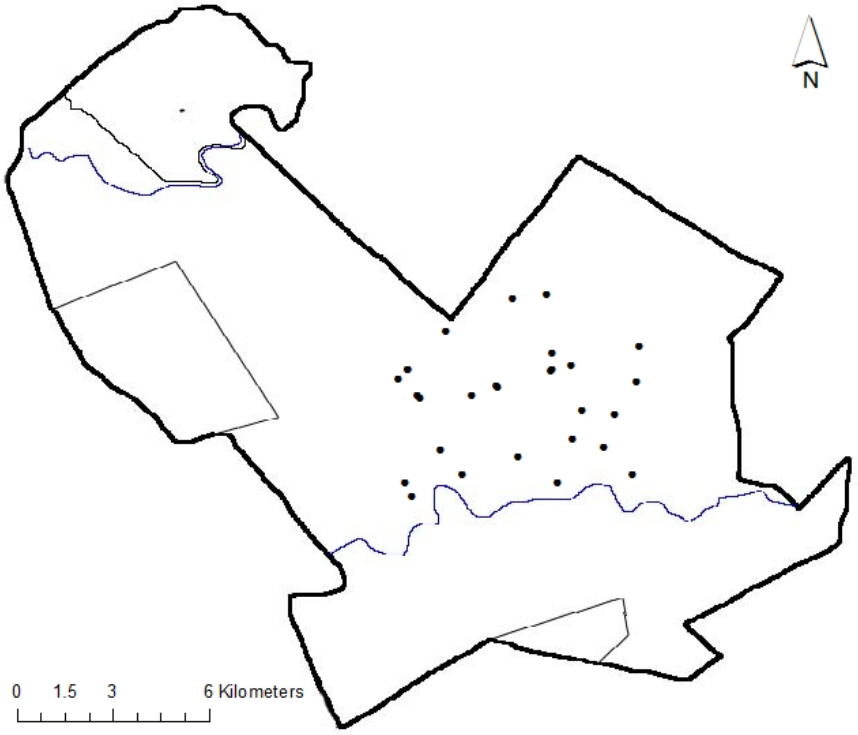



**Figure 3.1** Positions of two trail cameras set to record locations of spotted hyaenas and lions around the home ranges of brown hyaenas Spot and No.5.

Vegetation cover data collected at used (visited) and available (random) locations were assigned to one of three categories based on the mean visibility distance (see Table 3.3). For statistical analyses, data for the hyaenas living in the same part of the reserve were combined. Data from Jaggedy and Smoothy represented behaviour of brown hyaenas living in the absence of lions and spotted hyaenas, while data from Spot and No. 5 represented behaviour for those living in the presence of these large carnivores. Using a chi-squared test, the vegetation cover at nocturnal (used) locations was compared with data from available (random) points and the chi-squared value compared between the two groups of hyaenas. The use of roads was also compared for the pair of hyaenas living on the initial release area (without lions and spotted hyaenas) and the pair on the main, open system (with lions and spotted hyaenas).

**Table 3.3** Categories used to assess vegetation cover at a point.

| Mean distance (m) white disk travelled before disappearing | Vegetation cover category |
|---|---|
| 0 – 10 | Dense cover |
| 10-20 | Medium cover |
| >20 | Open cover |

*3.4.4 Feeding ecology*

Feeding data were collected randomly throughout the one year data collection period. During visits to the nocturnal GPS positions, all evidence of feeding was recorded. Data were also collected from trail cameras set up at various ungulate carcasses found during the study period. Food items were recorded during visits to the five dens used by breeding female Jaggedy. Counts were made of inedible food items such as horns and tusks and old carcasses were identified where possible. Further feeding data were collected from the trail camera (Ranger 2MP mini trail camera) set at the fifth and final den utilised by Jaggedy, Smoothy and the three cubs.

## 3.5 Results

*3.5.1 Habitat selection by brown hyaenas*

Habitat use was not random and both male Smoothy and female Jaggedy showed preference for some habitats over others (see Table 3.4). Riverine and drainage line habitats were used significantly more than expected as well as mixed eroded habitat. Jaggedy also used significantly less mixed shrub habitat than expected (see Table 3.4). Both hyaenas on the initial release site showed significant use of roads (see Table 3.4). In the main, open system, habitat use by No.5 and Spot was not significantly different to what was expected and no significant use of roads was recorded

**Table 3.4** Habitat and road use by the four brown hyaenas; Smoothy and Jaggedy were in the area without lions and spotted hyaenas and No.5 and Spot were in the area with lions and spotted hyaenas.

| Individual | Selection of habitat type | Habitat categories used significantly more | Habitat categories used significantly less | Selection of road use |
|---|---|---|---|---|
| Smoothy | Significant ($X^2$ = 14.39, p=0.0061, df=4) | Riverine & drainage ($X^2$ = 4.07, p=0.0436, df=1)<br>Mixed eroded ($X^2$ = 5.13, p=0.0235, df=1) | n/a | Significant ($X^2$ = 118.65, p<0.0001, df=1) |
| Jaggedy | Significant ($X^2$ = 26.16, p<0.0001, df=4) | Riverine & drainage ($X^2$ = 13.35, p=0.0003, df=1)<br>Mixed eroded ($X^2$ = 5.13, p=0.0235, df=1) | Mixed shrub ($X^2$ = 10.01, p=0.0016, df=1) | Significant ($X^2$ = 105.37, p<0.0001, df=1) |
| No. 5 | Not significant ($X^2$ = 3.89, p=0.274, df=3) | n/a | n/a | Not significant ($X^2$ = 2.28, p=0.1311, df=1) |
| Spot | Not significant ($X^2$ = 0.43, p=0.9344, df=3) | n/a | n/a | Not significant ($X^2$ = 2.76, p=0.0964, df=1) |

by individual hyaenas (see Table 3.4). Signs of hyaena presence were found at 38.4 % of all used (visited) sites (n=219) and 1.4 % of all available (random) sites (n=365) (see Figure 3.2). Spoor was the most common sign of hyaena presence at visited sites (see Figure 3.2).

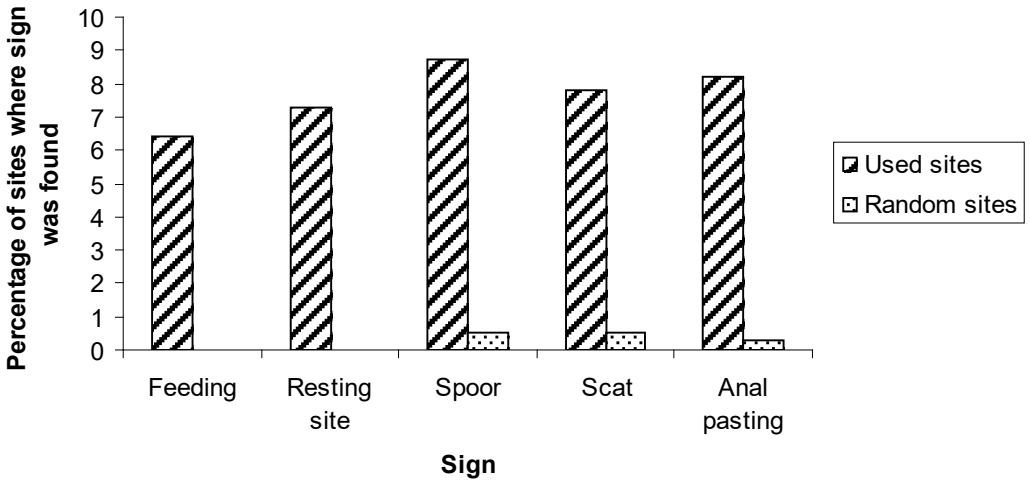



**Figure 3.2** Signs of brown hyaena presence found at used and available locations during habitat analysis.

*3.5.2 Food dispersion*

Mixed bushveld shrub habitat contained the highest biomass of ungulates on both the initial release site and the open, main system. *Mopane*-associated habitats supported the lowest ungulate biomass in both reserve sections (*Mopane/Combretum* mix in the open system and *Mopane* dominated in the initial release site). The initial release site supported a higher biomass of ungulate species in every habitat category than the main, open system (see Table 3.5).

*3.5.3 Other large carnivore demography*

The hyaenas (No.5 and Spot) living with the presence of lions and spotted hyaenas travelled a mean minimum distance of 11.2 km per night and both covered more than 30 km in one night on occasions. Their home range sizes (90% isopleth) were 45.3 $km^2$ (male No.5) and 50.4 $km^2$ (female Spot). The two hyaenas (Smoothy and Jaggedy) living with an absence of these large carnivores travelled a mean minimum distance of 9.3 km per night and only a maximum distance of up to 22.3 km in one night. Home

range sizes (90% isopleth) for these individual hyaenas were 19.1 $km^2$ (male Smoothy) and 15.0 $km^2$ (female Jaggedy). Figures 3.3 to 3.11 show the locations of spotted hyaenas and lions compared to brown hyaena locations and home ranges during consecutive two month periods of the study.

**Table 3.5** Calculated mean ungulate biomasses (± standard error) for different habitat categories in the study area in the presence and absence of large predators.

| Habitat category | Mean ungulate biomass (kg/$km^2$) on main open system | Mean ungulate biomass (kg/$km^2$) on initial release site | Overall mean ungulate biomass (kg/$km^2$) |
|---|---|---|---|
| Mixed bushveld tall | 2391 ± 303 | 6169 ± 849 | 3364 ± 372 |
| Mixed bushveld shrub | 27,555 ± 7433 | 76,335 ± 36,794 | 38,629 ± 10,245 |
| Mixed bushveld eroded | 478 ± 238 | 22,007 ± 9138 | 7383 ± 3195 |
| Riverine | 1207 ± 617 | n/a* | n/a |
| Drainage line | 3326 ± 1219 | 12,412 ± 12412 | 5556 ± 3167 |
| *Mopane/ Combretum* mixed | 256 ± 256 | 3585 ± 1802 | 1888 ± 916 |
| *Mopane* dominated | 2586 ± 2586 | 3097 ± 1605 | 2750 ± 1820 |
| Open grassland | 5762 ± 2795 | n/a* | n/a |

n/a* Habitat category not represented in transect

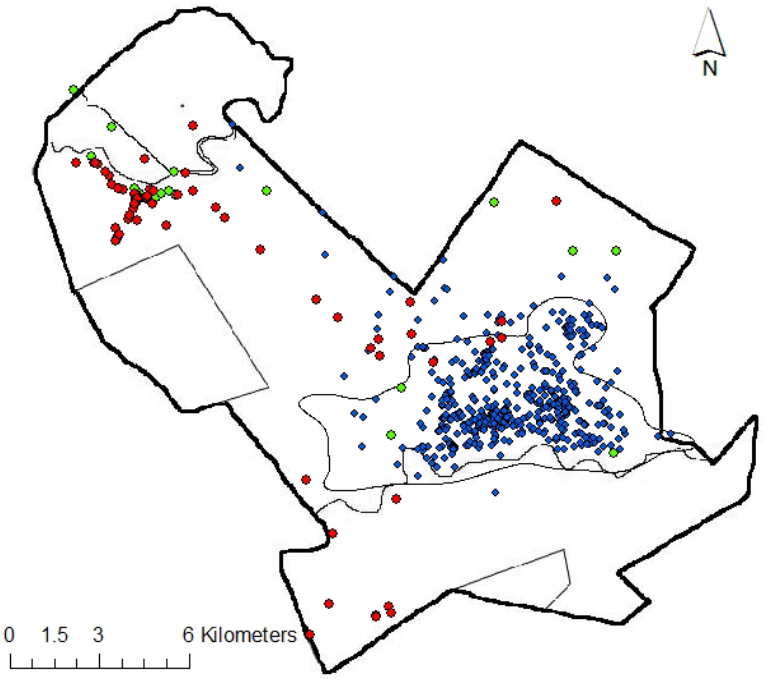



**Figure 3.3** Home range (90% isopleth) for entire study period and locations for brown hyaena male No.5 (blue), spotted hyaenas (red) and lions (green) for days 59 to 118 post release.

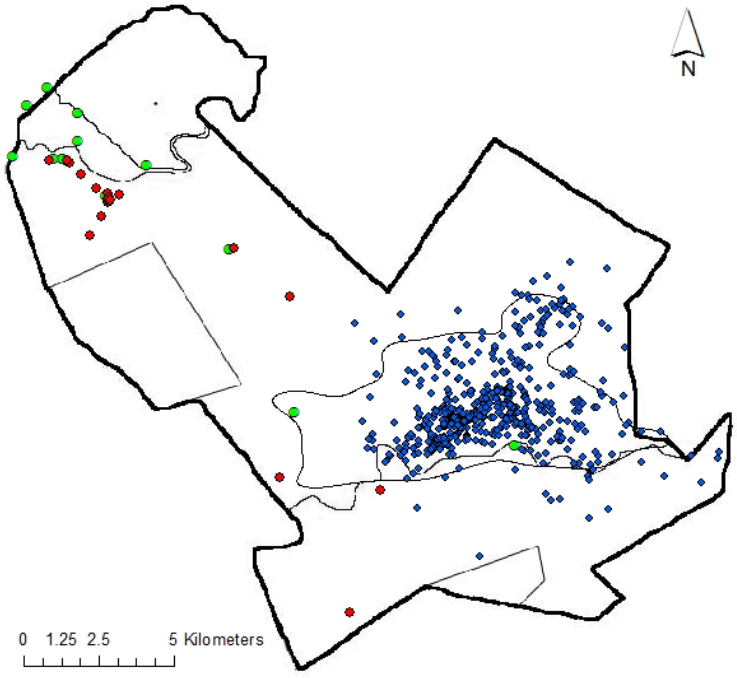



**Figure 3.4** Home range (90% isopleth) for entire study period and locations for brown hyaena male No.5 (blue), spotted hyaenas (red) and lions (green) for days 119 to 179 post release.

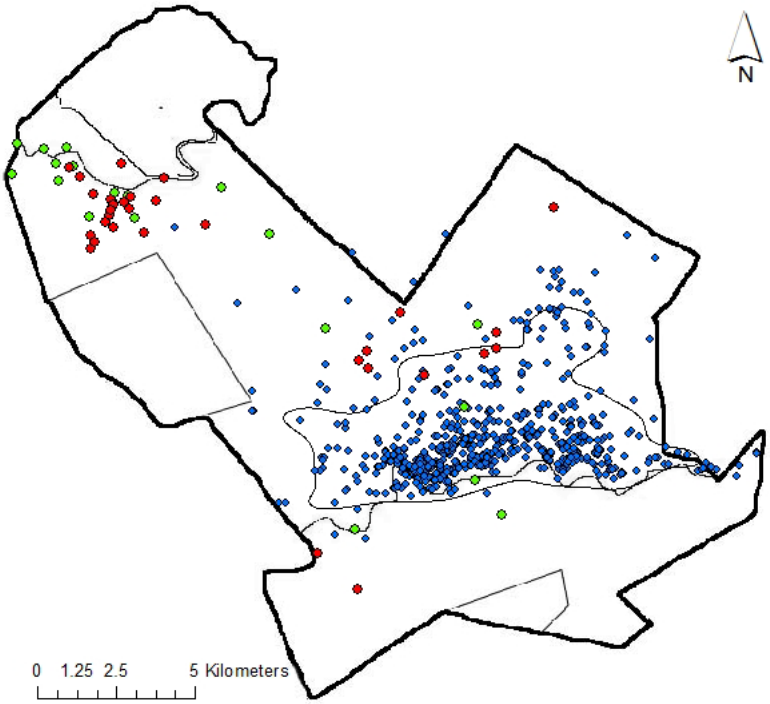



**Figure 3.5** Home range (90% isopleth) for entire study period and locations for brown hyaena male No.5 (blue), spotted hyaenas (red) and lions (green) for days 180 to 240 post release.

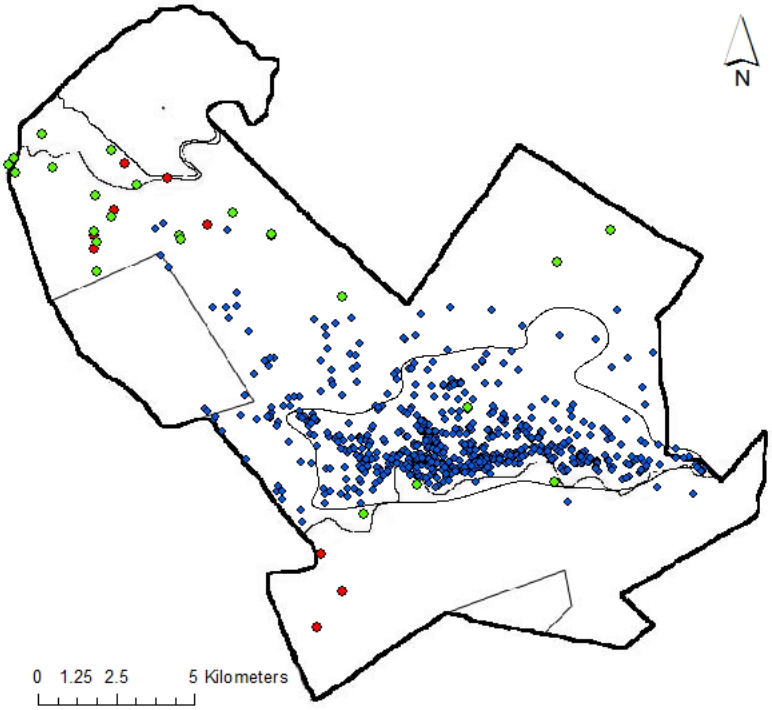



**Figure 3.6** Home range (90% isopleth) for entire study period and locations for brown hyaena male No.5 (blue), spotted hyaenas (red) and lions (green) for days 241 to 301 post release.

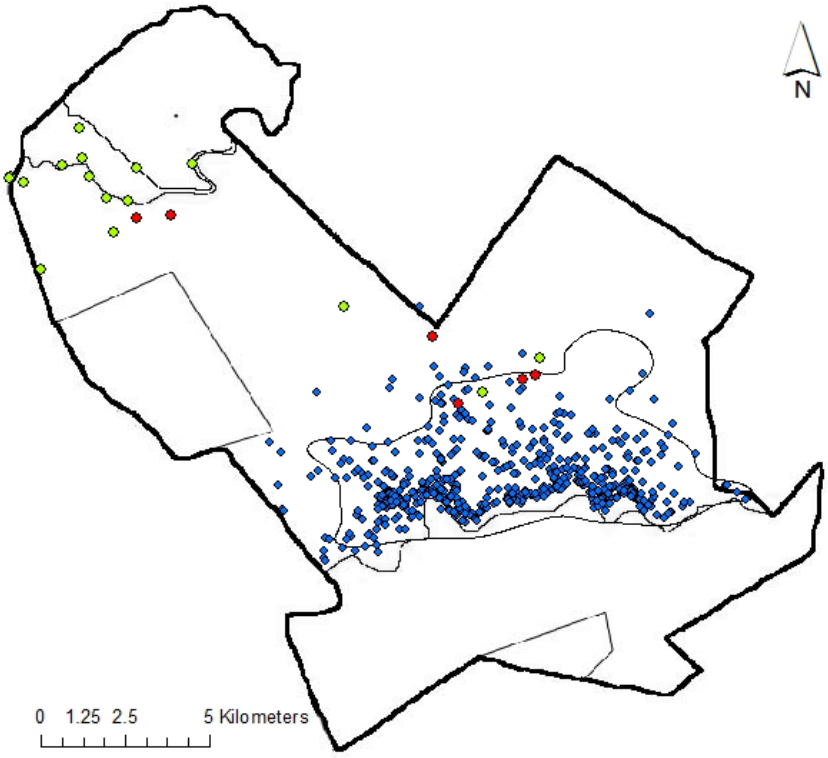



**Figure 3.7** Home range (90% isopleth) for entire study period and locations for brown hyaena male No.5 (blue), spotted hyaenas (red) and lions (green) for days 302 to 363 post release.

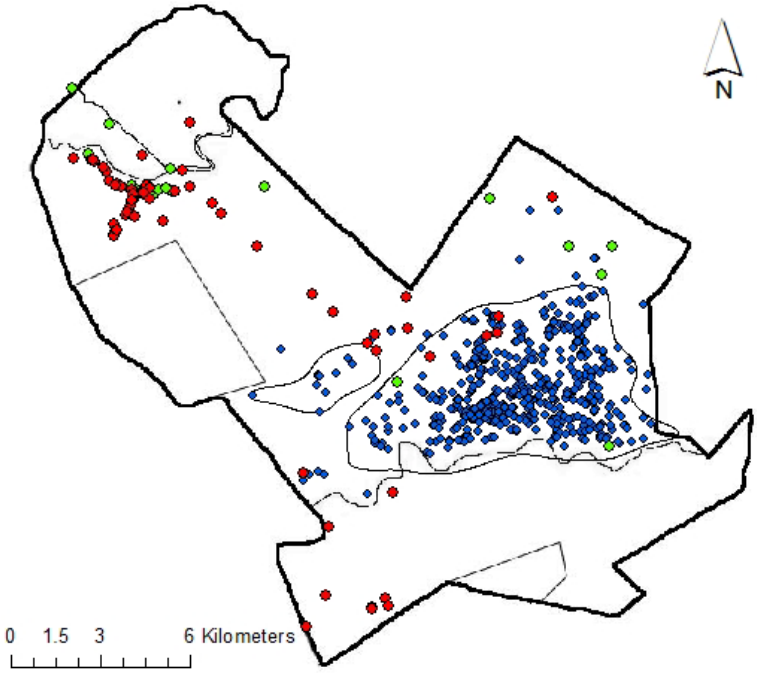



**Figure 3.8** Home range (90% isopleth) for entire study period and locations for brown hyaena female Spot (blue), spotted hyaenas (red) and lions (green) for days 59 to 118 post release.

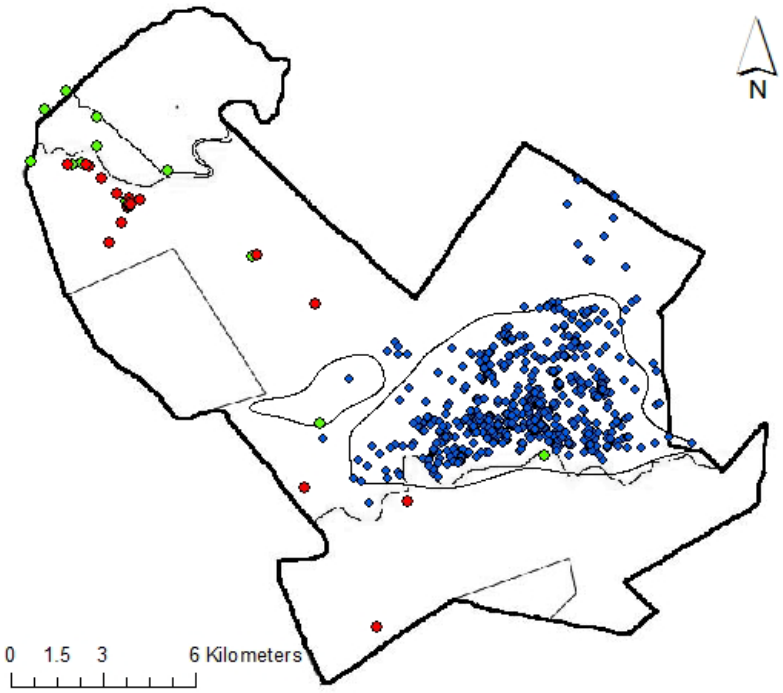



**Figure 3.9** Home range (90% isopleth) for entire study period and locations for brown hyaena female Spot (blue), spotted hyaenas (red) and lions (green) for days 119 to 179 post release.

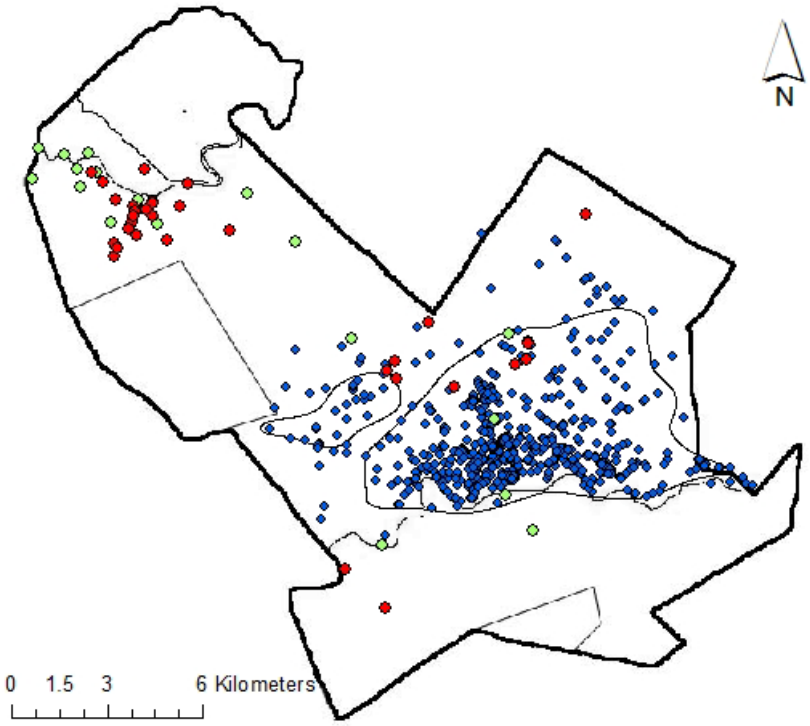



**Figure 3.10** Home range (90% isopleth) for entire study period and locations for brown hyaena female Spot (blue), spotted hyaenas (red) and lions (green) for days 180 to 240 post release.

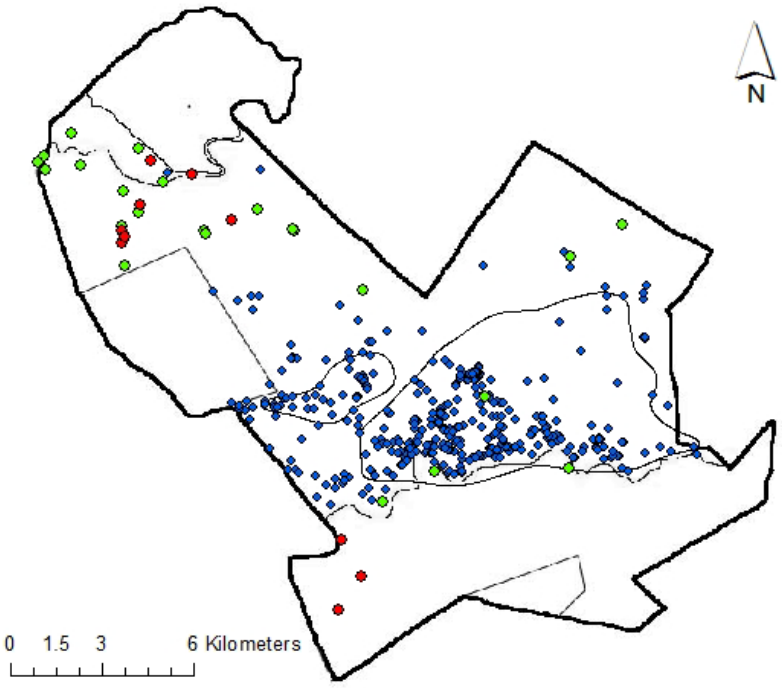



**Figure 3.11** Home range (90% isopleth) for entire study period and locations for brown hyaena female Spot (blue), spotted hyaenas (red) and lions (green) for days 241 to 279 post release.

Maps show that the selected home ranges of brown hyaenas (90% isopleths) incorporate areas used by both lions and spotted hyaenas. Concentrations of these two other carnivores do appear to be greater outside the brown hyaena home ranges. At some trail camera positions, brown hyaenas, lions and spotted hyaenas were all photographed travelling the same road over the period the camera was set.

The two brown hyaenas on the initial release site (without lions and spotted hyaenas) used significantly more open habitats than expected ($X^2$ = 43.02, $p<0.0001$, df=1). The pair of brown hyaenas in the main, open system showed no significant use of a particular vegetation cover ($X^2$ = 3.19, p=0.0742, df=2). When the data for each hyaena pair were combined, significant use of roads was recorded both on the initial release site ($X^2$ = 223.82, $p<0.0001$, df=1) and on the main, open system ($X^2$ = 5.04, p=0.0248, df=1). The significance is much greater for the pair on the initial release site (without lions and spotted hyaenas) than for the pair on the main, open system who lived in the presence of these large carnivores.

*3.5.4 Feeding ecology*

The hyaenas fed on a variety of vertebrate species including large and small mammals, birds and reptiles. Data collection was limited and the mammal species recorded made up only 13.5% of the mammal species present in the study area (see Table 3.6). Biomass and frequency figures (90.3% of all food items recorded) suggest mammal remains are the most important food resource for brown hyaenas in the Lowveld bushveld (see Table 3.6). Warthog remains were the most commonly recorded food source (see Figure 3.12).



**Figure 3.12** The remains of four warthog carcasses of varying age found at a brown hyaena den in the Lowveld bushveld, South Africa.

Large and small mammal (including African civet (*Civettictis civetta*); see Figure 3.13) and reptile remains were found at both nocturnal feeding sites



**Figure 3.13** One of three African civet carcasses found at a brown hyaena den in the Lowveld bushveld, South Africa.

**Table 3.6** Food items recorded at nocturnal GPS positions and dens for four translocated brown hyaenas over a 380 day period.

| **Prey item** | **Number of observations at nocturnal GPS positions** | | **Number of observations at den** | **% frequency total** |
|---|---|---|---|---|
| | Initial release site | Main open system | | |
| Large mammals | | | | |
| 1. Nyala (*Tragelaphus angasi*) | 1 | 2 | 1 | 12.9 |
| 2. Warthog (*Phaocochoerus africanus*) | 0 | 0 | 9 | 29.0 |
| 3. Impala (*Aepyceros melampus*) | 0 | 0 | 2 | 6.5 |
| 4. Blue wildebeest (*Connochaetes taurinus*) | 1 | 1 | 1 | 9.7 |
| 5. Giraffe (*Giraffa camelopardalis*) | 2* | 1 | 0 | 9.7 |
| Small mammals | | | | |
| 1. African civet (*Civettictis civetta*) | 0 | 0 | 3 | 9.7 |
| 2. Porcupine (*Hystrix africaeaustralis*) | 0 | 0 | 1 | 3.2 |
| Reptiles | | | | |
| 1. African rock python (*Python natalensis*) | 0 | 0 | 1 | 3.2 |
| 2. Monitor lizard (*Varanus albigularis*) | 1 | 0 | 0 | 3.2 |
| Birds | | | | |
| 1. Guinea fowl (*Numida meleagris*) | 0 | 1 | 0 | 3.2 |
| Unidentified mammal | 2 | 1 | 0 | 9.7 |

* Both occasions were at the same carcass but on different night

and the den. Bird remains were only recorded at nocturnal feeding sites. No direct feeding observations were made after release so it is not possible to say whether food items were predated or scavenged. The hyaenas were photographed feeding at two giraffe carcasses; one on the main, open system over a period of three days and one on the initial release site over a period of three weeks (see Figure 3.14).




**Figure 3.14** Brown hyaena visiting a giraffe carcass.

At 15 months old, one juvenile was photographed (Moultrie Gamespy I 40 trail camera) feeding on an impala carcass alongside its mother Jaggedy. Large mammal remains were taken to the den by adults for the cubs. Eating took place outside the den but items were also dragged inside. Outside the den there appeared to be one 'bone pile', five metres from the entrance, where most bones and food items were accumulated.

Direct observations were made of hyaenas feeding on fresh impala carcasses in the boma prior to release. The testicles were selected first for consumption in almost all cases followed by the penis. One hyaena (Gismo) always collected a leg and cached it before returning to feed on the main carcass (see Figure 3.15).



**Figure 3.15** Young, female brown hyaena caching an impala leg from carcass provided in holding boma.

## 3.6 Discussion

This study gave a unique opportunity to investigate the decisions that brown hyaenas made in the absence of any existing individuals to influence their movements. I can be confident that the behaviour the translocated individuals exhibited was a result of their own choices and not influenced in any way by an already resident population. I can assume that the factors discussed here, in terms of food dispersion and other large carnivores, are what really influenced their movements and the locations selected for their home ranges.

### Habitat selection

My hypothesis was supported by two of the hyaenas who selected particular habitats to utilise more than others. It is possible that riverine and drainage line habitats provided suitable food items (small items not counted in ungulate density transects) for the hyaenas. Habitat selection did not appear to be influenced by food availability of large ungulate species, as over-utilised habitats were not those with the highest ungulate densities.

### Food dispersion

No relationship was found between the habitats that hyaenas utilised and the biomass of live ungulates in those habitats. My hypothesis was not

supported as hyaenas did not select the habitats with the highest ungulate densities. In the southern Kalahari, the biomass of ungulates in a hyaena's territory is not important; more important is the average distance between successively available food sites, which is significantly correlated with territory size (Mills 1982b). If smaller food items class as 'food sites' then distribution of these may be more influential to the habitats and ranges the hyaenas use than the biomass of the large ungulates counted during transects.

The mean ungulate biomass (kg/km$^2$) was consistently higher on the initial release site, in all habitat types, and individual brown hyaena home ranges were also considerably smaller there than the main, open system. It is likely that larger numbers of ungulates in the study area meant more food was available overall to the hyaenas at the initial release site. Travelling larger distances and utilising larger home ranges may be necessary for hyaenas on the main, open system to obtain food occurring in lower densities and further apart than on the initial release site. In the southern Kalahari however there was no relationship between territory size and biomass of ungulates in a territory (Mills 1982b).

It is not possible to draw a full conclusion due to the existence of other potentially contributing factors such as the presence or absence of other large carnivores and both internal and external fences at the release site. The fact that hyaenas did not show a very strong pattern of habitat selection most likely reflects their behaviour as generalist carnivores.

**Interactions with other large carnivores**

My hypothesis was partially supported. Brown hyaenas do not avoid all areas with lions and spotted hyaenas but do appear to focus their activities in areas where concentrations of these large carnivores are lower. Conclusions must be drawn carefully as monitoring of lions and spotted hyaenas across the study area was not uniform. I spent a lot more time driving in the northern section of the reserve, thereby increasing my chances of lion and spotted hyaena sightings there. Areas in the south of the reserve were monitored much more sporadically and some data relied on trail cameras. No cameras were set south of the Makutsi river so large

carnivore activity here is likely to be grossly under estimated (see Figure 3.1).

As I hypothesised, brown hyaenas used roads less often in areas where lions and spotted hyaenas were present than areas where they were absent. For a brown hyaena, travelling on a road may increase vulnerability by increasing the probability of detection by a lion or spotted hyaena.

Habitat type was similar on both the initial release site and the main, open system, (see Table 3.2), so it is unlikely that the observed differences in movement behaviour between hyaenas are related to habitat differences. Linear habitat such as riverine vegetation is under-estimated on the initial release site transect due to the absence of roads near the river. The initial release site also contained more *Mopane*-associated habitats than the main, open system but this did not appear to be a habitat particularly important (or selected for) by the brown hyaenas.

Large predator presence may not be the only factor affecting movements and home range size in brown hyaenas. Food dispersion and the presence of internal and external fences at the release site may also influence these data.

**Feeding ecology**

My hypothesis was partially supported; the hyaenas fed on a wide range of species including mammals, reptiles and birds, but no insects or fruits were recorded. Mammal remains were from both large and small species and found on both reserve sections. This study documents the first record of African civet (*Civettictis civetta*) forming part of brown hyaena diet. Differences are apparent between this and past feeding studies (Mills 1978; Mills & Mills 1978; Owens & Owens 1978; Mills 1982b; Maude 2005). Some food items recorded from the Kalahari are not present in the Lowveld bushveld habitat such as springhares (*Pedetes capensis*) and bat-eared foxes (*Otocyon megalotis*). Collection methods in this study were limited, which probably explains why I recorded a smaller range of species consumed. Faecal analysis may widen the range of species recorded in the diet of brown hyaenas in the Lowveld bushveld habitat. Although faeces were collected during the study, to date I do not have enough for analysis.

Recording food items found at the den gives a good guide to the food that cubs are fed by adults but gives no indication of how the food was acquired. Due to the translocation nature of this study, interference with the hyaenas was kept to an absolute minimum. Following hyaenas at night is valuable to quantify methods of prey acquisition but the terrain and thick vegetation cover of the bushveld would make this impossible. All incidental sightings (14) during the study period were of individual animals, suggesting that brown hyaenas generally forage alone in the Lowveld bushveld habitat; this is also the case in the southern and central Kalahari (Mills 1978; Mills & Mills 1978) and Namib desert (Skinner *et al*. 1995).

In the southern Kalahari, lions were found to provide more carcasses to brown hyaenas than any other agent (Mills 1978). This study shows brown hyaenas are not solely dependent on these carcasses or those from spotted hyaenas and large vertebrate species are still utilised in their absence. Hyaenas on the initial release site fed on carcasses resulting from natural deaths and probably leopard's kills and small pieces of carrion (Mills 1978). I believe the presence of leopards is beneficial to this hyaena group, as many warthog carcasses were recorded at the den, a prey resource regularly used by leopards in this biome (pers obs). Brown hyaenas have been seen chasing leopards off their own kills on numerous occasions (Owens & Owens 1978). In the Kalahari, seasonality has been found to affect brown hyaena feeding habits with more hunting taking place in the dry season when the absence of large predators leads to reduced availability of carrion (Owens & Owens 1978; Mills 1982b). It is possible that the absence of large predators on the initial release site meant the brown hyaenas ranging there hunted more regularly.

## 3.7 Conclusion

It appears that brown hyaenas may select to use certain habitat types over others in the Lowveld bushveld biome. Some individuals show a preference for riverine and drainage line habitats as well as mixed eroded habitat. Habitat selection is not associated with ungulate density, and so small food items and the distance between them may be more important to

hyaenas than overall ungulate density. Habitat selection may also be related to finding suitable habitats for resting and denning.

Brown hyaenas in this biome can survive and establish in the presence of lions and spotted hyaenas but appear to range in areas where the concentrations of these large carnivores are lower. Brown hyaenas select to use roads in this biome but individuals living amongst spotted hyaenas and lions use roads to a lesser extent. In the absence of these other large carnivores, brown hyaenas also use more open habitats than expected. Brown hyaenas feed on a wide range of food items, predominantly large and small mammals but also birds and reptiles. The extent to which food is hunted or scavenged is unknown but brown hyaenas are not reliant on the carcasses produced by lions and spotted hyaenas.

# Discussion

As the fragmentation of wildlife areas increases, there is an increasing need to use intrusive management practices such as translocation. In some instances, translocation may provide the only option to secure a species' future survival (Spalton *et al*. 1999) and is increasingly used to remove problem animals (Fritts *et al*. 1984; Blanchard & Knight 1995; Mosillo *et al*. 1999; Sullivan *et al*. 2004).

## Determination of translocation success

A variety of factors are used to assess the success or failure of a translocation attempt. Survival and establishment are the main measures (Kleiman *et al*. 1991; Woodroffe & Ginsberg 1999) but survival long enough to breed is a further consideration (Sarrazin & Barbault 1996). All these criteria were met for the four individuals monitored in this study. All animals survived, formed a home range within the boundaries of the release site, and at least one group successfully reared three cubs. Preliminary conclusions indicate success (see Table 4.1); it appears that this population is likely to be established long-term, and that translocation may be an appropriate way to resolve human: brown hyaena conflicts in the future.

**Table 4.1** Measures of how this study met various criteria determining translocation success.

| Criteria* | Requirement for success | Preliminary status for this study |
|---|---|---|
| Survival | Long enough to breed | Success |
| Establishment | In the area where they were released | Success |
| Conflict | Does not continue at release site | Success |
| Observations | Incidental observations recorded within the vicinity of the release area | Success |
| Reproduction | Should be successful | Success |

* These criteria were based on Kleiman *et al.* 1991; Sarrazin & Barbault 1996; Woodfoffe & Ginsberg 1999; IUCN 2012

**Ecology of the brown hyaena in the Lowveld bushveld biome**

Most of the data on brown hyaena ecology is from the arid habitats with which they are most commonly associated (Skinner 1976; Skinner & Chimimba 2005). However, brown hyaenas are not confined to desert habitats and I have shown that the Lowveld bushveld biome is also suitable for them in the southern African sub-region. I present the first data on brown hyaena ecology in this biome where they survived and reproduced using a variety of habitats and food resources and in the presence of other large carnivores. I have presented information on movement patterns and home range sizes, increased knowledge on the habitats brown hyaenas use and discussed factors which may affect habitat selection. The first information on denning behaviour, reproductive success and feeding behaviour is presented for this biome.

These initial investigations suggest an association between brown hyaena ecology and rainfall. My data represent hyaena ecology at the upper end of a range, in a biome with the highest mean annual rainfall (see Table 4.2). Brown hyaenas use larger home ranges in arid areas and home ranges in the Lowveld bushveld biome are the smallest; the distances travelled in a night do not vary dramatically. Food distribution determines brown hyaena home range size and the average distances travelled between mammal food items are significantly correlated with territory size (Mills 1982b). In areas with lower rainfall, food resources may be more sparsely distributed, meaning brown hyaenas travel larger distances and range further to fulfil their feeding needs.

From the limited data collected, brown hyaena diet was not found to vary significantly between regions and mammals still formed the majority of their diet in the Lowveld bushveld. I confirmed that both male and female brown hyaena adults carried food back to the den to support their cubs. Breeding behaviour in the Lowveld bushveld may be more similar to that exhibited in the southern Kalahari than the central Kalahari, where fewer cubs are born per litter and only adult females take food to the den (Owens & Owens 1978).

**Table 4.2** Conclusions from this study compared to more arid and open habitats.

| Location | Mean annual rainfall (mm) | Range and/or mean for home-range size ($km^2$) | Range and/or mean for minimum distance (km) travelled per night | Predominant diet | No. of cubs per litter (n) |
|---|---|---|---|---|---|
| Lowveld bushveld[a] South Africa | 550 | 15.0 – 50.4 (ẋ=32.5, n=4 individuals) | 0.06 – 33.4 (ẋ=10.2, n=4 individuals) | Large mammal remains | 3 (1) |
| Makgadikgadi region[b] Botswana | 450 | 135 – 447 (ẋ=192, n=8 individuals) | (ẋ=37.6, n=4 individuals) | Large mammal remains | n/a |
| Central Kalahari[c] Botswana | 390 | ẋ=40, n=4 individuals | 10 – 30 (wet-dry season) | Large mammal remains Consumption of plant material high in dry season | 1.25 (4) |
| Southern Kalahari[d] South Africa & Botswana | 220 | 235 – 481 (ẋ=330, n=6 groups) | 1.5 – 54.4 (ẋ=32, n=1 individual) | Large mammal remains 39-50% | 3 (7) |
| Namib desert[e] Namibia | <100 | 31.9 – 220 (n=5 individuals) | ẋ = 12.9 – 19.9 (wet season-dry season) (n=5 individuals) | Large mammal remains (Cape fur seals) | n/a |

[a]Present study
[b]Maude 2005
[c] Owens & Owens 1978; Owens & Owens 1979
[d]Mills 1978; Mills 1982a; Mills 1982b; Mills & Mills 1978
[e]Skinner *et al*. 1995

Brown hyaenas in the Limpopo province favour rocky mountainous areas and are absent as a breeding population from reserves surrounding the Kruger National Park (Skinner 1976). The suggested, preferred habitat was absent in the study area but the hyaenas still established home ranges and successfully reared young. Data were only available from one previous translocation study and I have added to that through this study. Although 30 animals were moved over a nine year period in the earlier study, only five were monitored and data collected for three (Skinner & van Aarde 1976). Hyaenas were fitted with radio collars while I used GPS collars and home range size was estimated using the MCP method; I additionally presented home range data using the kernel distribution method. Like my own study, Skinner and van Aarde (1976) showed large variation between the home range size of individuals but the range between translocated animals was similar to those for the Lowveld bushveld biome (Table 4.3).

**Table 4.3** Comparison of brown hyaena ecology in Lowveld bushveld habitat and the Transvaal following translocation.

| Location | No. of individuals monitored | Range and mean for home-range area ($km^2$) | Range & mean for minimum distance (km) travelled per night | Main habitats utilised |
|---|---|---|---|---|
| Lowveld bushveld, South Africa | 4 | 15 – 50.4 (ẋ=32.5) | 0.06 – 33.4 (ẋ=10.2) | Mixed bushveld and associated habitats, particularly riverine habitats and drainage lines |
| Transvaal, South Africa | 3 | 5.5 - 48.9 (ẋ=21.1) | 8.4 – 22.6 (ẋ=12.5) | Mountainous slopes and valleys and agricultural flatlands |

Skinner and van Aarde (1976) found that their released hyaenas used mountainous slopes and valleys and agricultural flatlands. None of these

habitats were available in my study area. Instead brown hyaenas lived in mixed bushveld and its associated habitats, of which riverine habitat and drainage lines appeared to be particularly favoured as well as mixed eroded habitat.

My study presents the first data on successful reproduction following brown hyaena translocation. It appears that brown hyaena ecology in the Lowveld bushveld may be more similar to that in the Transvaal than the more arid Kalahari and Namib desert regions (see Tables 4.2 and 4.3). Both translocation studies concluded that brown hyaenas can establish and maintain themselves if conditions at the release site are suitable. I have shown that brown hyaenas are highly adaptable and suggest that current habitats used by brown hyaenas are perhaps more refuge habitats than true indications of the wider range of habitats they have occupied in the past. Although Skinner and van Aarde (1976) suggested agricultural development is advantageous to brown hyaenas, in my study it was not necessary for successful translocation.

With confirmation of the Lowveld bushveld being a suitable habitat for brown hyaenas, I make the first estimate of the densities at which the species can exist in this biome. It is likely that the release site could support a higher number of brown hyaenas than just the five which were translocated. I hypothesise two more social groups could be supported at the release site based on a group range of around 70km$^2$ not overlapping with any other group. This range should be considered the minimum space required as data are based on only two adults per group and although one group had three cubs, they were still young during the study period. A social group with more individuals or one supporting juveniles or sub-adults may need to increase their range beyond this estimate to find the necessary resources. This group range estimation does not include any spatial data from the fifth released hyaena, Gismo, whose collar malfunctioned. There were 14 incidental sightings of collared brown hyaenas during the study period. The identity of the hyaena was only confirmed on one occasion and so it is possible that Gismo survived and was seen alive during the study. From many of the photos taken by the trail camera at the final den, it was not possible to identify individuals. If Gismo survived she may have joined

this (or the other) social group and the estimated group range may be different if her data were also included.

**Limitations of the study**

The small number of animals translocated made it difficult to draw conclusions for the species as a whole and also compare the effect of particular factors on the hyaena's behaviour. On the other hand, low numbers may have been a key reason for success because brown hyaenas exist in relatively low densities. Moving more hyaenas into the release site may have resulted in translocation failure. In the holding boma, large numbers may have caused conflict and potentially death, especially because it is likely that some of the hyaenas did not have prior knowledge of each other before translocation. The young age (approximately 6 months when released into boma) of two of the hyaenas may have been helpful in reducing conflict in the boma; a different outcome could have resulted from five adults being placed together. Post release survivability might have decreased if the release site was saturated, causing erratic movements as hyaenas tried to find their own space.

It would have been beneficial from a scientific perspective to have a resident population of brown hyaenas with which movement patterns and ecology could be compared. It is hard to conclude which of the behaviours I recorded were a direct result of translocation and what would occur for a naturally existing population at the release site. Again however, the absence of a resident group could be another reason why this translocation was a success. Historical farming on the land was believed to be the cause for initial population decline. Although some land has since moved across to conservation, much of the surrounding area is still farmland, preventing natural recolonisation by brown hyaenas. Three individuals were seen moving through the study site in the years before translocation but the lack of viable breeding partners and potential clan members may have prevented establishment.

The hyaenas I released were wild-caught and so it is probable that their behaviour post-release indicates how brown hyaenas will behave naturally in this biome. However, the presence of both internal and external

fences could have influenced their behaviour following translocation. Although internal fences were crossed successfully, the natural boundary they form may have limited overall range use if fences were only crossed for important or specific reasons.

The costs associated with translocation and monitoring should be considered as, although this release was successful, the funding required may not make it a viable option in all circumstances (see Table 4.4). Costs for this study included feeding of hyaenas in the boma, veterinary bills to fit collars, GPS enabled collars and costs associated with monthly contracts and the receiving of data. Costs were reduced substantially because the holding boma had already been constructed for earlier releases of other species; building a boma specifically for this release would have added substantially to the overall costs. Staff time, fuel and basic equipment were required for the monitoring of habitat selection and ungulate densities and trail cameras and batteries were needed to collect data on the spatial distribution of other large predators and hyaena feeding behaviour. It should be noted that the holding time in the boma (12 months for this study) could potentially be shortened if hyaenas are at least 18 months old when translocated.

**Translocation as a method for experimental study**

Translocation presented the opportunity to fit GPS collars to brown hyaenas and subsequently monitor movements and associated behaviours. Data collected post release gave the opportunity to address fundamental questions about brown hyaena ecology in this biome which would not have been possible without the translocation. One factor studied was brown hyaena movements in relation to lions and spotted hyaenas. Although brown hyaenas avoid lions and are wary of spotted hyaenas in more open habitats (Owens & Owens 1978; Mills 1982b), I have shown that brown hyaenas in the Lowveld bushveld habitat use areas where both these carnivores are present. Furthermore, in this biome brown hyaenas do not require the kills made by spotted hyaenas and lions as a food source. The two brown hyaenas that ranged on the initial release site showed that

survival, establishment and reproduction were all possible in the absence of these large carnivores and hence the carcasses they provide.

**Table 4.4** Costs for translocation and post release monitoring of four brown hyaenas (including the 12 month holding period in boma prior to soft release).

| | **Initial translocation[a]** | **Post release monitoring[b]** |
|---|---|---|
| Staff | 4 hours per week | 20 hours per week |
| Transport (staff, food procurement) | $5,475 | $611 |
| Equipment (in boma and for monitoring) | $100 | $15,259 |
| Veterinary care (darting and collaring) | $2,593 | n/a |
| Brown hyaenas | n/a | n/a |
| Total (excluding staff time) | $8,168 | $15, 870 |

Costs were converted from South African rand and Euros to US$ using the exchange rate on the 4th June 2013.

**Staff costs included**: Hours per week required to carry out necessary [a]feeding and monitoring in boma. [b]Habitat analysis, ungulate biomass transects, monitoring of other large carnivores, trail camera management
**Transport costs included**: [a]Fuel to obtain food for hyaenas in boma and cost of impala based on R700 for each animal fed every 5th day for a period of 12 months. [b]Fuel costs for habitat analysis, ungulate biomass transects and trail camera management
**Equipment costs included**: [a]Cage trap for capture of hyaenas in boma. [b]4 x GPS enabled collars sending data via GSM network, digital rangefinder for ungulate density counts, 3 x trail cameras and batteries for large carnivore monitoring and feeding data collection
**Veterinary care costs included**: [a]Three vet call-outs for darting, anaesthesia, collar fitting and re-fitting following collar malfunction
**Brown hyaena costs**: As all brown hyaenas were donated, no costs were incurred

### Translocation as a method to address conflict issues

Translocation is associated with poor success rates in dealing with conflict animals due to high post-release mortality, homing behaviour and the resumption of conflict behaviour (Seddon *et al*. 2012). In this study, translocation was a useful technique for resolving conflict without the occurrence of any of these problems. Agricultural land poses a threat for brown hyaenas due to conflict with livestock farmers. Recent conservation assessments suggest brown hyaena numbers may be increasing where land use has shifted from intensive agriculture to wildlife farming (Friedmann

& Daly 2004). Although occasional individuals become adept at killing livestock (Skinner 1976), brown hyaenas are unfairly blamed and persecuted in many cases. Some hyaenas which are destroyed are probably not livestock killers. Translocation provides an alternative to destruction while removing the conflict and ensuring maintenance of a sustainable population of the species.

The welfare implications of translocation should be considered before it is used as a method to reduce conflict (Kleiman *et al*. 1991; Woodroffe & Ginsberg 1999). Four of the five animals in this study were confirmed to survive and none appeared to suffer any long-lasting negative effects from translocation. When the collar was removed from Jaggedy, the only evidence of its presence was flattened hair. No wounds or sores were visible and the hyaena was in excellent condition. The fate of the fifth individual is unknown due to collar malfunction but this individual may also have survived.

**Contribution to translocation knowledge from this study**

Translocation is now a well used tool for conservation and as its use increases we need to learn from every attempt through careful monitoring (Seddon *et al*. 2012). In some cases the translocated species is endangered and it is unacceptable to lose individuals due to poor methods. Mistakes must be rectified and lead to improvements in methodology and techniques. The ability of translocated individuals to survive and establish varies between species, age at release, release procedures and release site characteristics (Woodroffe & Ginsberg 1999; Moehrenschlager & Macdonald 2003). Broad scale guidelines detail translocation techniques which maximise the chances of success (see Table 4.5) but species specific recommendations are lacking (Lewis *et al*. 2012).

**Table 4.5** Meeting of this study with general recommended translocation methods.

| Criteria* | Recommendation | My study |
|---|---|---|
| Source | Wild caught individuals | Yes |
| Release site | Should be within the species natural range | Yes |
| Release technique | Soft | Soft |
| Gender | More females should be translocated than males to increase establishment of equal sex ratios (translocation of females less successful than males in some species) (Moehrenschlager & Macdonald 2003). | 3 females, 2 males |
| Age | Preferable to translocate juveniles over adults | 3 adults, 2 cubs |
| Animal welfare | Must be considered | Yes |
| Monitoring | Must be carried out post release | Yes |
| Collars | Should be GPS enabled when animals are likely to move large distances | Yes |

*Criteria based on Griffith *et al.* 1989; Kleiman *et al.* 1991; Fischer & Lindenmayer 2000; Moehrenschlager & Macdonald 2003; IUCN 2012

Through this study I can now present species-specific methods for brown hyaenas to guide future translocation attempts. I have detailed successful procedures for holding, darting, anaesthetising and collaring brown hyaenas. For the first time, a successful protocol for the soft release of brown hyaenas following translocation is presented. The use of a holding boma has been detailed including size, required fencing and feeding protocols. Details of the post-release feeding regime are given to ease the animals' transition from captivity to finding food in a new environment. I conclude both male and female wild caught brown hyaenas can successfully be translocated. Young and old individuals survive and have the ability to form a breeding population in a new area. They are able to

adapt to new surroundings, establish themselves, survive, find mates and select habitats in which to rear young successfully.

**The future for brown hyaena translocation**

My findings may prove useful as it concludes translocation can be a successful method in reducing conflict between brown hyaenas and farmers. In parts of their range across southern Africa, brown hyaenas overlap with farming areas and conflict is likely to continue (Skinner 1976). There are important ecological benefits to reducing the number of brown hyaenas killed due to farmer conflict as well as conservation considerations. Their intricate role in the ecosystem and population decline means efforts should be taken to ensure viable populations remain (Maude 2005).

The success of this translocation and monitoring was probably due to a combination of factors such as suitability of the release site, soft release procedure and potentially the number of individuals translocated. The importance of each factor alone is unknown and changing any one in future translocation attempts may alter the chances of success. As it may not be possible to replicate the exact criteria here in all future translocation attempts, it would be valuable to prioritise the importance of the different criteria where possible. Limited information is available on genetic markers for brown hyaenas but in Namibian individuals, females within clans are more related to each other than to males of the same clan (Knowles *et al*. 2009). It is therefore unlikely that relatedness of male and female translocated individuals is a pre-requisite for reproductive success post release.

For future translocations, different release sites will be needed. It must be considered that some release sites may already have resident populations of brown hyaenas and caution should be used in these circumstances to monitor the impact that releasing hyaenas has on a resident population. Any study of such translocations would provide valuable information on the viability of the method for use in different areas and the optimum number of individuals that should be moved.

This work covered an 18 month period and, although I identified no problems for the survivability and establishment of released hyaenas, long-

term studies would prove useful. Further monitoring could explore factors such as longevity and breeding success for brown hyaenas in this part of their range. I have presented estimates of the number of social groups which could be supported in the Lowveld bushveld habitat. The number of individuals that form a social group in unknown for this habitat and any study to estimate group size for this biome would be beneficial.

It was difficult to assess any influence that internal and external fences may have had on the hyaenas. No.5 showed clear exploratory movements, moving along the entire boundary fence of the release site in the first two weeks post release. Despite being held in the boma first, there is nothing to suggest he would not have moved further or even off the release site if the fence was not present. The outcome of translocation, for this hyaena in particular, may have been different in the absence of the external fence. The fencing at the release site is not a unique situation and much land in South Africa is privately owned for wildlife ranching; approximately 20.5 million ha, 16.8% of the total land in South Africa (Cousins *et al.* 2008). These privately owned and fenced areas may therefore prove to be suitable release sites for 'problem' hyaenas for the very reason that fencing will keep them away from further conflict situations. Further studies looking at the effects of fencing on brown hyaena behaviour would be valuable as well as monitoring of hyaena movements following translocation to an area without these boundaries.

At least two of the animals released in this study were only cubs (six months old) when originally captured, and so it is likely that they had limited experience of being away from the den and finding food for themselves before translocation. Despite the lower success rates associated with carnivore translocation over herbivores and omnivores (Griffith *et al*. 1989; Miller *et al*. 1999; Seddon *et al*. 2005), my study shows success can be achieved, even with relatively inexperienced animals. Monitoring can be time consuming and there are associated costs but translocation can decrease brown hyaena conflict with farmers, reduce population decline and provide valuable new information on the ecology of the species. My data suggest that this management option should be explored and used further.

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