POPULATION SIZE, DEMOGRAPHY AND SPATIAL ECOLOGY OF CHEETAHS IN THE TIMBAVATI PRIVATE NATURE RESERVE, SOUTH AFRICA

A thesis submitted in fulfilment of the
requirements for the degree of

MASTER OF SCIENCE

of

RHODES UNIVERSITY

by

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December 2012

ABSTRACT

The cheetah (*Acinonyx jubatus*) has experienced a drastic decline in numbers over the last 20 years globally and is currently listed as vulnerable by the International Union for the Conservation of Nature (IUCN). In South Africa, there are only an estimated 763 free-ranging cheetahs and conflict with humans is arguably the most significant reason for this low number. The aim of my study was to determine the population size and demographic characteristics of the cheetah population within the Timbavati Private Nature Reserve (TPNR), South Africa, and to contribute to a better understanding of cheetah space use and habitat selection. The research was conducted on TPNR between November 2009 and June 2011 and I used a photographic survey to assess cheetah population size and demographic characteristics. Location data was obtained by collaring two adult male cheetahs with GPS/GSM collars and *ad hoc* sightings data from across the reserve for an adult female with cubs and three adolescent females. A relatively high minimum population density of 4.46 cheetahs/100km² was estimated, signifying a relatively healthy cheetah population. The sex ratio data indicated a higher male to female ratio and an average litter size of three cubs. The relatively high cub survival rate and density is promising in terms of the status of species within the area, as the data denote the success and potential persistence of the species. Cheetah home ranges varied between 20.97km² for the female with cubs and 659.65km² for the younger collared male. Season did not appear to be a determining factor in terms of home range sizes for the three social groups within the TPNR. However, the males did show a slight increase in their home range sizes during the dry season when resources where presumably more widespread. My results indicate that the cheetah is an adaptable species, flexible in behaviour and able to tolerate a variety of habitat types. Such knowledge is fundamental for planning and implementing the effective management and conservation of cheetahs in South Africa.

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ACKNOWLEDGEMENTS

No study can operate alone without the support, guidance and understanding of various people and organisations. This was especially true for this study which relied heavily on information from rangers, managers and landowners as well as funding from certain individuals and organisations. I would therefore like to express my sincere gratitude and appreciation to all the people and organisations that made various contributions during the period of my study:

- My supervisor, Dan Parker, for his guidance, patience, encouragement, and support.
- The Ajubatus Foundation, my principal sponsor who so generously gave financial support as well as sponsored the research vehicle and petrol expenses.
- Paul Levey, Michael Goldberg and Makanyi Lodge, the second project sponsors whom I thank for their financial support, accommodation within the reserve and most of all for the wonderful opportunity to work on this project.
- Dave and Yvonne Jackaman, I am extremely grateful for all the help, support, and most of all friendship. I shall never forget the chats, good food and laughs we shared which I shall treasure always.
- Jeremy Kemp-Symonds for his assistance and support with the project.
- The warden of the Timbavati Private Nature Reserve, Jacques Brits, for permission to conduct the research and all his support and assistance during the project.
- The assistant warden of the Timbavati Private Nature Reserve, Paul White for all his support and always having time for me, and his wife Rose without whom I would not have had the opportunity to work on this project.
- The ecologist, Almero Bosch, for his endless time and assistance wherever he could help.
- Timbavati landowners for the opportunity to conduct the research and for permitting me access to traverse their land. To certain landowners, thank you for your hospitality and interest shown in the research and for all the photographs

submitted. I give very special thanks to the following people: Geoff and Jeanette Bowers-Winters, Graeme Naylor, Dennis and Jean Rutter, Happy Hapelt and Kevin Blatherwick. I am ever grateful for your support.

- Suchar Blatherwick, I will fondly remember our tea breaks spent on your “stoep” with all the mongooses, these times and tales I shall cherish always.
- Luckson and the rest of the Makanyi Lodge team for all their support and smiles.
- The various lodges including: Motswari, Umlani, Tanda Tula, King‟s Camp, Ngala, Simbavati, Shindzela, Kambaku, Royal Legend and Hermansburg, for their encouraging assistance and all the photographs submitted.
- A special mention to the following people – Dave Falkner, Bruce and Theresa Macdonald, Ziggi Hugo, and most especially Chad Cocking. I cannot thank you all enough for your assistance and support.
- Laurie Marker for her support and expertise throughout the project.
- Michelle Henley, for her assistance during the project.
- The graduate students in our department for all the technical help, and particularly assistance with the GIS component.
- Sandra Urquhart, for always being there to help and especially with all her assistance with administrative duties.
- And lastly to my family, particularly my wonderful parents, I cannot begin to thank you enough for the opportunities you have given me, and for your endless love and support, your encouragement throughout has kept me going through the harder times, and most of all thank you for always believing in me.
- Finally, thank you to the numerous others who helped me during this study who did not receive a special mention.

CHAPTER 1

GENERAL INTRODUCTION

Terrestrial carnivores are a very important component of a functioning system (Gros *et al.* 1996). The existence of a healthy population of large predators signifies ecosystem integrity, as large carnivores are only capable of surviving when lower trophic levels (e.g. primary consumers such as ungulates) are in a relatively undisturbed state and able to support the higher level organisms (Gros *et al.* 1996; Marker 2002). According to the IUCN Cat Specialist Group (2009), the loss of a carnivore species within a biological community will ultimately change the ecological balance of the system, as this potentially gives way for other species to flourish. Carnivores influence all aspects of an ecosystem through predation, diverting what they do not utilise for their own energetic requirements to scavengers, detritivores and microorganisms (Ricklefs 1990; IUCN Cat Specialist Group 2009). However, large carnivore populations are facing significant global declines as they are subject to an array of pressures and threats which include commercial trade, hunting, habitat loss, human conflict and disease (Marker 2002). According to the IUCN Red List of Threatened Species, 29 of the 36 recognised species of felids are currently in decline, nine of which are classified as near threatened, a further nine are classed as vulnerable, six species are listed as endangered and a single species, the Iberian lynx (*Lynx pardinus*) has been classified as critically endangered.

The cheetah (*Acinonyx jubatus*) was formerly one of the most widely distributed of all land mammals, however over the past few decades the species has faced a drastic decline in numbers globally, dropping from approximately 100 000 in 1900 to less than 12 000 in 1990, a decrease of almost 90% (Gros *et al.* 1996; Marker 1998; Bartels *et al.* 2002; Macdonald and Loveridge 2010). Over roughly the same period, cheetahs ranged across at least 44 different countries across the Middle East, the Indian sub-continent and throughout Africa. However, the remaining populations now only exist in small, fragmented areas across 29 countries (Nowell and Jackson 1996; Marker 1998; Marker 2002; Macdonald and Loveridge 2010). The global wild population is currently estimated at approximately 10 000 individuals (Nowell and Jackson 1996; Marker 1998; Marker 2002; Macdonald and Loveridge 2010). Even

this dismally low figure masks the reality that 50% of the countries which cheetahs currently inhabit no longer support viable populations (Marker 2002; Macdonald and Loveridge 2010). All large cats require large tracts of land on which to survive, cheetahs even more so as they range even more widely and therefore need larger areas than most other species (Macdonald and Loveridge 2010).

Due to its dramatic decline, the cheetah is currently globally classified as vulnerable, with a high risk of extinction in the wild (IUCN Red List 2011). The northern parts of the species" historical range have suffered the greatest decline, the Asiatic cheetah (*Acinonyx jubatus venaticus*) is listed as critically endangered in Iran and North Africa, surviving in small, isolated pockets, as do the populations remaining in north, west and central Africa (Nowell and Jackson 1996; Marker 1998; Macdonald and Loveridge 2010; IUCN Red List 2011). Five cheetah subspecies have been identified and are listed in the Convention on International Trade of Endangered Species (CITES) Appendix 1 (Caro 1994). The southern African subspecies is *Acinonyx jubatus jubatus* (Friedmann and Daly 2004).

The causes for the precipitous decline in cheetah numbers differ across their range but include combinations of habitat loss and fragmentation, depletion of the natural prey base, and human persecution arising from conflict situations (Gros *et al.* 1996; Nowell and Jackson 1996; Marker 1998; Marker 2002; Macdonald and Loveridge 2010). Bearing in mind the vulnerability of the remaining cheetah populations, it is the larger, less fragmented populations that are likely to be the most secure. These larger populations are restricted to sub-Saharan Africa, predominantly Kenya, Tanzania and in particular, Namibia which currently supports a population of approximately 3000 cheetahs (25% of the global population) (Marker 1998; Marker *et al.* 2007). Significantly, the majority of the Namibian population ranges over a largely human-dominated environment outside of the boundaries of protected areas (Marker 1998; Marker *et al.* 2007; Macdonald and Loveridge 2010). This is a situation that is likely to become increasingly prevalent for wild felids as wilderness areas continue to shrink and has important conservation implications for cheetahs (Macdonald and Loveridge 2010).

In some areas, cheetah persistence may also be affected by interspecific competition with larger, more aggressive predators such as lions (*Panthera leo*) and

spotted hyaenas (*Crocuta crocuta*) (Gros *et al.* 1996; Marker 1998; Bartels *et al.* 2002). Larger predators reduce the survivability of cheetahs in protected game reserve/conservation areas through both direct mortality and indirect exclusion from resources (Caro 1994; Laurenson 1994; Bartels *et al.* 2002). Thus, competition with superior predators sometimes forces cheetahs to range outside of the boundaries of protected areas which renders them highly susceptible to anthropogenic activities and results in increased conflict with humans (Caro 1994; Nowell and Jackson 1996; Marker 1998; Marker 2002).

Further concern is that cheetahs are known to breed very poorly in captivity (Marker 2002). Nevertheless, since 1986 captive breeding success has improved markedly although restricted to a limited few institutions such as De Wildt Breeding Centre in South Africa, Whipsnade Zoological Park in England and a few institutions in North America (Caro 1994; Bissett and Bernard 2007). However, it is the reintroduction of these captive populations into the wild which is a much more complicated process, as captive-bred cheetahs lack the ability to hunt effectively. Additionally, concerns are that these captive individuals have no experience of interaction with larger, superior predators such as lions (Caro 1994; Bissett and Bernard 2007). The success of such reintroductions is therefore dependent on a number of factors that include resource availability (food and water), available hunting habitat as well as cover for refuge (Pettifer *et al.* 1982; Bissett and Bernard 2007).

Until recently, the cheetah has generally been regarded as a species of open grassland habitats (Caro 1994; Durant 1998; Laver 2005). This impression arose because most of our previous knowledge regarding cheetah behaviour and ecology was derived from the long-term studies conducted on cheetahs within the Serengeti Plains in East Africa (Caro 1994; Caro and Laurenson 1994; Kelly *et al.* 1998; Broomhall 2006). The Serengeti Plains are mostly comprised of short to medium grasslands, the most abundant herbivores are wildebeest (*Connochaetes taurinus*), Burchell‟s zebra (*Equus burchelli*) and the Thompson‟s gazelle (*Eudorcas thomsonii*), all of which undertake annual, seasonal migrations (Broomhall 2006). However, cheetahs historically inhabited a diverse variety of habitat types and often also occurred in dense vegetation (Broomhall 2006). In denser habitats such as woodlands and mixed savanna bushveld, hunting and range use adaptations (which differ from those recorded in the Serengeti) have been observed in Namibia (Marker

et al. 2003), Kruger National Park (KNP), South Africa (Broomhall 2006), Phinda Resource Reserve, South Africa (Hunter 1998), Kwandwe Private Game Reserve, South Africa (Bissett and Bernard 2007), Matusadona National Park, Zimbabwe (Purchase and Du Toit 2000), Kora Reserve, Kenya (Gros 1998) and Botswana‟s Okavango Delta (Klein 2007). Consequently, it is believed that the density and distribution of the cheetah‟s main prey species, suitable habitat (offering sufficient cover for refuge and open areas for hunting) and the presence/absence of competing larger predators are the primary ecological factors influencing the behaviour, density and distribution of the species (Caro 1994; Nowell and Jackson 1996; Broomhall 2006).

Although good data exists on cheetah spatial ecology, habitat use and demography, the vast majority of information derives from long-term studies in the Serengeti, and it is important to collect that data on local populations for most effective management. Approximately 125 150km² of land is regarded as suitable cheetah habitat within South Africa (Marnewick *et al.* 2007). Only 44.5% (55 654km²) of this land is formally protected, comprising the KNP, Pilanesberg National Park, Hluhluwe-iMfolozi Park, Phinda Resource Reserve and the Kgalagadi Transfrontier Park (Friedmann and Daly 2004). The KNP population is estimated at approximately 175 animals, Kgalagadi Transfrontier Park supports around 65 individuals, and 223 animals inhabit the remaining smaller reserves and national parks. Only 300 cheetahs are thought to roam freely, beyond the boundaries of protected areas, mainly on ranchlands within the Limpopo and North West provinces (Friedmann and Daly 2004).

Knowledge regarding a species‟ ranging behaviour is not only fundamental to gaining an understanding of its behavioural ecology, but is also a prerequisite in terms of planning its effective management (Marker *et al.* 2008). Management decisions cannot merely be extrapolated from one area to another due to the flexible nature of carnivore behaviour when under different ecological conditions, and so further research into gaining a better understanding with regards to cheetah ecology and behaviour in denser habitats such as woodland savanna will aid in improving re-introduction, management and conservation of the species in Africa (Mills 1998; Broomhall 2006).

By monitoring, managing and ensuring the conservation of a single umbrella species (usually species with large home ranges covering a variety of habitats) such as the cheetah, conservationists are essentially preserving the entire ecosystem that supports it, as extensive areas of suitable habitat required for the survival of the cheetah will need to be preserved simultaneously (Fleishman *et al.* 2000; Caro 2003; Roberge and Angelstam 2004; Dalerum *et al.* 2008). In ensuring the preservation of such large tracts of land for one endangered species, it is possible that other co-existing organisms within that same ecosystem will be preserved indirectly, essentially providing a protective umbrella to those co-existing species (Gros *et al.* 1996; Fleishman *et al.* 2000; Roberge and Angelstam 2004).

The following thesis is aimed at establishing an estimate of the population size, demographic characteristics and an understanding of the spatial ecology (home range size and habitat use) of the cheetah population supported within the Timbavati Private Nature Reserve (TPNR), located in the Limpopo Province of South Africa.

CHAPTER 2

STUDY AREA

LOCATION

The study was conducted within the Timbavati Private Nature Reserve, near the town of Hoedspruit in the Limpopo Province of South Africa, between latitudes 24º 34‟ S and 24º 03‟ S and longitudes 31º 03‟ E and 31º 31‟ E (Anon 2012). The reserve covers an area of 53 392 hectares, comprising 50 privately owned farms, and houses approximately 12 luxury guest lodges (Anon 2012). The reserve is situated between the Kruger National Park (KNP) on the eastern boundary and the Klaserie and Umbabat Private Nature Reserves to the north. Thornybush Private Nature Reserve lies to the west (Figure 1). Altitude varies between 300 and 500 metres above sea level.

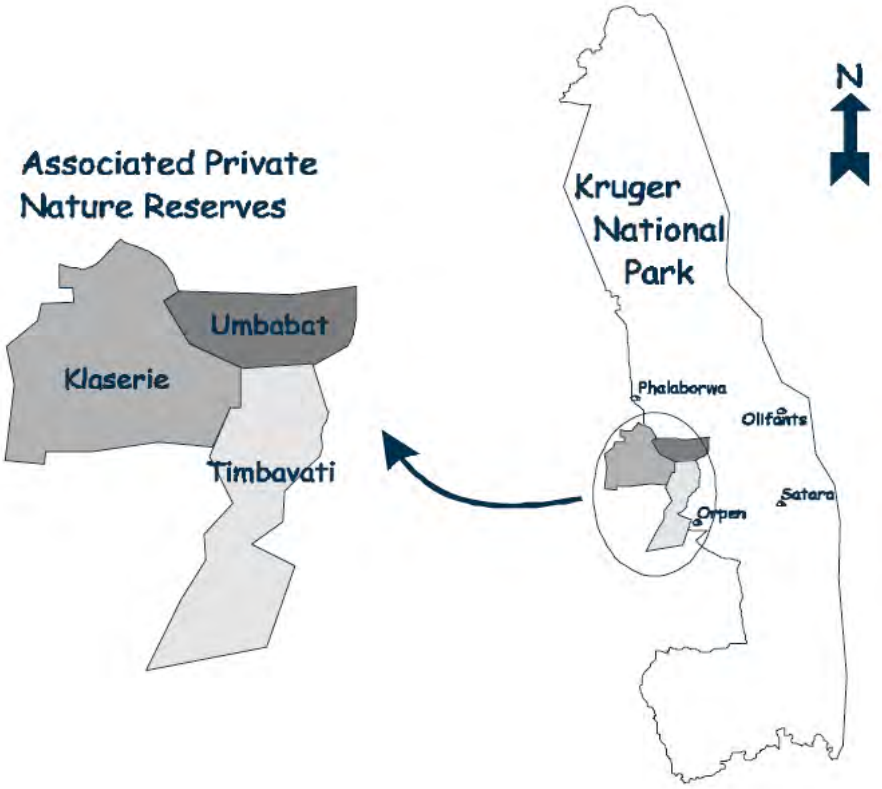

Figure 1: Location of the Association of Private Nature reserves (including the Timbavati Private Nature Reserve) in relation to the Kruger National Park (Greyling 2004)

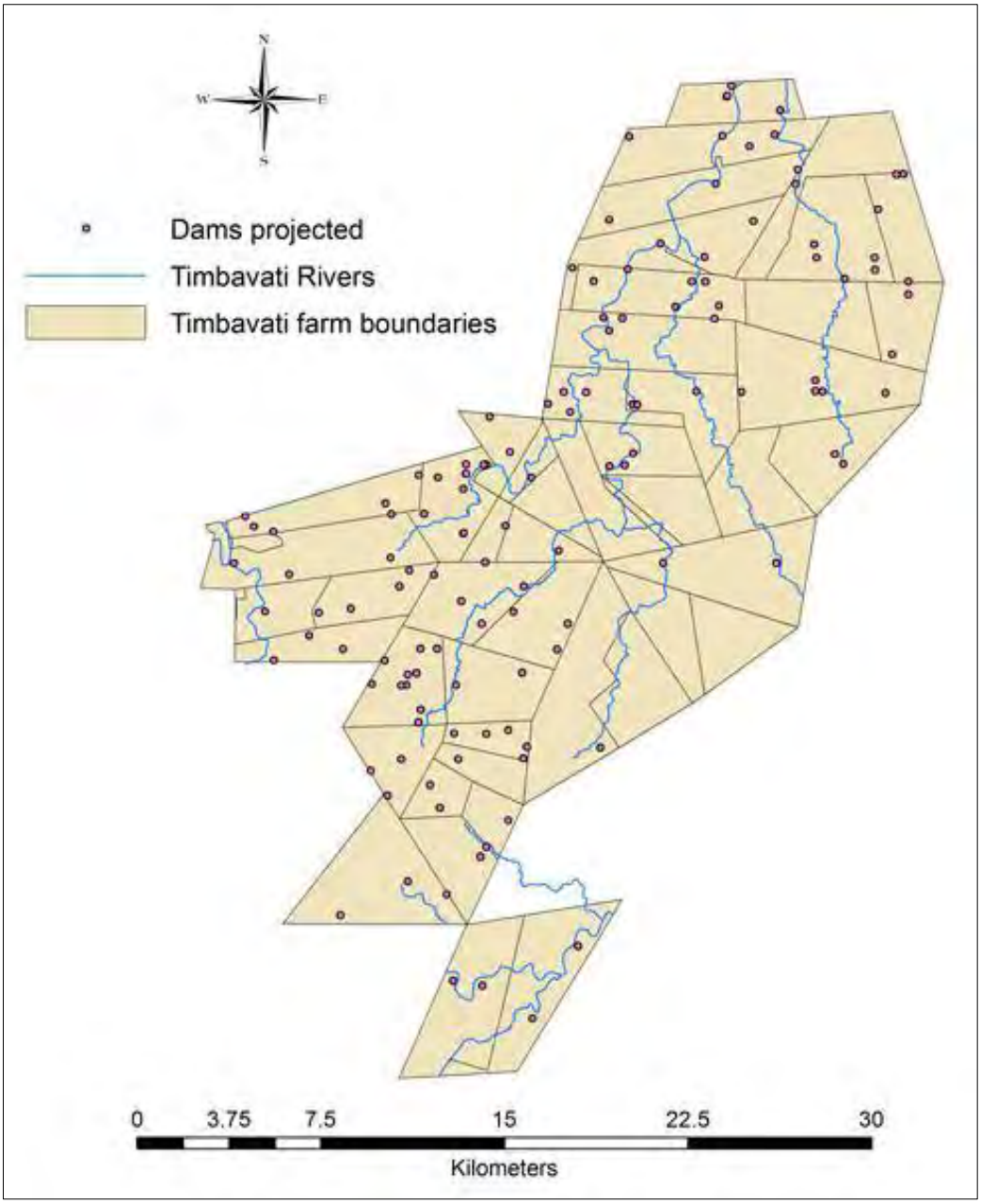

Figure 2: Drainage lines and dams (wet) during the dry season of the Timbavati Private Nature Reserve

BRIEF HISTORY

The Timbavati Private Nature Reserve (TPNR) was formed in 1956 by a group of landowners who joined together in a conservation effort to preserve the area that was undergoing degradation (Greyling 2004). The TPNR forms part of the Association of Private Nature Reserves (APNR), which presently comprises the

Timbavati, Klaserie, Umbabat and Balule Private Nature Reserves, a combined unfenced area of 180 000ha (Figure 1) (Greyling 2004). Within the APNR, a varied land-use history exists, with certain farms having been subjected to more intensive use than others, including cattle *Bos* spp. and crop farming, wildlife hunting, the creation of artificial water points and veld fire control (Figure 2, Greyling 2004). This inevitably caused soil erosion and the destruction of indigenous vegetation and certain wildlife species (Pretorious 1993; Joubert 1996; Greyling 2004). In 1993, fences between the Timbavati and the KNP were removed to promote species migration (Greyling 2004). All four reserves which make up the APNR have since adopted the KNP management principles and policies, and now form part of the greater Kruger National Park biosphere (Joubert 1996).

CLIMATE

The TPNR study area falls within the summer (October – March) rainfall region of South Africa and has a semi-arid climate (Greyling 2004). Most of the rain falls between the months of December and February (Greyling 2004; Anon 2012), with a mean annual rainfall of approximately 550mm – 600mm per annum (Figure 3). The average rainfall increases from east to west and from north to south (Gertenbach 1980; Venter and Gertenbach 1986; Greyling 2004). Mean minimum and maximum temperatures (Figure 4) for the winter months are 12°C and 26°C respectively, and 23°C and 32°C for the summer months (A. Bosch unpublished work 2009).

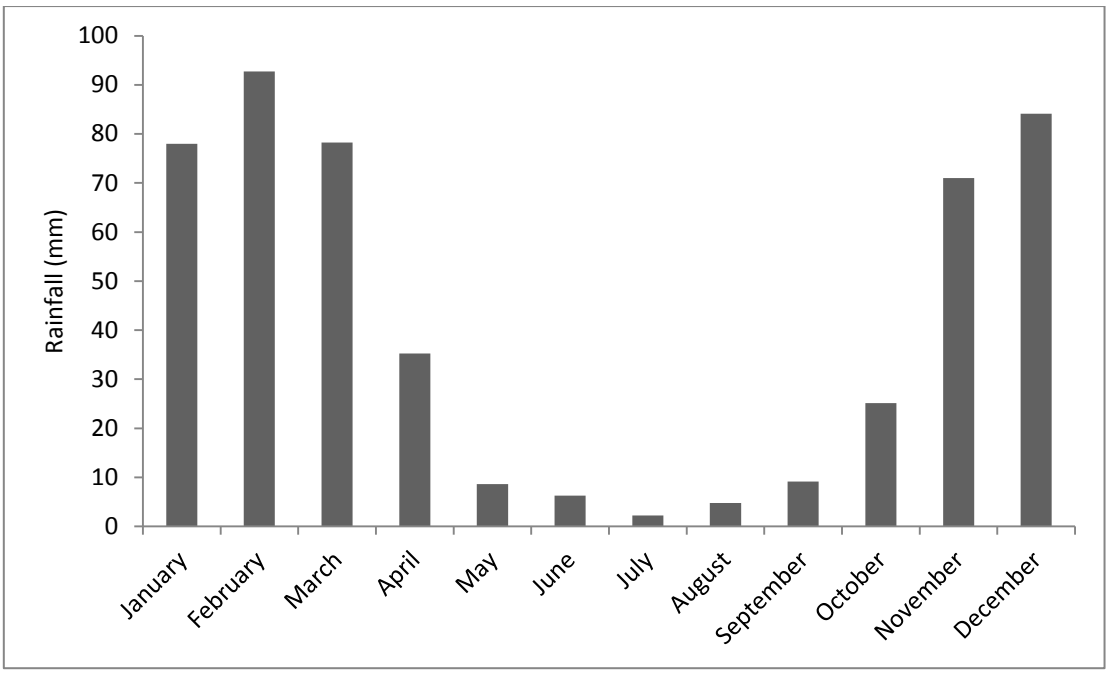

Figure 3: Mean monthly rainfall within the Timbavati Private Nature Reserve from January 2002 - August 2009

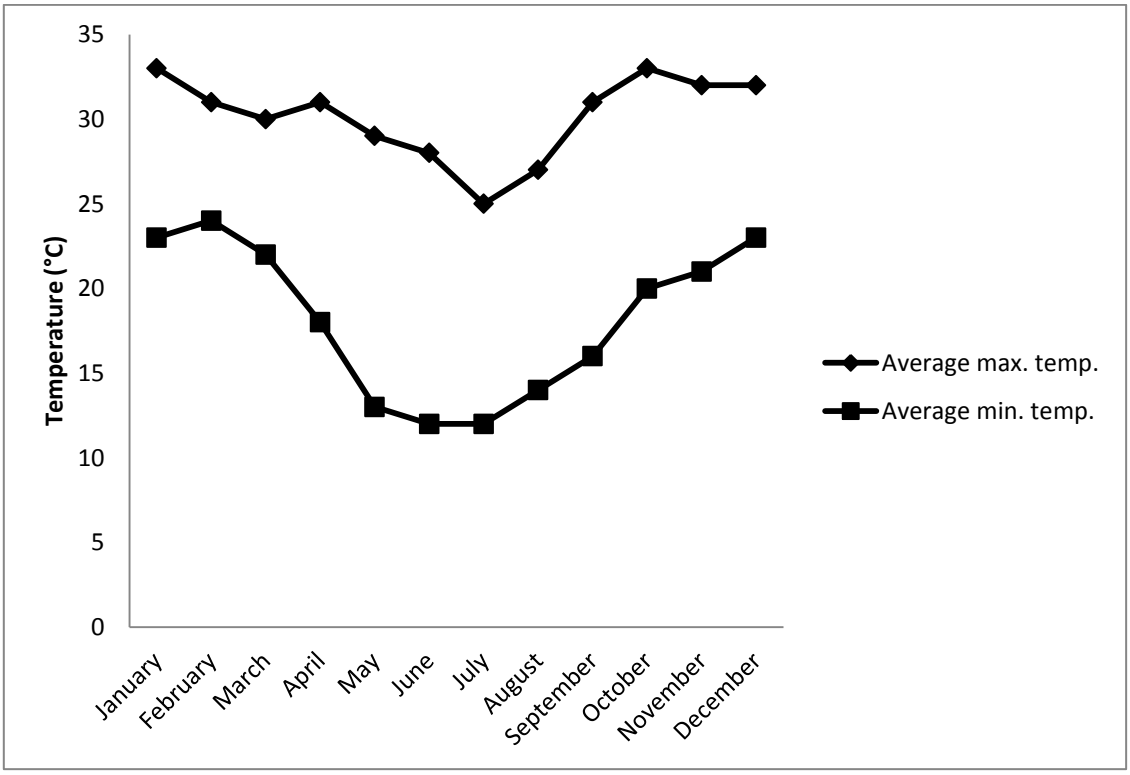

Figure 4: Average monthly maximum and minimum temperatures within the Timbavati Private Nature Reserve

VEGETATION

The study area is situated within the Savanna biome of South Africa, a vegetation type classified as consisting of both a tree and a grass layer, between which complex interactions exist (Anon 2012). According to Mucina and Rutherford (2006), two broad vegetation categories are found on the TPNR; Granite Lowveld (Figure 5) and Phalaborwa-Timbavati Mopaneveld (Figure 6). Within these two broad vegetation categories, six vegetation types are recognised (Figure 7; Mucina and Rutherford 2006).

Granite Lowveld is classified as vulnerable and the deep, sandy uplands are comprised of tall shrubland with only a small number of trees, to reasonably dense low woodland including *Terminalia sericea, Combretum zeyheri, C. apiculatum and Sclerocarya birrea* (Mucina and Rutherford 2006). The ground layer consists mainly of *Eragrostis rigidor, Pogonarthria squarrose* and *Tricholaena monachne* (Mucina and Rutherford 2006). The bottomlands (low-lying areas near a watercourse such as a river) comprise a mixture between dense thicket to open savanna, with the woody component supporting *Grewia bicolor, Dichrostachys cinerea* and *Vachellia nigrescens.* The herbaceous layer is of a dense nature, with the dominant species on the finer soils being *Digitaria eriantha, Panicum maximum* and *Aristida congesta,* whilst the more brackish bottomlands sustain species such as *Sporobolus nitens, Chloris virgata* and *Urochloa mosambicensis. Terminalia sericea* typically grows in thick stands along seeplines (Mucina and Rutherford 2006).

Phalaborwa-Timbavati Mopaneveld occurs on the border between the TPNR and the KNP, as well as certain areas of the Umbabat and Klaserie Nature Reserves (Figure 1). It is characterised by open tree savanna on undulating terrain, whereby the sandy uplands are dominated by species including *Combretum apiculatum, Colophospermum mopane* and *T. sericea.* Termite mounds are abundant within the northern upland areas (Mucina and Rutherford 2006). Within the clayey bottomlands, *T. sericea* usually disappears and *C. apiculatum* becomes scarce. These tree species are replaced by *A. nigrescens* with *C. mopane* increasing in dominance. A well-developed field layer of grasses is also present (Mucina and Rutherford 2006).

Figure 5: Granite Lowveld dominated by *Sclerocarya birrea, Combretum apiculatum* and *C. zeyheri* (Mucina and Rutherford 2006).

Figure 6: Phalaborwa-Timbavati Mopaneveld with *Colophospermum mopane* and *Combretum apiculatum* across a savanna plain (Mucina and Rutherford 2006).

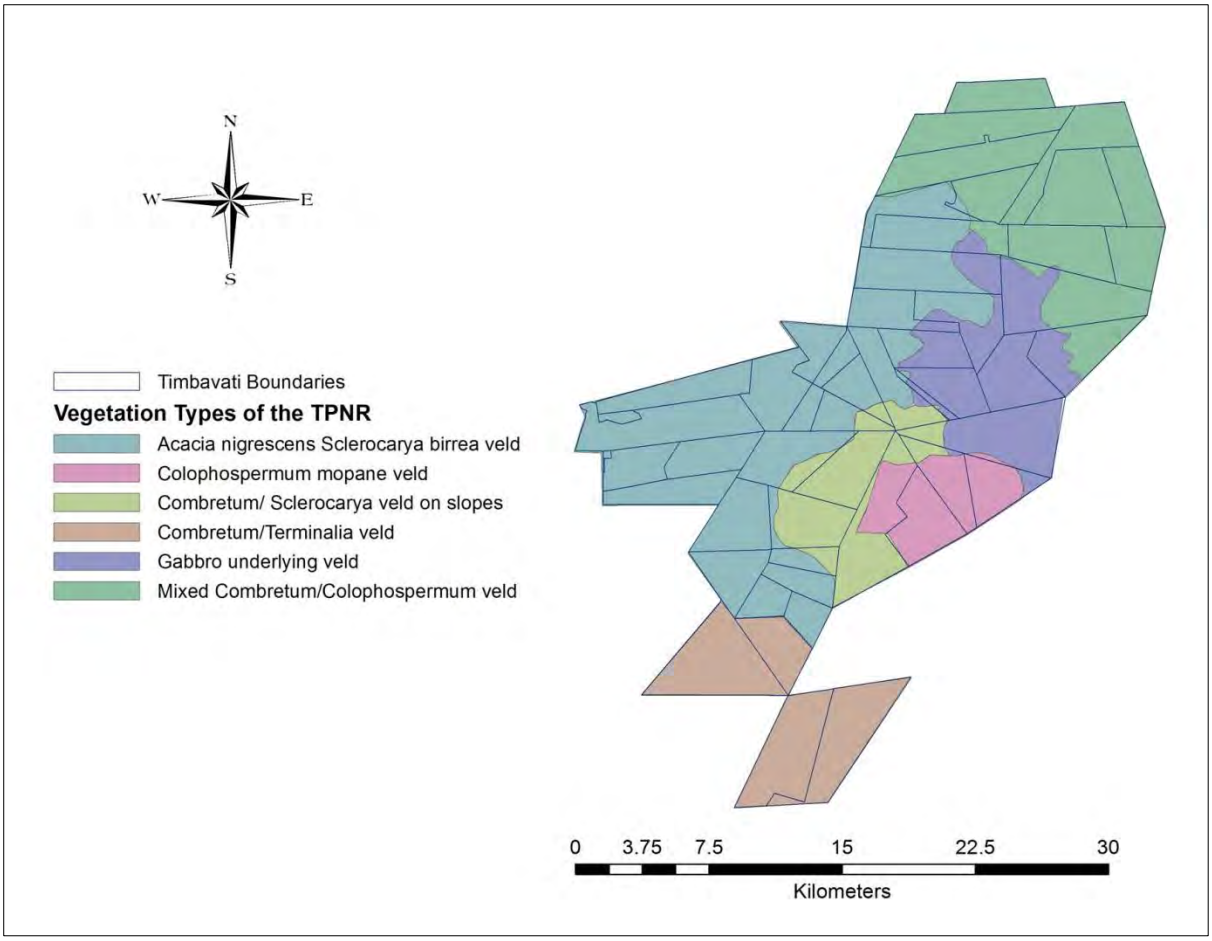

Figure 7: Distribution of the six vegetation types of the Timbavati Private Game Reserve

TOPOGRAPHY AND GEOLOGY

Geologically, granite and gneiss dominate the area, which are rich in feldspar and quartzite consisting of silica and oxygen, with very little iron and magnesium (Anon 2012). Due to this geology, the TPNR landscape is mostly characterised by sandy soils. Gabbro does, however, also occur in the more southerly regions of the reserve (Gertenbach 1983).

Upland soils are derived from granitic rock that has undergone weathering are light in colour and are of a course, sandy and gravely nature resulting in high permeability and infiltration rates (Gertenbach 1983; Bristow and Venter 1986; Venter 1986; Walraven 1986; Greyling 2004). This promotes the leaching process and soils are therefore generally of low fertility. Bottomland soils from granites and soils

weathered from gabbro are, in contrast, rich in clay minerals. Timbavati Gabbro weathers to heavy textured clays, dark in colour and rich in minerals that contain both iron and magnesium, resulting in a low infiltration rate and are therefore non-leached, with calcium and magnesium solution dominating the composition (Gertenbach 1983; Bristow and Venter 1986; Venter 1986; Walraven 1986; Greyling 2004).

PREDATOR AND PREY SPECIES

With conservation and eco-tourism both important functions of the TPNR, a large number of wildlife species are present, including over 40 mammalian species (Anon 2012). Apart from cheetahs, other large carnivores include lions (*Panthera leo*), leopards (*Panthera pardus*), wild dogs (*Lycaon pictus*) and spotted hyeanas (*Crocuta crocuta*). The mean lion density within the APNR is 8.0 lions per 100 km², an intermediate density in comparison to lion densities in other savanna woodland habitats (Turner 2007). A wide variety of ungulate species support these carnivores.

CHAPTER 3

POPULATION SIZE AND SELECTED DEMOGRAPHIC CHARACTERISTICS OF CHEETAHS IN THE TIMBAVATI PRIVATE NATURE RESERVE, SOUTH AFRICA

INTRODUCTION

The cheetah (*Acinonyx jubatus*) can be defined as one of the most threatened large predator species on the African continent, having disappeared over the last few decades from about 76% of their historical distribution (De Wildt Cheetah and Wildlife Trust 2005; IUCN Red List 2011). According to the IUCN Red List (2011), cheetahs are classified as globally vulnerable, with approximately 7500 free-ranging adults remaining in the world. The total population is not expected to surpass 10 000 adult animals (IUCN Red List 2011). The global population has suffered a decrease of around 90% over the last 100 years (IUCN Cat Specialist Group 2009). Two of the main causes of this decline are human-cheetah conflict and interspecific competition with lions (*Panthera leo*) and hyaenas (*Crocuta crocuta*) (Bartels *et al.* 2002).

Cheetahs are particularly vulnerable to population declines because they typically occur at lower densities than other predators such as lions or hyaenas and are wide-ranging, which exposes them to a wide range of threats (Gros *et al.* 1996). For example, the potential conflict with many landownders within an area (due to the great distances they cover), and habitat fragmentation (Gros *et al.* 1996; Marker 1998). The erection of fences and the continual fragmentation of land threatens cheetah movement (Gros *et al.* 1996; Marker 1998). The species‟ low genetic diversity further renders them vulnerable to disease and any other ecological changes (Lacy 1997; Bartels *et al.* 2002). Even cheetahs occurring within protected wildlife reserves are vulnerable to increased competition from superior predators such as lions and hyaenas (Caro 1994; Laurenson 1994; Bartels *et al.* 2002). Laurenson (1994) reported a cub mortality of 95% in the Serengeti Plains, Tanzania, and that lions were responsible for 73% of these deaths.

Cheetahs are therefore caught in a conservation quandary, with national parks and protected reserves on the one hand, providing areas relatively free of human pressures but because they also protect lions, hyaenas and other large predators,

cheetah numbers are kept low because of inter-specific competition (Hunter 2000). Conversely, outside of these protected areas, carnivore competition may be reduced, but cheetahs are faced with increased human conflict and persecution (Hunter 2000). Nevertheless, southern Africa is considered a stronghold for cheetahs, supporting approximately 4500 adults (IUCN Red List 2011). South Africa supports around 550 cheetahs, while Namibia supports the majority of the population, totalling around 2000-3000 animals (Marker 1998; Marker *et al.* 2007; IUCN Red List 2011). However, conflict with landowners is still a major threat to cheetahs in southern Africa. It is a misconception by landowners that cheetahs pose a major threat to their livestock because they are responsible for a mere 3% of livestock losses in Namibia (Marker 2002). Nevertheless, cheetahs are often killed as perceived pests (IUCN Red List 2011). In South Africa, it is generally accepted that leopards *Panthera pardus*, spotted hyaenas and jackals *Canis* spp. are responsible for the majority of valuable game losses to landowners (De Wildt Cheetah and Wildlife Trust 2005). However, because of the diurnal hunting habits of cheetahs, they are routinely blamed for stock losses (Marker 2002).

Cheetah/landowner conflict has been particularly problematic within Namibia where, between 1978 and 1995, government permit records showed that over 9500 cheetahs were legally removed (IUCN Red List 2011). As a result of effective conservation and education efforts, these rates have since fallen, but cheetahs are unfortunately still viewed as problem animals by a small portion of landowners (IUCN Red List 2011). A survey of Namibian landowners showed that landowners who considered cheetahs as problem animals removed about 29 cheetahs a year, whereas those who did not view cheetahs as problematic, removed an average of 14 per year (Marker *et al.* 2003). After the introduction of long term conservation research and various conservation and educational measures (e.g. making information on predator ecology available to landowners, promotion of farm management techniques that reduce livestock losses, and introducing livestock guarding dog programs), these figures fell significantly (< 4 removed per year). This study suggests that even though cheetahs may still be perceived as problem animals by landowners, human tolerance towards the species has grown and this has assisted cheetah conservation in Namibia (Marker *et al.* 2003).

The enumeration of wild animals is important as it shows trends in population growth by providing information on a population‟s age and sex structure and reproductive success (Bothma 2002). These parameters are invaluable for the making of appropriate management decisions such as the need to restock or translocate predator/prey species (Bothma 2002). These data also assist managers in monitoring the effects of herbivores on vegetation or the possible negative effects that carnivore species may have on prey populations (Bothma 2002).

The abundance of cheetahs will vary in accordance to habitat, prey availability and the existence of other large predators (IUCN Cat Specialist Group 2009). There are a number of characteristics that make cheetahs a difficult species to count (Mulama *et al.* 2002; Marnewick 2006b; Marnewick *et al.* 2008). Firstly, there is no one method regarded as completely acceptable in terms of monitoring cheetah populations as the various methods each have their specific advantages and disadvantages (Marnewick 2006b). Secondly, cheetahs are a wide-ranging species and this, coupled with their low density, cryptic appearance and relatively shy, elusive nature, makes direct observations extremely difficult (Gros *et al.* 1996; Marker 1998; Marnewick 2006b; Marnewick *et al.* 2007). Thirdly, the largest portion of the cheetah population within South Africa is free-ranging on both cattle *Bos* spp. and wildlife ranches that are privately owned (Marnewick 2006b; Marnewick *et al.* 2008). This can restrict access to study areas, depending on landowner cooperation (Marnewick 2006b; Marnewick *et al.* 2008). Determining cheetah abundance is further complicated by their unusual social organisation, with semi-nomadic solitary males and females having large overlapping home ranges (Caro 1994; Marker 2002). Male coalitions, however, tend to defend a smaller territory (Skinner and Chimimba 2005; Durant *et al.* 2007). Consequently, cheetah population sizes are often over-exaggerated as the same animals are repeatedly seen over a very large area (Marker *et al.* 2008a). Therefore, to directly establish a population size, each individual cheetah within a population should be identified by its unique coat pattern (Gros *et al.* 1996).

Bowland and Mills (1994) conducted the first photographic census of cheetahs in the Kruger National Park (KNP), and concluded that the population stood at 172 animals (Bowland and Mills 1994). In a similar, but shorter study by Kemp and Mills (2005), only 103 individuals were identified. It was concluded that an insufficient number of

animals were photographically “captured” for a satisfactory population estimate to be made. Their figure was thus regarded as a minimum number (Marnewick *et al.* 2007). Preliminary analysis of data from a study conducted in 2009 suggests a current population of 135 cheetahs within the KNP (Lindsey *et al.* 2009a).

Due to human persecution, and the majority of the remaining cheetah population in South Africa being classified as free-ranging, it is very important that existing populations are effectively monitored in order to conserve the species (Gros *et al.* 1996; Marnewick *et al.* 2007a). If informed management decisions are to be taken and various conservation efforts made are to be evaluated (e.g. translocations), then population monitoring is fundamental in influencing such decisions (Gros *et al.* 1996; Marnewick *et al.* 2007).

Although cheetah population assessments have been conducted within the KNP, very little data exists for the cheetah populations outside of the park where cheetahs are known to occur. Therefore, this study aimed to supply data on population numbers and status within the TPNR. Although, there are a number of techniques available to count free-ranging cheetahs (Bowland and Mills 1994; Mulama *et al.* 2002; Marnewick *et al.* 2008; Houser *et al.* 2009b), I used a photographic survey technique using a reference collection of photographs taken by lodge field guides and their guests, landowners, visitors, field rangers, wildlife staff and myself. The photographic identification of animals that are uniquely identifiable by natural marks (e.g. spots or stripes) is a non-intrusive and powerful method for gathering data on population size and demographics (Kelly 2001).

METHODS

Data collection

Photographic survey

Every cheetah has its own unique combination of spotted markings, enabling actual recognition of different individuals (Appendix A; Maddock and Mills 1994). However, the location of cheetahs within wooded savanna is difficult due to the dense nature of the vegetation, and so the likelihood of a single individual locating any one cheetah

on a certain day is low (Maddock and Mills 1994). For this reason, a widespread workforce was necessary to increase the probability of cheetah sightings and photographs (Maddock and Mills 1994). The workforce utilised in this photographic survey included a variety of people: lodge owners, lodge staff (managers and game guides), guests visiting the lodges, TPNR wildlife staff employed within the reserve (ecologist, warden, assistant warden and field rangers), various private landowners and their visitors and myself. The survey was conducted between November 2009 and April 2011.

Sightings and photographs from field rangers were vital to the census, as they signify a body of skilled observers that are capable of covering areas often not frequented or accessible to guests (Ginsberg *et al.* 1997). By way of facilitating this process, the reserve‟s field ranger patrols (n = 6) were issued with durable, easy to use Canon PowerShot D10 digital cameras.

Permanent landowners and lodges (n = 10) were visited on a frequent basis (monthly/bimonthly) in order to both retrieve any photographs of cheetahs collected, as well as to ensure they were communicated with and regularly updated with respect to the survey‟s progress via electronic newletters, a website and personal communications (Marnewick 2006b).

Observers were asked to record and submit various details with each photograph taken. These details included: time, date, location (sighting locations were pinpointed as precisely as possible via GPS coordinates or a description in terms of road networks, surrounding landmarks and rivers), group composition (total number of individuals, ages and sexes) and any other relevant details (Gros 1999).

Data on demographic parameters such as age, sex ratios, social structure, litter size and (to a lesser degree) survivorship of the cheetahs were determined from the photographs and direct observations. For the direct observations, I either followed up on any recent sightings or actively searched for animals whilst driving within the reserve (Gros 1999).

Left and right-hand photographs of each cheetah (provided both sides were available) were used to create an individual profile for each cheetah (n = 32) (Maddock and Mills 1994). If only one side of cheetah was available, this was used

to generate a half profile (n = 3). In this way, a near-complete cheetah identikit was constructed for the TPNR population (Appendix B).

The population size of the cheetahs within the study area was then assessed by totalling the number of individual cheetahs positively identified over the duration of the survey (Maddock and Mills 1994; Ginsberg *et al.* 1997). This estimate was considered a minimum estimate (Maddock and Mills 1994; Ginsberg *et al.* 1997). However, it is recognised that the TPNR forms part of an open network system of reserves that are not fenced and that this could have affected my data. Nevertheless, with a large enough set of photographs, this type of survey can be less biased than other methods as it allows for the identification of repeated sightings of the same individual (Table 1) (Maddock and Mills 1994; Ginsberg *et al.* 1997). The number of times each cheetah individual/group was sighted and photographed varied (Table 1).

Although computer aided matching software is available, it is only effective when very large quantities of photographs require analysis (Marnewick 2006a). Therefore, in this study I used manual matching (Marnewick 2006a).

RESULTS

Numbers

During the study, 235 individual cheetah sightings were reported and these were accompanied by 3809 photographs (Appendix C). The frequency of sightings increased in the dry season when visibility was increased and the animals became easier to find and observe. An average of 61.1 cheetah sightings were recorded during the wet season (October – March), compared to 105.4 sightings during the dry season months (April – September).

The cheetah sightings were unevenly distributed across the reserve, and tended to be concentrated in the areas where the commercial lodges and permanent landowners were positioned (Figure 8). This is because there was constant human activity within those areas, increasing the number of sightings. There were gaps in areas such as Sumatra and Ceylon (Figure 8). Neither of these properties have

commercial lodges and I was not granted access by the landowners. However, any animals occurring within these areas are likely to have crossed onto neighbouring farms where they could have been photographed.

From these observations, a total of 35 individual cheetahs were identified (Appendix B, Figure 9 and Table 1) during the study period of 18 months.

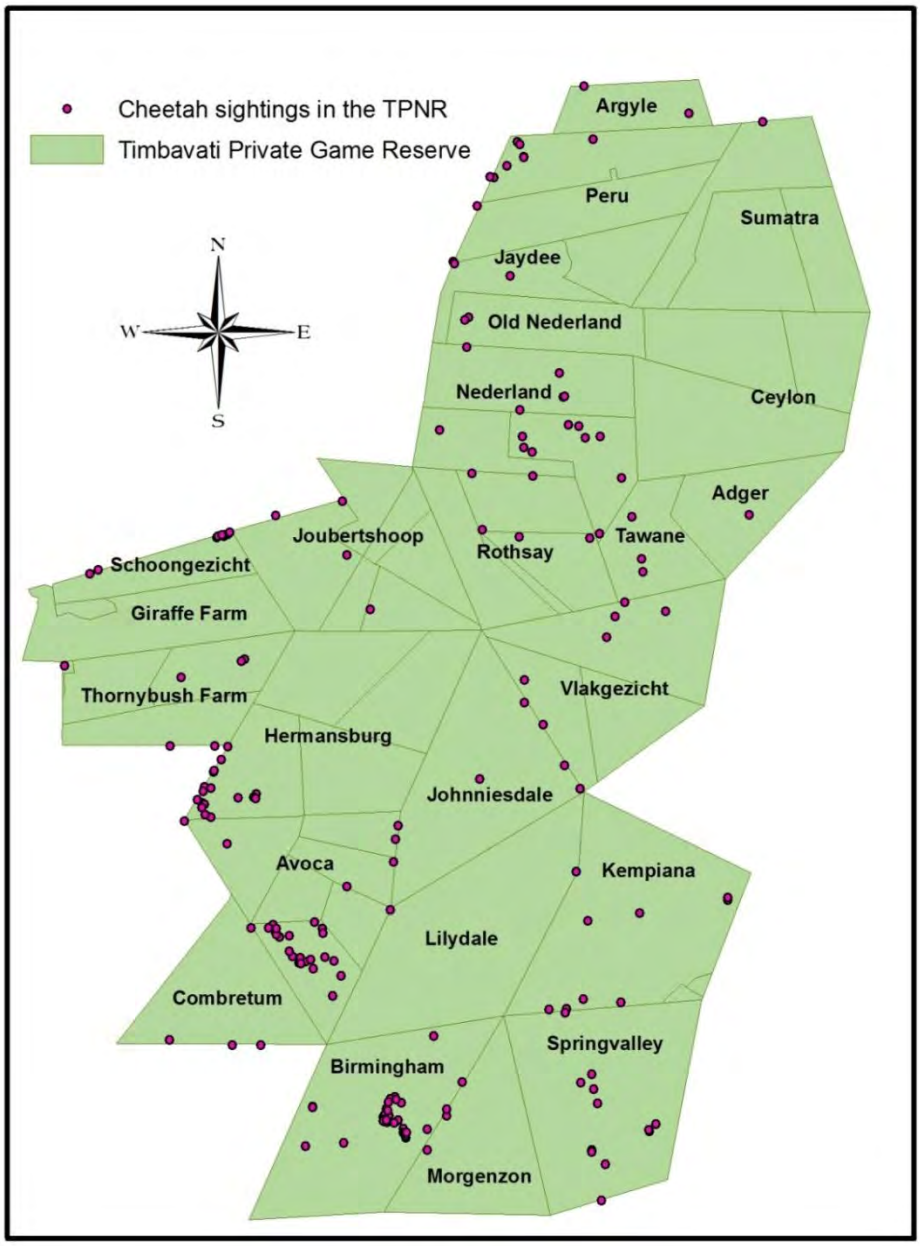

Figure 8: The distribution of photographs/cheetah sightings throughout the Timbavati Private Nature Reserve between 2009 and 2011.

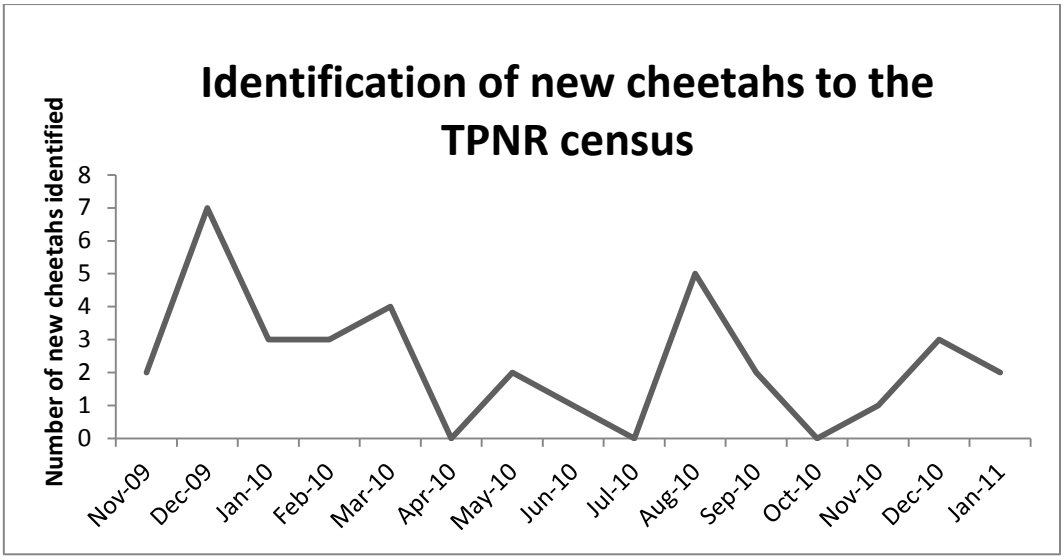

Figure 9: The monthly identification rate of new cheetahs on the Timbavati Private Game Reserve during the period of 2009 to 2011.

Table 1: The sighting frequencies of each individual cheetah identified on the Timbavati Private Game Reserve during the census, including age classes (cub/adolescent cub < 20 months; young adult < 3 years; adult/prime 3-7 years; old adult > 7 years) and sex (if known).

ID:	Age class/sex:	Sighting Frequency:
F1	Adult female (old)	6
F2	Adult female	40
F3	Adult female	2
F4	Adult female (young)	25
F5	Female cub	41
F6	Adult female	20
F7	Adult female	2
F8	Independent adolescent cub	42
F9	Independent adolescent cub	42

F10	Independent adolescent cub	42
F11	Adult female	41
F12	Adult female	7
F12"s 2 cubs from 2nd known litter	Cubs – sex unknown	2
M1	Adult male (old)	5 + collar data (177 fixes)
M2	Adult male	10
M3	Male cub	41
M4	Male cub	41
M5	Male cub	35
M6	Male cub	35
M7	Adult male (young)	26 + collar data (360 fixes)
M8	Adult male	1
M9	Adult male	2
M10	Adult male (old)	1
M11	Adult male	2
M13	Adult male	7
M14, M15, M16, M17	Adult male coalition of four	3
M18, M19	Adult male coalition of two	9
F11"s 3rd cub (sex unknown)	Cub – sex unknown	35
F12"s only cub from 1st known litter	Independent adolescent – sex unknown	3
New adult of unknown sex	Adult – sex unknown	1

Direct observations revealed two confirmed mortalities (F1 and one cub) and potentially another three (M1, M10 and another cub). Thus, the population size of cheetahs on the TPNR during the study was likely to be 30 animals. This results in a minimum density of 4.46 cheetahs/100km², or 1 cheetah/22.41km². Only 25% of all cheetah sightings were of single animals (15% single males; 10% single females). Just over 28% of sightings were of independent cubs, and 41% of females with cubs. The lowest proportion of sightings belonged to male coalitions (5%) (Figure 10). Only two coalitions were identified, one of two males and a second of four which was only seen on three occasions (Table 1). The coalition of two was seen nine times during the study period as their home range only just overlapped with the TPNR (Table 1). Appendix B and Appendix C show the identikit of photographic profiles constructed to determining population size and the sightings tables per month for the duration of the study.

It does however need to be highlighted that one of the limitations of these results is that it is also possible that the high figure obtained from the cheetah census may possibly be inflated and a product of the open network of reserves. This would imply that the study identified a large number of cheetahs that came through from Kruger and were therefore not resident within the TPNR. If this is the case, then cheetah densities across the KNP and TPNR are naturally low. Analysis of Table 1‟s results confirms this, with only 16 cheetahs having been sighted ≥10 times within the TPNR. This means that about half of the cheetahs identified within the census may likely have only been passing through.

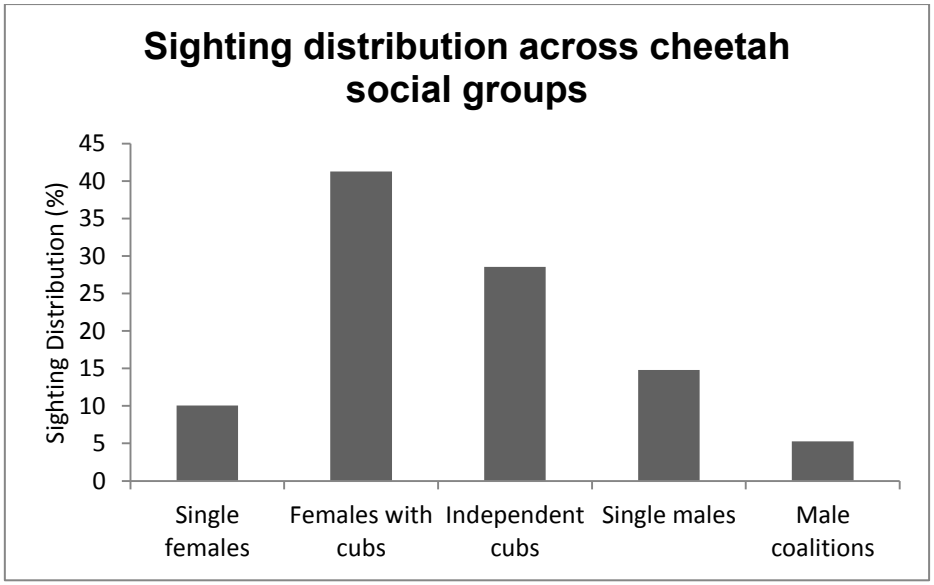

Figure 10: Sighting distribution across cheetah social groups within the Timbavati Private Nature Reserve between 2009 and 2011.

Sex ratios

Most of the cheetahs identified could be sexed (Table 1). Five individuals were not sexed; four were cubs and the fifth an adult individual that was only seen passing through the reserve on a single occasion (Table 1). The sex ratio of known individuals was 1 female: 1.5 males. Figure 11 illustrates the distribution of male to female sightings as dispersed across the Timbavati Private Game Reserve. The northern sector was clearly dominated by females, whereas the males were more evenly distributed across the reserve.

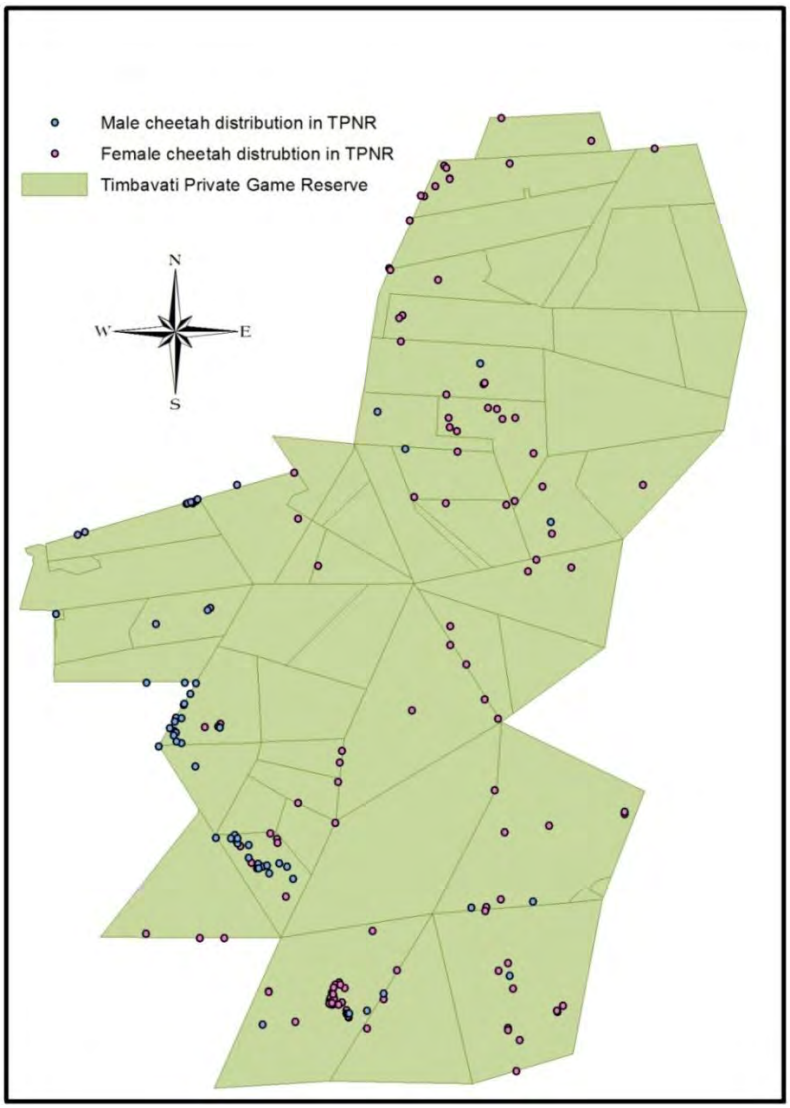

Figure 11: Male (blue) and female (pink) cheetah sightings distribution across the Timbavati Private Game Reserve between 2009 and 2011.

Reproduction

The average litter size of cubs between the five sexually mature females (F2; F6; F7; F11 and F12) was three. Unfortunately original litter size at birth could not be determined. Five of the cubs could not be sexed during the study. However, F2‟s three cubs had a sex ratio of two males to one female; F6‟s three cubs were all females, F7 raised one male and one female cub, and two of F11‟s three cubs were male with the third one‟s sex unknown but suspected to be a female (Table 2). Litter size did not appear to differ from parity, showing consistency with litter sizes previously recorded from other studies (Table 2).

Table 2: Cheetah litter sizes and cub sex ratios for each cheetah mother identified during the study, including the number of cubs that could not be sexed.

Mother:	Male cubs	Female cubs	Cubs of unknown sex	Total litter size:
F2	M3, M4	F5	-	3
F6	-	F8, F9, F10	-	3
F7	M7	F4	-	2
F11	M5, M6	?	1	3
F12	?	?	4	1; 3

Mortalities

Although litter sizes at birth were not known, observations of litters of different ages did allow some estimation of potential cub mortalities. Of the seven sexually mature females identified during the study, only four of these females (F2; F6; F7 and F11) raised cubs past the age of 12 months. One of the remaining three females (F1) was one of the mortalities recorded early on in the study, whilst the second one (F12) was believed to have lost all of her three known cubs. One was killed by lions before ever having entered into the TPNR and so was not included in the census total. The seventh adult female (F3) was only seen twice during the study and both times without cubs.

A further three mortalities were suspected during the study. The single old adult female F1 (at least seven years of age) was killed by a leopard; one of the collared males (M1) (also believed to have been at least seven years of age) was killed by a younger two-male coalition. M10, also an older male of unknown age was seen only once and is also a highly-probable fatality as he was injured and emaciated and not very mobile when sighted (Table 1).

DISCUSSION

In this study I utilised a technique (photographic survey) that is not commonly applied when gathering population size and demographic data, as it can be expensive, time-consuming and requires a large workforce (Maddock and Mills 1994). The assessment of a species‟ demographics based on sighting reports alone does have its limitations (Gros 1999): (1) incorrect determination of number, sex or age of the cheetahs when observed by respondents; (2) larger cubs are often mistaken for adults and sexes are often confused; (3) an extra source of error is that a perceived necessity often exists whereby respondents feel the need to supply information and answers regardless of actual knowledge (Gros 1999). All doubtful information was therefore discarded unless I could independently verify age, sex and new identifications.

Despite many of the observations having been made by untrained observers, they were always supported and confirmed by photographic evidence. For this reason, individual cheetahs could be identified from most sightings. The fact that there was not an even distribution of private lodges and permanent landowners throughout the study area meant that a more active presence was required in certain areas. Some cheetahs were located regularly whilst others more infrequently, some possibly never having been sighted and therefore identified. Nevertheless, it is likely that most of the cheetahs within the reserve were recorded because (1) the study ran for 18-months, and a cheetah had to be sighted once in order to be included in the population survey, provided that there was no evidence that the animal had perished come the conclusion of the study period; (2) cheetahs are well known to be a wide-ranging species, making it highly probable that they would all have come into contact with humans to some degree. However, the opposite is also true, where certain individuals may never have been sighted; (3) the number of cheetahs recorded within the TPNR is of a similar density to other reserves in South Africa (Bowland and Mills 1994; Marnewick *et al.* 2007; Lindsey *et al.* 2009a; Buk and Marnewick 2010).

The population estimate obtained in my study is a minimum figure for the density of cheetahs within the area. The relatively high figure of 35 animals (a density of 4.46 cheetahs/100km²), is in fact higher than previously predicted when comparing the

data with the neighbouring KNP (Maddock and Mills 1994; Bowland and Mills 1994; Kemp and Mills 2005; Marnewick *et al.* 2007; Lindsey *et al.* 2009a; Buk and Marnewick 2010). Taking 200 animals as the estimated cheetah population size for the 20,000 km² of the KNP, an estimated density of one cheetah every 100 km² (Buk and Marnewick 2010), the density results obtained from the current study within the TPNR are therefore relatively high. This density is further unexpected when reviewing the results produced by Lindsey *et al.* (2009a), which suggests an even lower density of 135 cheetahs within the KNP, a density of 0.675 cheetahs/100km². The results produced in the current study are however similar to what Marnewick (2006a) found for cheetahs in the Thabazimbi district in the south-western part of the Limpopo Province of South Africa (savanna biome) (4.6 cheetahs/100km²).

When it is considered that the KNP and TPNR share an unfenced boundary, forming an open network with other private reserves, the results obtained either indicate that a healthy population of cheetahs that, if not resident in the TPNR, are still at least passing through on regular intervals, and that the density obtained for cheetahs in KNP is a very modest estimate for such a large protected conservation area. The true population density perhaps being potentially higher than suggested in the KNP. This is further supported by a rarefaction analysis of the data obtained from the Kemp and Mills (2005) study. This study indicated that an insufficient number of animals were “captured” in order to determine a satisfactory estimate regarding population size and so a longer study duration than the six months period of the previous study was suggested (Marnewick *et al.* 2007).

The second possibility that needs to be recognised, is that it is also highly likely that the high estimate obtained from the TPNR cheetah census may perhaps be an artefact of the open system, suggesting that cheetah densities across the KNP and TPNR are instead naturally low, indicating that the study identified a large number of “Kruger” cheetahs in the TPNR during the census. Results illustrated within Table 1 certainly support this statement, with 15 cheetahs having been sighted 10 times or less and were likely just passing through the reserve from elsewhere. This could potentially indicate some form of perturbation within the population.

In terms of the sex ratio of the population, my results differed slightly from parity with fewer females than males identified. Generally the population sex ratio favours

females (Frame 1977; Caro 1994; Nowell 1996; Marker 2002). This adult disparity is often attributed to differing sex-specific rates of dispersal and mortality, with there usually being a male bias towards removals (Nowell 1996; Marker 2002). The reason behind the higher male sex ratio in the TPNR could possibly be due to a high density of lions occurring within the reserve (A Bosch pers. comm.). Male cheetahs and coalitions may stand a better chance of survival than single animals or more vulnerable females and cubs, which have been known to seek out areas of refuge from lions (Laurenson 1994; Durant *et al.* 2004).

Litter sizes obtained from the study showed parity with existing literature on litter sizes for cheetahs (Caro 1994; Laurenson 1995; Nowell 1996). Four females raised full litters of cubs to independence. It is hypothesized that this is probably due to the dense cover afforded over much of the reserve (Laurenson 1993; Broomhall *et al.* 2003). This enables mothers to not only hide their litters when cubs are very young, but also to conceal their kills (Hunter *et al.* 2007). This ensures minimal disturbance from scavengers and potentially deadly, rival, apex predator species (Hunter *et al.* 2007).

Open boundaries promote the free movement of the cheetahs between many reserves. Monitoring particular animals can therefore become logistically impossible. Sometimes several months would go by with known individuals not being sighted. Access within the reserve was also limited to some degree with all the land consisting of privately owned farms, each owner enforcing different regulations and traverse agreements. These factors made it hard to track survivorship and continually monitor the cheetahs identified within the reserve. New births and unknown mortalities are both possibilities. It was also difficult to age individuals and to establish some form of family tree as no previous studies had taken place, so the existing population was unknown and ages of cubs and adults had to be knowledgably estimated.

The cheetah situation in South Africa is one of a complex nature with such a large proportion of the population ranging beyond the borders of protected areas, private landowners therefore play a key role in their ultimate survival (Lindsey *et al.* 2009b). It is unknown what a minimum viable population for wild cheetahs would constitute, although it is clear that the larger and more dispersed the population is, the greater

safeguard it holds against localised epidemic mortality, widespread episodic catastrophe or even genetic failings (Marker 1998). A crucial factor that needs to be considered is the existing lack of genetic variation within the species. This renders the species more susceptible to ecological as well as environmental changes (Marker 1998).

Even with the wealth of existing research that has been conducted on large carnivores (Gittleman and Harvey 1982; Mills 1991; van Valkenburgh 1996; Durant 1998; Radloff and Du Toit 2004; Hayward *et al.* 2007a), our knowledge of the roles of large predators such as cheetahs in ecosystems is still somewhat inadequate in terms of making sound management decisions (Mills 1991). Knowledge regarding population density as well as determining demographic parameters within a given area is vitally important to effectively gaining an understanding of the distribution and status of a population of a species, this being essential for conservation planning and the formulation of effective management strategies (Marker 2002; Marnewick *et al.* 2007; Houser *et al.* 2009b).

CHAPTER 4

HOME RANGE CHARACTERISTICS AND HABITAT USE OF CHEETAH SOCIAL GROUPS WITHIN THE TIMBAVATI PRIVATE NATURE RESERVE, SOUTH AFRICA

INTRODUCTION

Cheetahs (*Acinonyx jubatus)* have been described as predators that prefer open habitats where they can use their speed to capture prey (i.e. savanna specialists), however in recent years increasing studies are confirming otherwise (Purchase and du Toit 2000; Broomhall 2001). Recent work in the Eastern Cape, South Africa has shown that cheetahs are able to survive and hunt successfully in areas where denser vegetation dominates the environment (Bissett and Bernard 2007). In addition, studies conducted on Namibian farmlands and within the Kruger National Park (KNP), South Africa further support the notion that cheetahs are able to successfully utilise woodland and shrubland habitats (Broomhall 2001; Broomhall *et al.* 2003; Marker *et al.* 2008). Historically, cheetahs inhabited a diverse range of habitats and topography, indicating that they are both a tolerant and adaptable species (Purchase and du Toit 2000; Broomhall 2001).

The concept of a „home range" is an important spatial parameter as it defines the space utilised by a particular animal, illustrating patterns of movement and overlap with other animals, as well as identifies land needed for protection of a species (Caro and Durant 1995). A home range is defined as typically including 95% of an animal's location points (White and Garrott 1990), whilst the area used more intensively is defined as the core area, described as the 50% probability kernel (Samuel *et al*. 1985). Calculations of the extent of core areas are important as they reflect the areas more intensively utilised, identifying critical habitats within the environment for the species (Samuel *et al*. 1985).

Cheetah home range sizes show great variation between sexes, among social groups, and prey densities (Caro 1994; Marker 2002; Broomhall *et al.* 2003; Bissett 2004). However, all cheetah home ranges tend to include at least some open areas

for hunting, and sufficient cover for concealment from other predators such as lions (*Panthera leo)* and hyaenas (*Crocuta crocuta*).

Home range estimates for cheetahs vary from 11km² for males and 23km² for females, within the Matusadona National Park (MNP) in Zimbabwe (Purchase and du Toit 2000), to as large as 1651km² for cheetahs on Namibian farmlands (Marker *et al.* 2008). Variation in home range size is often determined by resource availability (Bissett and Bernard 2007). In the Serengeti, female cheetahs tend to have relatively larger home ranges because they track the movements of migratory Thompson‟s gazelles (*Eudorcas thomsonii),* their preferred prey (Caro 1994). By contrast, when prey density is higher and more sedentary, such as within the MNP and Kruger National Park (KNP), South Africa, cheetah home ranges tend to be smaller (Purchase and du Toit 2000; Broomhall *et al.* 2003).

The social system of cheetahs also influences home range size and movement patterns (Caro 1994; Hunter 1998; Broomhall *et al.* 2003). Adult females are generally solitary, except when they are accompanied by cubs (Hunter 2000; Skinner and Chimimba 2005). Male cheetahs can either be solitary or form coalitions with other adult males (Hunter 2000) and, related groups of independent cubs will often stay together for the first few months of their independence before establishing their own home ranges (Hunter 2000; Skinner and Chimimba 2005). Cheetah cubs become independent of their mothers between 13 - 20 months of age (Skinner and Chimimba 2005). Consequently, females generally occupy larger home ranges than their male counterparts (Skinner and Chimimba 2005). Females also prefer to stay mobile as a predator/competitor avoidance strategy, and are more dependent on factors such as adequate food supply, sufficient water, and appropriate denning sites for rearing of cubs (Caro 1994; Laurenson 1995). By contrast, the spatial distribution of male cheetahs is likely to be influenced more by the distribution of females within an area (Swihart and Sunquist 2002). Male cheetahs generally position their home ranges to overlap with those of several females, thereby increasing the likelihood of encounters with females and mating opportunities (Caro 1994; Hunter 1998; Purchase and du Toit 2000; Broomhall *et al.* 2003).

Co-existing carnivore species also play an important role in the size and position of cheetah home ranges (Durant 2000a; Durant 2000b). Cheetahs are known to be

negatively affected by the presence of species such as lions and hyaenas, both known to steal kills (kleptoparasitism) and cause direct mortalities (Caro 1994; Durant 2000a; Durant 2000b). For this reason, to minimise encounters and conflict, cheetahs (independent cubs and females, in particular) are known to avoid superior carnivores in terms of placement of core areas (Caro 1994; Laurenson 1994; Durant 2000a; Durant 2000b).

Establishing whether habitat use within a home range is at random or whether particular areas are preferred is vital for gaining an understanding of a species" unique habitat requirements. If a preference is identified it indicates that a particular habitat is being selected for over others within the same area (Neu *et al*. 1974; Byers *et al*. 1984). Preference is indicated when a certain habitat is utilised to a greater extent than what would be expected in terms of its available proportion within the environment (Aebischer *et al.* 1993). Knowledge of a species" habitat requirements and ranging behaviour is fundamental to understanding their behavioural ecology, allowing for efficient management and effective conservation of the species (Marker *et al.* 2008; Pettorelli *et al.* 2008).

The aims of this chapter were to examine the home range and core area sizes of cheetahs in the Timbavati Private Nature Reserve, South Africa, and to determine whether a preference was displayed for certain habitat types. The extent to which selected spatial variables (i.e. home range size, habitat use, distance from drainage lines, slope and aspect) differed amongst individual cheetah social groups (i.e. single males, female with cubs and independent cubs) was also investigated.

METHODS

Data collection

Collaring of male cheetahs

Location data for two male cheetahs was obtained by using cellular (GPS/GSM) collars (supplier: Africa Wildlife Tracking, http://www.awt.co.za, Pretoria, South Africa). The two males (M1 and M7) were darted and collared in the Timbavati Private Nature Reserve (TPNR) on consecutive days, 14 and 15 July 2010. The

collars contained two C cells to reduce the overall size of the unit and the total weight of the collar (~450g, which is less than 2% of the average body weight of a cheetah) (Skinner and Chimimba 2005; Sikes *et al.* 2011).

Both M1 and M7 were darted by a qualified veterinarian using an X-Caliber CO_2 dart rifle, with 2.0 ml, gel-collared (drop-out) darts, stabilised containing 100.0 mg ketamine hydrochloride, 2.0 mg medetomidine hydrochloride and 0.8 ml sterile water (Jalanka 1989; Lewandowski *et al*. 2002; Walser-Reinhardt *et al*. 2010). Both cheetahs were darted from a range of between 10 and 20 metres and anaesthesia was induced within nine minutes for both animals.

Once darted, the animals were laid in a lateral recumbency, and fitted with the GPS/GSM collars (African Wildlife Tracking, Pretoria, South Africa). Twenty millilitres of blood was taken from each cheetah for routine haematology and for DNA profiling (to be assayed by the Cheetah Conservation Fund in Namibia). In addition, a further 5.0 ml of blood was taken for the State Veterinary Service to test for rabies. Based on dentition, M1 was estimated to be approximately seven years of age and M7 was estimated to be approximately two years old (Marker 2002).

The entire darting procedure took less than 20 minutes for each animal, and there were no complications during anaesthesia for either animal. Both individuals were administered with prophylactic doses of both 20.0 mg of the non-steroidal anti-inflammatory meloxicam and a broad-spectrum antibiotic combination containing 250.0 mg neomycin sulphate and 500.0 mg (500,000 i.u.) procaine benzylpenicillin, before the anaesthesia was reversed using 5.0 mg atipamezole hydrochloride. In addition, both animals‟ eyes were treated with antibiotic, viscous, ophthalmic drops containing 1% fusidic acid. The darting and handling procedures described above were granted ethical clearance by the Rhodes University Ethical Standards Committee, clearance number ZOOL-01-2010.

Male cheetah GPS location data

The cellular (GPS/GSM) collars allowed for the daily collection of data, whereby the collars were programmed to take latitude and longitude readings at four intervals per

day (GPS fixes were set at 06:00, 10:00, 13:00 and 18:00). These times were chosen to include periods of both activity and rest at various times of the day (Houser *et al.* 2009a). Incorporating mobile periods increased the likelihood of receiving a satellite fix of the cheetah‟s location and for improving the accuracy of daily movement determinations (Houser *et al.* 2009a). Including times of rest also allowed for direct observations to be made if required. The collars were also set to download any stored data to the cellular network at 07:00 and 14:00 each day. These data were then relayed to an internet server (http://www.yrless.co.za) via the GSM network where they could be accessed remotely. During periods when there was insufficient GSM network coverage in order to transmit data, GPS location data were stored on-board the collars. However, when the animal re-entered an area with sufficient network coverage, the stored data was transferred to the server. The GPS units within the collars were programmed to have a GPS log time of three minutes. Once all GPS location data were downloaded from the internet, the co-ordinates were converted to Universal Transverse Mercator (UTM) format compatible with the spatial software ArcMap 10 (Environmental Systems Research Institute (ESRI), California, USA).

GPS location data for other cheetah social groups

Due to logistical constraints and aesthetic reasons, it was not possible to collar cheetahs from other social groups during the study period. However, because cheetahs are individually identifiable (Kelly 2001; Marnewick *et al.* 2008) it was possible to utilise sightings data for other cheetah social groups as determined by direct observations (Bissett 2004). These observations were made by lodge staff, game guides, field rangers and wildlife staff (ecologist, warden and assistant warden) on the reserve. An adult female with cubs and a trio of independent (adolescent) cubs were seen regularly enough (> 25 reliable GPS fixes) to generate sufficient location data to make meaningful comparisons with the data collected for the collared males (Harris *et al*. 1990; Kenward and Hodder 1996; Houser *et al*. 2009a). All sightings recorded by the various individuals within the reserve were reported, and details and photographs of the sightings were submitted. Actual GPS co-ordinates seldom accompanied a sighting. Thus, when only an approximate

location was submitted, the actual location was determined by triangulating the descriptive location using Google Earth (Google Earth, Version 6.1.0.5001, Mountain View, CA, USA: Google Inc. 2009). The accuracy of this location was corroborated by checking it in relation to the roads, rivers and other prominent landmarks present on the reserve.

The locations of the three cheetah social groups were recorded over the period of a year (July 2010 to June 2011). Data for M1 was the only exception due to a collar malfunction six months after collaring.

Home range characterization

Home range size

Home range and core area sizes of the three cheetah social groups were calculated using the home range analysis tool of Biotas version 2.0a (Ecological Software Solutions LLC, Florida, USA). Data points from both the GPS/GSM collars and direct observations were used to determine the home ranges of the respective animals (Broomhall *et al.* 2003). To prevent auto-correlation of GPS fixes and to ensure statistical independence, only one GPS fix per day was used in the calculation of home range size for the two male cheetahs (Gehrt and Fritzell 1998; Broomhall *et al.* 2003; Bissett 2004). One fix per day was randomly chosen using the RANDBETWEEN function in Microsoft Excel (Microsoft Corporation, 2010).

The non-parametric kernel utilisation distribution (UD) method was chosen to calculate home range (95% UD) and core area (50% UD) sizes (Worton 1989). This technique provides a more accurate representation of habitat use than the more traditional Minimum Convex Polygon (MCP) approach (Worton 1989; Seaman and Powell 1996; Swihart and Slade 1997; Seaman *et al.* 1999). The MCP method is the simplest method in terms of home range analysis, generating only a single polygon by linking the outermost GPS fixes (Harris *et al.* 1990). This is a major drawback as home range size is influenced considerably by outlying fixes, which often results in the inclusion of vast unused areas (Harris *et al*. 1990). In contrast, the kernel UD approach is a probability density estimation, which takes into consideration the amount of time that an animal spends in different parts of its range, thereby

introducing a useful third dimension to home range estimates (Worton 1989; Seaman *et al.* 1999; Rodgers and Kie 2011). The Kernel UD method assigns a kernel (a probability density) to each location point (GPS fix); the data is then superimposed with a regular grid, whereby a density estimate is acquired for each grid intersection for all the overlapping kernels at that point (Seaman and Powell 1996; Rodgers and Kie 2011). Using the probability density estimates from each intersection, a kernel probability density estimator (UD) is then calculated across the entire grid. The density estimate will therefore be high in areas with higher volumes of fixes and lower in areas with less fixes (Seaman and Powell 1996). Based on the calculated volumes of the kernels at the grid intersections, contour lines (or isopleths) are created, allowing for home range estimates to be made (Rodgers and Kie 2011). Home range polygons can then be defined at different probability levels by the isopleths, and the areas of the polygons can be calculated (Rodgers and Kie 2011).

Home ranges were analysed at the 50% and 95% levels; the most suitable estimators of core area and overall home range size (Mizutani and Jewell 1998). The study period was also divided into the two main ecological seasons, the wet and dry season (Marker 2002; Houser *et al.* 2009a). The wet season was defined as the period between October and March and the dry season was defined as the period between April and September, consistent with the climatic data provided by the Hoedspruit weather station (Station number: 0638052; Latitude 24º 22‟S; Longitude 31º 02‟ E; Altitude: 513m above sea level). Seasonal core areas and total home ranges (km²) were only calculated for the two males due to insufficient data for the female with cubs (n = 1) and independent cubs (n = 1).

Habitat use

An existing vegetation layer for the study area (Mucina and Rutherford 2006; Figure 12) was utilised to determine habitat availability. The proportion of each habitat type which occurred within each cheetah social group‟s home range was determined using Biotas 2.0a. Observed habitat use was calculated as the proportion of GPS location points within each vegetation type within each respective cheetah social group‟s home range (Bissett 2004). Habitat preference was analysed for each

cheetah social group using chi-square goodness-of-fit tests (Biotas 2.0a), with the null hypothesis that observed habitat usage occurred in proportion to the expected use (Alldredge and Ratti 1986).

Since habitat selection was determined using the proportion of points in each habitat type, it should be noted that the results will be biased for the cheetahs whose ranges were estimated through sightings, as cheetahs are intrinsically more likely to be located in more open areas than dense bush. Therefore, the collared cheetahs have less bias in this regard than the female and the independent cubs.

Further habitat characterization

Drainage lines are important to cheetahs, in particular females as their banks are lined with denser riverine vegetation. Female cheetahs tend to prefer thicker habitats and drainage lines not only because of the high prey availability, but also to avoid conflict with other larger predators such as lions (Broomhall *et al.* 2003).

The mean distance from drainage lines for each cheetah social group‟s core area and home range was calculated using ArcMap 10‟s Analysis Tools and the Proximity tool available (Environmental Systems Research Institute (ESRI), California, USA).

To determine whether any of the cheetah social groups were specifically choosing to be closer or further away from drainage lines, four sets of random points were generated using the Hawth‟s Tools extension for ArcMap (Beyer, H. L. 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com/htools). Each set of random points had the same number of GPS fixes as those observed within the core areas and home ranges of the three cheetah social groups. The two sets of expected (random) and observed values for the male cheetahs were compared statistically using a chi-square goodness-of-fit test in Statistica (Statsoft, Tulsa, OK, USA). To determine whether a significant difference could be found between the cheetah social groups in terms of average distance to drainage lines, two Kruskal-Wallis tests were conducted (one for the home range data and one for the core area data) in Statistica. The independent variable for each test was cheetah social group.

To calculate slope and aspect for each GPS data point, a digital elevation model (DEM) was generated within ArcMap10. The DEM was then used to determine slope and aspect for each GPS fix using the slope tool under Spatial Analyst Tools within ArcMap10. Mean slope and aspect for the two collared male cheetahs were determined from all GPS fixes. As with distance to drainage lines, two sets of expected (random) and observed values of each single male cheetah were also then compared statistically using chi-square goodness-of-fit tests in Statistica. A Rayleigh‟s Uniformity Test (Oriana) was used to analyse whether the two collared males preferred certain aspects (Flat -1°; North 0 - 22.5°; Northeast 22.5° - 67.5°; East 67.5° - 112.5°; Southeast 112.5° - 157.5°; South 157.5° - 202.5°; Southwest 202.5° - 247.5°; West 247.5° - 292.5°; Northwest 292.5° - 337.5°; North 337.5° - 360°). Slope and aspect could not be calculated for the female with cubs and the independent cubs as exact positions of the sightings were not recorded.

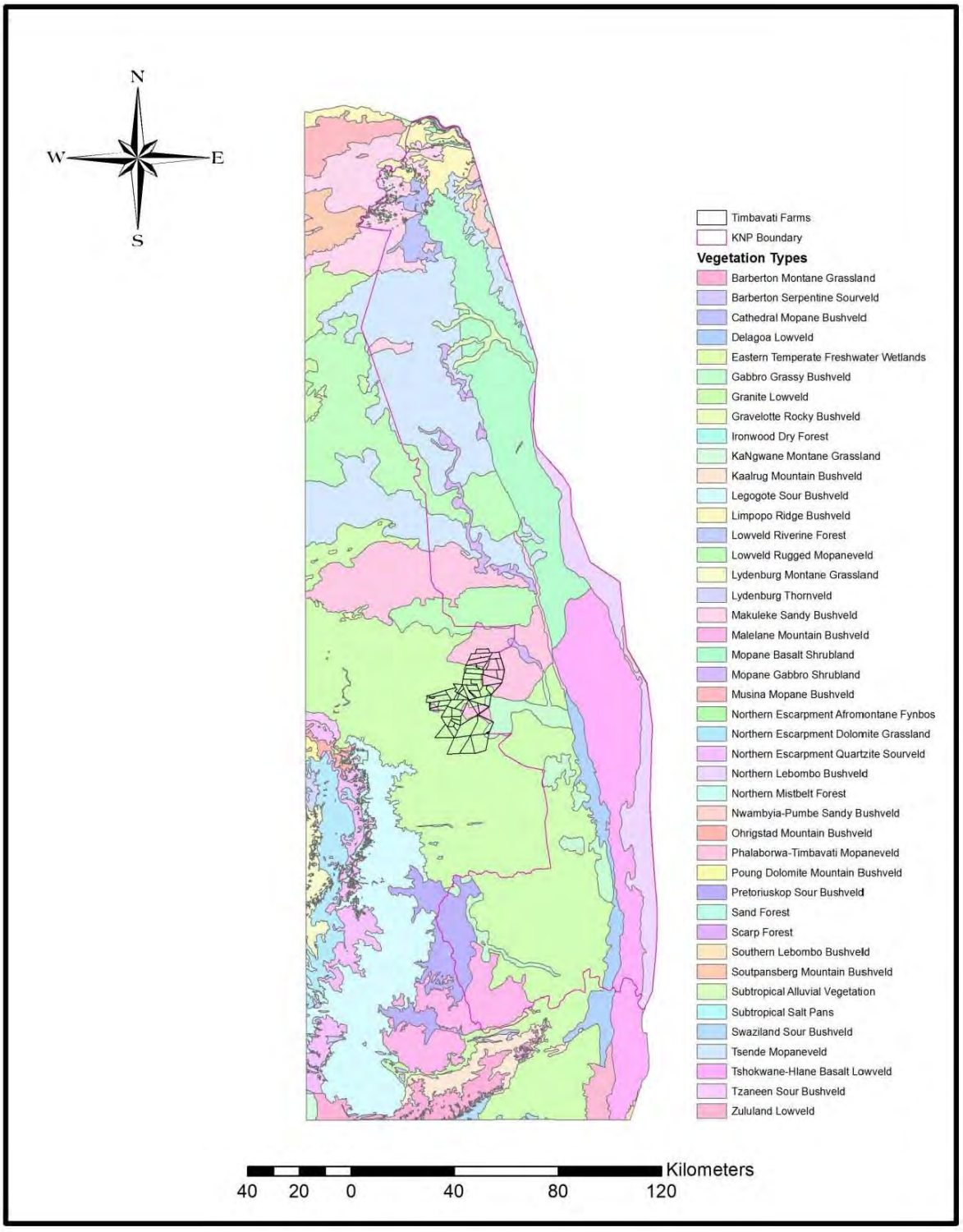

Figure 12: The distribution of the 43 vegetation types of Timbavati Private Game Reserve and surrounding area. The boundary of the Timbavati Private Game Reserve is shown in black and the boundary of the Kruger National Park is shown in pink.

RESULTS

Home range and core area sizes

M7, the younger collared male, displayed the largest 95% UD, covering a substantial (659.65km²) area (Table 3; Figure 13). In sharp contrast, M1 the older of the two collared males, remained within a substantially smaller area (28.96km²) (Table 3; Figure 14).

The female with cubs had the smallest 95% UD of all the cheetah social groups, and ranged within a relatively small area of the reserve, covering 20.97km² (Table 3; Figure 15). The independent cubs displayed a much larger (82.75km²) 95% UD (Table 3; Figure 16), the second largest when compared with the female with cubs and M1 (Table 3). However, the results for the female with cubs and the independent cubs should be interpreted with caution due to the small sample sizes for these social groups (Table 3).

In terms of wet and dry season ranges for the two collared males, M1‟s wet season 95% UD (27.85km², Figure 17) was only slightly smaller than his dry season UD of 32.15km² (Table 3; Figure 18). Conversely, M7 showed a considerable difference in size between the areas he covered during the wet and dry seasons (Figures 19 and 20). M7‟s dry season UD (595.02km²) was much larger than his wet season range of 304.17km² (Table 3).

Table 3: Home range and core area sizes of the three cheetah social groups within the Timbavati Private Nature Reserve as calculated by the fixed kernel UD method. The total number of GPS fixes used to calculate home range & core area estimates is also provided.

Cheetah Group	Sample Size (total number of GPS fixes)	Area (km²) 50%	Area (km²) 95%
M1 (overall home range)	177	3.16	28.96
M1 (dry season)	78	3.65	32.15
M1 (wet season)	99	2.88	27.85
M7 (overall home range)	360	4.83	659.65
M7 (dry season)	179	11.87	595.02
M7 (wet season)	181	3.54	304.17
Female with cubs	33	2.36	20.97
Independent cubs	30	5.10	82.75

Movement of the cheetahs

M7 remained within the TPNR for only a short period of time after being collared. After two months, M7 moved well beyond the reserve‟s unfenced boundaries, passing into a number of the surrounding private game reserves north of the TPNR, including Klaserie and Balule. From there, he moved south, back into the Timbavati, but only briefly before moving into the KNP. Upon entering the KNP, he ranged southwards to an area just south of the Tshokwane picnic site, only to return north along the foothills of the Lebombo Mountains a short time later. From here, he moved in a north-westerly direction, to where he finally settled and established himself in an area between the town of Phalaborwa and the Mopani rest camp within the KNP (Figure 13).

M1 was collared within the TPNR and moved into the neighbouring Thornybush Game Reserve on the same day. He remained within Thornybush for the duration of the study period (Figure 14).

The female with cubs‟ home range was positioned in the south-western portion of the reserve (Figure 15) and the independent cubs‟ home range was more dispersed with the majority falling within the northern sector of the reserve (Figure 16).

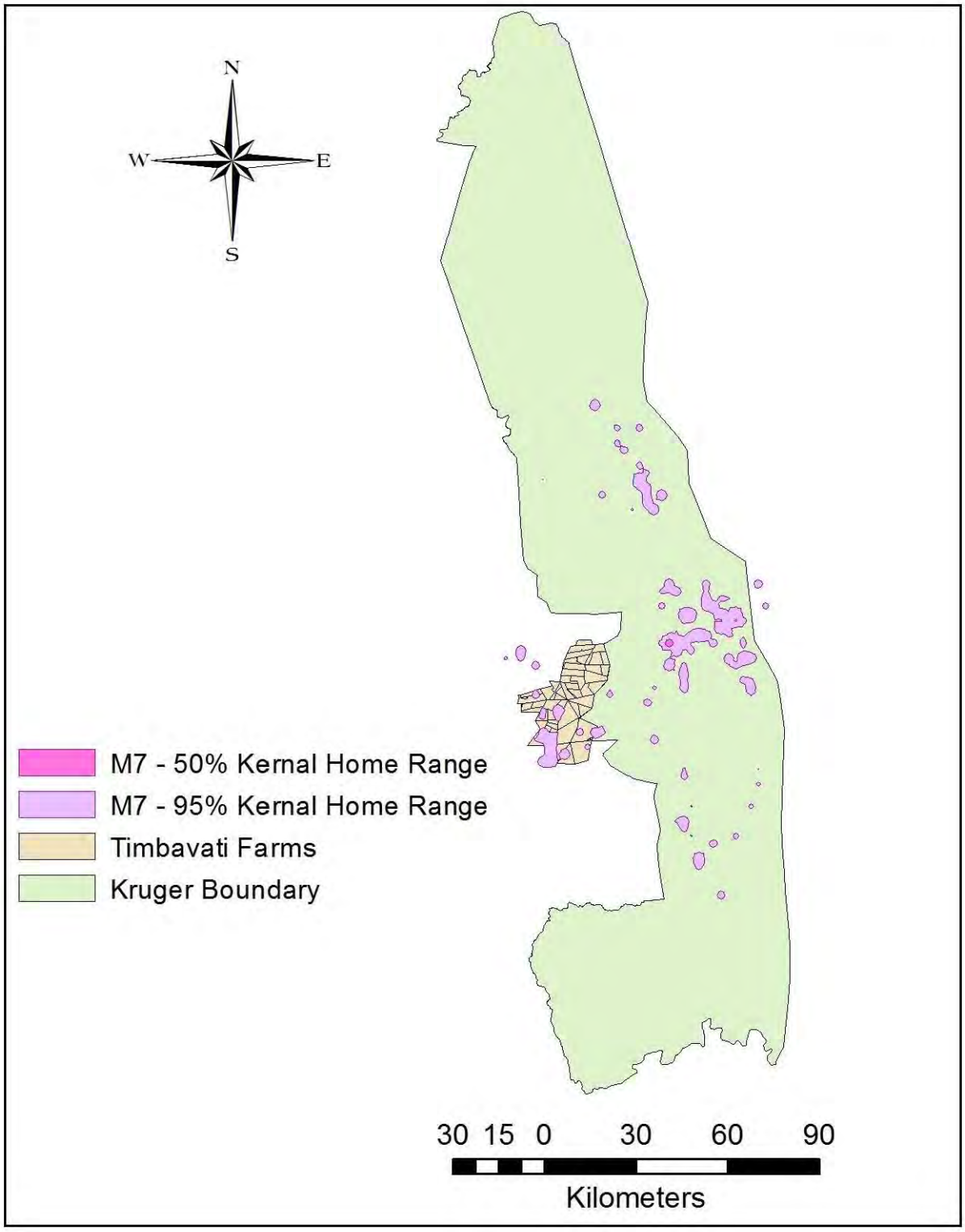

Figure 13: Home range and core areas of M7. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown and the Kruger National Park is shown in green.

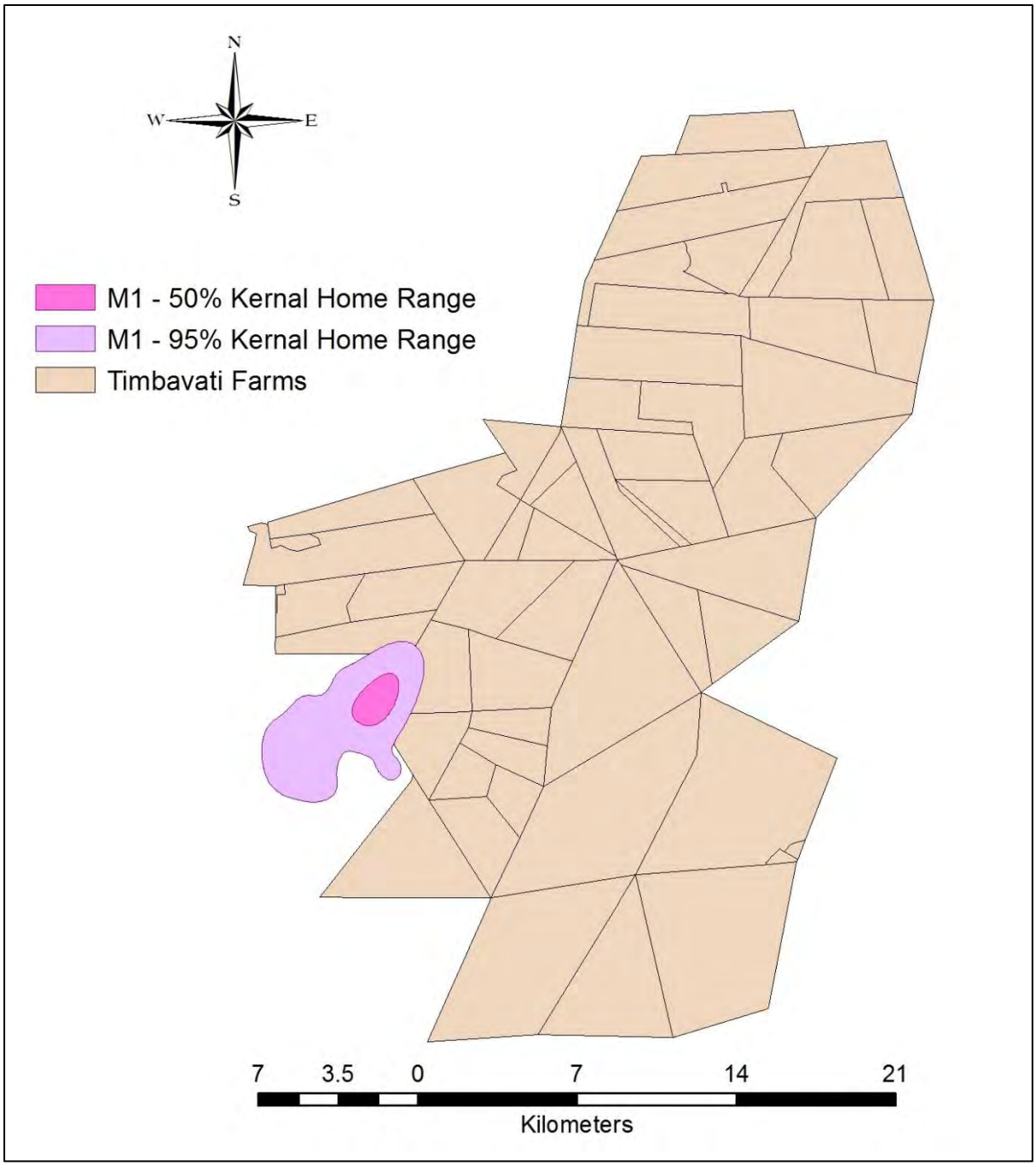

Figure 14: Home range and core areas of M1. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown.

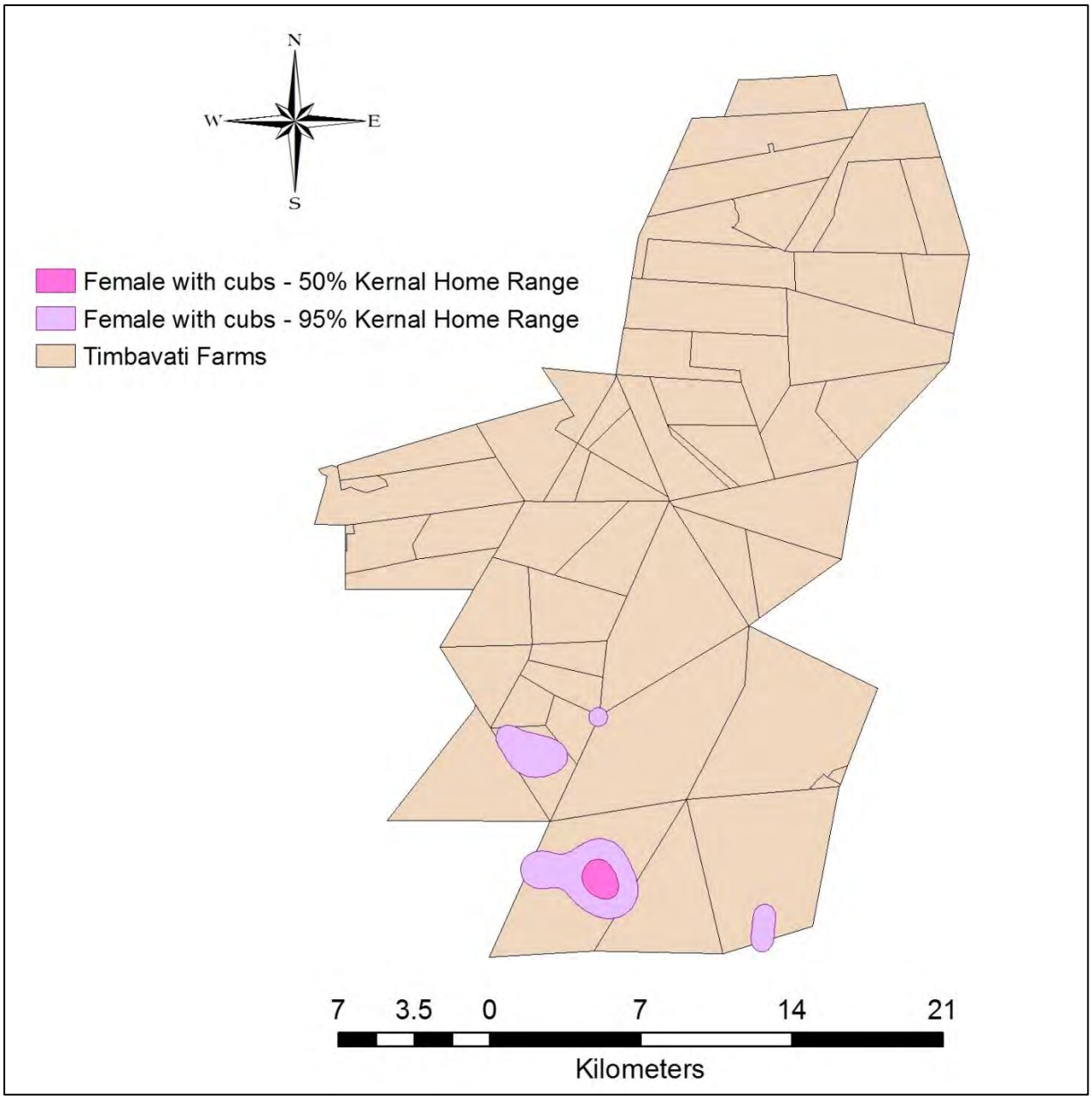

Figure 15: Home range and core area of the female with cubs. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown.

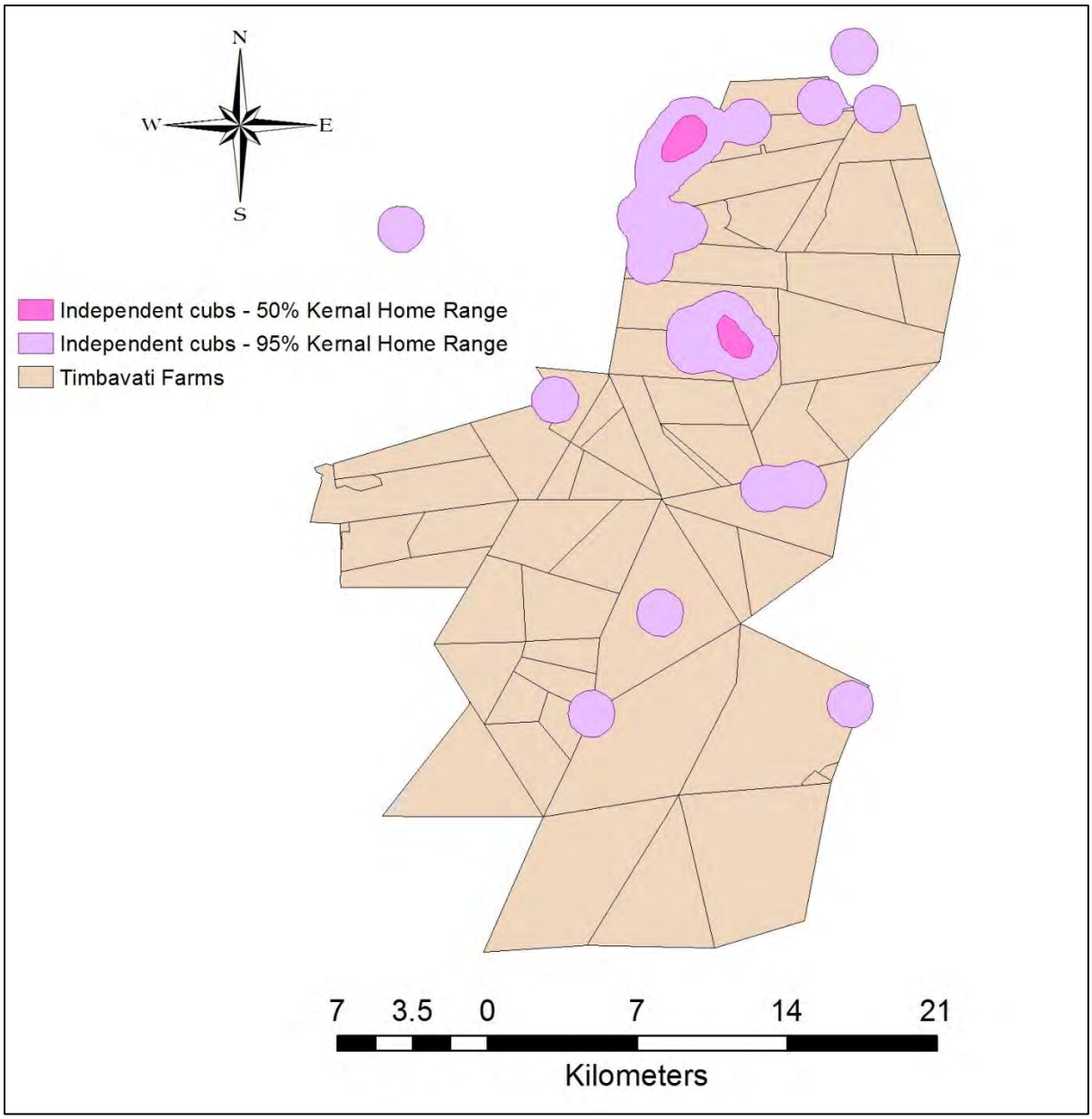

Figure 16: Home range and core areas of the independent cubs. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown.

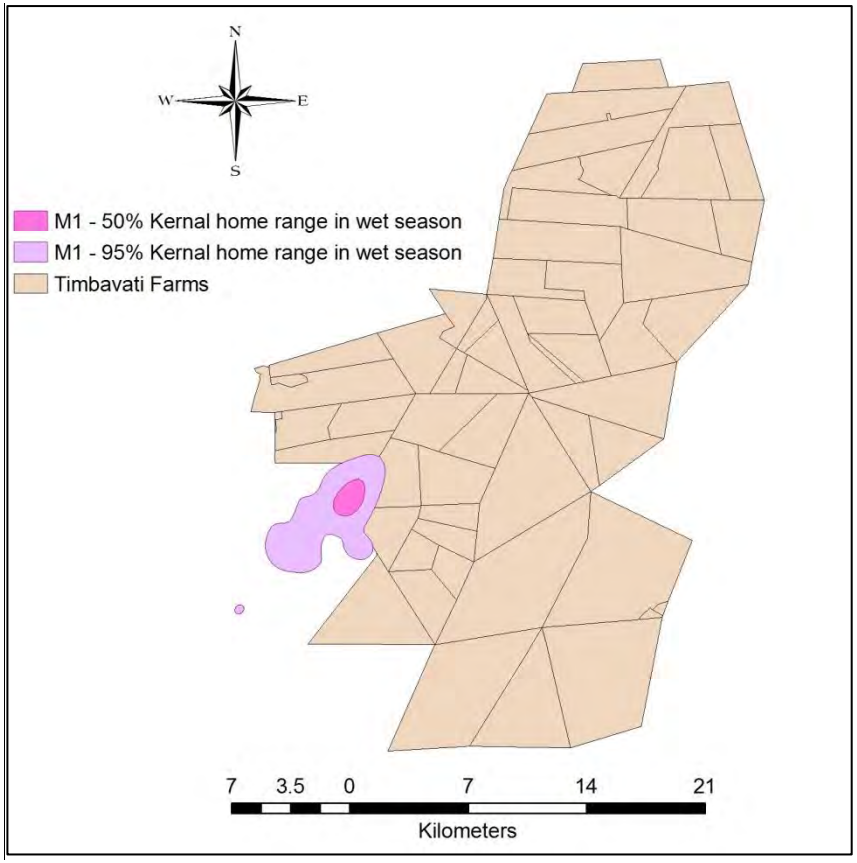

Figure 17: Wet season home range and core area of M1. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown.

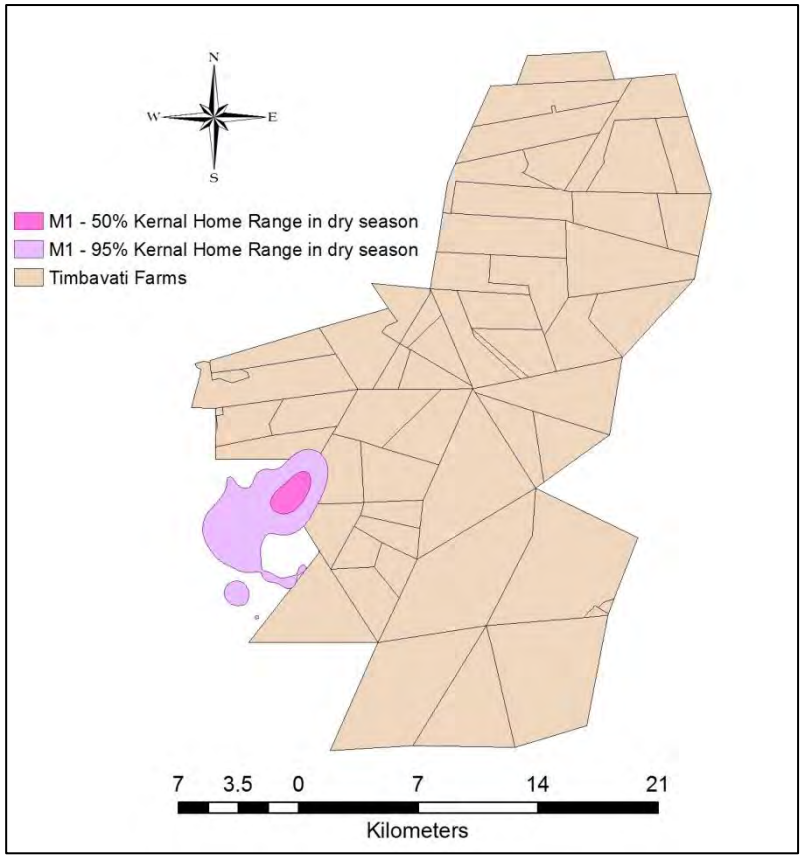

Figure 18: Dry season home range and core area of M1. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown.

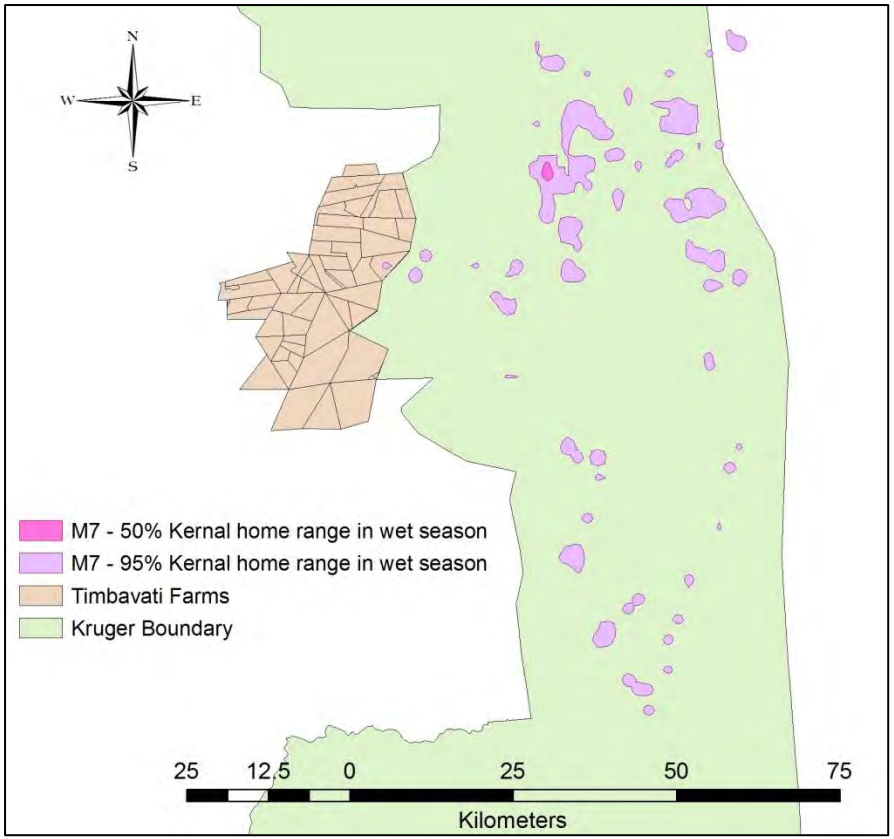

Figure 19: Wet season home range and core area of M7. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown and the Kruger National Park is shown in green.

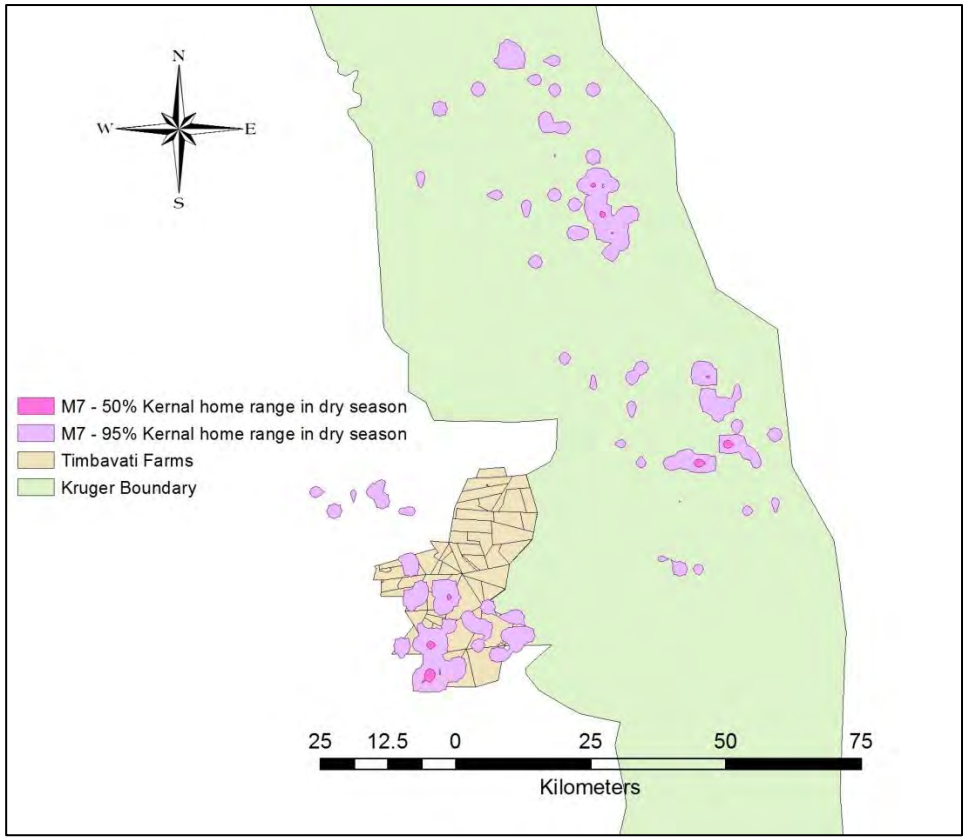

Figure 20: Dry season home range and core areas of M7. 95% and 50% UDs were determined by the fixed kernel method. The Timbavati Private Game Reserve is shown in brown and the Kruger National Park is shown in green.

Habitat use

M1‟s home range was characterised by only two vegetation types, these being Granite Lowveld (GL) and Phalaborwa-Timbavati Mopaneveld (PTM). The PTM represented approximately 1% of his total home range (Table 4). GL therefore dominated the home range of this cheetah (Table 4). M7‟s home range supported a total of 10 different vegetation types (Table 4). Tshokwane-Hlane Basalt Lowveld formed the dominant vegetation type within this cheetah‟s 95% home range, covering 45.45% of the overall area (Table 4). The second most important vegetation type was Granite Lowveld at 25.66%, followed by Mopane Basalt Shrubland covering 17.67% of his home range (Table 4). The remaining seven vegetation types: Delagoa Lowveld; Gabbro Grassy Bushveld; Lowveld Rugged Mopaneveld; Makuleke Sandy Bushveld; Northern Lebombo Bushveld; Phalaborwa-Timbavati Mopaneveld and Tsende Mopaneveld were all only marginally represented within M7‟s home range (Table 4). M7 used the habitat available to him within his home range at random ($p > 0.05$ for all vegetation types). Only two vegetation types occurred within M7‟s core area with THBL characterising 97.92% and MSB only 2.08%, whereas M1‟s core area was comprised entirely by GL (Table 5).

In the dry season, M7 used the same 10 vegetation types as his overall annual home range (Table 4). However, the THBL accounted for a much lower proportion of the vegetation than it represented within the overall annual home range (Table 4). During the dry season, GL formed the dominant vegetation type at 33.88% (Table 4). MBS was the second most dominant type representing 26.24% of the total area during this time (Table 4). Nevertheless, M7 still utilised the habitats available to him at random ($p > 0.05$ for all vegetation types). GL dominated M7‟s dry season core area at 46.28% (Table 5). M7‟s wet season home range was characterised by nine vegetation types, with THBL (65.24%) and GL (15.39%) being used the most (Table 4). However, M7 still used the available habitat at random ($p > 0.05$ for all vegetation types). The core area of the wet season home range was supported exclusively by THBL (Table 5).

During the dry season, M1‟s home range was dominated almost exclusively by GL (99.23%), with PTM comprising the remaining 0.77% (Table 4). M1‟s habitat use in the wet season was similar (Table 4). M1‟s dry and wet season core areas were supported exclusively by GL (Table 5).

The home range of the female with cubs was characterised by Granite Lowveld only, whereas three vegetation types were represented within the home range of the independent cubs (Table 4). These vegetation types were Gabbro Grassy Bushveld (5.7%), Granite Lowveld (50.55%) and Phalaborwa-Timbavati Mopaneveld (43.75%). GGB did not form part of the core area of the independent cubs (Table 5). However, PTM (58.97%) was more important in the core area of the independent cubs than GL (41.03%; Table 5). The core area of the female with cubs consisted of GL only (Table 5).

Table 4: Home range size (km²), mean distance from drainage lines (m) and habitat use (% of each vegetation type) of the three cheetah social groups, including the seasonal home ranges of the two single male cheetahs (M1 and M7).

	Cheetah Group							
	M1	M1 (Dry)	M1 (Wet)	M7	M7 (Dry)	M7 (Wet)	Female + cubs	Independent cubs
Characteristics								
HR Size (km²)	28.96	32.15	27.85	659.65	595.02	304.17	20.97	82.75
Vegetation Types (%)								
DL	-	-	-	0.42	0.03	2.18	-	-
GGB	-	-	-	4.20	5.03	5.89	-	5.70
GL	99.13	99.23	99.02	25.66	33.88	15.39	100	50.55
LRM	-	-	-	0.53	3.44	-	-	-
MSB	-	-	-	1.49	0.09	2.53	-	-
MBS	-	-	-	17.67	26.24	4.47	-	-
NLB	-	-	-	1.55	0.82	1.62	-	-
NPSB	-	-	-	-	-	0.36	-	-
PTM	0.87	0.77	00.98	1.62	3.09	2.33	-	43.75
TM	-	-	-	1.41	6.97	-	-	-
THBL	-	-	-	45.45	20.40	65.24	-	-
Drainage lines (m)	192.74±134.98	202.93±143.81	179.68±126.63	250.01±280.89	270.92±332.44	214.58±167.53	435.04±257.37	105.88±72.19

Vegetation types are as described in chapter 2: DL = Delagoa Lowveld; GGB = Gabbro Grassy Bushveld; GL = Granite Lowveld; LRM = Lowveld Rugged Mopaneveld; MSB = Makuleke Sandy Bushveld; MBS = Mopane Basalt Shrubland; NLB = Northern Lebombo Bushveld; NPSB = Nwambyia-Pumbe Sandy Bushveld; PTM = Phalaborwa-Timbavati Mopaneveld; TM = Tsende Mopaneveld; THBL = Tshokwane-Hlane Basalt Lowveld;

Table 5: Core area size (km²), mean distance from drainage lines (m) and habitat use (% of vegetation types) of the three cheetah social groups, including the seasonal home ranges of the two single male cheetahs (M1 and M7).

	Cheetah Group							
	M1	M1 (Dry)	M1 (Wet)	M7	M7 (Dry)	M7 (Wet)	Female + cubs	Independent cubs
Characteristics								
Core area Size (km²)	3.16	3.65	2.88	4.83	11.87	3.54	2.36	5.10
Vegetation Types (%)								
DL	-	-	-	-	-	-	-	-
GGB	-	-	-	-	-	-	-	-
GL	100	100	100	-	46.28	-	100	41.03
LRM	-	-	-	-	-	-	-	-
MSB	-	-	-	2.08	-	-	-	-
MBS	-	-	-	-	12.64	-	-	-
NLB	-	-	-	-	-	-	-	-
NPSB	-	-	-	-	-	-	-	-
PTM	-	-	-	-	4.88	-	-	58.97
TM	-	-	-	-	-	-	-	-
THBL	-	-	-	97.92	36.2	100	-	-
Drainage lines (m)	187.25±137.96	201.52±135.06	170.90±141.25	132.41±97.51	255.65±333.50	131.87±100.91	525.14±258.76	69.11±53.36

Vegetation types are as described in chapter 2: DL = Delagoa Lowveld; GGB = Gabbro Grassy Bushveld; GL = Granite Lowveld; LRM = Lowveld Rugged Mopaneveld; MSB = Makuleke Sandy Bushveld; MBS = Mopane Basalt Shrubland; NLB = Northern Lebombo Bushveld; NPSB = Nwambyia-Pumbe Sandy Bushveld; PTM = Phalaborwa-Timbavati Mopaneveld; TM = Tsende Mopaneveld; THBL = Tshokwane-Hlane Basalt Lowveld;

Further characterization of home ranges

Distance to drainage lines

For the 95% UD data, the average distance to drainage lines was significantly different across cheetah social groups (Table 4; $H_{(3, 482)} = 42.68$, $P < 0.0001$). M7 and M1 were found to be significantly further away from drainage lines than the independent cubs but significantly closer to drainage lines than the female with cubs (Table 4). The independent cubs were significantly closer to drainage lines than any other cheetah social group (Table 4). The female with cubs was significantly further away from drainage lines than the other social groups (Table 4).

For the 50% UD data, the average distance to water was also significantly different across the cheetah social groups (Table 5; $H_{(3, 135)} = 40.36$, $P < 0.0001$). M7 and M1 were significantly closer to drainage lines than the female with cubs (Table 5). M1 was significantly further from drainage lines than the independent cubs (Table 5). The female with cubs was again significantly further away from drainage lines than any of the other cheetah social groups (Table 5).

The observed distances to drainage lines for the 95 and 50% UD"s of all cheetah social groups were significantly different to the expected values. The female with cubs was significantly further away from drainage lines than expected for both her 50% ($\chi^2 = 20302.95$, df = 21, $P < 0.001$) and 95% UDs ($\chi^2 = 99632.22$, df = 31, $P < 0.001$; Table 4 and 5). The independent cubs were significantly further away from drainage lines than expected within their core area (Table 5; $\chi^2 = 2069.40$, df = 11, $P < 0.001$), but were significantly closer to drainage than expected in their overall home range (Table 4; $\chi^2 = 11530.72$, df = 29, $P < 0.001$). By comparison, M1 chose to be significantly closer ($\chi^2 = 132556.70$, df = 160, $P < 0.001$; $\chi^2 = 56753.21$, df = 85, $P < 0.001$) to drainage lines within both his 95 and 50% UD"s, and M7 selected to be further away from drainage line within his 50% UD ($\chi^2 = 3856.88$, df = 14, $P < 0.001$) but significantly closer than expected to drainage lines in his 95% UD ($\chi^2 = 1275999.00$, df = 256, $P < 0.001$).

The wet and dry season home ranges for both M1 and M7 also showed significant differences between mean distance from drainage lines and random points. M1

preferred to select for areas closer to drainage lines for both his 50% and his 95% UD‟s in both the wet and the dry seasons (wet = χ^2 = 38825.64, df = 48, P < 0.001 and χ^2 = 48566.92, df = 92, P < 0.001; dry = χ^2 = 397313.10, df = 34, P < 0.001 and χ^2 = 125685.00, df = 75, P < 0.001, respectively). With the exception of M7‟s 95% UD during the dry season, he tended to be nearer to drainage lines during both the wet and the dry season core areas and home ranges (wet = χ^2 = 3913.11, df = 13, P < 0.001 and χ^2 = 201221.2, df = 156, P < 0.001; dry = χ^2 = 26777.27, df = 19, P < 0.001 and χ^2 = 299917.80, df = 172, P < 0.001, respectively).

Slope

M1 generally occupied steeper slopes for his overall and seasonal home ranges than did M7 (Table 6). Both M1‟s and M7‟s actual fixes were found to be significantly different from random points for both their 95% and 50% UD‟s during the wet and dry seasons, and for their annual home ranges (Table 6). The only exception was M7‟s overall 50% UD for which no significant difference was found, suggesting he used the slopes available to him at random (Table 6). For both annual and seasonal home ranges (50% and 95% UD‟s), both the male cheetahs selected for steeper slopes, except during the wet season where M1 selected for more gradual slopes within his core area (50% UD), and M7 within his 95% UD for the wet season and his annual home range (Table 6).

Table 6: Mean slope (°) at which the two male cheetahs occurred within their home ranges and core areas, with expected vs observed means and respective χ^2 Results.

Individual Male	Expected	Observed	χ^2 Results
M1			
50% UD	1.24±0.87	1.64±1.03	$\chi^2 = 274.27$, df = 85, $p < 0.001$
95% UD	1.39±1.06	1.63±1.10	$\chi^2 = 1272.83$, df = 160, $p < 0.001$
M1 (Dry)			
50% UD	1.25±0.83	1.62±1.09	$\chi^2 = 104.13$, df = 34, $p < 0.001$
95% UD	1.44±0.89	1.60±1.12	$\chi^2 = 337.8$, df =75 , $p < 0.001$
M1 (Wet)			
50% UD	1.77±1.09	1.69±0.96	$\chi^2 = 81.68$, df = 48, $p < 0.001$
95% UD	1.30±0.92	1.67±1.06	$\chi^2 = 295.49$, df = 92, $p < 0.001$
M7			
50% UD	0.71±0.32	1.00±0.26	$\chi^2 = 6.87$, df = 14, $p > 0.05$
95% UD	0.92±0.89	0.87±0.81	$\chi^2 = 1223.31$, df = 256, $p < 0.001$
M7 (Dry)			
50% UD	0.97±0.59	1.11±0.82	$\chi^2 = 54.62$, df = 19, $p < 0.001$
95% UD	0.91±0.81	0.96±0.94	$\chi^2 = 562.37$, df = 172, $p < 0.001$
M7 (Wet)			
50% UD	0.51±0.30	1.02±0.25	$\chi^2 = 36.5$, df = 13, $p < 0.001$
95% UD	0.81±0.74	0.79±0.67	$\chi^2 = 738.73$, df = 156, $p < 0.001$

Aspect

All the results from the Rayleigh Z tests were significantly different from a uniform distribution, indicating that the adult male cheetahs preferred particular aspects. The exceptions to this trend were M7‟s overall 95% UD; M7‟s dry season 50% UD; and M7‟s dry season 95% UD, where the Z values were below the critical threshold (Table 7). Thus, selection for aspect by M7 during these periods was random (Table 7).

For M1‟s dry season home ranges and his overall 95% UD, the NW facing slopes were selected for, whereas during the wet season and his overall 50% UD (core area), M1 preferred north facing slopes (Table 7 and Figure 21). M7 selected for NW facing slopes for his overall and wet season home ranges (50% and 95% UD‟s) (Table 7 and Figure 22). However, the preference for NW facing slopes within his overall 95% UD was not significant (Table 7). In contrast, during the dry season M7 showed a preference for south facing slopes within his 95% UD, and a preference for north facing slopes within his core area (50% UD) (Table 7 and Figure 22).

Table 7: Mean aspects (°) of the slopes selected by the two single males within their overall and seasonal home ranges and core areas. Z test statistics are also shown.

Individual Male	Mean angle (°)	Z Test Results
M1		
50% UD	344.805° = N	Z = 12.762, p < 0.001
95% UD	336.653° = NW	Z = 22.55, p < 0.001
M1 (Dry)		
50% UD	317.715° = NW	Z = 7.637, p < 0.001
95% UD	324.457° = NW	Z = 14.022, p < 0.001
M1 (Wet)		
50% UD	354.85° = N	Z = 6.714, p < 0.001

95% UD	346.26° = N	Z = 11.471, p < 0.001
M7		
50% UD	301.512° = NW	Z = 12.656, p < 0.001
95% UD	306.702° = NW	Z = 3.072, p > 0.001
M7 (Dry)		
50% UD	341.037° = N	Z = 0.439, p > 0.001
95% UD	182.433° = S	Z = 1.763, p > 0.001
M7 (Wet)		
50% UD	297.864° = NW	Z = 12.577, p < 0.001
95% UD	332.494° = NW	Z = 7.049, p < 0.001

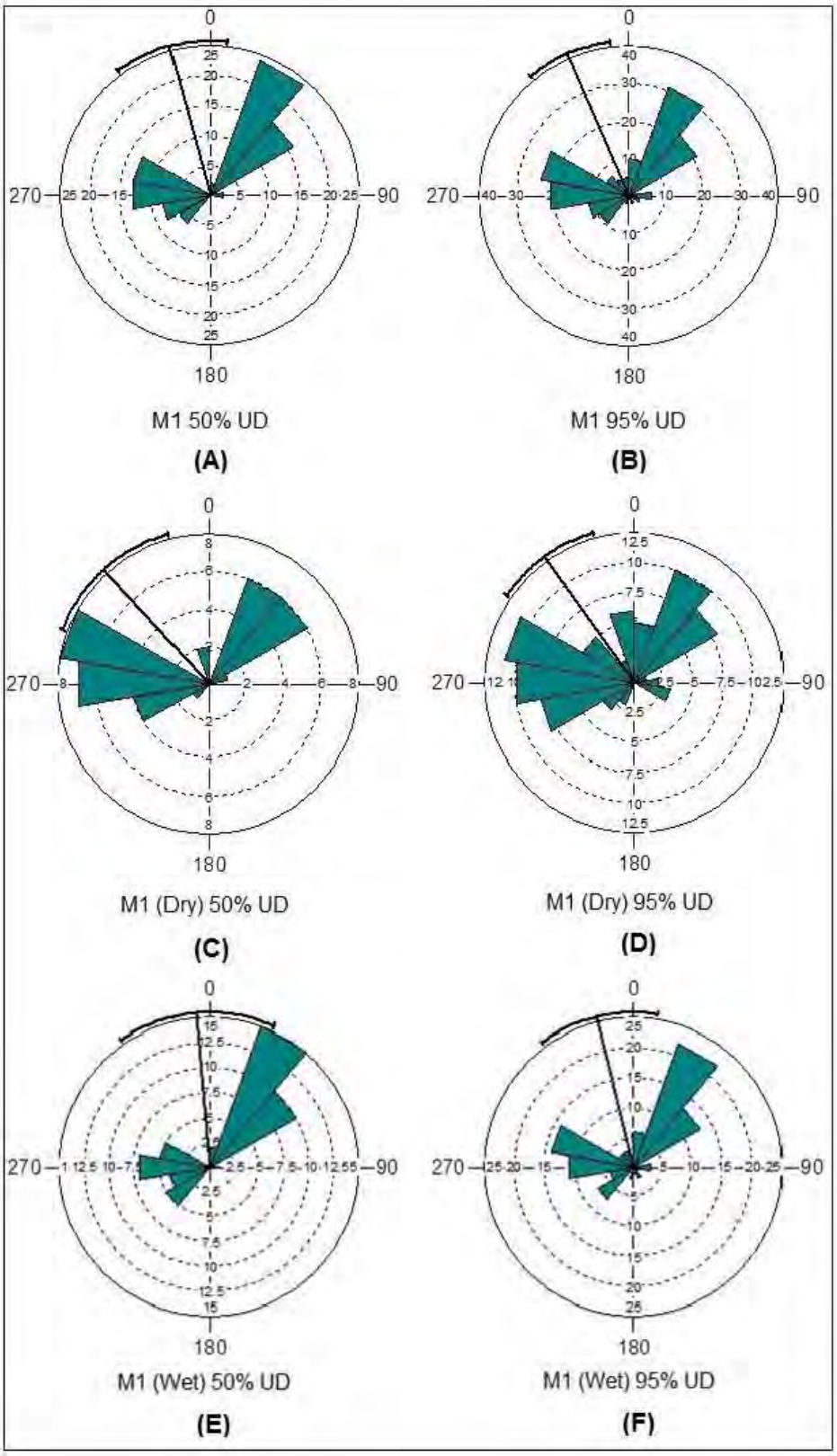

Figure 21: Rose histograms illustrating M1's mean aspects (degrees) selected for within his overall core area (A); overall home range (B); dry season core area (C); dry season home range (D); wet season core area (E); and wet season home range (F).

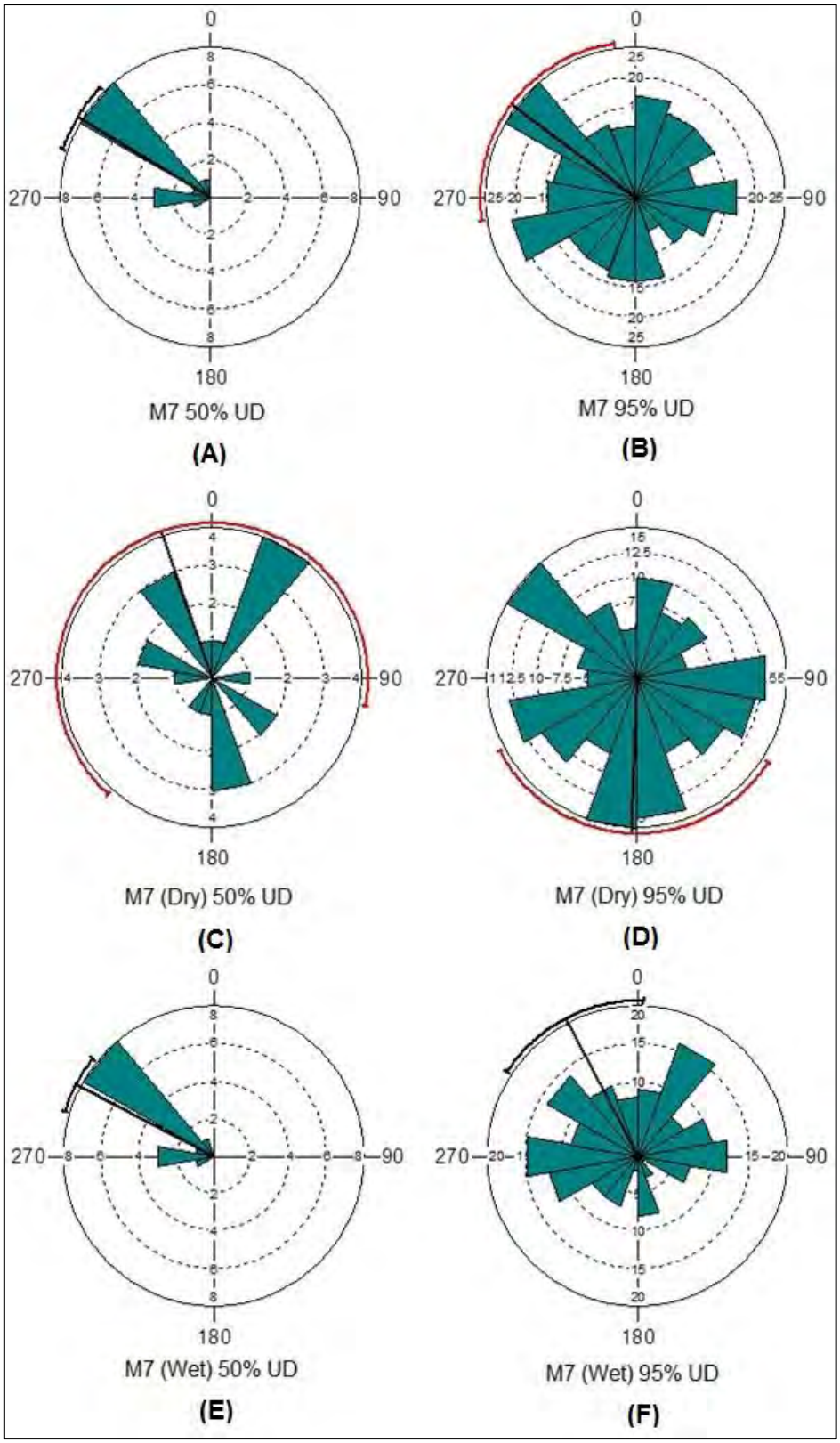

Figure 22: Rose histograms illustrating M7's mean aspects (degrees) selected for within his overall core area (A); overall home range (B); dry season core area (C); dry season home range (D); wet season core area (E); and wet season home range (F).

DISCUSSION

Space use

Some studies have shown that cheetahs move within small home ranges and this was evident for M1, the female with cubs and the independent cubs in my study. According to Purchase and du Toit (2000), two solitary male cheetahs in the MNP had home ranges of 11km² and 53.2km², respectively and a female cheetah ranged over an area of 23km². Purchase and du Toit (2000) concluded that the small home ranges of these cheetah areas were related to high prey densities and easily accessible cover. Unfortunately, prey density data were not available for the current study. However, the dense savanna woodland habitat of my study area is likely to have provided the cheetahs of the TPNR with sufficient cover (Broomhall 2001; Marker 2002; Mills *et al.* 2004). Cover is important for providing protection and shelter from larger competing predators such as lions and hyaenas, and this factor perhaps provides an explanation for the smaller home range sizes found for some of the cheetahs in the current study (Durant 1998; Broomhall 2001; Mills *et al.* 2004).

By contrast, other cheetah spatial ecology studies have demonstrated that cheetahs can have extremely large (>800km²) home ranges (Caro 1994; Marker 2002). For example, Marker *(*2002) found the average home range for cheetahs on Namibian farmlands was 1642km² over their lifetimes and approximately 1056km² annually. Although not as large, M7"s home range in this study was much larger than the home ranges of the other cheetah social groups. M7 a young male cheetah entering adulthood and therefore indicated dispersing behaviour (Laver 2005). Another possible explanation for such wide ranging behaviour could be to avoid other large predators (such as lions and hyaenas), and the intra-guild hostility that arises from these competing species (Laurenson 1994). Even though inter-specific competition with superior predators such as lions has been of importance to cheetah status in other areas, no real evidence was found from the results of the current study. However, although no lion or hyaena related cheetah mortalities were identified, pressure arising from these superior predators could nonetheless still influence cheetah spatial usage by pressurising them to seek refuge in areas with lower densities of lions, thereby avoiding conflict.

Within the Kruger National Park (KNP), Broomhall *et al.* (2003) found that cheetah home range estimates, using the MCP method, at 95% were 126km² for a three-male coalition, 195km² for a single male, and 150km² and 171km² for two females. When Broomhall (2001) later applied the kernel UD method to analyse cheetah home range sizes using the same data, the coalition of three males had a range of 188km², the single male occupied an area of 250km², and the two females were found to have home ranges of 179km² and 244km² (Broomhall 2001). In my study, M7 showed a much larger home range than what Broomhall (2001) determined for the nearby KNP, and M1 made use of a much smaller area (Broomhall 2001).

According to Houser *et al.* 2009a, solitary male cheetahs in Botswana occupied home ranges of between 494km² and 663km², whilst a coalition of two males had a home range of 849km². These home ranges are of similar size to the young male, M7 in my study. Female home ranges were found to be between 241km² and 306km² in Botswana (Houser *et al.* 2009a). The variation in range size between the sexes is possibly due to males having to cover larger distances in search of females to increase mating opportunities (Caro 1994). During the dry season, the females' home range sizes expanded to 166.65 km² (Houser *et al.* 2009a). Houser *et al.* (2009a) suggested this may be due to the increase in movement of prey species in search of water and food resources which become sparser in the dry season. Change in vegetation structure during the dry season could also affect cover for the cheetah and therefore their hunting capabilities, the area becoming more sparsely vegetated with less cover available (Houser *et al.* 2009a).

A study by Bissett and Bernard (2007) on Kwandwe Private Game Reserve (KPGR) in the Eastern Cape, South Africa documented cheetah home ranges, and found that they varied between sexes, ages and social groups. This variation is consistent with the study conducted within the TPNR. Using the kernel method, a female still denning with cubs was recorded to have a home range of only 11km², whilst the next smallest home range was displayed by the three-male coalition which had a range of 32.7km² (Bissett and Bernard 2007). Single females occupied a larger area of 65.6km², and independent cubs proved to have the largest home range of 94km² (Bissett 2004). Bissett (2004) concluded that these small home range sizes were

due to a combination of factors that included a high prey density, the sedentary nature of the prey species, the restrictive reserve boundaries and the increased availability of suitable habitat.

In my study, the total home range and core areas sizes of the two males were larger than that of the female with cubs. However, the independent female cubs had a much larger home range and core area than M1. The female with cubs and the independent cubs, displayed very similar home range sizes to those found in the Eastern Cape study (Bissett and Bernard 2007). This similarity could be due to both reserves supporting relatively dense habitats (Broomhall 2001; Bissett and Bernard 2007). M7 had the largest home range and core area of all the cheetah social groups. His nomadic behaviour can be explained by his youth and therefore dispersing nature at the time of collaring (Broomhall *et al.* 2003). Before having been collared, M7 had only recently gained independence from his mother (Hunter 2000; Skinner and Chimimba 2005). In search of a potential territory, he would have encountered and ventured into many rival territories and those of co-existing predator species (Caro 1994). This behaviour could have resulted in a large area being covered before finally utilising a much reduced area (Caro 1994; Broomhall *et al.* 2003).

M1 had a much smaller home range and core area than M7. M1 was a much older male with an already established and well-defined territory (Hunter 2000; Skinner and Chimimba 2005). M1 was also likely to have maintained a much smaller area as an avoidance strategy to minimize encounters with other younger males and stronger coalitions which would have been a direct threat (Caro 1994).

The independent cubs utilised a larger area than that of M1 and the female with cubs. This was probably also a result of the independent cubs having just entered adulthood, and would have been in search of their own home ranges (Broomhall *et al.* 2003). Remaining together initially would also serve to increase their chances of survival (Hunter 2000). The female with cubs displayed a considerably smaller home range size and core area than the other cheetah social groups. This female was accompanied by cubs and therefore would not want to risk or maximise encounters with other cheetahs and/or co-existing predators (Laurenson 1994). The sedentary nature of prey species as well as the abundance of suitable habitat

(providing both open areas for hunting and sufficient cover for concealment and denning) within the TPNR are likely to be the most important factors influencing the home ranges of the cheetah social groups.

In Namibia, Marker (2002) found that rainfall also proved to be an important determining factor of cheetah home range sizes at a seasonal level. Prey abundance and distribution are inevitably determined by precipitation in more arid habitats (Marker 2002). Vegetation becomes denser after the arrival of the wet season and is linked to the onset of the lambing season of prey species (Marker 2002). Consequently, cheetah home ranges shrink in response to increased prey abundance during this period (Marker 2002). This was only partly observed in my study, where both males decreased the size of their home ranges during the wet season. This is probably because the TPNR enjoys a more mesic climate to Namibia (Broomhall 2001). However, it may also be influenced by my relatively small sample sizes. Limitations such as the low sample sizes, and considering home ranges were estimated using two very different methods (collaring data versus sightings data) both need to be taken into account.

Habitat selection

Durant (1998) suggests that available cover is important to cheetah survival in areas such as the Serengeti. Cover provides suitable habitat for denning sites, offering protection for females with cubs (Laurenson 1995; Durant 1998; Mills *et al.* 2004). Adequate cover is also required for concealment when stalking prey (Fitzgibbon 1990; Gros and Rejmanek 1999) and refuge from co-existing predators (Mills *et al.* 2004). Broomhall (2001) also found that patches of denser habitat proved beneficial by providing cover and opportunities for ambush hunting. Females often select for „patchy" home ranges that support an array of different vegetation types, thereby improving hunting success, whilst simultaneously concealing kills and allowing sufficient cover from predators (Broomhall 2001; Marker 2002). However, denser habitats can also hinder cheetahs when hunting by increasing the risk of the animal becoming injured during the hunt (Marker 2002).

Solitary male cheetahs in Namibia displayed a preference for denser bush (Marker 2002). This was believed to be a direct result of competitive exclusion, whereby stronger male coalitions dominated the resource-rich areas in terms of both prey abundance and mating opportunities (Marker 2002). Indeed, cases of intraspecific aggression among male cheetahs have been recorded on numerous occasions (Caro 1989; Caro 1994). However, Marker (2002) also found that female cheetahs tended to favour areas of sparser bush, suggesting that prey abundance is likely to be a determining factor in the distribution of female cheetahs across Namibian farmlands.

Hunter (1998) found that in Phinda Resource Reserve (PRR), KwaZulu-Natal, South Africa, small open grassland patches in woodland comprised a mere 8.6% of the total habitat available, yet cheetahs sought out this habitat type over others for hunting activities. It was therefore concluded that it was the most suitable hunting habitat (Hunter 1998). Core areas of territorial males were all situated in areas that supported the most extensive grasslands within the woodland savanna system within the PRR (Hunter 1998). Similarly, Gros and Rejmanek (1999) found that cheetahs in Uganda tended to select for more open areas over closed habitats when both were available. According to Purchase and du Toit (2000), cheetah home ranges in MNP comprised both woodland and grassland habitat, where open grassland areas were selected for hunting.

Broomhall *et al.* (2003) found that cheetahs within the KNP utilised all habitats according to their availability and the proportion in which they occurred. However, core areas and home ranges were centred on open savanna habitats, indicating a certain preference by the cheetahs for this particular habitat, known to be favourable for hunting (Broomhall *et al.* 2003). The females were found to display regular use of denser woodland habitat when compared to the males, because females were influenced more than males by prey distribution (Broomhall *et al.* 2003). In this case, the preferred prey species was impala (*Aepyceros melampus*) which tend to show preference for denser woodland habitats (Broomhall *et al.* 2003).

A study on cheetah habitat selection on KPGR by Bissett (2004), also found that habitat selection varied amongst social groups, and that it was most influenced by the presence of lions and the need for both water and cover. The male coalition

preferred the open, flat vegetation types adjacent to denser habitats, whilst females actively selected for denser areas of vegetation on steeper slopes (Bissett 2004). The coalition‟s core area was also located the closest to the lion pride, suggesting that the lions had little influence on cheetah coalition habitat selection (Bissett 2004). On the other hand, the females selected for areas much further away from the lion pride than the cheetah coalition, indicating that predator avoidance is an important factor in their habitat selection (Bissett 2004). Lions are often responsible for the scavenging of kills made by cheetahs and high cub mortalities (Caro 1994; Durant 2000a; 2000b). Habitat selection for the coalition was determined by suitable hunting habitat, prey abundance and available cover rather than avoidance of lions (Bissett 2004).

Bissett (2004) stated that the females with cubs in a den displayed extreme selection of habitat within an extremely small area. Accessible water played an important role in the location of the den site, as water demands on lactating females are higher (Laurenson 1995). The female denning with cubs therefore selected for an area closest to drainage lines in comparison with the other social groups (Bissett 2004). The den site was also situated in the densest vegetation and positioned as far away as possible from the local lion pride and the male coalition (Bissett 2004). The independent cubs occupied the largest home range and core areas, utilising vegetation types with low visibility (Bissett 2004). The independent cubs were located the furthest distance from the pride of lions of all the social groups, indicating their vulnerability to predation (Bissett 2004). Cheetahs are known to seek out “competition refugia”, which are areas that have low lion and hyaena densities, thereby prolonging and improving their chances of survival (Durant 1998).

None of the cheetah social groups in my study displayed an actual preference for any of the habitat types within their home ranges, habitat usage occurred in proportion with relative availability. However, all cheetah home ranges were broadly positioned within open savanna. M7, the younger male, positioned his home range in THBL, therefore using areas of open tree savanna characterised by *Acacia nigrescens* and *Sclerocarya birrea,* which also had a reasonably developed shrub layer (Mucina and Rutherford 2006). In contrast, M1 occupied vegetation types with taller shrubland and fewer trees. The female with cubs used the same vegetation type as M1, selecting areas of moderately open savanna. The independent cubs

generally used open tree savanna, which is dominated by trees such as *Colophospermum mopane and Combretum apiculatum* (Mucina and Rutherford 2006). They were also found closest to drainage lines out of all the cheetah social groups. This could be because they were more dependent on water than the other cheetahs (Caro 1994; Laurenson 1995). In contrast, the female with cubs situated her home range further away from drainage lines than any of the other social groups. The female was no longer lactating meaning water demands were lessened (Laurenson 1995) and so she probably wanted to minimise encounters with other predators such as leopards (*Panthera pardus*), which tend to frequent riverine areas and drainage lines (Steyn and Funston 2009).

The female with cubs and M1 might have preferred denser savanna as they may have been more vulnerable to stronger male coalitions and other predators than the other cheetah social groups (Caro 1994; Laurenson 1994; Laurenson 1995; Marker 2002). M1, being an older male, would be seen as direct competition by younger and stronger male coalitions (Caro 1994; Marker 2002; Bissett and Bernard 2007). Occupying thicker areas would provide him with greater concealment (Caro 1994). The female with cubs could be utilising denser areas for similar reasons, aiming to provide her cubs with protection (Broomhall 2001; Mills *et al.* 2004). Like the study conducted in KNP by Broomhall *et al.* (2003), the female with cubs in this study could also have been influenced by prey distribution. Impala, which are the preferred prey of cheetahs (Hayward *et al.* 2006), also prefer denser vegetation types (Broomhall *et al.* 2003). Thus, by utilising denser habitats, female cheetahs may have increased the likelihood of encounters with impala (Broomhall *et al.* 2003).

My study therefore supports previous work on cheetah habitat preference spatial ecology. It is likely that a combination of both grassland and woodland savanna provided the optimal habitat for cheetahs in the TPNR (Broomhall 2001). Open savanna (with sparse tree cover) can be described as a very important habitat for cheetahs, especially in terms of their hunting (Mills *et al.* 2004; Broomhall 2001). In addition, surrounding denser habitats are also important for providing cover and concealment for the species from other predators, and for the concealment of cubs and kills made (Caro 1994; Broomhall 2001; Mills *et al*. 2004).

Spatial use studies such as this one give an indication of the types of habitat as well as the proportion of land that needs to be conserved if the species is to persist. Cheetah spatial organisation observed in this study followed the typical spatial organisation patterns previously documented for cheetahs elsewhere. A compromise between sufficient cover and open grassland areas is necessary in terms of satisfying both hunting preferences, and providing adequate shelter/concealment from other predators (Broomhall *et al.* 2003). Consequently, cheetahs display flexibility in their behaviour, in fact proving more adaptable to habitat diversity than formerly reported (Bissett and Bernard 2007). As documented in many previous studies, cheetahs often have extensive home ranges that span much further than the boundaries of a single reserve (Caro 1994; Marker 2002). Being such a wide-ranging species renders them vulnerable to extinction, as it subjects them to a wider range of threats (Gros *et al.* 1996). Such threats could be for example, the exposure of cheetahs to potential conflict from a variety of landowners within an area (due to the great distances they cover), as well as the threat of habitat fragmentation whereby the species naturally requires large areas of land in which to range, however the erection of fences and continual fragmentation of land threatens these movements (Marker 2002; Buk and Marnewick 2010).

Spatial studies on cheetah movements therefore give insight into the areas they are covering and potential threats they are likely to face. Monitoring and information regarding cheetah ranging patterns is thus key to gaining an understanding of their behavioural ecology, which in turn is essential for the effective management and future conservation of these predators (Marker *et al.* 2008).

CHAPTER 5

SUMMARY AND CONCLUDING REMARKS

The current study revealed valuable information regarding various aspects of the TPNR‟s cheetah population. It indicated that a healthier population may exist than formerly believed. A minimum estimated density of 4.46 cheetahs/100km² was estimated, a comparatively high number considering previous censuses conducted in the neighbouring KNP were much lower (~ 1 cheetah/100km²) (Maddock and Mills 1994; Bowland and Mills 1994; Kemp and Mills 2005; Marnewick *et al.* 2007; Lindsey *et al.* 2009a; Buk and Marnewick 2010). The TPNR population is however consistent with the density recorded in the Thabazimbi region of South Africa by Marnewick (2006a). This is encouraging given that it may be possible that the previous densities estimated for KNP were perhaps modest and therefore an underestimate of the actual population. It must however be acknowledged, that it is also a possibility that the estimated TPNR density may be a result of the open reserve system, implying that the census which I conducted identified a substantial number of cheetahs that were merely passing through from elsewhere and were not resident.

The sex ratio data gathered from my study indicated a bias towards male cheetahs, and these findings are inconsistent with other studies which showed a higher female sex ratio (Frame 1977; Caro 1994; Nowell 1996; Marker 2002). One explanation for this is that the TPNR supports a high density of lions, which are superior predators, known to impact cheetah numbers and male cheetahs are naturally less vulnerable to larger predator species than females and cubs. It must however be acknowledged that given these facts, no cheetah mortalities as a direct result of lions or spotted hyaenas were documented during this particular study. Furthermore, lion densities in the Serengeti are slightly higher than the TPNR, this wouldn‟t support why a higher male to female sex ratio exists within the TPNR when the opposite is true for the Serengeti which supports a higher female to male ratio. Further research would be required to investigate the reasoning for the sex ratio difference. Litter sizes obtained did show consistency with current literature.

One of the limitations of my study, was that data collection and the continued monitoring of animals was hindered at times by the dense vegetation and inaccessibility of many areas given the strict no off-road policy in the study area. In addition, the observation of un-collared animals was made even more difficult as the reserve was unfenced and formed part of a much larger open network of reserves, promoting the movement of animals over large distances. This made tracking of movements and survivorship difficult.

The collared female with cubs and M1 displayed very similar sized, small home ranges. The small home range size possibly served to minimise encounters with stronger male cheetahs/coalitions and larger predators such as lions and hyaenas. The independent cubs also displayed a small home range but slightly larger than those of M1 and the female with cubs, probably because of them having recently entered adulthood and gained independence. These home ranges are similar in size to cheetahs in the Eastern Cape, South Africa (Bissett 2004). This is probably because of the high prey densities afforded within the TPNR as well as the relatively dense savanna habitat which provided sufficient cover for refuge and raising of cubs (Laurenson 1993; Broomhall *et al.* 2003; Bissett 2004; Hunter *et al.* 2007). By contrast, M7 moved over a considerably larger area, and this is attributed to the dispersing behaviour of such a young male having recently become independent (Laver 2005). This meant that a large difference was observed in home range size between the two collared males M1 and M7. However, M1 was a much older animal with an established and well-defined territory (Hunter 2000; Skinner and Chimimba 2005). Season did not appear to be a determining factor in terms of home range sizes for the cheetah social groups within the TPNR. However, the males did appear to show a slight seasonal change with an increase in their home range sizes in the dry season, presumably because of potential prey being more dispersed at this time (Marker 2002).

Consistent with Broomhall *et al.* (2003), the current study established that the different cheetah social groups all utilised the habitat available to them at random and therefore in proportion with availability. Home ranges were however all positioned within open savanna suggesting a preference for this habitat, which is important for the species as it is the preferred habitat for hunting (Broomhall 2001). The independent cubs were located nearest to drainage lines of all the social groups,

indicating their greater dependence upon water sources (Caro 1994; Laurenson 1995). Conversely, the female with cubs positioned herself the furthest from the drainage lines which probably indicates her vulnerability to predation from stronger co-existing predator species, preferring to minimise encounters which were more likely nearer water sources (Steyn and Funston 2009).

My study supports and shows consistency with studies conducted on cheetah spatial ecology (Hunter 1998; Purchase and Du Toit 2000; Marker *et al.* 2003; Broomhall 2006), indicating that the results obtained are likely a true reflection of cheetah spatial behaviour in woodland savanna habitats. It can be concluded that open savanna serves as vital habitat for cheetah survival and persistence, provided there are areas of adjacent denser habitat that essentially provide sufficient cover for the species.

Recruitment, mortality and migration keep the predator guild within a reserve dynamic (Durant *et al.* 2004; Thomas 2005). For this reason, monitoring and on-going studies of the ecology and behaviour of predators are both important and necessary. The conservation of any species is ultimately best informed by good science (Bissett 2004; Macdonald and Loveridge 2010). This allows for appropriate decisions to be made by management in a system which is constantly changing. For instance, accurate knowledge regarding a species‟ home range size as well as abundance within the area, is essential for management decisions as it provides managers with important information about the number of animals the land can support (Lehmann 2007). Habitat use and preference offers information regarding the significance of various features to the particular species within the landscape (Lehmann 2007; Houser *et al.* 2009a).

Even though it has been shown that the cheetah is an adaptable species, able to tolerate and succeed in a variety of different habitat types, cheetah conservation is ultimately dependent upon people. The future of cheetahs will only be preserved if we are able to minimise the key threats of conflict with humans, habitat loss and fragmentation of land (Marker 1998; Marker 2002). Considering the species‟ large range and its characteristically low density, conservation of cheetahs will depend upon the maintenance of large landscapes with suitable habitat and adequate prey densities (Marker 1998; Marker 2002). This requires land use planning on an

incredibly large scale which is understandably difficult to achieve (Marker 2002; Macdonald and Loveridge 2010). The already fragmented, isolated subpopulations currently in smaller reserves across South Africa will best be addressed through the application of metapopulation techniques (Lindsey *et al.* 2009b).

In spite of their respective disadvantages, both protected reserves and unprotected areas are vital in terms of cheetah survival (Hunter 2000). While cheetah densities tend to remain low in areas where other larger predator densities are high, conservation areas nonetheless function to protect a core population which can be regarded as relatively free of human persecution (Hunter 2000). These numbers will however never be excessive, not forgetting the fact that small populations are vulnerable to the effects of local catastrophes (Hunter 2000). Thus, areas surrounding parks and reserves become essential in terms of the persistence of the species (Hunter 2000). An understanding and tolerance of the species also needs to be cultivated amongst those people competing with cheetahs for resources (Hunter 2000).

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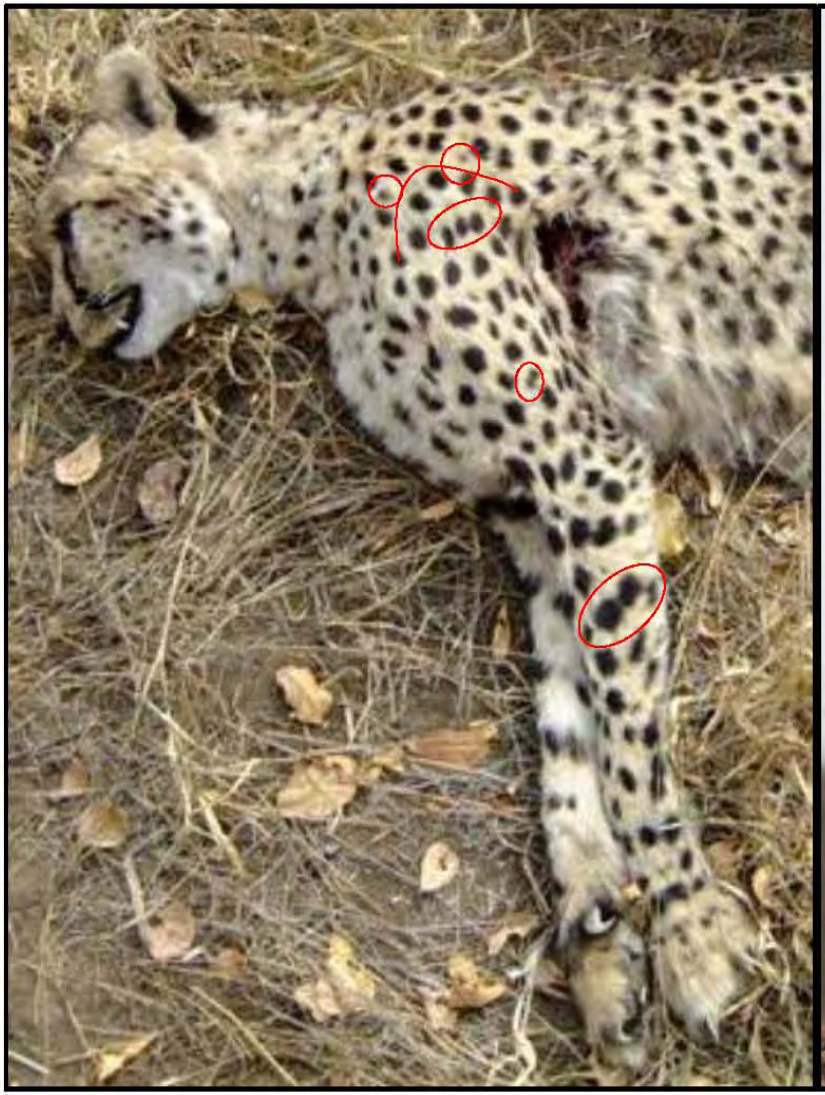
APPENDIX A

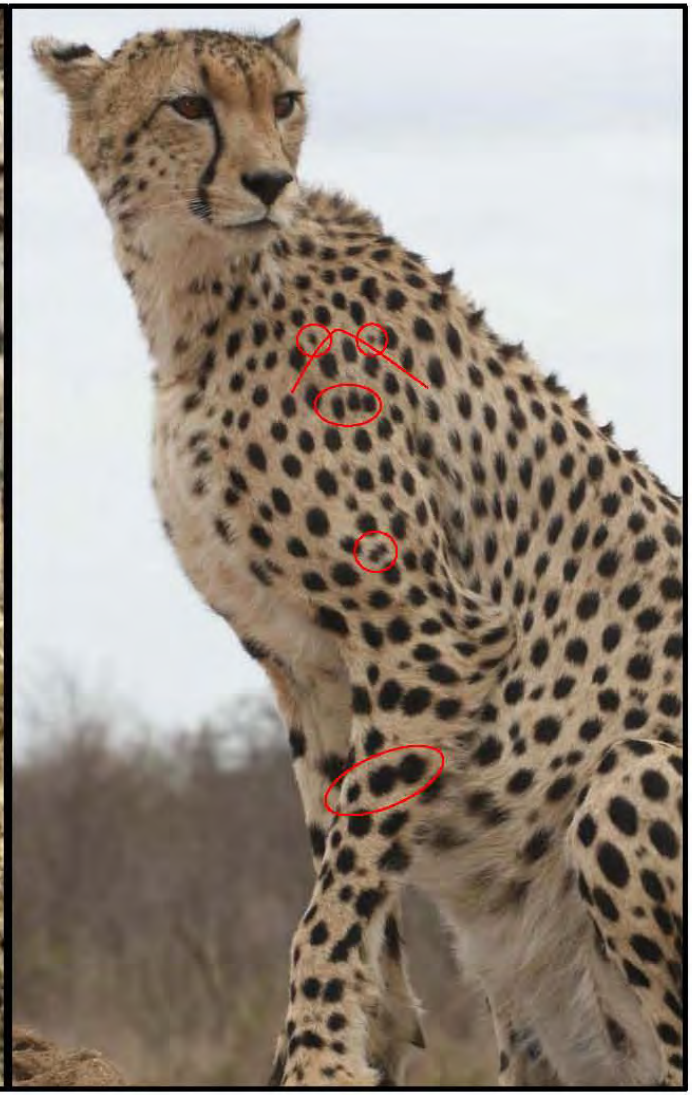
Cheetah Spot Pattern Recognition (Examples) – Timbavati Private Nature Reserve

Date: 07/04/2010, 07:19
Observer: Dave Jackaman
ID/Assigned to cheetah: M13

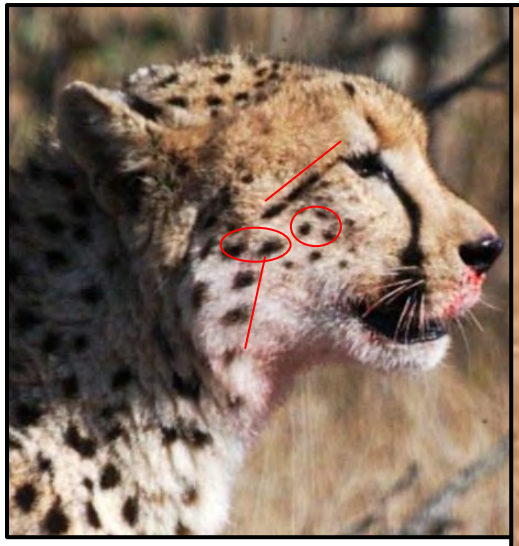
Date: 02/06/2009, 07:14
Observer: Dave Jackaman
ID/Assigned to cheetah: M13



Date: 27/06/2010, 14:54
Observer: Anton - Chimanimani
ID/Assigned to cheetah: F1

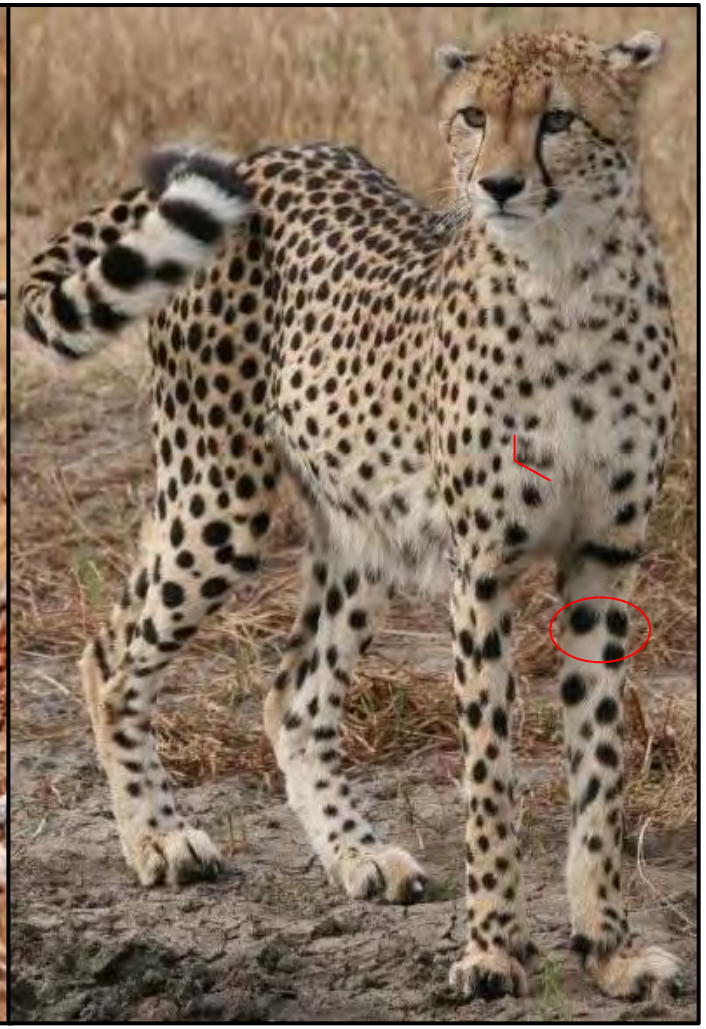


Date: 01/11/2009, 15:49
Observer: Ziggy Hugo
ID/Assigned to cheetah: F1

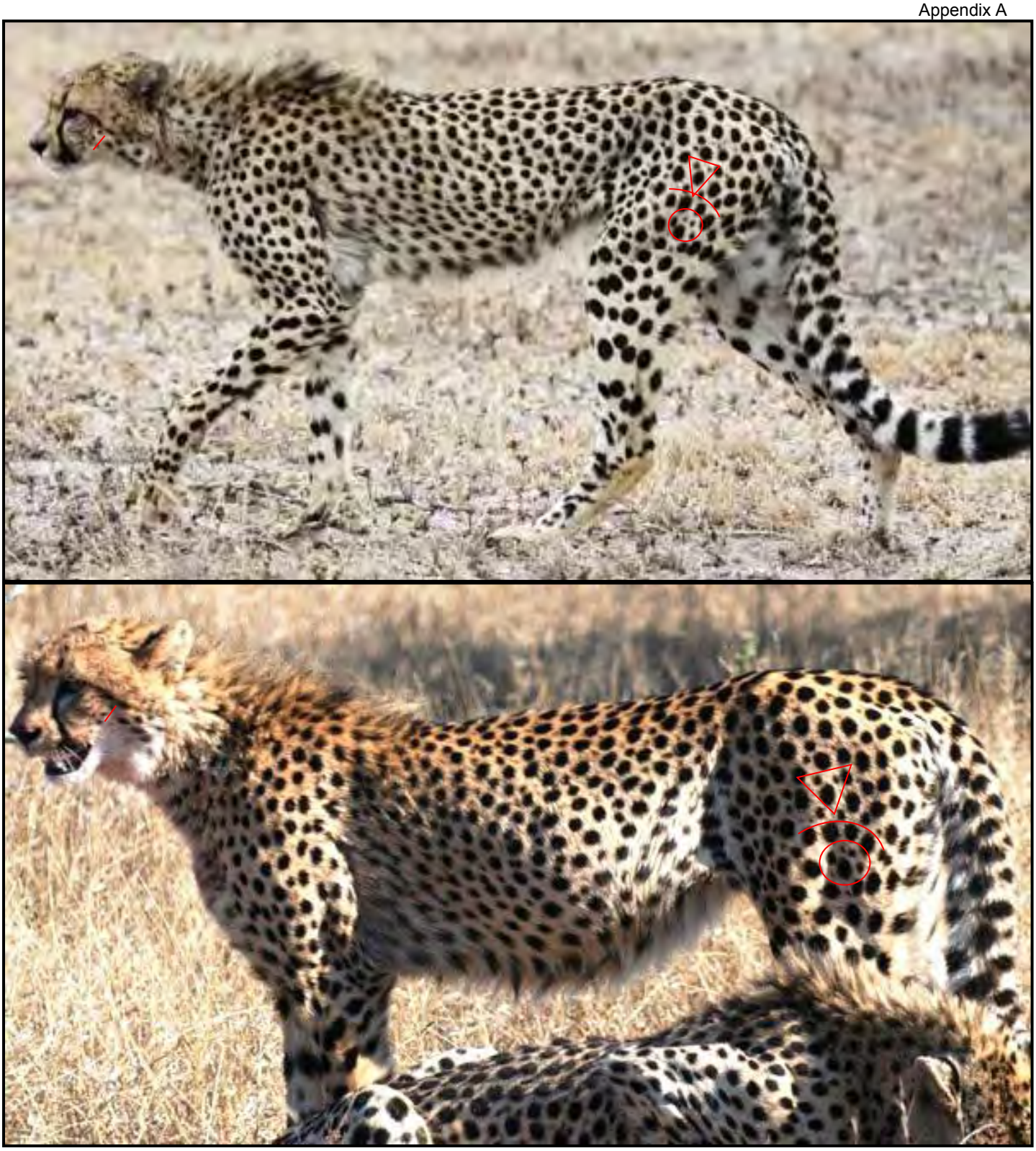


Date: 15/07/2010, 08:00
Observer: Jeanette Bowers-Winters
ID/Assigned to cheetah: F6

Date: 15/10/2010, 17:22
Observer: Patrick O'Brien
ID/Assigned to cheetah: F6

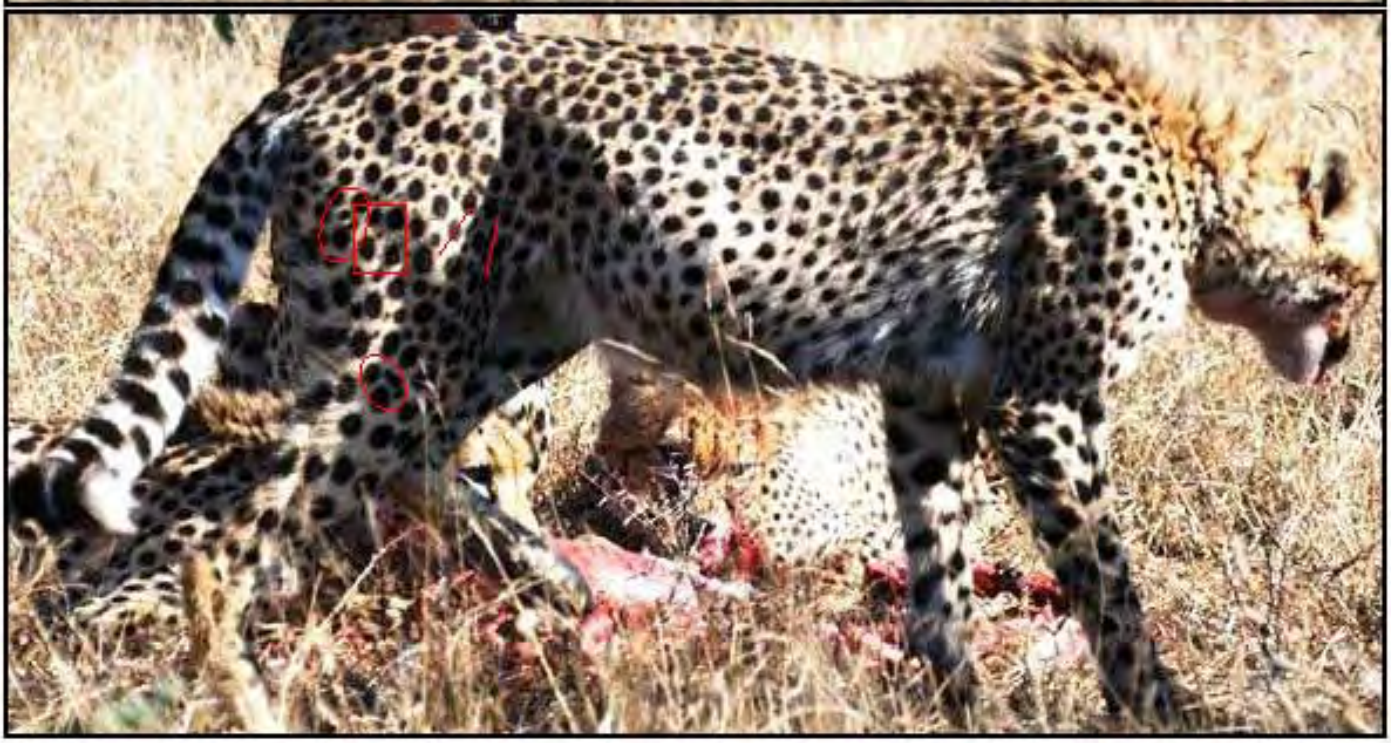


Date: 10/04/2009, 07:09
Observer: Dylan Davies
ID/Assigned to cheetah: F6



Date: 08/09/2010, 07:44 (**Above**)
Observer: Leanne South
ID/Assigned to cheetah: F8

Date: 15/07/2010, 08:00 (**Below**)
Observer: Jeanette Bowers-Winters
ID/Assigned to cheetah: F8



Date: 08/09/2010, 07:58 (**Above**)
Observer: Leanne South
ID/Assigned to cheetah: F10

Date: 15/07/2010, 08:06 (**Below**)
Observer: Jeanette Bowers-Winters
ID/Assigned to cheetah: F8

APPENDIX B

Photographic identification profiles for cheetah individuals identified within the Timbavati Private Nature Reserve 2010-2011.

Cheetah Identikit

Timbavati Private Game Reserve

Siobhan Dyer

Name: F1

Sex: Female

Date of Birth/Age: Adult (DOB: ± June 2004 as was ± 6 years of age when deceased [likely due to leopard attack] on 26th of June 2010)

Group Composition: Single female

Home Range: Hermansburg/Ngala – Southern section of reserve

Diagnostic Features: Limped on front left leg.

Name: F2

Sex: Female

Date of Birth/Age: Adult

Group Composition: Single female; last litter of 3 comprised: 2 males [M3 & M4] & 1 female [F5], which became independent of her ± October 2010.

Home Range: Ngala/Avoca/Birmingham

Name: F3

Sex: Female

Date of Birth/Age: Adult

Group Composition: Single female

Home Range: Ngala/Tawane

Diagnostic Features: Nervous female

Name: F4 (F7's cub)

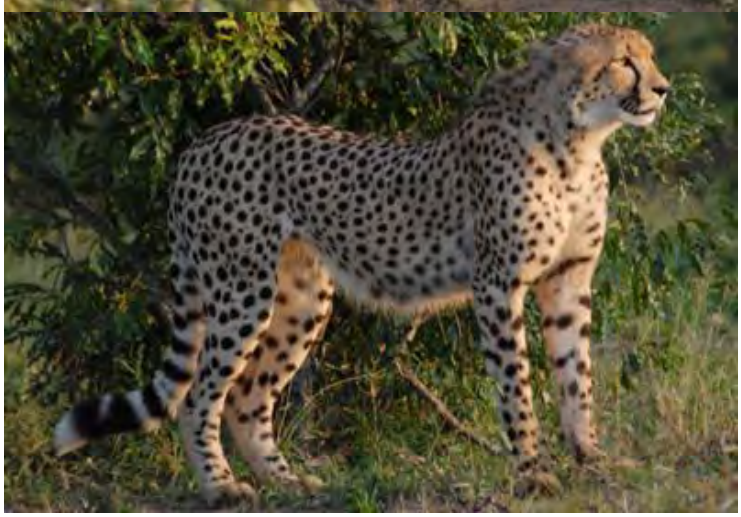
Sex: Female

Date of Birth/Age: young adult (DOB: ± end of September 2008)

Group Composition: Female & male sib-group; the pair then split and she became solitary from brother (M7).

Home Range: Ngala/Makanyi (Avoca) whilst in sib-group

Diagnostic Features: Very nervous



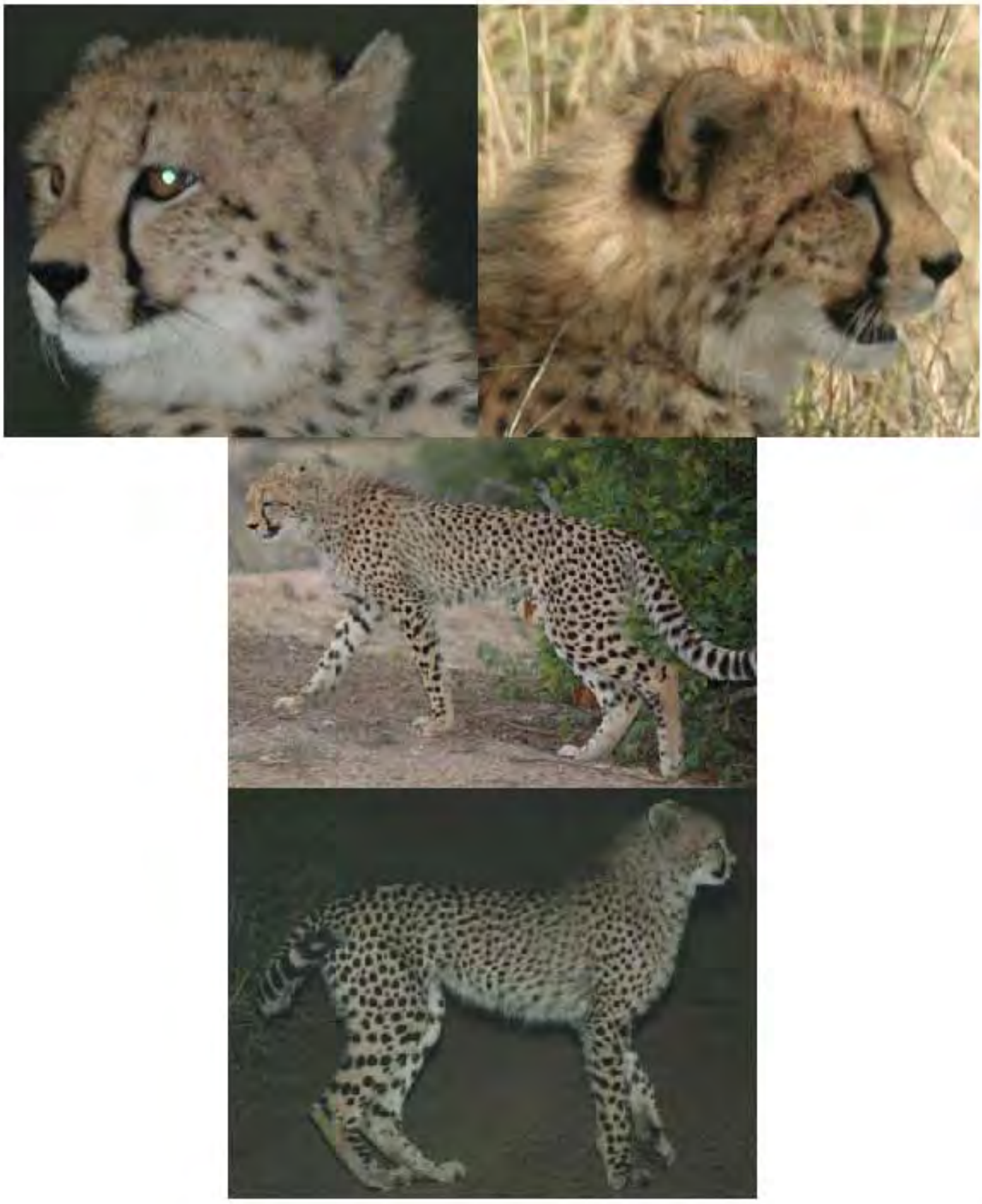
Name: F5 (F2"s cub)

Sex: Female

Date of Birth/Age: Sub-adult (Est. DOB: April 2009)

Group Composition: Three adolescent cubs (2 males & 1 female) with mother; became independent ± October 2010

Home Range: Avoca/Ngala/Birmingham



Name: F6 (F1's daughter)

Sex: Female

Date of Birth/Age: Adult ± 5yrs; DOB: ± October 2006

Group Composition: Single female; last litter of 3 female cubs (F8; F9; F10) became independent of her early August 2010.

Home Range: Birmingham/Orpen – Kruger

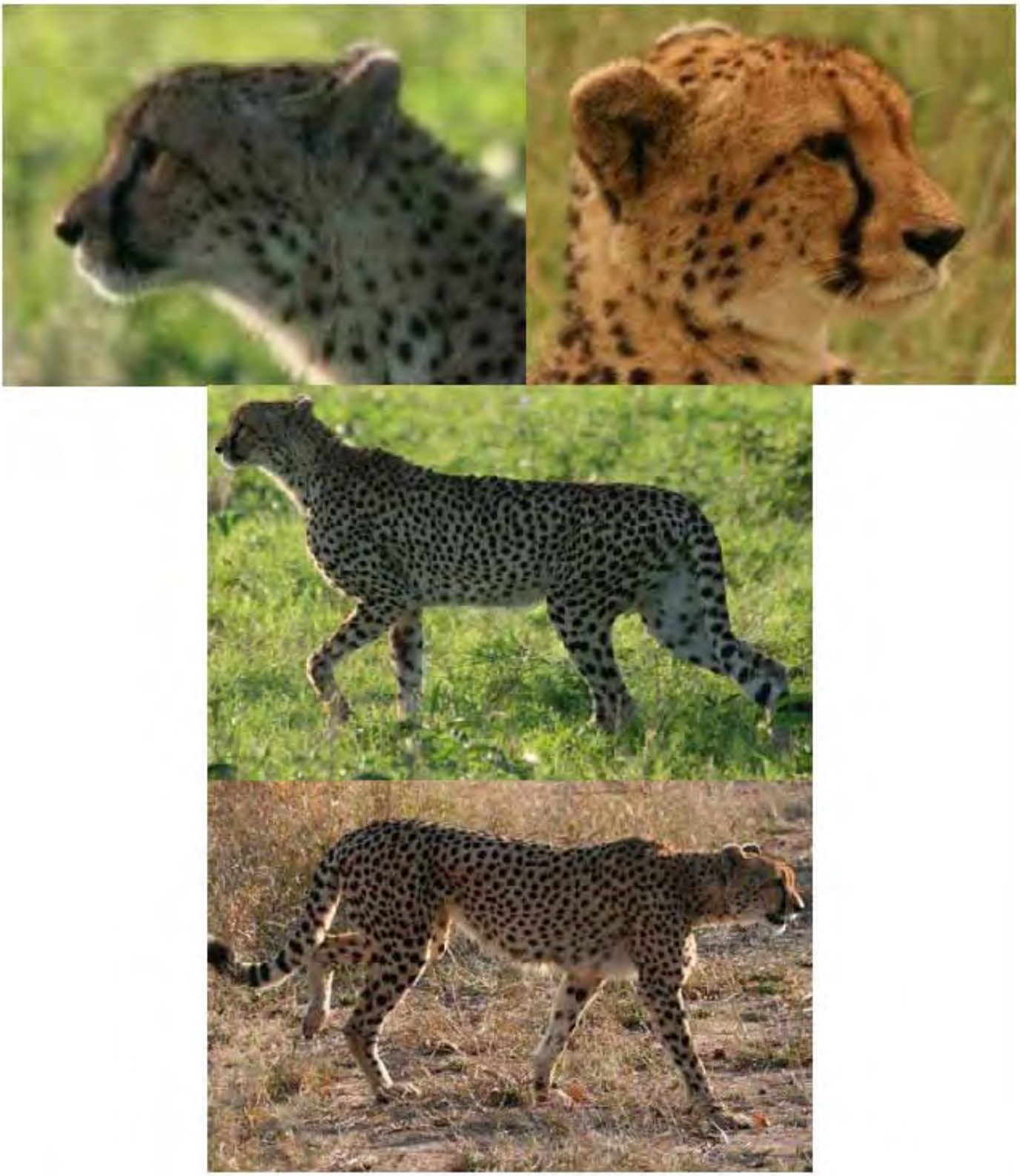
Name: F7

Sex: Female

Date of Birth/Age: Adult

Group Composition: Mother with 2 adolescent cubs (now independent M7 & F4)

Home Range: Ngala



Name: F8 (F6's cub)

Sex: Female

Date of Birth/Age: Sub-adult (Est. DOB: Mid February 2009)

Group Composition: Three adolescent cubs (all female) with mother; became independent early August 2010, remaining in sib-group for several months after with sisters F9 and F10.

Home Range: southern portion of reserve when with mother but northern section once gained independence.

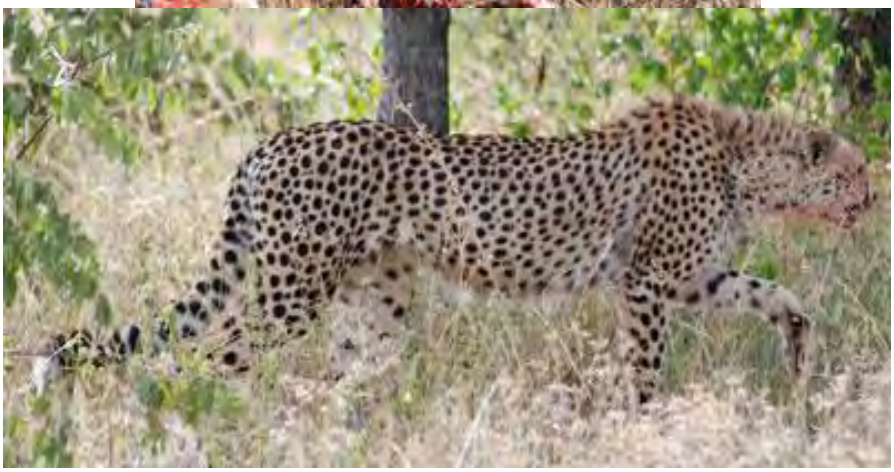
Name: F9 (F6's cub)

Sex: Female

Date of Birth/Age: Sub-adult (Est. DOB: Mid February 2009)

Group Composition: Three adolescent cubs (all female) with mother; became independent early August 2010, remaining in sib-group for several months after with sisters F8 and F10.

Home Range: southern portion of reserve when with mother but northern section once gained independence.



Name: F10 (F6"s cub)

Sex: Female

Date of Birth/Age: Sub-adult (Est. DOB: Mid February 2009)

Group Composition: Three adolescent cubs (all female) with mother; became independent early August 2010, remaining in sib-group for several months after with sisters F8 and F9.

Home Range: southern portion of reserve when with mother but northern section once gained independence.

Name: F11

Sex: Female

Date of Birth/Age: Adult +7 yrs of age; DOB: ± Feb 2004; first litter of 3 cubs born ± Dec 2006 and became independent ± July 2008; then second litter of one surviving cub (M12) last seen together in May 2009. F11 now has a third litter of 3 cubs that were born ± early Sep 2010.

Group Composition: Adult female with 3 adolescent cubs (M5, M6 & 3rd cub sex unknown).

Home Range: Avoca/Ngala/Birmingham

Name: F12

Sex: Female

Date of Birth/Age: Adult

Group Composition: Last seen on 19th March 2011 with a single king cub (sex unknown) from an original litter of three (two normal cubs and one king). She had a previous litter of only a single surviving cub that became independent of her in May 2010.

Home Range: Moved from Thornybush with cub into and through the Timbavati up to Balule/Klaserie where left cub; then came back down into Thornybush to give birth to second known litter thereafter moving back into TPNR.

Diagnostic Features: **C**ollared female from Thornybush with a king cub.

Name: F12's two cubs (January/March 2011)

Sex: Unknown

Date of Birth/Age: Unknown ± 4 months; normal cub last seen Jan 2011 and king cub last seen March 2011, it is unlikely it survived.

Name: F12"s single cub (not named as sex unknown); photos from July/August 2009

Sex: Unknown

Date of Birth/Age: Young adult; Est. DOB: ± November 2008 as became independent of F12 in early May 2010

Group Composition: Solitary adult; became independent of mother F12 in May 2010, where it remained in Olifants South where they were last seen together.

Name: M1

Sex: Male

Date of Birth/Age: Older Adult + 7 years of age (est. DOB: ± Jan 2005)

Group Composition: Was in a coalition with two other males in April 08; in September 08, M1 was still in coalition but with only one of the two original males; M1 then became a solitary male but is since believed to have died from injuries sustained during an aggressive encounter with a younger male coalition (early June 2011).

Home Range: White's Avoca/Makanyi – Southern section of reserve; upon collaring he moved into Thornybush where he chose to remain for the duration of the study.

Diagnostic Features: Three scars above nose and dark scar below right eye.

Name: M2

Sex: Male

Date of Birth/Age: Adult

Group Composition: Single male

Home Range: seen throughout TPNR

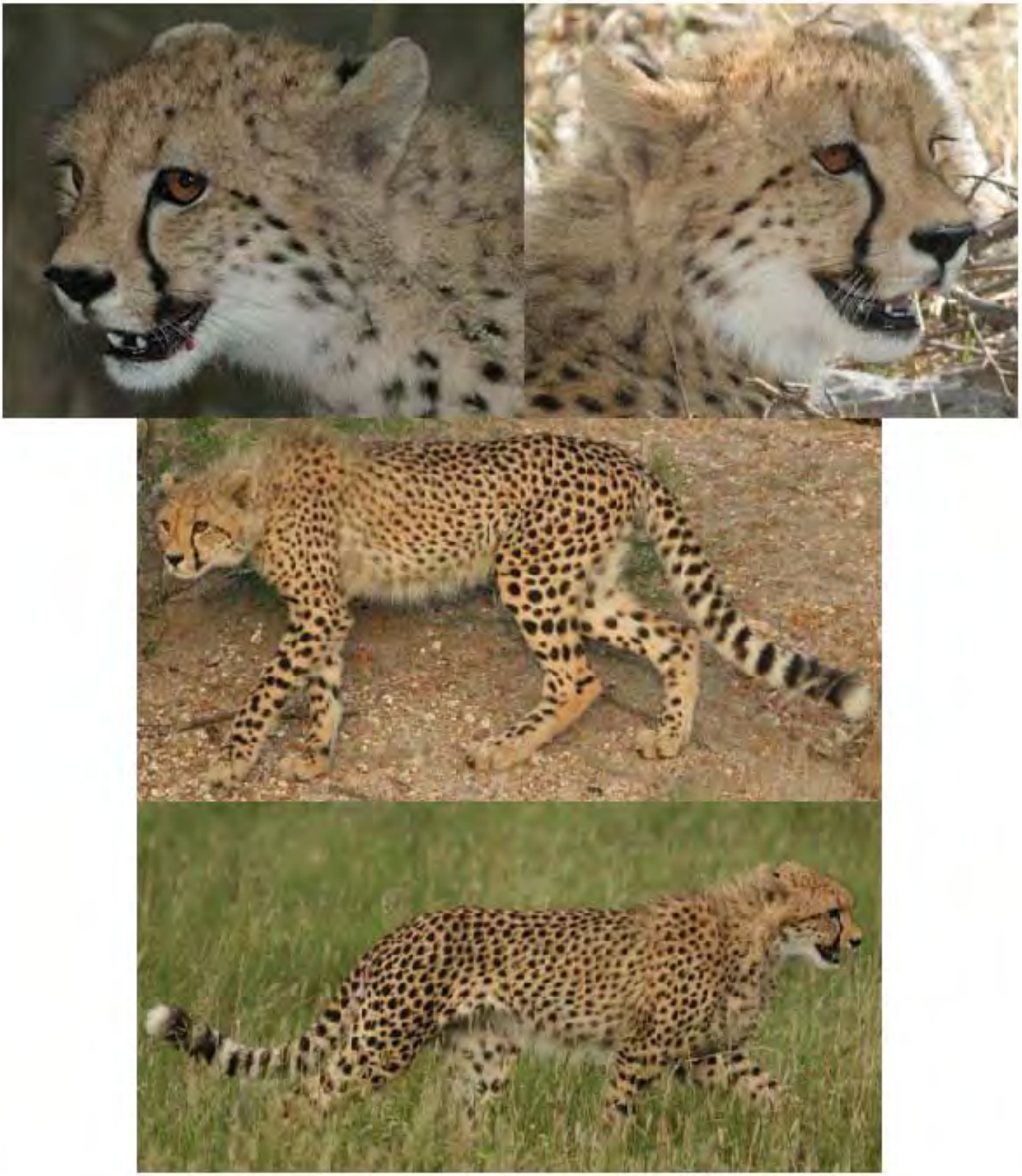
Name: M3 (F2's cub)

Sex: Male

Date of Birth/Age: Sub-adult (Est. DOB: April 2009)

Group Composition: Three adolescent cubs (2 males & 1 female) with mother; became independent ± October 2010

Home Range: Avoca/Ngala/Birmingham



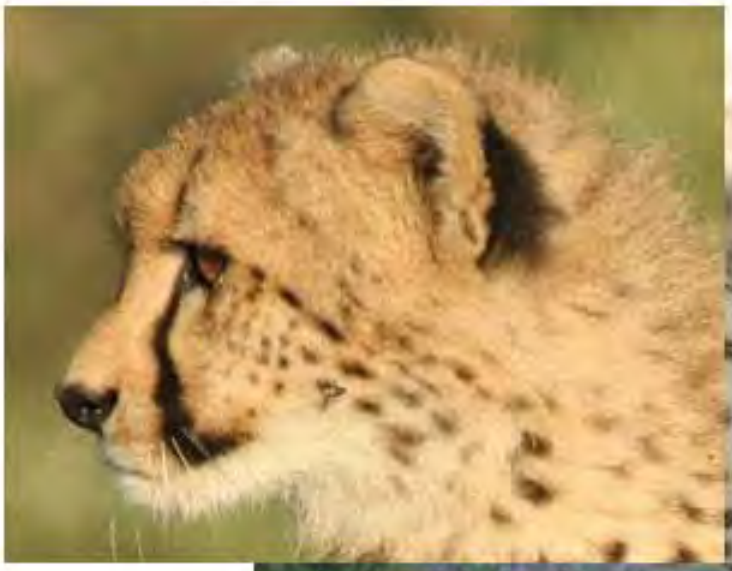
Name: M4 (F2's cub)

Sex: Male

Date of Birth/Age: Sub-adult (Est. DOB: April 2009)

Group Composition: Three adolescent cubs (2 males & 1 female) with mother; became independent ± October 2010

Home Range: Avoca/Ngala/Birmingham



Name: M5 (F11's cub)

Sex: Male

Date of Birth/Age: Sub-adult (Est. DOB: Early Sep 2010)

Group Composition: Three adolescent cubs (2 males [M5 & M6] & 1 unknown sex) with mother.

Home Range: Birmingham

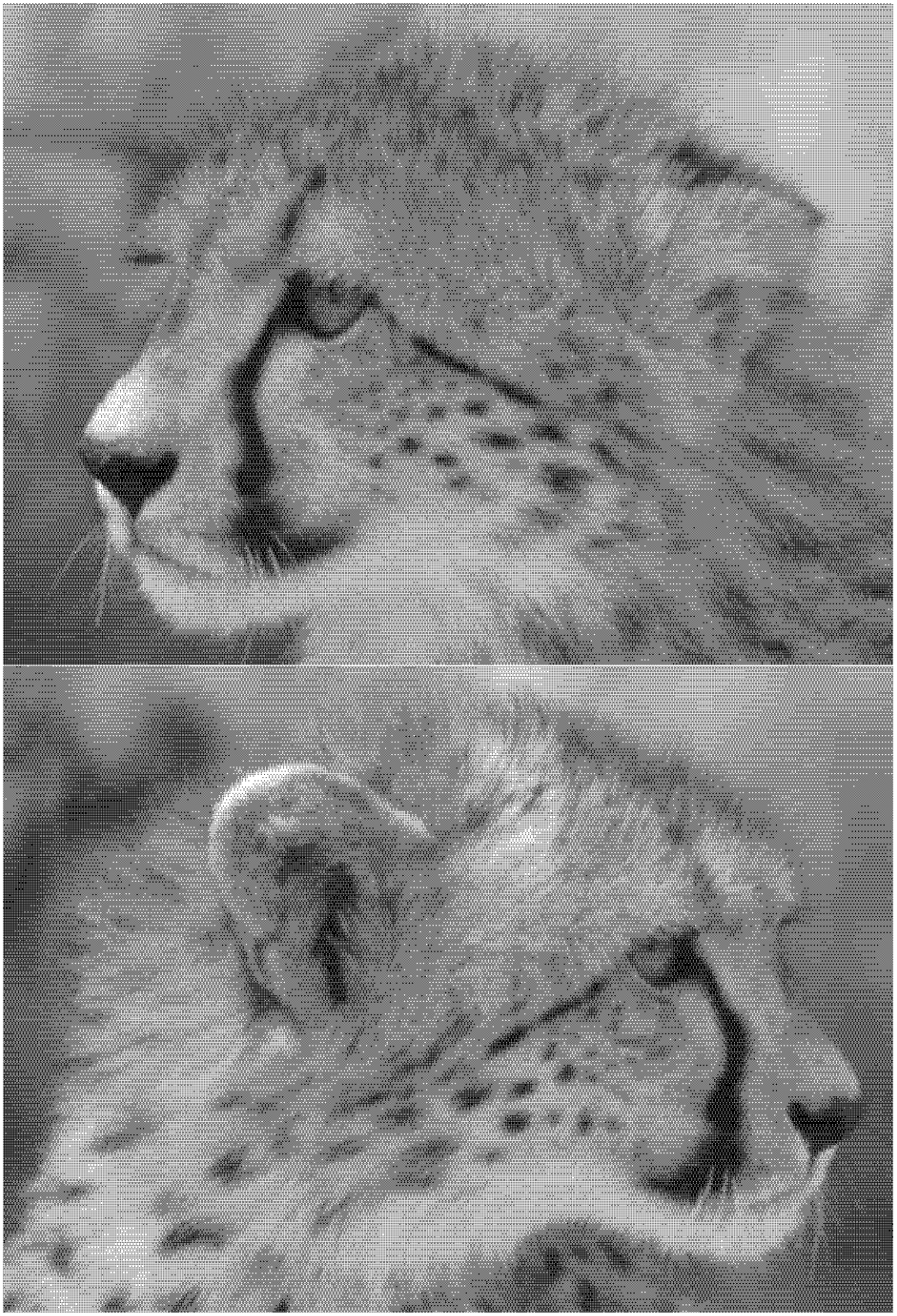
Name: M6 (F11's cub)

Sex: Male

Date of Birth/Age: Sub-adult (Est. DOB: Early Sep 2010)

Group Composition: Three adolescent cubs (2 males [M5 & M6] & 1 unknown sex) with mother.

Home Range: Birmingham



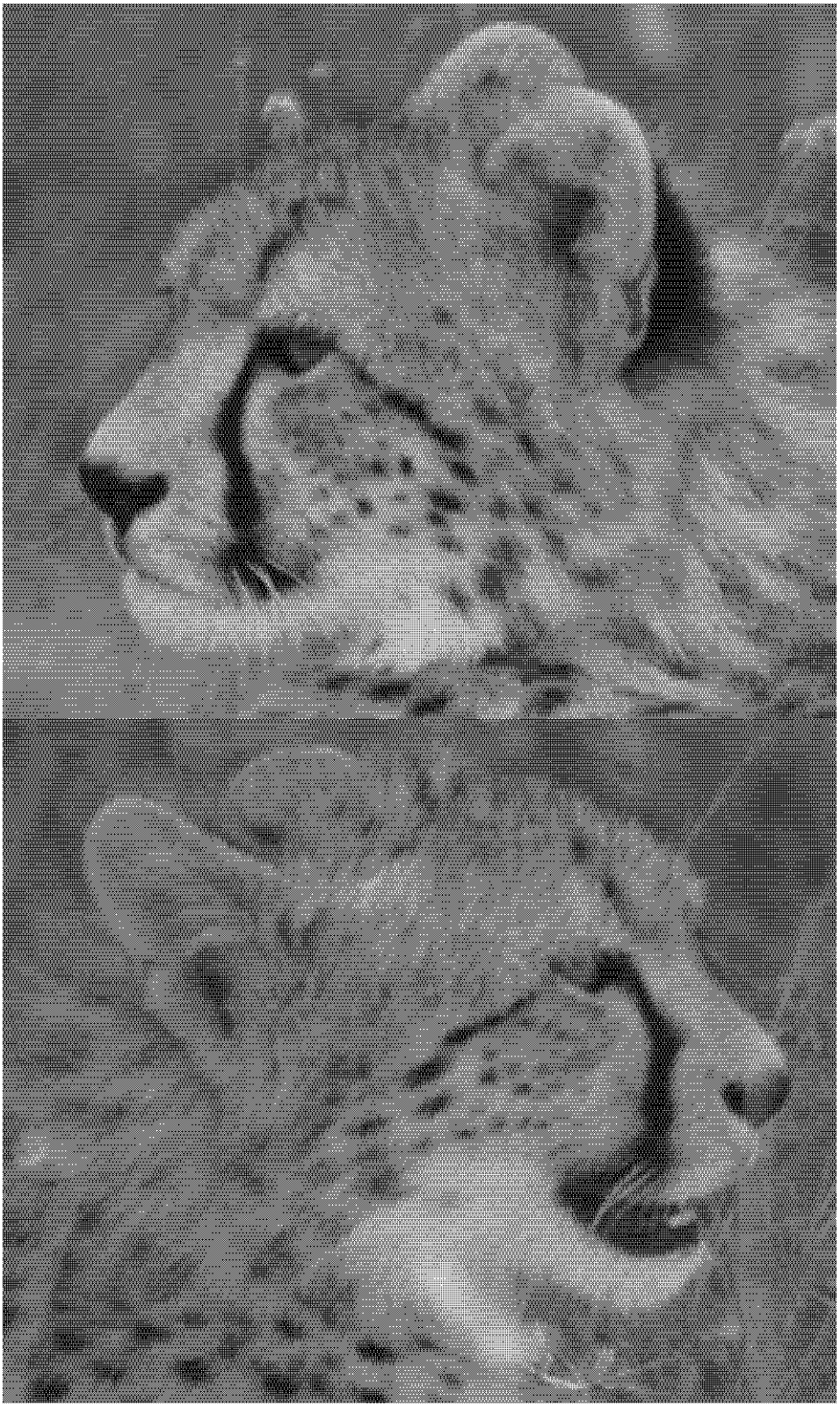
Name: F11"s third cub

Sex: Unknown

Date of Birth/Age: Sub-adult (Est. DOB: Early Sep 2010)

Group Composition: Three adolescent cubs (2 males [M5 & M6] & 1 unknown sex) with mother.

Home Range: Birmingham



Name: M7 (F7's cub)

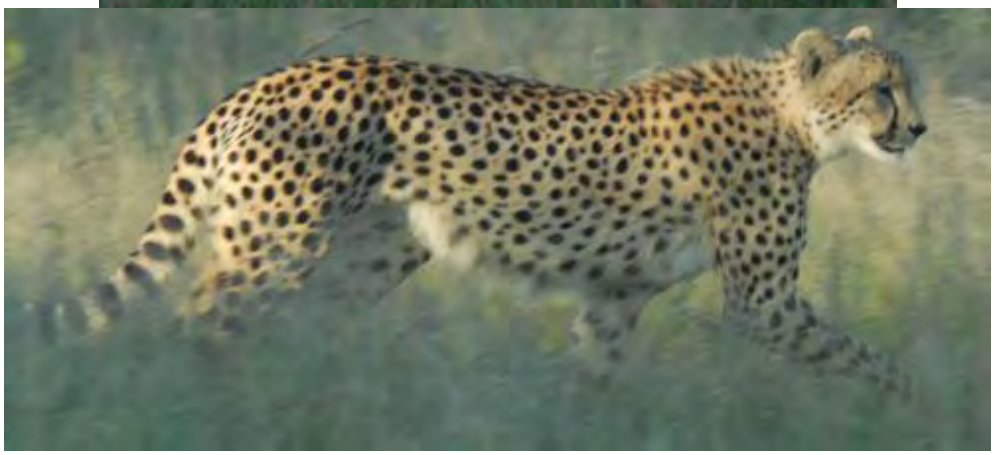
Sex: Male

Date of Birth/Age: young adult (DOB: ± end of September 2008)

Group Composition: Female and male sib-group; then became solitary of his sister (F4)

Home Range: Ngala/Makanyi (Avoca) whilst in sib-group; then ranged throughout KNP when he became solitary, settling in the Mopani (central) region of the Park.

Diagnostic Features: collared male



Name: M8

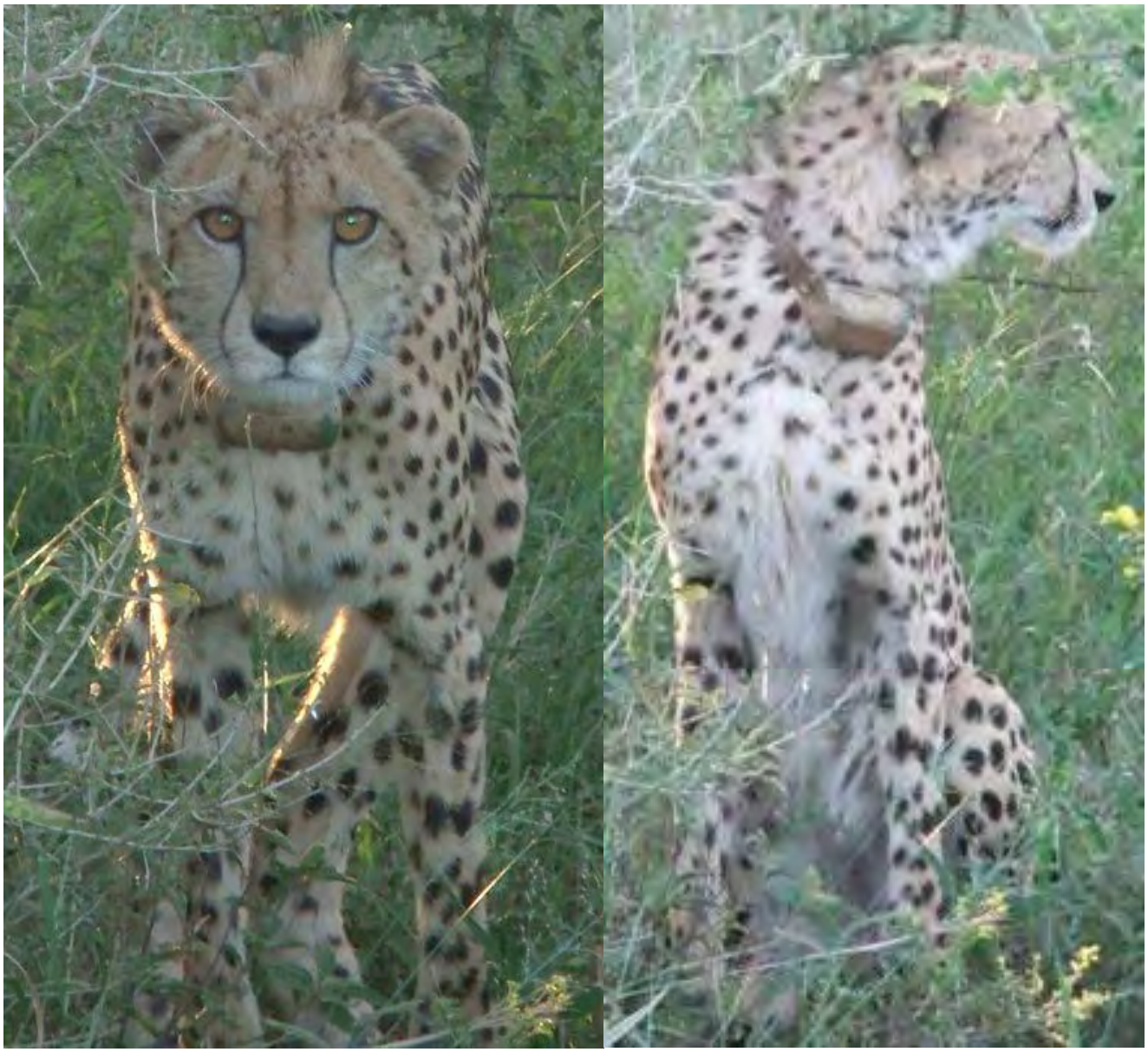
Sex: Male

Date of Birth/Age: Adult

Group Composition: Solitary male

Home Range: Thornybush

Diagnostic Features: collared male from Thornybush; very skittish



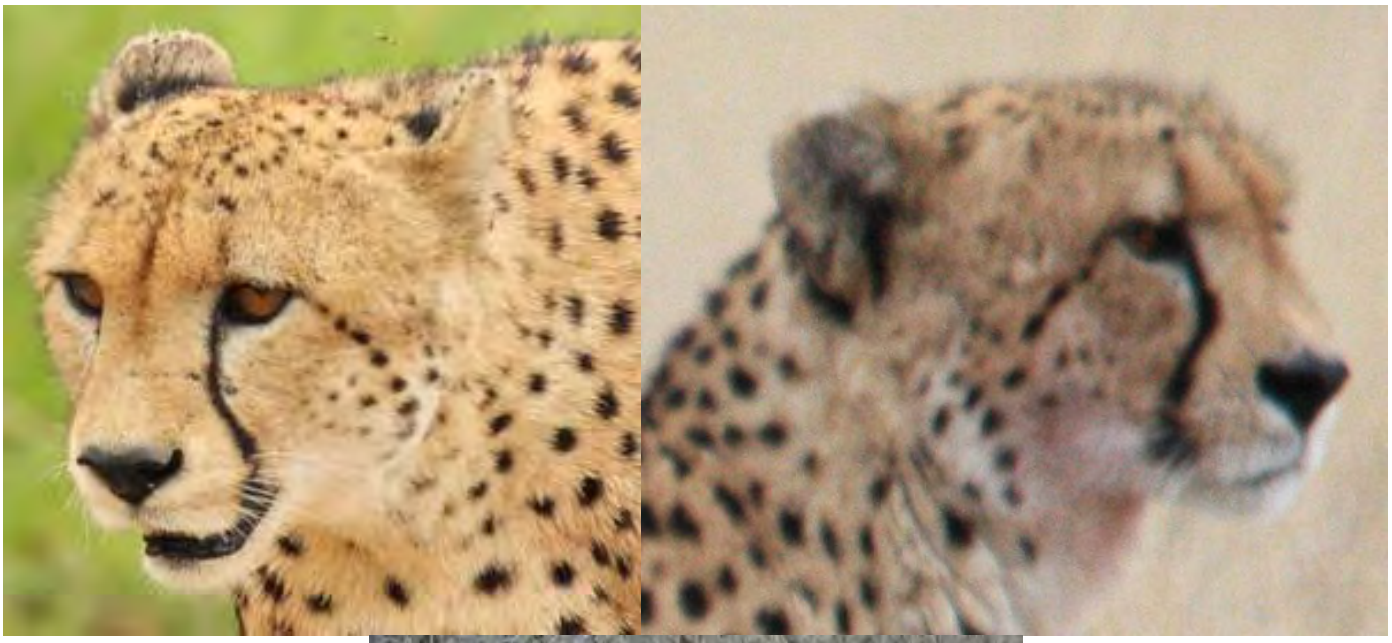
Name: M9

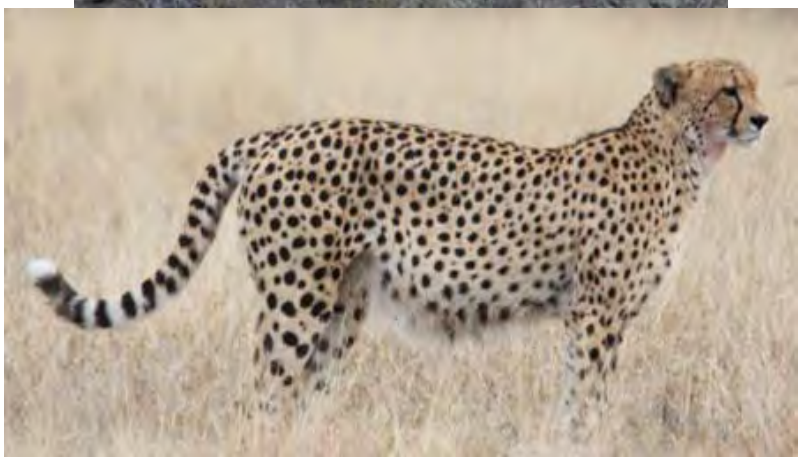
Sex: Male

Date of Birth/Age: Adult

Group Composition: Solitary male

Home Range: Thornybush/Lornay (TPNR); was previously sighting in the Sabi Sands





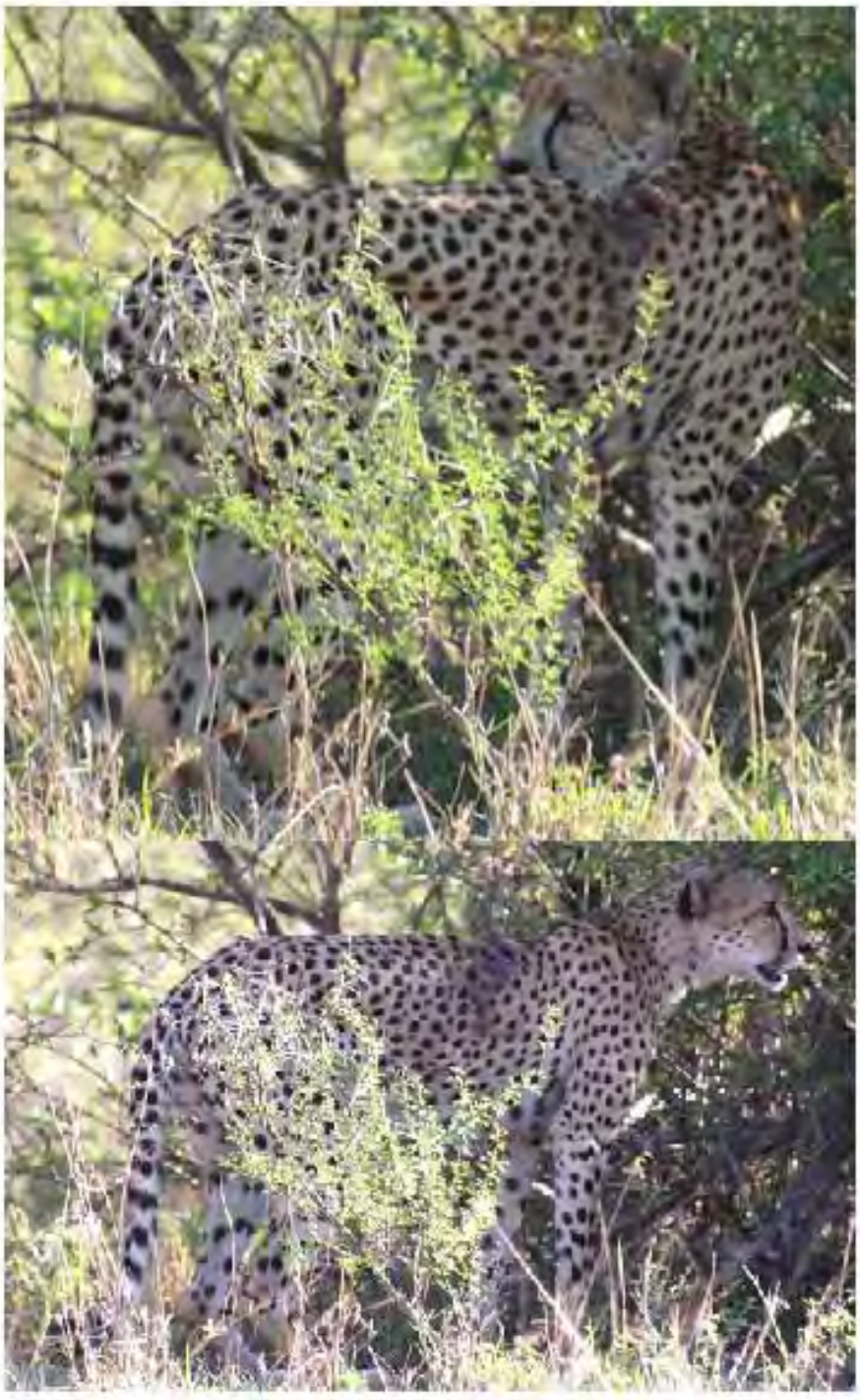
Name: M10

Sex: Male

Date of Birth/Age: Very old male; suspected to have died as was badly wounded and emaciated.

Group Composition: Solitary male

Home Range: ? Seen at Tanda Tula



Name: M11

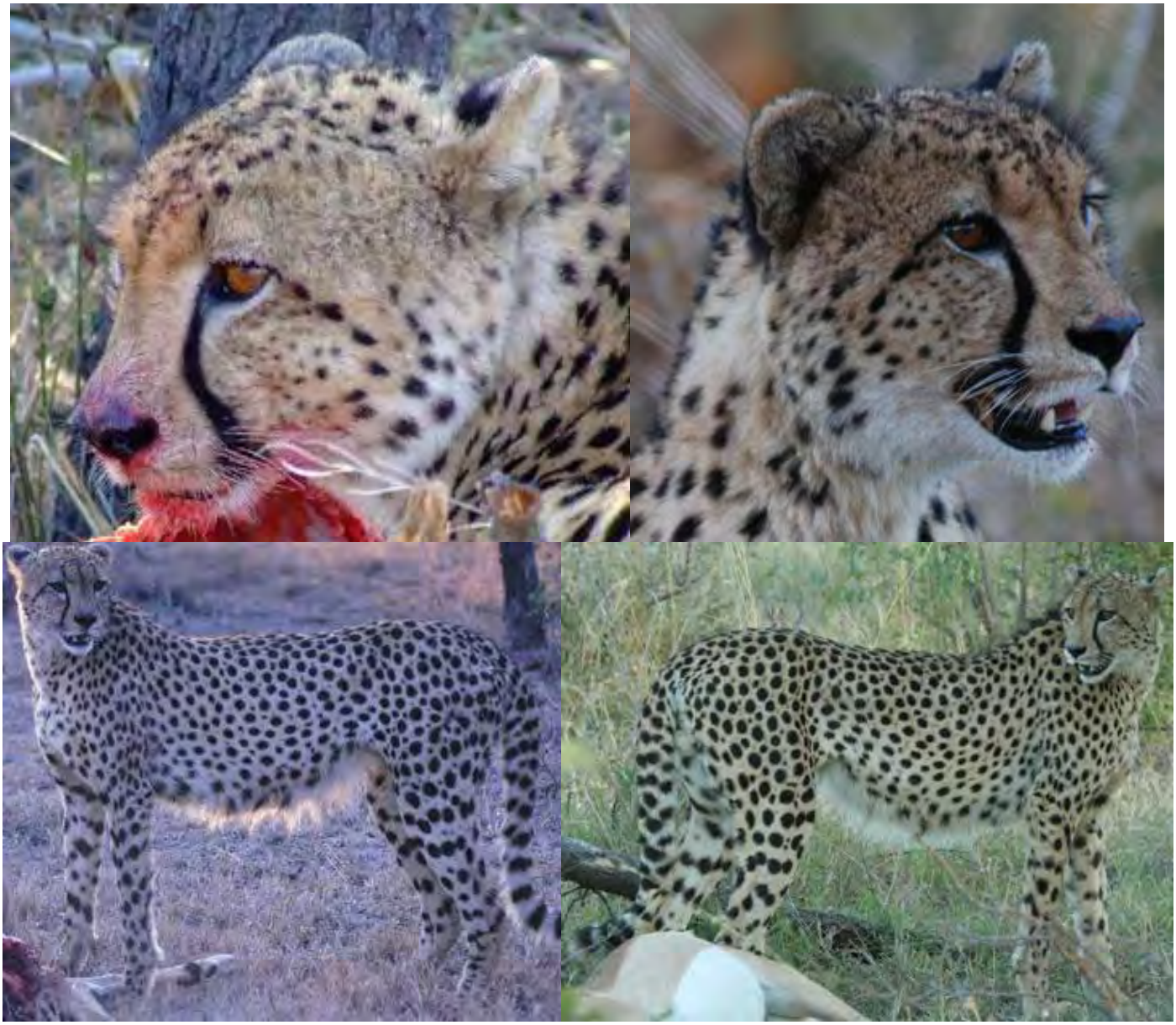
Sex: Male

Date of Birth/Age: Adult ±6 yrs; est. DOB: ±July 2005

Group Composition: Single male

Home Range: White"s Avoca/Hermansburg – Southern section of reserve

Diagnostic Features: Triangular spot pattern to right of eye. Walks with a permanent limp.



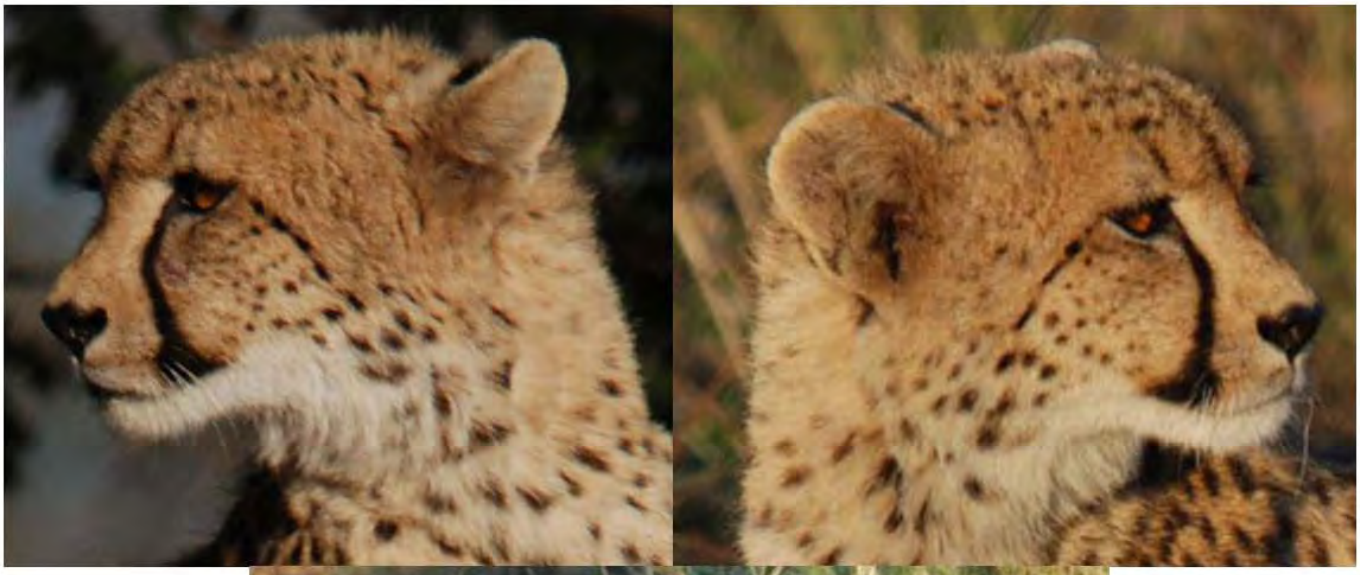
Name: M13

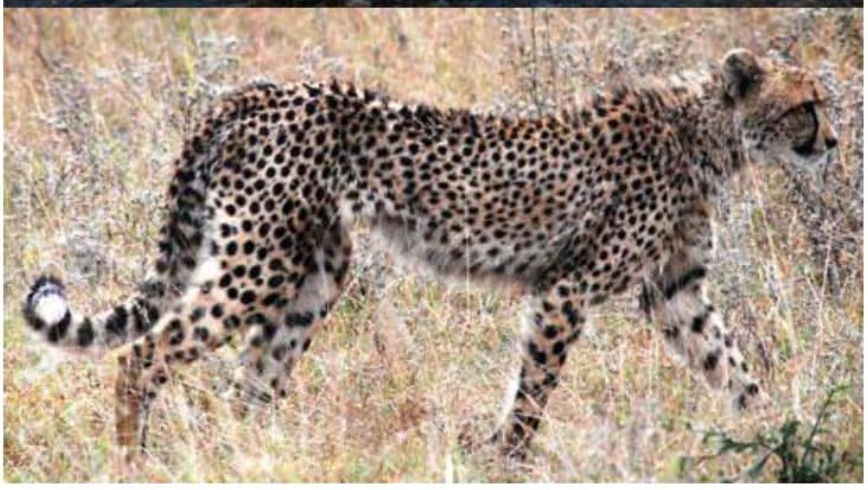
Sex: Male

Date of Birth/Age: Young adult

Group Composition: Single male

Home Range: Birmingham/Avoca/Hermansburg (southern portion of reserve)





Name: M14

Sex: Male

Date of Birth/Age: Adult

Group Composition: In a coalition with three other adult males (M15, M16 & M17).

Home Range: Ngala

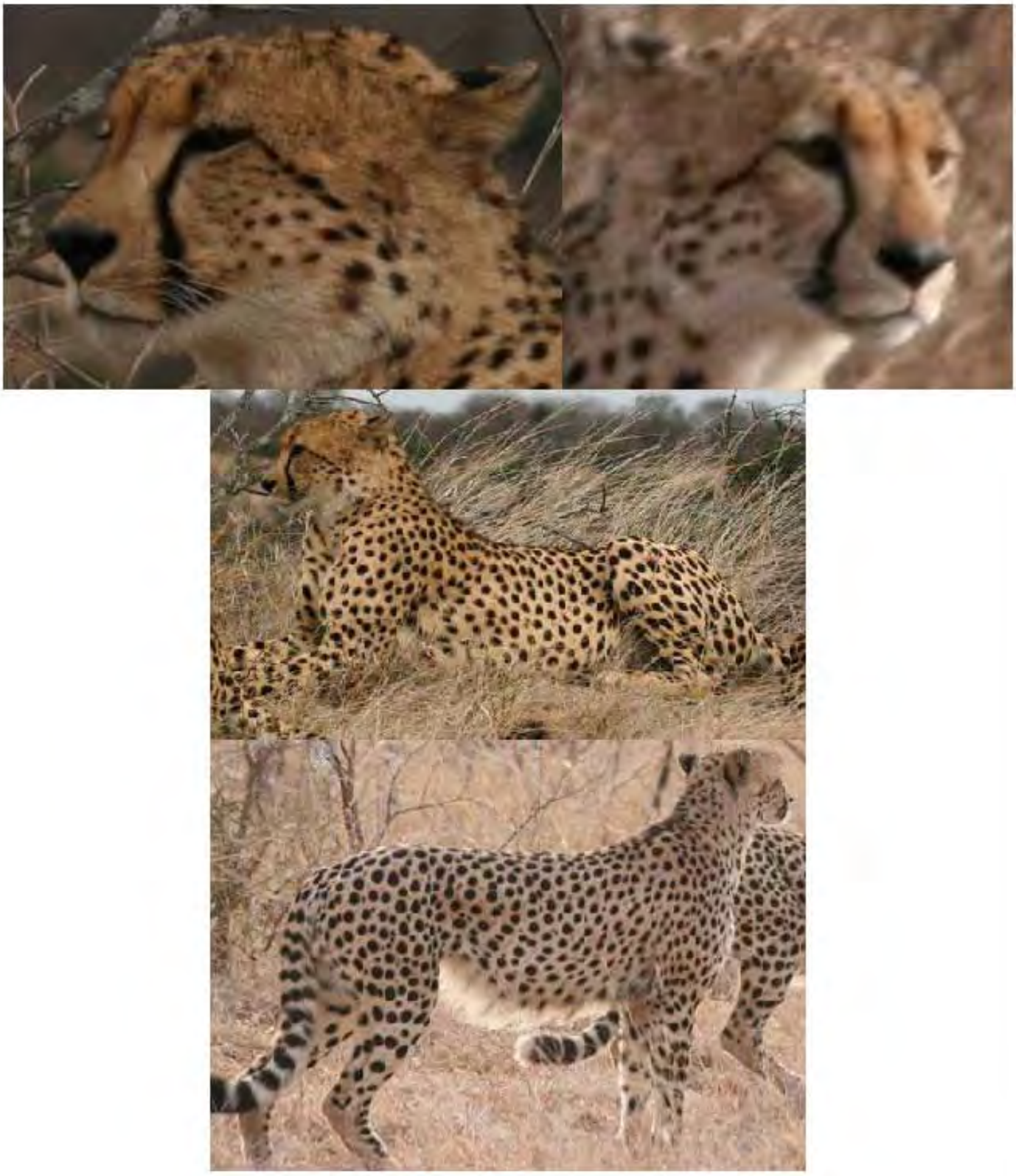
Name: M15

Sex: Male

Date of Birth/Age: Adult

Group Composition: In a coalition with three other adult males (M14, M16 & M17).

Home Range: Ngala



Name: M16

Sex: Male

Date of Birth/Age: Adult

Group Composition: In a coalition with three other adult males (M14, M15 & M17).

Home Range: Ngala

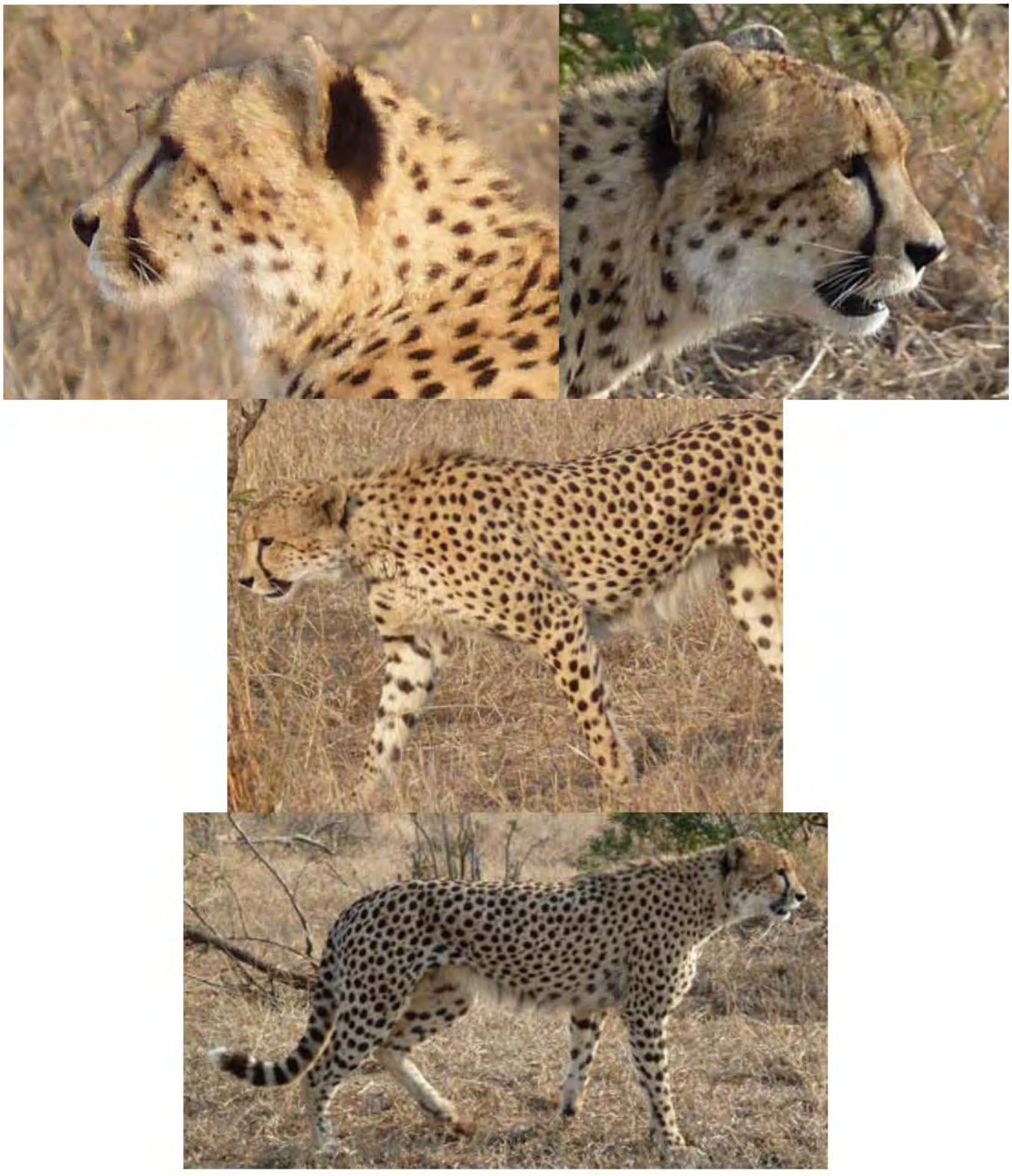
Name: M17

Sex: Male

Date of Birth/Age: Adult

Group Composition: In a coalition with three other adult males (M14, M15 & M16).

Home Range: Ngala



Name: M18

Sex: Male

Date of Birth/Age: Adult

Group Composition: In coalition with another adult male (M19).

Home Range: Gomo Gomo down to Thornybush

Name: M19

Sex: Male

Date of Birth/Age: Adult

Group Composition: In coalition with another adult male (M18).

Home Range: Gomo Gomo down to Thornybush

Name: New Individual (no name as sex unknown)

Sex: Unknown

Date of Birth/Age: Adult

Group Composition: Solitary

Home Range: Seen on Vlakgezicht

APPENDIX C

Cheetah sightings table – Timbavati Private Nature Reserve

November 2009 – April 2011

Cheetah Sightings (1st November 2009 – 30th April 2011)						
ID:	**Date:**	**Time:**	**Location (Farm) + GPS:**	**Group Composition**	**Notes**	**Observer**
November 2009						
F1	01-Nov-2009	15:49	Hermansburg: -24.41883 31.22275	1 adult female	Female resting.	Ziegfried Hugo (Hermansburg)
F1	03-Nov-2009	07:47	In front of Hermansburg Lodge: -24.41757 31.22903	1 adult female	Female resting on anthill.	Ziegfried Hugo (Hermansburg)
M1	07-Nov-2009	06:52	Makanyi (White"s Avoca): -24.46827 31.24083	1 adult male	Scratched on tree; dropped scat; rested on anthill.	Dave Jackaman (Makanyi)
F7 & cubs M7 & F4	Dec-2009	-	Ngala: Devonshire - Little Kenya & Duiker Road & Manyaleti -24.484643 31.358031	Adult female with 2 sub-adult cubs (M+F)	Resting	Dylan Davies
?	19-Dec-2009	10:28	In front of D.Rutter"s camp (Hermansburg) -24.41585 31.21240	1 adult (possibly male)	Male alert on anthill.	Dennis Rutter (Hermansburg)
F2 & 3 cubs	28-Dec-2009	07:31	Tawane – Piggy Dam: -24.34115 31.36498	1 adult female + 3 cubs (est. age: 9-11months)	Cubs playing.	Sean Savage (Tanda Tula)
?	29-Dec-2009	08:38	Ngala – Oppy Triangle: -24.46134 31.33611	Single adult	-	Ray Hume (Ngala)
January 2010						
F2 & 3 cubs	03-Jan-2010	AM	Tawane Buffalo Plains: -24.32765 31.36148	Adult female with 3 cubs (±10 months old)	Chased by lions (Machattan Pride); killed impala	Patrick O'Brien (Kings Camp) Dale Jackson (Tanda Tula)
M2	04-Jan-2010	06:57	Tawane, Piggy Dam: -24.34115 31.36498	Single adult male	Actively calling; nervous	Dale Jackson (Tanda Tula)
M1	12-Jan-2010	10:00	Off main entrance road to Makanyi Lodge: -24.4682667 31.24083	Single adult male	Active	Dave Jackaman (Makanyi)
F3	13-Jan-2010	07:29	Tawane – Tanda Tula -24.3455 31.36533	Single adult female	Hunting early AM kill successful (impala ± 4 months old); Did not lose kill. Scar on right cheek.	Patrick O'Brien (Kings Camp)
F1	17-Jan-2010	06:22	East of Ngala Safari Lodge: -24.3804667 31.32377	Single adult female	Relaxed	Dave Waddington (Ngala)

?	±18-Jan-2010	19:00	Western cutline/Java @ junction of Java airstrip access: -24.248834 31.367226	Single adult female	Located late – female nervous, sighting closed immediately	Johannes (Motswari)
F3	19-Jan-2010	06:29	Ngala airstrip: -24.3877667 31.32378	Single adult female	Skittish	Dave Waddington (Ngala)
M11	21-Jan- 2010	14:54	Makanyi airstrip: -24.47225 31.24493	Single male	Mobile, lay under tree.	Jeremy and Siobhan
?	24-Jan-2010	-	Hermansburg Gate: -24.4175667 31.22903	Single adult male	-	Robert (Hermansburg)
F2 & 3 cubs	29-Jan-2010	PM	Tanda Tula – Southern boundary: -24.3144944 31.32646	Adult female with 3 cubs (±10 months old)	-	Dale Jackson (Tanda Tula)
February 2010						
F1	09-Feb-2010	07:22	Ngala Airstrip: -24.38777 31.32378	Single adult female	Killed a young female impala.	Mark (Ngala)
?	14-Feb-2010	AM	Eastern cutline – Tanda Tula: -24.31052 31.36209	Single adult female	-	Dale Jackson (Tanda Tula)
M11	15–Feb- 2010	10:45	Hermansburg (ThornyBush Corner): -24.40225 31.21900	Single adult male	Scent marking, limping	Almero Bosch (Chimanimani)
F2 & cubs	24-Feb-2010	07:17	Ngala: End of Skankaan rd close to river -24.486721 31.338750	Mother with 3 adolescent cubs	-	Ray Hume (Ngala)
F2 & cubs	25-Feb-2010	08:01	Ngala: End of Skankaan rd close to river -24.488098 31.338426	Mother with 3 adolescent cubs	-	Ray Hume (Ngala)
F1	27-Feb-2010	07:47	Royal Legend: -24.34015 31.26098	Single adult female	Resting	Neville (Kambaku)
March 2010						
M8	03-Mar-2010	AM	Chimanimani: -24.3762 31.16142	Single adult male	Collared from Thorny Bush, battery flat	Paul White (Chimanimani)
F2 & cubs	06-Mar-2010	17:30	Spookhouse: -24.4474 31.26125	Mother with 3 adolescent cubs (± 13 months)	Active and hunting, killed an adult impala.	Ziegfried Hugo (Hermansburg)
M13	06-Mar-2010	PM	Birmingham airstrip: -24.5259 31.28973	Single adult, sex unknown	-	Jeanette Bowers-Winters (Birmingham)
M13	07-Mar-2010	AM	Birmingham – old Orpen road junction with access road: -24.5194 31.29668	Single adult	-	Jeanette Bowers-Winters (Birmingham)
F2 & cubs	09-Mar-2010	18:30-20:00	New Puza: -24.4638 31.23745	Mother with 3 adolescent cubs (± 13 months)	Active	Jeremy
F2 & cubs	10-Mar-2010	05:30 & 18:00	New Puza & Broken Dam: -24.461 31.25247	Mother with 3 adolescent cubs (± 13 months)	Active and hunting. Youngsters killed baby warthog.	Jeremy & Siobhan
F2 & cubs	11-Mar-2010	06:00-08:15	Broken Dam: -24.4625 31.25268	Mother with 3 adolescent cubs (± 13 months)	Active/Playful	Jeremy, Siobhan & Ziegfried Hugo
F2 & cubs	12-Mar-2010	17:00	Makanyi Airstrip:	Mother with 3 adolescent cubs (±	Active	Luckson (Makanyi)

			-24.4722 31.24437	13 months)		
?	12-Mar-2010	PM	Schoongezicht: -24.3456 31.18698	Single adult male	Active	Howard Walker
F4 & M7	17-Mar-2010	08:11 - Sunset	Ngala – Cheetah Flats: -24.487 31.3327	Adult male and female	Active	Meghan (Ngala)
F4 & M7	18-Mar-2010	PM	Ngala – South: -24.4378 31.35357	Adult male and female	Active	Ngala, Jeremy and Siobhan
F2 & cubs	20-Mar-2010	AM	Johnniesdale cutline: -24.4081 31.33803	Mother and 3 cubs	-	Dave Falkner (Johnniesdale)
?	21-Mar-2010	AM	Tanda Tula Airstrip: -24.3018 31.29073	Five adults, sexes unknown	Active	Pamela (Elephant Research)
?	21-Mar-2010	AM	Ngala – North: -24.3771 31.32107	Single adult male	Nervous	Meghan (Ngala)
F4 & M7	22-Mar-2010	07:08	Ngala: -24.4116 31.34388	Adult male and female	Nervous	Meghan (Ngala)
?	27-Mar-2010	PM	Umlani: -24.3318 31.30883	Four cheetahs, ages & sexes unknown	-	Umlani
F2 & 3 cubs	28-Mar-2010	16:15	Nick vd Merwe/Johnniesdale cutline: -24.4277 31.27932	Mother with 3 adolescent cubs	Feeding on impala kill	Jeremy
F2 & 3 cubs	29-Mar-2010	08:00	Nick vd Merwe/Johnniesdale cutline, top dam: -24.4321 31.27823	Mother with 3 adolescent cubs	-	Jeremy
F2 & 3 cubs	30-Mar-2010	08:30	Nick vd Merwe/Johnniesdale cutline; middle dam: -24.4395 31.2776	Mother with 3 adolescent cubs (2 male and 1 female)	Moving and intermittently resting	Jeremy
F11	31-Mar-2010	05:54	Ngala -24.4832 31.33995	Single adult	Resting	Megan (Ngala)
April 2010						
F2 & 3 cubs	01-Apr-2010	PM	Ngala airstrip crossing over cutline into Johnniesdale: -24.47022 31.25342	Mother and 3 adolescent cubs	Active/slightly nervous	Dave Waddington (Ngala)
F2 & 3 cubs	04-Apr-2010	07:04	Ngala -24.47730 31.33927	Mother and 3 adolescent cubs	Drinking water from a puddle in the road.	Megan (Ngala)
M1	04-Apr-2010	AM	Makanyi airstrip: -24.47108 31.24843	Single adult male	Killed impala ewe on airstrip	Jeremy Kemp-Symonds
M13	07-Apr-2010	AM	Clearing near Dennis Rutter's Camp – Hermansburg: -24.42199 31.20982	Single adult male	Active	Dave Jackaman (Makanyi)
F11	10-Apr-2010	09:46	Ngala -24.48482 31.35803	Single adult female	Resting	Megan (Ngala)
?	11-Apr-2010	09:15	Tanda Tula: -24.30427 31.33042	Single adult female	Active	Sean Savage (Tanda Tula)
F6 & 3 cubs	14-Apr-2010	08:30	Beretta/Makanyi cutline near Broken Dam: -24.45897 31.24973	Mother and 3 adolescent cubs	Drinking at pan	Suchar Blatherwick
?	14-Apr-2010	14:00	Johnniesdale – pan 500m past drainage crossing with old plough: -24.43537 31.29725	Single young male	Feeding on impala kill	Dave Falkner (Johnniesdale)

F6 & 3 cubs	14-Apr-2010	14:45	Makanyi: Rhino Loop – airstrip side: -24.47002 31.24195	Mother and 3 adolescent cubs	Active	Dave Jackaman; Kevin Blatherwick (Makanyi)
F2 & 3 cubs	14-Apr-2010	08:14	Orpen tar road just after entering first Kruger gate	Mother and 3 adolescent cubs	Active	Annie van den Berg
F2 & 3 cubs	18-Apr-2010	05:06	Birmingham – old Orpen rd near Jackal Plain: -24.52292 31.27947	Mother and three adolescent cubs	Feeding on an impala kill	Geoff and Jeanette Bowers-Winters (Birmingham)
?	21-Apr-2010	AM	Ngala: -24.48873 31.33300	Mother and three adolescent cubs	-	JP (Ngala)
?	?	AM	Ngala: -24.38812 31.32685	Single adult female	-	Meghan (Ngala)
F2 & 3 cubs	27-Apr-2010	AM	Birmingham, Jackal Plain: -24.51932 31.27540	Mother and 3 adolescent cubs	-	Geoff & Jeanette Bowers-Winters
?	28-Apr-2010	PM	Ngala: -24.38607 31.33466	Single adult, sex unknown	Active	Rob (Ngala)
M7 & F4	30-Apr-2010	06:30	Makanyi Airstrip: -24.47162 31.24658	Adult male and female	Hunting banded mongoose & impala, very skittish	Siobhan Dyer
May 2010						
F2 & 3 cubs	03-May-2010	07:50 - 08:45	Birmingham/Morgenzon cutline: -24.52148 31.29657	Adult female and 3 adolescent cubs	-	Geoff & Jeanette Bowers-Winters
F2 & 3 cubs	04-May-2010	AM	Plain East of access rd off Old Orpen rd: -24.51053 31.30203	Adult female and 3 adolescent cubs	-	Geoff & Jeanette Bowers-Winters
M7 & F4	07-May-2010	06:00	Makanyi airstrip: -24.47225 31.24493	Adult male and female	-	Dave Jackaman
M13	08-May-2010	13:11	Hermansburg camp gate -24.41905 31.22885	Adult male	Resting	Ziggy
?	08-May-2010	PM	Tanda Tula: -24.30427 31.33042	Single adult male	Nervous	Foreman (Tanda Tula)
M7 & F4	(Early on in month)	AM	Hermansburg: -24.42500 31.21310	Single adult male and female	-	Willie Sonnenberg
F12 & cub	Beginning of month	-	Olifants South	Adult female and adolescent cub	Collared Thorny Bush female	Mario Cesare
F2 & 3 cubs	09-May-2010	08:15	Jackal Plain, Birmingham: -24.52338 31.27455	Adult female and 3 adolescent cubs (2 males, 1 female)	Hunting & playing	Happy Hapelt & Jeremy Kemp-Symonds
M2	09-May-2010	17:15	Eagle-Owl Plain, King's Camp: -24.281281 31.335847	Adult male	Hunting	Grant Murphy (Motswari)
M2	11-May-2010	AM	Access road to Motswari: -24.46337 31.24087	Adult male	Hunting kudu	Grant Murphy (Motswari)
3 cubs	11-May-2010	14:40	Combretum/Sandringham fenceline: -24.49868 31.23092	Three adolescent cubs, sexes unknown, no adult female apparent	Distressed and split by fenceline (2 cubs on Sandringham side). Location of mother unknown.	Siobhan Dyer and Jeremy Kemp-Symonds
M7 & F4	12-May-2010	07:10	Makanyi/Combretum cutline, moved onto Combretum near entrance road: -24.46080 31.22730	Adult male and female, suspected siblings	Active	Siobhan Dyer & Jeremy Kemp-Symonds

3 cubs	13-May-2011	15:20	Sandringham-Combretum fenceline: -24.49873 31.22080	3 adolescent cubs; no adult female apparent	Distressed and split by fenceline (2 cubs on Sandringham side)	Jeremy Kemp-Symonds
?	14-May-2010	10:30	Old Orpen Road, Birmingham: -24.52943 31.25692	Adult female and 3 adolescent cubs	Moving	Jacques Brits and Jeremy Kemp-Symonds
?	17-May-2010	15:30	Kambaku Lodge: -24.36403 31.26435	Adult female	Hunting; lame on left foreleg.	Kambaku staff
M7 & F4	18-May-2010	PM	Happy's Plain, Birmingham: -24.52695 31.28240	Adult male and female	Moving	Happy Hapelt
F6 & 3 cubs	21-May-2010	AM	Southern boundary of Liebenberg: -24.33413 31.32170	Adult female with 3 adolescent cubs	Moving	Umlani
M13	21-May-2010	06:30	150m East of Dennis Rutter's camp: -24.41558 31.21308	Adult male	Moving	Kevin Burger
M13	21-May-2010	AM	Clearing near Dennis Rutter's camp: -24.41733 31.21193	Adult male	Moving	Ziegfried Hugo
M13	21-May-2010	PM	Main road to green gate in the South of the reserve/Old Avoca: -24.43372 31.21892	Adult male	Moving	Rene (Hermansburg)
F6 & 3 cubs	23-May-2010	AM	Serengeti Plains – Tanda Tula -24.333155 31.349987	Adult female and 3 adolescent cubs	-	Brendon Schmikl
F6 & 3 cubs	24-May-2010	PM	Umlani: -24.33183 31.30883	Adult female with 3 adolescent cubs	Moving	Umlani
F6 & 3 cubs	24-May-2010	16:30	Near Tanda Tula camp: -24.30535 31.32322	Adult female and 3 adolescent cubs	Moving	Tanda Tula staff
?	26-May-2010	17:30	Boma near Sandringham Corner, Birmingham: -24.51297 31.26610	Adult female with 3 adolescent cubs	Moving	TPNR Rangers
F6 & 3 cubs	27-May-2010	16:03	Southern boundary of Tawane/Ele walk going south -24.35527 31.35907	Adult female with 3 adolescent cubs	-	Dale Jackson
F2 & 3 cubs	27-May-2010	17:45	Old Orpen Road, Birmingham at Bush School junction: -24.53028 31.26018	Adult female with 3 adolescent cubs	Moving	Jeremy Kemp-Symonds
M13	31-May-2010	07:29	Makanyi workshop entrance: -24.47022 31.25342	Single adult male	Nervous	Dave Jackaman
F12	31-May-2010	AM	Ntsiri entrance: -24.18849 31.34413	Adult female without cub	Collared Thorny Bush female	-
June 2010						
New Individual	03-June-2010	13:55	Vlakgezicht -24.366560 31.352672	Single adult, sex unknown	Resting	TPNR Ranger patrol
F2 & 3 cubs	07-June-2010	PM	Birmingham: -24.525717 31.281167	Adult female with three adolescent cubs.	On an impala kill. Went to drink at a pan and were then chased off by baboons.	Geoff & Jeanette Bowers-Winters
M2	01-June-2010	07:02	Hermansburg: clearing between Dennis and Willie's camps -24.420407 31.210129	Single adult male	Moving	Almero Bosch

?	05-June-2010	AM	Royal Legend: -24.338283 31.254700	-	-	Pollen Ndlovu (Royal Legend)
?	08-June-2010	?	Birmingham: south of the Orpen road along fenceline in open area -24.539335 31.235299	-	Hunting	Almero Bosch & Paul White
?	13-June-2010	AM	Charles Devillier's camp, Birmingham: -24.517867 31.248984	Single adult male	Moving	Camp staff
F2 & 3 cubs	13-June-2010	07:15	Happy's Pan, Birmingham: -24.526921 31.281358	Adult female with three adolescent cubs.	Moving	Happy Hapelt
F12	14-June-2010	10:43	Jaydee access/Argyle rd junction: -24.245894 31.298722	Single adult female	Moving	Chad Cocking/Adam Whitfield
?	15-June-2010	AM	Old Avoca/Beretta cut-line towards the plinth -24.457853 31.228191	Adult female with three adolescent cubs	Moving	Kevin Blatherwick
?	15-June-2010	PM	Paul's Dam in front of Makanyi: -24.471816 31.257099	Single adult, sex unknown	Hunting impala	Kevin Blatherwick
M2	16-June-2010	05:46	On main road close to open area before control gate -24.345148 31.173195	Single adult male	Relaxed	Auriel and Chris Thorpe
M18 & M19	16-June-2010	09:57	Southern end of Ingwelala -24.183325 31.350668	Two adult males	Active	Ingwelala Owner
?	20-June-2010	AM	Little Serengeti, Makanyi -24.463372 31.235932	Adult female with three adolescent cubs	Hunting	Kevin Blatherwick
?	20-June-2010	PM	Makanyi: Main road -24.467074 31.240035	Adult female with three cubs	-	Luckson (Makanyi)
F2 & 3 cubs	23-June-2010	AM	Ngala: South of Deep Quarry (SE of Spring valley): -24.523969 31.370603	Adult female with three adolescent cubs.	-	Ngala
M7 & F4	24-June-2010	08:27	Willie's house: Hermansburg: -24.424238 31.211166	Adult male and female	-	Ziggy
F2 & 3 cubs	26-June-2010	10:30	Morgenzon rd, Birmingham: -24.532650 31.289850	Adult female with three adolescent cubs	Very nervous, which is unusual for this group	Geoff and Jeanette Bowers-Winters
F2 & 3 cubs	27-June-2010	AM	Ngala: South of Old Orpen -24.510737 31.344005	Adult female with three adolescent cubs.	-	Ngala
F2 & 3 cubs	27-June-2010	PM	Ngala: Old Orpen – Manyeleti -24.507870 31.347786	Adult female with three adolescent cubs.	-	Ngala
F2 & 3 cubs	28-June-2010	AM	Ngala: Manyeleti 1st Clearings (north of Fountains West). -24.517445 31.349844	Adult female with three adolescent cubs.	-	Ngala
F2 & 3 cubs	28-June-2010	PM	Ngala: Spring Valley-Fountains East -24.526255 31.368262	Adult female with three adolescent cubs.	-	Ngala
F2 & 3 cubs	29-June-2010	PM	Ngala: Spring Valley-Fountains East	Adult female with	-	Ngala

			-24.525795 31.368108	three adolescent cubs.		
F2 & 3 cubs	30-June-2010	AM & PM	Ngala: centre of Spring Valley-Manyeleti -24.532381 31.347934	Adult female with three adolescent cubs.	-	Ngala
July 2010						
F2 & 3 cubs	01-July-2010	AM	Ngala: centre of Spring Valley-Manyeleti -24.533155 31.347996	Adult female with three adolescent cubs	-	Mark (Ngala)
M7 & F4	02-July-2010	14:46	Makanyi: Puza open plain -24.461880 31.235810	Adult male and female	Adult female limping badly on back right leg. Leg swollen and gashed.	Dave Jackaman
M7 & F4	03-July-2010	AM	Makanyi: Puza open plain -24.462819 31.236262	Adult male and female	-	Dave Jackaman
M7 & F4	08-July-2010	07:15	Makanyi: Puza open plain on termite mound -24.460999 31.236267	Adult male and female	Resting and playing, female still limping badly on the back leg.	Siobhan Dyer
?	10-July-2010	PM	Hermansburg Western cutline, near ThornyBush corner -24.404605 31.217893	Single adult male	-	Paul White
M7	12-July-2010	08:00	In road on Thornybush/Hermansburg fenceline, near Dennis' open clearing. -24.419353 31.208199	Single adult male	Very nervous/anxious, was seen alone and so separated from F4 (suspected sibling) for the first time.	Siobhan Dyer
M18 & M19	12-July-2010	11:10	Southern end of Ingwelala -24.180153 31.362420	Two adult males	Resting and walking	Ingwelala owner
F2 & 3 cubs	12-July-2010	PM	Caracal -24.458383 31.346301	Adult female with three adolescent cubs	-	Dylan Davies
M7 & F4	12-July-2010	21:00	Thornybush/Hermansburg fenceline in line with Dennis Rutter's camp -24.415246 31.210866	Adult male and female including a third cheetah with sex unknown	Male and female separated by fenceline with a third unknown cheetah on the Thornybush side with F4.	Anton (TPNR)
M7 & F4	13-July-2010	08:30	Thornybush/Hermansburg fenceline at Dam 1 -24.410496 31.214051	Adult male and female	Male and female separated by fenceline with female stuck on the Thornybush side. Both animals very nervous. Female still limping on back right leg.	Siobhan Dyer
F2 & 3 cubs	13-July-2010	AM	Ngala: Fuldts and Hyaena Road -24.455748 31.364683	Adult female with three adolescent	-	Dave Waddington

				cubs		
F2 & 3 cubs	13-July-2010	PM	Ngala: Gagga Faults -24.442490 31.342152	Adult female with three adolescent cubs	-	Dylan Davies
M7 & F4	14-July-2010	07:45	Thornybush/Hermansburg fenceline at Dam 1 -24.410014 31.214348	Adult male and female	We darted and collared M7.	Siobhan Dyer & Jeremy Kemp-Symonds
M7 & F4	15-July-2010	08:00	Thornybush/Hermansburg fenceline: between Dam 1 and Dam 2 -24.406359 31.216747	Adult male and female	The fence was jacked and an impala placed on the TPNR side to lure the female back under the fence. The male began eating the impala and it wasn't long thereafter that the male joined her.	Siobhan Dyer & Jeremy Kemp-Symonds
M1	15-July-2010	09:30	Thornybush/Hermansburg fenceline: 500metres south of Dennis Rutters' camp -24.416738 31.210301	Adult male	We darted and collared M7.	Luckson (Makanyi)
F6 & 3 cubs	15-July-2010	08:00	Birmingham: behind Winters camp, on other side of river: -24.495783 31.291917	Adult female with 3 adolescent cubs	On an impala kill	Geoff & Jeanette Bowers-Winters
F2 & 3 cubs	15-July-2010	13:30	Middle road: Makanyi Lodge -24.482767 31.256319	Adult female with 3 adolescent cubs	Killed a steenbok	Dave Jackaman & Kevin Blatherwick
M7 & F4	17-July-2010	08:40	Hermansburg: on edge of clearing between Willie's and Dennis's camps; moving towards clinic. -24.420925 31.210880	Adult male and female siblings	Nervous	Jeremy Kemp-Symonds
M7 & F4	18-July-2010	16:30	Far end of Rhino Loop at junction with Main Road; moving towards Airstrip -24.460883 31.233500	Adult male and female siblings	Both looked well- and recently-fed	Jeremy Kemp-Symonds
M7 & F4	19-July-2010	08:10	Near end of Rhino Loop at junction with Main Road; moving towards Sunset Drive -24.470483 31.244767	Adult male and female siblings	-	Jeremy Kemp-Symonds
M2	21-July-2010	09:00	1.3 km from control gate on the tar road heading into the Walkens property -24.346329 31.170216	Single adult male	Moving	John Manning (Kambaku)
M2	-	-	Near control gate -24.343626 31.183395	Single adult male	-	Dale Jackson
-	-	-	-	Single adult female	-	Foreman
M7 & F4	26-July-2010	11:30	Birmingham: -24.531283 31.246817	Adult male and female siblings	-	Jeremy
F6 & 3 cubs	28-July-2010	16:36	Dam at Adgar camp -24.326983 31.402972	Adult female and 3 adolescent cubs	-	Paul White
F6 & 3 cubs	30-July-2010	07:36	Buffalo Plains: Rhino Loop/ Park Link 3 -24.315122 31.357788	Adult female and 3 adolescent cubs	-	Dale Jackson

August 2010						
M9	02-Aug-2010	08:02	Lornay: open clearing south east of airstrip -24.379928 31.202599	Single adult sex unknown	-	Ziegfried Hugo
F2 & 3 cubs	02-Aug-2010	14:50	Ngala -24.480553 31.340373	Adult female and three adolescent cubs	-	Ngala
F6 & 3 cubs	03-Aug-2010	AM	Near entrance dam at Kings Camp -24.272970 31.303163	Adult female and three adolescent cubs	Feeding on impala kill	David – Tanda Tula
M7 & F4	03-Aug-2010	08:00	Middle Rd – Makanyi: -24.474083 31.249267	Adult male and female siblings	-	Dave Jackaman
M9	04-Aug-2010	06:48	Thornybush fenceline between western corner and Hermansburg corner. -24.402038 31.198688	Two adults sexes unknown	One adult on TPNR side of fenceline and other adult on Thornybush side of fence.	Paul White
M7 & F4	09-Aug-2010	16:45	Paul's Dam in front of Makanyi Lodge -24.471558 31.256778	Adult male and female siblings	Drinking water at the dam	Dave Jackaman
M2	04-Aug-2010	08:56	Northern Thornybush fenceline: Thornybush farm -24.402061 31.214359	Single adult male	Mobile and scent marking	Ziggy
F6 & 3 cubs	04-Aug-2010	07:44	Elephant walk, Serengeti Middle Road -24.334598 31.346625	Adult female and three adolescent cubs	-	Dale Jackson
F6's 3 cubs	09-Aug-2010	07:29	Buffalo Flats: Ngala -24.450622 31.395669	Three adolescent female cubs	Feeding on impala kill; first time cubs seen independent of their mother.	Mark (Ngala)
M2	21-Aug-2010	17:37	Beretta Drive, Makanyi -24.459759 31.235213	Single adult male	Settling for the night	Dave Jackaman & Jeremy Kemp-Symonds
F12	23-Aug-2010	07:30	Tar road along Wiggel's fence -24.333514 31.218856	Single adult female	Moving	Gomo Gomo
M14, M15, M16 & M17	27-Aug-2010	07:13	Manyeleti -24.512665 31.348537	Coalition of four adult males	Hunting	Mike Robertson (Ngala)
September 2010						
F6	02-Sep-2010	06:47	Just north of radio mast on Johnniesdale cutline -24.415549 31.343412	Single adult female	Moving into J'dale; distinctive scar on upper lip.	Finn (Ngala)
F12	02-Sep-2010	09:15	Kambaku -24.357751 31.269343	Single adult female	-	Kambaku
M2	06-Sep-2010	AM	Val Berretta's on left -24.455422 31.242195	Single adult male	On anthill	Steven Blatherwick
F6's three Cubs	06-Sep-2010	-	Kings – Pat's Drive -24.293132 31.321936	3 adolescent cubs seen without mother F6	-	Grant
F6's 3 cubs (F8,F9, F10)	08-Sep-2010	07:39	1Km north of Tanda Tula camp, heading west	3 adolescent females	Moving	Kambaka & Dale Jackson

			-24.301735 31.322715			
?	11-Sep-2010	?	South of control gate -24.350463 31.160845	Single adult male	Moving	Abel Erasmus
?	18-Sep-2010	?	Sandringham corner -24.499013 31.253937	Single adult male	Hunting	TPNR Patrol
?	21-Sep-2010	?	Oppy Dam, Ngala -24.457849 31.340879	Single adult male	Drinking, very nervous	Finn (Ngala)
F6	25-Sep-2010	?	Buffalo Flats: Ngala -24.451455 31.395776	Single adult female	Limping on front leg	Ian (Ngala)
M18 & M19	27-Sep-2010	06:52	Tar road between Wiggels and Gomo Gomo Entrance: -24.334209 31.217565	Two adult males	Relaxed, lying on tar road	Gomo Gomo
? Possibly M7 & F4	28-Sep-2010	AM & PM	Airstrip Dam: Tanda Tula -24.299642 31.293658	Collared adult male with a female	Very skittish	Bruce Jenkins/Dale Jackson
October 2010						
F6	03-Oct-2010	?	Airstrip: Ngala -24.394958 31.330363	Single adult female	Limping on front leg	Brett (Ngala)
?	06-Oct-2010	PM	1km north of Morgenzon gate -24.547066 31.278589	Possible a young male	Moving, slightly nervous	Happy Hapelt
F6	15-Oct-2010	17:22	Near entrance road to Ele Research TT -24.306838 31.326351	Single adult female	Fresh impala kill, female still has an injured front right leg	Patrick/Dale (Photos)
F8, F9 & F10	18-Oct-2010	AM	Argyle Dam -24.197012 31.381236	Three young adult females	Feeding on steenbuck kill	Arend Schoeman, Grant Murphy & Patrick
F8, F9 & F10	19-Oct-2010	AM	Karans – Timbavati/Umbabat cutline: -24.199819 31.407351	Three young females	-	Grant Murphy
F8, F9 & F10	20-Oct-2010	PM	Ekuvukeni - Western Cutline -24.175584 31.396522	Three young females	-	Grant Murphy
M2	22-Oct-2010	AM	Makanyi: East of dam on Terminalia drive just off power line road. -24.476233 31.259222	Adult male	-	Dave Jackaman
F8, F9 & F10	23-Oct-2010	PM	Peru – Voeldam -24.206529 31.320806	Three young females	-	Grant Murphy
F8, F9 & F10	24-Oct-2010	PM	Voeldam (big dam right next to tar road, close to Simbavati turn-off) -24.207314 31.321733	Three young females	-	Arend, Patrick
F8, F9 & F10	28-Oct-2010	17:06	Peru – Wildwest, close to Voeldam (800m south of dam) -24.214276 31.317164	Three young females	Full from impala kill stolen away from them by 3 young male lions	Grant Murphy & Patrick
F8, F9 & F10	29-Oct-2010	PM	Peru: on wild west, close to tar road -24.218040 31.312561	Three young females	Resting	Arend & Grant Murphy
F8, F9 & F10	30-Oct-2010	AM	Close to tar road, then crossed over into Klaserie -24.217845 31.311136	Three young females	Moving north	Arend
F8, F9 & F10	31-Oct-2010	17:30	Tar Argyle rd, just north of Jaydee and Peru cutline, TPNR side walking north parallel with tar road. -24.245317 31.298269	Three young females	Moving north	Simbavati staff

November 2010						
F8, F9, F10	19-Nov-2010	AM	Peru – Link Rd between Voeldam & Voeldam Southern Access -24.211318 31.322984	Three young adult sisters	-	Grant Murphy
F6's 3 cubs	19-Nov-2010	07:00	Simbavati Lodge entrance road at Signal Hill, East of Old Gate, heading south before resting on termite mound. -24.205564 31.347570	Three young adult sisters	Good condition	Arend Schoeman
F8, F9, F10	19-Nov-2010	13:00	Voel Dam Southern Access, Peru -24.211479 31.323144	Three young adult sisters	Static on termite mound, moved west off of the property and into Klaserie in afternoon	Chad Cocking
F8, F9, F10	21-Nov-2010	18:00	Peru – At T-junction of Argyle rd (tar) and Woza Woza Cutline/Wild West North -24.227229 31.306602	Three young adult sisters	Static in Mopani woodland	Grant Murphy/Chad Cocking/Arend
F8, F9, F10	22-Nov-2010	07:00	Jaydee airstrip Nhlaramisa rd/ Vielmieter – Travelled South ending @ Sweetwater Pan -24.249764 31.318444 -24.263175 31.303784	Three young adult sisters	-	Grant Murphy/Arend
F8, F9, F10	22-Nov-2010	17:30	Vilmieter – Piva Rd, Southwest of Sweetwater Pan -24.264074 31.302328	Three young adult sisters	Feeding on fully grown impala ewe	Grant Murphy/Chad Cocking/Arend
F8, F9, F10	24-Nov-2010	-	Old control gate near entrance rd to Royal Legend -24.322743 31.259381	Three young adult sisters	-	Tim Nutbeam
M1	25-Nov-2010	09:40	Thornybush GR -24.448183 31.174633	Adult male	Relaxed, has a puncture wound and laceration on left flank	Jeremy
M10	26-Nov-2010	17:00	Eloff entrance rd to TT, between the two rivers -24.313605 31.305125	Adult male?	Emaciated with a deep, extensive wound behind shoulder	Dale Jackson
F6's 3 cubs	29-Nov-2010	AM	Johnniesdale – Jdale corner -24.454926 31.276494	Three young adult sisters	-	Mike Lentz
December 2010						
M18, M19	03-12-2010	06:45	Tar rd from control gate, 500m before Winston Wiggel's fence ends. -24.334536 31.214921	Two young males	-	Roderick – Royal Legend/Gomo Gomo
M18 & M19	03-Dec-2010	08:00	Walking North along Argyle round parallel to Winston Wiggel's fence between the road and the fence marking their territory -24.333791 31.217492	Two young adult males	Trying to go through fence onto Wiggel property	Bruce McDonald/Grant Murphy
F8, F9, F10	05-Dec-2010	AM	Johnniesdale – near green water tank north of camp. -24.412462 31.307904	Three young adult sisters	-	Mike Lentz

M18, M19	07-Dec-2010	09:00	Near Wiggel fenceline with Gomo Gomo -24.332823 31.219496	Two adult males	-	Gomo Gomo
M18, M19	08-Dec-2010	AM	Gomo Gomo – near entrance off of tar rd. -24.327387 31.235826	Two adult males	Killed impala lamb	Gomo Gomo
M18 & M19	09-Dec-2010	08:14	Tar rd, on Wiggel property -24.334219 31.215467	Two young adult males	Both males up a marula tree attempting to go back over fence into the Timbavati	Bruce McDonald
M18 & M19	10-Dec-2010	AM	Inside Wiggel property along fenceline -24.333829 31.216964	Two young adult males	-	Bruce McDonald
?	?		Vlak -24.390273 31.362854	Single adult	-	Paul White
F11 with 3 cubs	27-Dec-2010	AM	Orpen road - South of sighting day after -24.548679 31.351382	Adult female with three young cubs (±4-5months)	-	-
F11 with 3 cubs	28-Dec-2010	09:18	Ngala: Sprinvalley rd, west side of rd in clearing, East of Morgenzon's cutline -24.536952 31.352663	Adult female with three young cubs (±4-5months)	Feeding on two impala lambs	Andrew Nicholson
January 2011						
F8, F9 & F10	11-Jan-2011	06:50	Vlakgezicht -24.358190 31.373433	Three young adult females	Resting	Nick Hancock
F8, F9 & F10	12-Jan-2011	06:16	Vlakgezicht -24.359847 31.355547	Three young adult females	Resting	Nick Hancock
F11 & 3 cubs	15-Jan-2011	10:30	Birmingham: old Orpen rd near Sesetse camp -24.52372 31.27815	Adult female with 3 young cubs	Mother hunting	Jeanette Bowers-Winters
F11 & 3 cubs	23-Jan-2011	07:30	Birmingham: under Acacia tree on Jackal plain -24.51916 31.27539	F11's 3 young cubs	3 cubs resting and waiting for mother under Acacia tree when mother called them as they all ran off into thick bush	Jeanette Bowers-Winters
F11 & 3 cubs	24-Jan-2011	10:00	Birmingham: bottom of Jackal plain under a bush in thick grass -24.52196 31.27428	Adult female with 3 young cubs	Resting	Jeanette Bowers-Winters
F11 & 3 cubs	25-Jan-2011	08:00	Birmingham: at bottom of Jackal plain in tall grass 31.27459 24.52120	Adult female with 3 young cubs	Resting	Jeanette Bowers-Winters
F11 & 3 cubs	27-Jan-2011	Midday	Birmingham: pans in middle of Jackal plain -24.51984 31.27579	Adult female with 3 young cubs	Cubs playing, mother scouting for prey	Jeanette Bowers-Winters
F8, F9 & F10	31-Jan-2011	17:34	-24.298015 31.339073	Three young adult females	Resting under a bush, looking to hunt but too hot.	Patrick
F12 & 2 cubs	-	-	Combretum -24.49704 31.19862	Adult female with two young cubs	Moving	Juan Pinto (collar)

February 2011						
F11 & 3 cubs	02-Mar-2011	07:30	Birmingham: Entrance rd to Happy's place -24.52854 31.28212	Adult female with 3 young cubs	Resting in the road at the entrance	Happy
F11 & 3 cubs	03-Mar-2011	08:10	Birmingham: Jackal plain, west of marula tree near boma on bushline. -24.52325 31.27408	Adult female with 3 young cubs	Active and moving west	Siobhan
F8, F9 & F10	04-Mar-2011	07:45	Tanda Tula: Giraffe plains -24.298345 31.342571	Three young adult females	Feeding on two impala lambs	Moshe – Kambaku/Patrick
F8, F9 & F10	04-Mar-2011	17:43	-24.289000 31.337167	-	8	Patrick
F11 & 3 cubs	04-Mar-2011	17:08	Birmingham: top west of Jackal plain -24.517141 31.275962	Adult female with 3 young cubs	Mother killed a baby impala at 17:30	Bill and Vicky
F11's 3 cubs	05-Mar-2011	07:55	Birmingham: top east of JP -24.517388 31.280522	Three young cubs	Mother off hunting, cubs alone	Bill and Vicky
F8, F9 & F10	05-Mar-2011	AM	Same as PM of 4th -24.288626 31.337576	-	-	Patrick
F11 & 3 cubs	05-Mar-2011	17:43	Birmingham: Happy's waterhole -24.526967 31.281668	Adult female with 3 young cubs	-	Bill and Vicky
F11 & 3 cubs	12-Mar-2011	08:00	Birmingham: Happy's Plain near camp -24.527960 31.281996	Adult female with three young cubs	Cubs playing	Happy
F11 & 3 cubs	13-Mar-2011	07:30-09:00	Birmingham: Happys Plain Sesetse camp waterhole -24.527062 31.281791	Adult female with three young cubs	-	Bill and Vicky/Jen
F11 & 3 cubs	14-Mar-2011	07:49-08:37	JP -24.52304 31.275275	-	-	Jen
F11 & 3 cubs	15-Mar-2011	07:45	JP -24.516186 31.278628	Adult female with three young cubs	cheetah were on the top part of Jackal Plain and two female lions with about 8 cubs below the pans on the left hand side	Jen
F12 & single king cub	19-Mar-2011	07:!2	Hermansburg in front of camp -24.418604 31.228233	Adult female with young cub ±4 months	Actively moving	Ziggi
M18 & M19	19-Mar-2011	10:32	Lornay – Ou Missis dam -24.37387 31.22499	Two adult males	-	Graeme Naylor
M18 & M19	26-Mar-2011	-	Lornay – Ou Missis dam -24.37463 31.22370	Two adult males	-	Naylor's nephew
April 2011						
F2	11-Apr-2011	07:56	Ngala: Northriver rd north of Devonshire crossing -24.483640 31.344797	Single adult female	relaxed	Ian Pletzer
F11 & 3 cubs	26-Apr-2011	AM	Birmingham: C Devilliers dam -24.518614 31.249258	Mother with cubs	Playing	Okki
F11 & 3 cubs	27-Apr-2011	08:00	Birmingham: C Devilliers dam -24.518814 31.249210	Mother with cubs	Playing	Okki