ASSESSMENT OF CHEETAH PREY BASE OUTSIDE PROTECTED AREAS IN SALAMA AND KAPITI PLAINS OF SOUTHERN KENYA

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DECLARATION

I declare that this Thesis is my original work and has not been submitted to any other college or University for academic credits.

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DEDICATION

This thesis is dedicated to my dear parents: Prof. Henry Wangutusi Mutoro and Dr. Juliana Munialo Mutoro.

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LIST OF ABBREVIATIONS AND ACCRONYMS

ACK- Action for Cheetahs in Kenya

AKCP- Athi- Kapiti Cheetah Project

CCF-K- Cheetah Conservation Fund, Kenya

DBH- Diameter at Breast Height

KWS- Kenya Wildlife Service

ABSTRACT

Over 80% of Kenya's cheetah *(Acinonyx jubatus)* population range falls in community and private lands. Conversion of cheetahs' historical and geographical ranges into farmlands has led to loss of habitat quality and natural resources necessary for their survival. Understanding food resources and habitat characteristics that maintain cheetah populations outside protected areas is critical for cheetah conservation. This study therefore sought to assess density and distribution of potential cheetah prey in various habitat types in Kapiti and Salama areas of southern Kenya and the significance of each prey species in the cheetah diet. It also investigated vegetation characteristics of available cheetah habitats in the study area. Data on potential prey distribution and abundance were collected from July 2013 to February 2014 by means of transect counts. Cheetah scats were collected opportunistically in the study area for prey species determination using hair characteristics and their frequency of occurrence computed. Plot and plotless sampling methods were used to determine vegetation characteristics in sites frequently used/visited by the cheetah. A total of 19 wild mammalian prey species were recorded in woodland, bushed grasslands and open grassland habitats. Habitat type did not significantly influence cheetah prey species abundance in the three habitat types apart from the warthog ($\chi^2_{0.05, 2}$= 0.8). Hairs from 21 mammalian species were identified from 27 confirmed cheetah scats. Cheetah diet in the study area was dominated by Grant's gazelle (25.9%), Cape hare (22.2%) and goat (18.5%). Cheetah showed preference for wild ungulate prey (40.7%) compared to domestic animals (11.1%). Cheetah frequently used woodlands, shrub lands and bushed grasslands but did not show preference for any of the three habitat types. Strategies that encourage habitat and species conservation in farmlands should be developed to promote survival of the cheetah and other carnivore species. Monitoring of cheetah prey and their influence on cheetah movement patterns outside protected areas should be continued with a view to enhance cheetah conservation by minimizing conflict between cheetahs and people.

Key Words: *Acinonyx jubatus*, habitat assessment, scats, prey, faecal hair analysis.

CHAPTER ONE: INTRODUCTION AND LITERATURE REVEIW

1.1 Introduction

Conservation biology and natural ecosystem functioning on farmlands are becoming increasingly important as human population and economic pressures on wildlife reserves increase (Bowland and Perrin, 1993). In Africa, human population continues to encroach on the last of the continent's wild areas (KWS, 2010). This has negatively affected conservation of biodiversity in the continent.

Carnivores play a critical role within their respective ecosystems. Their status can often be used to indicate the dynamic balance within any given ecosystem as they have an important function in structuring herbivore (ecological) communities (Ray and Zigouris, 2005; Woodroffe and Ginsberg, 2005). Economically, carnivores play a critical role in a country's tourism industry due to their iconic and charismatic nature (Ripple *et al.*, 2014).

All large carnivores require large areas to survive (Ray and Zigouris, 2005). Among all the terrestrial carnivores in the world, the cheetah (*Acinonyx jubatus*) ranges more widely and needs larger areas for survival (KWS, 2010).However, as human populations encroach on the last wild areas in various continents, especially Africa, it is predicted that the cheetah is often the first species to disappear because about two thirds of its entire population lives outside protected area systems and its ecology is inadequate for coping with the pressures inflicted by humans (Durant, 2004). This has presented a major challenge for conservationists in the 21st Century (KWS, 2010).

Historically, cheetahs were distributed in most of Africa and Asia (Durant, 2004). In Asia, they have become extinct in most of their geographical range (Marker, 1998). They are now known to survive only in Iran, where they are critically endangered (Durant *et al.,* 2015). In Africa, cheetahs occur widely but sparsely. Most of the remaining cheetah populations are concentrated in sub-Saharan Africa with only a few populations remaining in North and West Africa (Durant, 2004; Durant *et al.,* 2015).

In Kenya, the cheetah population was widely distributed across the country in the past but their population has since then reduced greatly (Myers, 1975). According to KWS (2010), this decline has been attributed to an increase in human population which has resulted in the loss of habitat, reduction in prey base, human-wildlife conflict, diseases and poorly managed tourism. Despite of its reduced cheetah populations, Kenya currently supports globally important population of cheetahs. It is estimated that over 80% of the resident range and over 90% of possible range falls outside government-designated protected areas (KWS, 2010). This implies that cheetah populations within protected areas will not be viable if they are isolated from unprotected land (Durant, 2004; KWS, 2010).

Most of the land outside protected areas where cheetahs occur is either privately owned or belongs to the community (Durant, 2004; Andresen *et al.,* 2014). Negative contact and interaction with cheetahs has been reported within these areas in different parts of Africa. In South Africa, a shift from cattle to wildlife ranching in private ranches has created conflict between land owners and free-roaming cheetahs (Wilson, 2006). According to Wilson (2006), these ranches are usually stocked with wildlife species for the main purpose of hunting. However, these same species of wildlife are natural prey to cheetahs; which happen to be the only large carnivore species that occur in these ranches. In the Kapiti and Salama area of Southern Kenya, where a total of 22 cheetahs have been documented by the Action for Cheetahs in Kenya (2012) and the Athi- Kapiti Cheetah Project (AKCP), cheetahs have been reported to have killed goats and sheep in the Kiu area (Wykstra, 2006).

Currently, there is inadequate information on cheetah prey selection, habitat use and their impact on livelihoods in relation to human-wildlife conflict outside protected areas (Marker-Kraus and Kraus, 1993; Andresen *et al.,* 2014). This has resulted from a lack of understanding of the economic impacts of cheetahs on people's livelihoods and perceptions and impacts of land sub-division on the existing wildlife populations (CCF-K, 2003). This information is crucial for the conservation of cheetahs outside protected areas as it is absolutely critical for the long-term survival of the species.

The aim of this study was to determine cheetah prey base outside protected areas in Southern Kenya by assessing density and distribution of available cheetah prey through monthly game counts and how they influenced cheetah utilization of different vegetation types. This study also assessed cheetah prey selection and preference in the study area through scat analysis and identified available cheetah habitat types in community and private land within Kapiti area by assessing their vegetation characteristics through vegetation sampling.

1.2 Literature review

1.2.1 Large Carnivores of Africa

The African continent is known to retain some of the largest and wildest places on earth which present unique opportunities for conservation (Ray and Zigouris, 2005). These natural ecosystems are rich in biodiversity. They create conducive habitats for diverse species of carnivores that are both large and small.

According to Ray and Zigouris (2005), carnivores are generally known for their important role in structuring an ecosystem through their impacts on prey, on each other and ultimately on the vegetation. Large carnivores, in particular, are assumed to have the greatest impact on other components of biodiversity compared to the smaller ones and are the focus of most research studies and conservation efforts (Ray and Zigouris, 2005). In addition to their ecosystem contribution, Africa's large carnivores are important generators of revenue in developing countries through tourism (Cheung, 2012) and hunting (Braczkowski *et al.*, 2015).

Large and medium-sized African carnivores have been classified as those species that have an average weight of > 7kg (Ray and Zigouris, 2005). They include the African Wild dog (*Lycaon pictus*), Ethiopian Wolf (*Canis simensis*), Black- backed Jackal (*C. mesomelas*), Side- striped Jackal (*C. adustus*), Golden Jackal(*C. aureus*), Cheetah (*Acinonyx jubatus*), African Lion (*Panthera leo*), Leopard (*P. pardus)*, Serval cat (*Leptailurus serval*), African Golden Cat (*Profelis aurata*), Caracal (*Caracal caracal*), Aardwolf (*Proteles cristatus*), Spotted Hyena (*Crocuta crocuta*), Brown Hyena (*Hyaena brunnea*), Striped Hyena (*H. hyaena*), Cape clawless Otter (*Aonyx congicus*), Spotted- necked Otter (*A. capensis*), African Civet (*Lutra maculicollis*), Honey Badger (*Mellivora capensis*) and Bat- Eared Fox (*Civettictis civetta*) (Ray and Zigouris, 2005) (Appendix 1).

1.2.2 Challenges Facing Carnivore Conservation

Carnivores, especially large carnivores present enormous challenges to conservation (Ray and Zigouris, 2005). Due to their position as apex predators, large carnivores require large areas to exist (Macdonald and Sillero-Zubiri, 2002). Owing to their large ranging areas, they are predisposed to conflict with humans because their foraging ranges extend beyond protected area boundaries (Woodroffe and Frank, 2005); and are therefore consequently more difficult to conserve than other taxonomic groups (Linell, *et al.*, 2001). Most large carnivores are experiencing ongoing global declines caused almost entirely by human activities (Ogada *et al.*, 2003). As noted by Woodroffe (2001), humans have been responsible for the extinction of some large carnivore species such as the Falkland Island Wolf *(Dusicyon australis)* and for the substantial reductions in the distribution of many other species like Brown bears *(Ursus arctos)*, lion *(Panthera leo)*, jaguar *(P. Onca)* and wolves *(Canis lupus)* (Johnson *et al*., 2001 cited in Woodroffe, 2001).

In spite of Africa's large wild areas which are known to present unique opportunities for conservation, the fast growing human population in the continent has led to increased human pressure for natural resources leading to loss of biodiversity (Ray and Zigouris, 2005). Over the past 30 years, Africa's large carnivores have declined (Nowell and Jackson, 1996) with several species listed as near threatened-leopard, endangered-Ethiopian wolf and African wild dog and vulnerable Lion and Cheetah by the World Conservation Union (IUCN, 2008).

Large carnivores require large areas to survive. These large area requirements reduce the number of protected areas or habitat fragments outside protected areas capable of effectively conserving large carnivore species (Woodroffe, 2001). Human encroachment and land use change in areas previously occupied by wildlife have led to habitat loss. Wild dogs and cheetahs range more widely, and hence need larger areas, than almost any other terrestrial carnivore species anywhere in the world (KWS, 2010). Studies show that they are particularly susceptible to the destruction and fragmentation of habitats and are often the first species to disappear (KWS, 2010). Bush encroachment as a result of historical claims of over grazing in Namibia has reduced the overall productivity of ranches and the cheetah's hunting success leading to an increase in intolerance to livestock depredation by cheetahs (Marker-Kraus and Kraus, 1993). Other carnivore species such as the leopard and caracal have also been affected by human-induced habitat loss (Wilson and Mittermeier, 2009).

Most carnivores are considered to be problem animals especially in areas where they co-exist with humans. Their existence is often at times at odds with human settlement and pastoralism. Human-carnivore conflict has threatened species both directly and indirectly when they are killed due to threats on humans and livestock (KWS, 2010). The leopard and the lion, for instance, are at an odd position of being endangered in some parts of their ranges and as a pest in others (Wilson and Mittermeier, 2009). In Namibia, this conflict has historically been a major cause of death and removal of cheetahs from the wild although there is evidence that this is reducing (Purchase *et al.*, 2007).

Retaliatory killing of predators by livestock owners was also reported as a major problem in Africa. Studies carried out by Kissui (2008) in the Maasai Steppe, Tanzania showed lions to be exceptionally vulnerable to direct retaliatory killing compared to hyenas and leopards. He noted that livestock predation by lions was the major drive toward retaliation. All predation events by lions recorded during his study were followed by retaliatory lion hunts. In South Africa and Zimbabwe, retaliatory killings both now and historically have led to the loss of many wild cheetah populations (Purchase *et al.*, 2007). In Kenya, more retaliatory killing is targeted towards lions but also affects leopards, cheetahs and hyenas. For instance, two cheetahs were reported to have been killed by herders in the former Machakos Wildlife Forum (Wykstra, 2006).

Retaliatory responses against predators by use of poison as noted by Kissui (2008) have been used as the most effective strategy for targeting hyenas. They are very susceptible to poisoning and slow to recover in areas from which they have been extirpated. Hence, their numbers are severely depleted outside protected areas. Their limited ability to recover in areas where they have been extirpated makes spotted hyenas particularly reliant on conservation efforts. Lion fatalities as a result of poisoning have also been reported. According to Wilson and Mittermeier (2009), this occurs when lions scavenge. In 2010, five lions and a hyena were reported to have died in southern Kenya, after eating bait that had been laced with the pesticide known as Furadan. These lions were said to have killed two cows a few days earlier and nomadic herders retaliated by using pesticide-laced meat to kill the lions (Wadhams, 2010).

Globally, large carnivores have caused hundreds of human fatalities every year (Woodroffe, 2001). Attacks on humans typically result from injury to individual carnivores reducing their ability to catch natural prey, habituation and loss of fear of humans, the defence of kills by carnivores from prospective thieves or the occurrence of problem animals (Treves and Naughton, 1999). An additional problem according to Woodroffe (2001) is the continued encroachment by humans into wildlife areas resulting in an increase in contact between large carnivores and people.

According to Ray and Zigouris (2005), limited data on the status, population trend, ecology and distribution of carnivore species has also affected carnivore conservation efforts in different parts of Africa and the world. The status of species throughout their African range remains obscure and studies have concentrated on individual species rather than on whole assemblages or guilds inhabiting an area. Little is known about carnivores, habitat requirements, adaptation to and tolerance of human encroachment, food habits and interactions with other guild members among others. Availability of baseline data of species especially smaller carnivores have never been collected (Ginsberg, 2001).

Large carnivore species are characterized by a K-selected life history pattern with delayed reproductive maturity and small litter sizes, reducing their capacity to tolerate persecution (Ferguson and Lariviere, 2002). Other species like the cheetah which experienced a severe demographic bottleneck after the loss of its range at the end of the last glacial period have experienced reduced levels of molecular genetic variation (O'Brien *et al.,* 1987). The bottle neck and associated loss of genetic variation have been linked to several important life history characteristics of cheetah including relatively low levels of normal sperm in males, focal palatine erosion (FPE), kinked tails and an increased susceptibility to infectious disease agents (Purchase *et al.*,2007).

Loss or decline of populations of prey species has directly impacted carnivore populations. Decline in abundance and wildlife diversity has been attributed to unsustainable harvest, high livestock densities and deteriorating habitats (Kissui, 2008; KWS, 2010). Prey loss has been identified as a potential threat to all wild dog and cheetah populations that are resident in Kenya (KWS, 2010). Prey loss can also have serious indirect effects since predation on livestock may become more frequent where wild prey is depleted (Woodroffe and Ginsberg, 2005), intensifying conflict with livestock farmers.

Competition for the same wildlife resources has also presented major conservation problems to carnivores especially cheetahs. For instance in South Africa, Wilson (2006) noted after the shift from cattle ranching to wildlife ranching, ranches were surrounded by game fencing and stocked with wildlife meant for hunting. Cheetahs which mainly occur outside protected areas were observed to be preying on wildlife that land owners intended to hunt in order to generate income from the ranch. Utilisation of the same wildlife resource resulted in conflict between land owners and cheetahs (Wilson, 2006).

Human perceptions and attitudes play an important role in determining which species are tolerated in a given area (Woodroffe, 2001). Carnivores such as spotted hyenas are persecuted in Kenyan ranches more than other large felids despite the fact that felids kill more livestock than the hyenas (Frank and Woodroffe, 2001). African wild dogs have a reputation for being wanton killers (Fanshware *et al.,* 1991 cited in Woodroffe, 2001) making them fare poorly in the public eye compared to other carnivores. These perceptions create major challenges in promoting coexistence between people and predators.

High-speed roads and railways represent a threat to carnivore conservation as they cause habitat fragmentation, disturbance and direct mortality through collisions (Kusak *et al.,* 2000). According to Kusak *et al.,* (2000), as traffic is becoming faster, quieter and denser and the number of traffic routes is increasing, so traffic kills of large carnivores are on the increase in Croatia. Paved roads that cross or adjoin major wildlife areas such as the Nairobi-Mombasa road which traverses Tsavo National Park are of particular concern to conservationists (KWS, 2010). Cheetah and wild dog populations are vulnerable to road accidents. Wild dogs in particular use roads to travel and rest, making them highly vulnerable to accidents (KWS, 2010). Fatalities of other species such as the spotted hyena and serval cats have also been recorded along major highways in Kenya (Personal observation).

According to the KWS (2010), unregulated tourism has the capacity to threaten carnivore populations within national parks, game reserves and private conservancies. Tourism has negatively affected cheetahs in Maasai Mara Game Reserve by interfering with hunting, scaring cheetahs away from kills to which they are unlikely to return, and separation of mothers from cubs, due to the presence of large numbers of tourist vehicles (KWS 2010). Other species like wild dogs are affected when tourists visit active dens on foot, causing packs to move dens or even abandon their pups. This has been an occasional problem in the Samburu-Laikipia wild dog population (KWS 2010).

Commercial exploitation of valuable carnivore species has resulted in conservation problems. Illegal trade in live cheetahs and skins was highlighted as a current problem by several country representatives from Djibouti, Ethiopia, Somalia, South Sudan and the Sudan (CoP, 2013). Many wild cheetahs in South Africa that have been subjected to illegal trade have ended up in captive breeding centres. The Horn of Africa, and especially Somalia, has been reported for several years to represent a commonly used transit route for the illegal trafficking of cheetahs (Amir, 2006; CAWT, 2012). The illegal wildlife trade is believed to have contributed significantly to the current situation in which wild cheetahs are very rare in the region and their continued existence there is thought to be threatened by the trade (IUCN/SSC, 2007; EWCA, 2012).

Carnivores are susceptible to infectious diseases such as rabies, canine distemper, bovine tuberculosis and Feline Immuno-Virus (FIV). Disease outbreaks have wiped out a large population of carnivores in various ecosystems. For instance, rabies contributed to the extinction of the wild dog population in the Serengeti-Mara ecosystem in 1991 (Gascoyne *et al.*, 1993). This resulted from wild dog interactions with domestic dogs (*Canis lupis* *familiaris*) which act as reservoirs of potentially lethal disease. Canine distemper decimated a captive population of wild dogs held in Mkomazi National Reserve (van de Bildt *et al.*, 2002) and killed 33% of an estimated population of 3,000 lions in the Serengeti- Mara ecosystem (Wilson and Mittermeier, 2009). This illustrates the capacity of both viruses to provoke major population crashes (KWS, 2010). Cheetahs are exceptionally vulnerable to diseases especially in captivity where epidemics of highly infectious diseases such as mange have resulted in high mortalities (Caro *et al.*, 1987). Other carnivores such as the side-striped jackal found in West, Central and South Africa have been persecuted because of their role in rabies transmission (Wilson and Mittermeier, 2009).

1.2.3 Approaches to Carnivore Conservation

According to Woodroffe (2001), approaches to carnivore conservation can be summarized into three broad categories; ecological approach, sociological approach and economic approach.

Ecological approach entails conservation outside protected areas. This can be achieved through in-situ conservation by protecting intact habitat patches, adding existing populations by realizing additional animals or through the reintroduction of species into areas from which they have been removed as a result of human activity. In this approach, the design of the conservation strategy is dependent on the behavioural ecology of a given species. Other factors such as availability of suitable prey will affect the conservation efforts of carnivore species. Variation in life history traits also leads to a variation in conservation strategies. Understanding the life history traits of a species helps in determining the sensitivity to adult and juvenile mortality, ability to tolerate habitat modification and the size of founder populations required for re-introductions (Laurenson, 1994).

Sociological approaches to carnivore conservation involve socio-political and economic considerations toward carnivore conservation. This, according to Woodroffe (2001) becomes more important when carnivore conservation is extended beyond protected areas where there is an increase of conflict with humans. Working with communities that are most affected by human-carnivore conflicts is usually the first step in conserving predators outside protected areas. This way, the source, extent of conflict determined and ways of reducing conflict can be identified. Effective public relations and education campaigns can also be carried out especially in areas where there are carnivore introduction programmes. Changing people's attitudes towards wildlife conservation can also be achieved by acknowledging how communities are adversely affected by the presence of large carnivores.

Economic approaches entail the designing of conservation strategies in ways that local communities can sustainably exploit large carnivores. These strategies would reduce the costs incurred by local communities while at the same time promote the exploitation of the values of large carnivores that can be captured by conventional markets to create financial incentives for conservation. Potential benefits associated with conserving large carnivores can either be consumptive through sport hunting, animal products, capture or live trade or non-consumptive through ecotourism.

Attempts to reduce costs associated with conservation of large carnivores can include improved livestock husbandry by constructing strong fences around bomas to reduce livestock losses (Ogada *et al.,* 2003; Kissui, 2008), problem animal control, compensation schemes that promote co-existence between large carnivores and people through reimbursement of livestock or lives lost and well regulated tourism activities especially in private conservancies and reserves to generate income for conservation and to raise awareness.

Ray and Zigouris (2005) further recommended that distribution and range-wide knowledge on key species in Africa, such as the cheetah, lion, leopard, African wild dog and spotted hyenas should be improved. He suggested that local research and conservation should be pursued from a regional and continental level. He also noted that conservation action and research should focus on addressing threat impacts and solutions towards species and tools for conservation planning outside protected areas should be refined. Knowledge of mesocarnivores- small mid-sized carnivores less than 15 kilograms (Roemer *et al.,* 2009) - should be improved as little is known about their ecology. Studies should especially focus on areas where mesocarnivores have assumed top predator roles following eradication of large carnivores, such as in South Africa where black-backed jackals *(C. mesomelas)* and caracals *(C. caracal)* became the primary predators after the demise of large carnivores (Bergman *et al.,* 2013).

1.2.4 Status and distribution of cheetahs in Africa

The cheetah is classified as Vulnerable on the IUCN Red List with subspecies *Acinonyx jubatus venaticus* remaining only in Iran and *A. j. Hecki* in North West Africa classified as Critically Endangered (IUCN/SSC, 2007). The population estimate for Sub-Saharan Africa was 15,000 in the 1970s and 9,000-12000 in the 1990s (Wilson and Mittermeier, 2009).

Historically, cheetahs were distributed in most parts of Africa and Asia. In Asia, they have become extinct in most of their geographical range (Marker 1998). In Africa, cheetahs occur widely but sparsely. They are native to Algeria, Angola, Benin, Botswana, Burkina Faso, Central African Republic, Chad, Ethiopia, Kenya, Mali, Mozambique, Namibia, Niger, South Africa, South Sudan, Tanzania, Uganda, Zambia and Zimbabwe (Durant *et al.,* 2015). An estimate of 76% of cheetah populations has disappeared from their historical range (Ray and Zigouris, 2005). Regionally, they are extinct in Burundi, Cameroon, Congo, Côte d'Ivoire, Ghana, Guinea, Guinea-Bissau, Malawi, Mauritania, Morocco, Nigeria, Rwanda, Senegal, Sierra Leone, Tunisia and Western Sahara (Durant *et al.,* 2015). The species strongholds are in Southern and Eastern Africa. The largest meta-populations in East Africa occur in Kenya, Tanzania and Ethiopia; and Namibia, Botswana, Zimbabwe and Zambia in Southern Africa (Durant *et al.,* 2015).

In Southern Africa, cheetahs occur predominantly in the central area of the southern African region, including the central and western districts of Namibia, Botswana and Zimbabwe. They were also reported as present in one protected area in Angola, from protected areas in the west and central part of Zambia and from a small area in the Tete Province and Limpopo National Park in Mozambique (Purchase *et al.,* 2007). The minimum population of adult cheetahs in the region can be tentatively estimated to be not more than 5,000: Namibia – 2,000; Botswana – 1,800; Zimbabwe – 400; South Africa – 550; Angola – not known; Mozambique - <50; Zambia – 100; Malawi - <10 (Purchase *et al.*, 2007).

The major range states within the region are Namibia where about 95% of the population occurs on commercial farmland as these areas provided refuges from competition with other large predators (Purchase *et al.,* 2007; Wilson and Mittermeier, 2009). Botswana has the next highest documented population of cheetahs, distributed throughout the country.

South Africa's population is well studied and is confined to the northern part of the country. Approximately 250 cheetahs occur in protected areas, with a similar number occurring on commercial farmland. In Zimbabwe, cheetahs are also documented to be more common on commercial farmland, especially in the southern lowveld area of the country (Purchase *et al.,* 2007).

In Eastern Africa (Ethiopia, Southern Sudan, Uganda, Kenya, and Tanzania), adult and independent adolescent cheetah population has been estimated to be at 2,572: Kenya-1,500 (KWS, 2010); Uganda- 20 (Tenywa, 2014), Tanzania- 569-1007 and Southern Sudan- not known (IUCN / SSC 2007). In the East African region, cheetah strongholds are in Kenya and Tanzania where they only occur in 6% of their historical range (310,586 km^2) and possibly occur in another 892,658 km^2 (Anonymous, 2007; IUCN/ SSC 2007; KWS,2010). In Kenya, cheetahs historically occurred across most landscapes before human activity modified substantial proportions of their natural habitats (Myers, 1975). Currently, a comparatively small proportion of cheetahs' geographical range falls within Kenya's national parks and reserves (KWS, 2010).

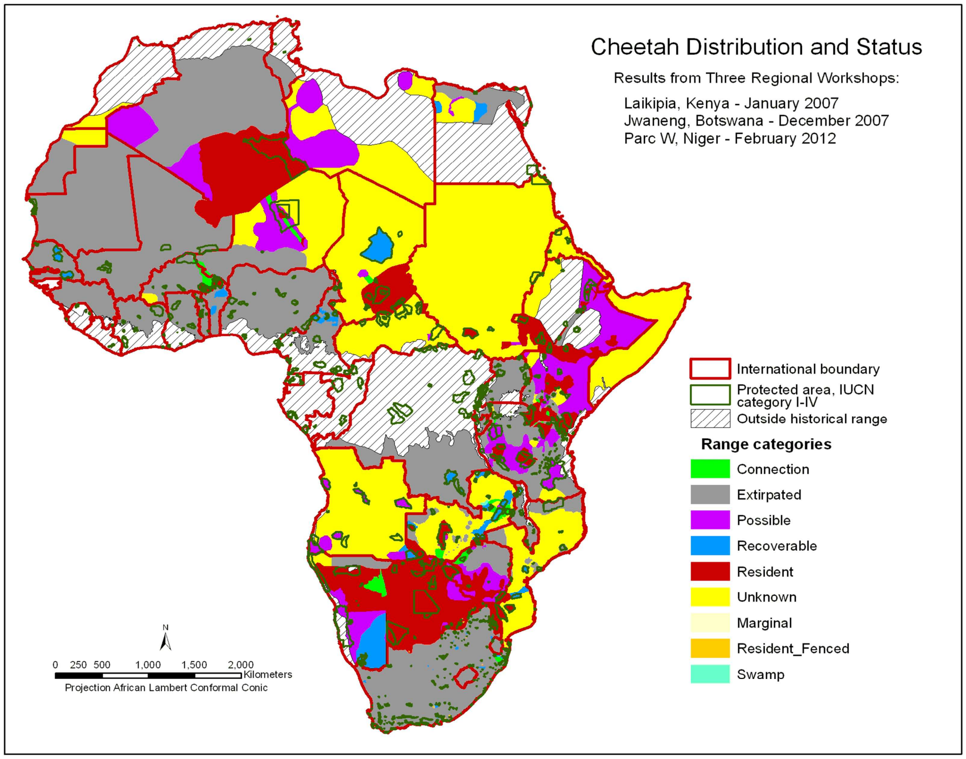


Figure 1: Cheetah distribution and status in Africa 2012.
(Source: Conservation Planning for Cheetah and Wild dog)

According to KWS (2010), cheetah distribution within Kenya is imperfectly known. However, majority of cheetahs live outside protected areas with over 80% of occupied habitat falling on community and private lands. Two extensive cheetah populations in Laikipia/Samburu and Tsavo/ Serengeti are known to remain. The Laikipia/ Samburu population is the only resident population that falls entirely in Kenya while the Tsavo/ Serengeti population spans the Kenya-Tanzania border.

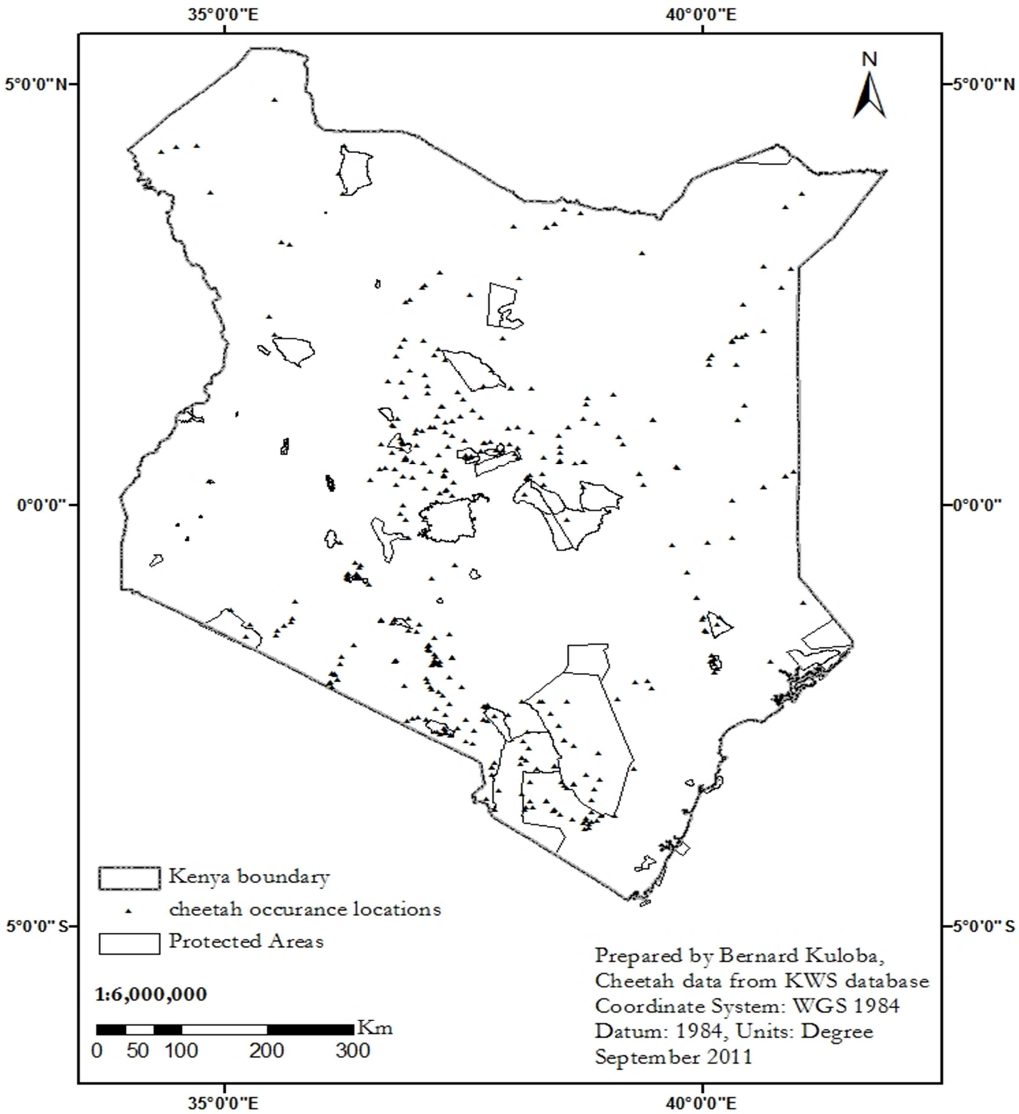


Figure 2: Cheetah range and distribution in Kenya in 2011
(Source: Bernard Kuloba/Kenya Wildlife Service, 2011)

1.2.5 Habitat selection and utilization by cheetahs

Initially, cheetahs were perceived to be savanna specialists which required open savanna vegetation in which it could use its high speed to chase small to medium-sized prey such as the spring hare, blesbok, impala, springbok, Thomson's and Grant's gazelles, common and bohor reedbuck and common duiker (Bisset and Bernard, 2006; Hayward *et al.*, 2006). Current studies show that cheetahs are more adaptable to habitat diversity than previously thought (Bisset and Bernard, 2006). They require a mosaic of habitat characteristics that on the whole can be categorized into two: grasslands or open habitat and wooded habitats (Broekhuis *et al.*, 2007).

Factors that affect habitat selection among cheetahs of different social groupings and sexes vary. A coalition of male cheetahs in Namibia was observed to select habitat ranges that had highest percentages of open habitats whereas female groups and independent cubs established home ranges with significantly more thicket habitats (Bisset and Bernard, 2006). Habitat selection by male cheetahs is therefore based on hunting requirements than prey abundance. In female cheetahs, selection of heavily wooded habitat is interpreted as a predator avoidance strategy. In this habitat, they have an additional benefit of reduced kleptoparasitism as noted by Bisset and Bernard (2006). However, the species lives at low density wherever it occurs, partly because of competition with other large carnivores, such as lions and spotted hyenas (Durant, 1998).

1.2.6 Feeding ecology of cheetahs

Cheetahs are predominantly diurnal, although hunting at night is not uncommon (Caro, 1994). According to Wilson and Mittermeier, (2009), they are predominantly diurnal when competing with other predators, such as lions and spotted hyenas, which are less active during the day. They take a wide variety of prey depending on habitat and geographic location, but their diet is specialised on gazelles and small to medium-sized antelopes which weigh about 23-56kg (Hayward *et al.*, 2006). Their prey species are recorded to range in size from rats to wildebeest with preference for Thompson’s and Grant’s Gazelle, Gerenuk, Impala, Lesser Kudu and dik-dik in East Africa (Frame, 1986; Hamilton, 1986 and Caro, 1994); Springbok, Impala, calves of Greater Kudu, Giraffe and even Africa Buffalo, Southern

Reedbuck, Puku (*Kobus vardonii*) and Common Warthog in southern Africa (Mitchel *et al*., 1965and Hirst, 1969; Mills, 1984) Hartebeest, Oribi (*Ourebia ourebi*) , and Kob in Central Africa (Nowell and Jackson, 1996). In the absence of ungulate prey, cheetahs may entirely subsist on smaller prey like guinea fowls and other ground-living birds and hares (Wilson and Mittermeier, 2009).

Cheetah kill rates are affected by group size, presence of cubs, prey size and availability, habitat structure and competition with other predators. According to Bisset and Bernard, (2006), feeding ecology of cheetahs varies among different social groupings. An increase in group size through birth or formation of a male coalition brings with it increased nutritional requirements which must be met either through increasing the kill rate and not changing the selection of prey or by preying on larger species without changing the kill rate, or a combination of the two. Coalitions comprising of male cheetahs have been observed to kill significantly large-sized animals like Blue Wildebeest (Wilson and Mittermeier, 2009). Females with cubs preyed on medium sized prey while female groups and independent cubs have been observed to kill small-sized prey in Kwandwe Private Game Reserve located in the Eastern Cape Province in South Africa (Bisset and Bernard, 2006). In other studies as noted by Wilson and Mittermeier (2009), cheetahs have shown preference for young prey animals compared to adults.

1.3 Justification

Cheetahs currently inhabit geographical ranges outside protected areas which are highly subjected to human activities leading to habitat loss and fragmentation. The ecology and adaptability of cheetahs in such areas, especially in wooded bush lands, is not clearly understood. According to Marker *et al.*, (2003), the diet of free-ranging cheetahs in different countries is not fully documented. Cheetah prey selection and preference in Kenya, especially outside protected areas, in community and private land, has never been documented. Therefore, there is insufficient data to show how cheetahs are adapting to human encroachment in relation to prey availability and selection which can be used in the formulation of policies for the conservation of cheetahs outside protected areas. Furthermore, there is lack of information on the effect of types and densities of available prey on the cheetahs' hunting behaviour. The aim of this study was to determine available cheetah prey species, their abundance, distribution and overall contribution to the cheetah's diet in the study area. It also assessed vegetation characteristics of available cheetah habitats in community and private land.

This information will be useful in the formulation of policies by relevant stakeholders on cheetah conservation and in the establishment of carnivore conservation zones outside protected areas where majority of the cheetah populations is found.

1.4 Problem Statement

Over the years, many studies have been done on the East and South African cheetahs. However, most of these studies were done inside national parks, small reserves or private game reserves; and primarily focused on the behavioural ecology of the cheetah in those particular areas (Marker-Kraus and Kraus, 1993). Information collected on cheetahs in conservation areas as noted by Marker-Kraus and Kraus (1993), does not always directly apply to free-ranging cheetahs. Very little work has been done on free-ranging cheetahs outside reserves where the largest populations are found.

Majority of Kenya's free-ranging cheetah populations occur outside government-designated protected areas. Loss of prey as a result of hunting, high livestock densities and habitat conversion is proving to be a potential threat to Kenya's cheetah populations. Documentation is an important component of any conservation plan (Marker *et al.*, 2003). Nevertheless, the diet of free-ranging cheetahs in community and private lands in Kenya has not been documented thus hindering conservation management of the species and its prey outside protected areas.

1.5 Objectives

1.5.1 Main objective

The main objective of this study was to assess potential and actual cheetah prey base outside the protected areas in Kapiti and Salama areas.

1.5.2 Specific Objectives

The specific objectives of this study were;

1. To assess the density and distribution of available prey for cheetahs in the study area.
2. To determine the frequency of occurrence of different prey species and their importance in the cheetah diet.
3. To assess the available cheetah habitat types and their characteristics in Kapiti and Salama areas.

1.6 Hypotheses

This study hypothesised that

(i) Cheetah prey selection is not influenced by prey availability, prey densities and vegetation type.

(ii) Available cheetah habitats are similar to those found in protected areas.

CHAPTER TWO: STUDY AREA, MATERIALS AND METHODS

2.1 Description of the study area

2.1.1 Location and size

Salama and Kapiti plains are located in Mukaa district (UTM S 1.42.44, E 37.12.0) which lies in southeastern Kenya where a total of 22 cheetahs have been documented by ACK and AKCP (Wykstra, 2006). Salama- Kiu area covers 400 square kilometres of bushed grassland and lies in the counties of Machakos, Makueni and Kajiado and is approximately 70 km south-east of Nairobi (Figure 3).

Kapiti area covers approximately 425 square kilometres and lies in the greater Athi-Kapiti ecosystem, which extends eastwards to Tsavo National Park and southwards to Amboseli National Park. Kapiti ranches form the link between the Salama-Kiu area and Nairobi National Park. This ecosystem straddles both the counties of Kajiado and Machakos with the larger ranches falling on the western boundary of Machakos County (UTM S 1.30.25, E 37.0.3). The ranches in the study area included Lisa Ranch, Machakos Ranching, Game Ranching and the Kapiti Plains Estate (Figure 3).

2.1.2 Climatic conditions

The study area falls under Agro-Ecological Zone V, which is classified as semi-arid with an annual rainfall of 450- 900 mm, falling in two seasons. Long rains occur in March/April continuing to the end of May, and the short rains in October/November continuing to the end of December (Anonymous, 1997; Norconsult, 2003). The study area is generally hot and dry; experiencing high temperatures during the day and low temperatures during the night with temperatures ranging from 20.2° C to 24.6° C with an average of 22.1° C. Extreme heat is more pronounced during the dry season (January – February) and (August – October) (Anonymous, 1997; Norconsult, 2003).

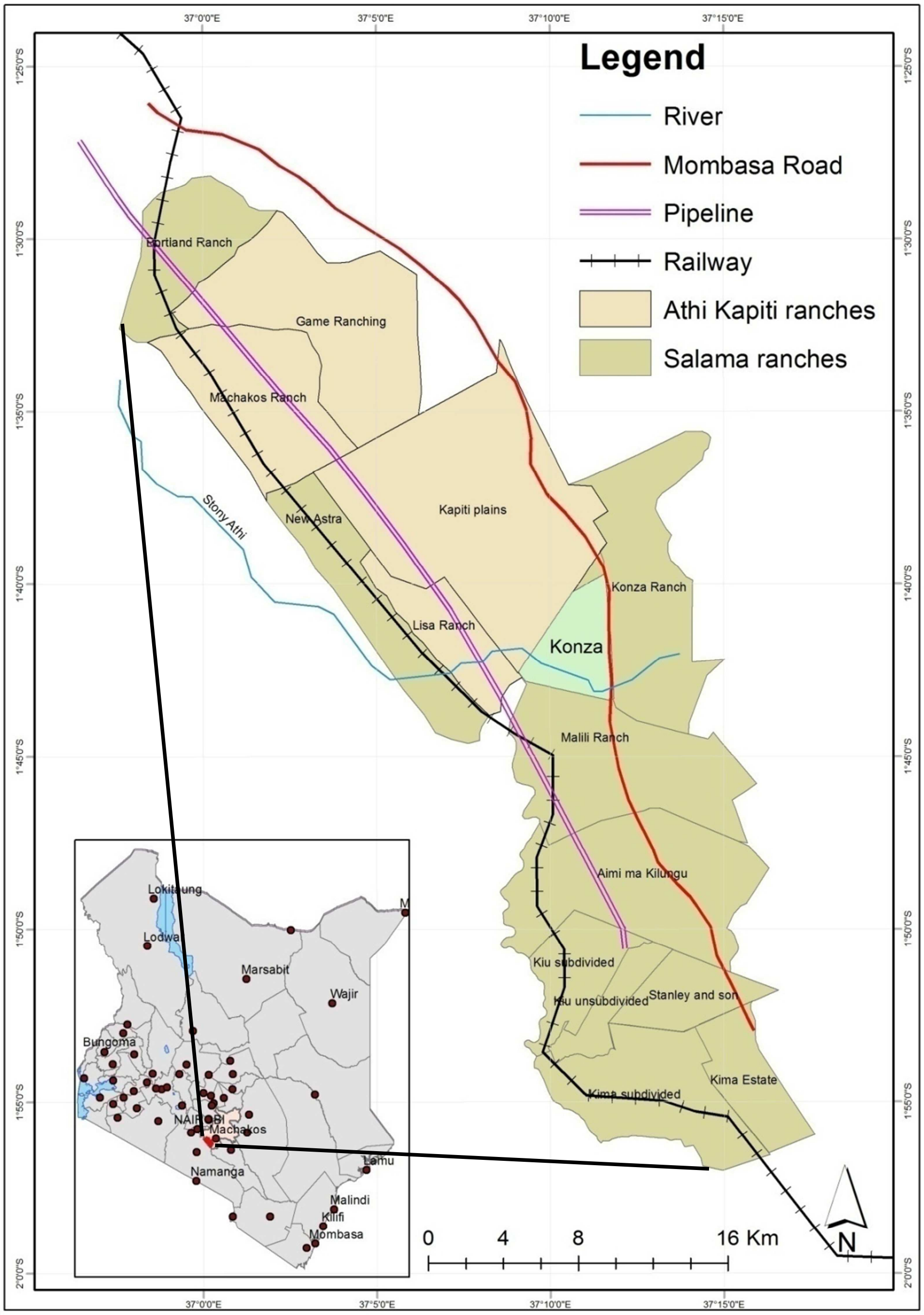


Figure 3: Study area showing private ranches and other features in Machakos and Makueni Counties in Kenya (inset map).

2.1.3 Topography and soils

The terrain is characterized by plains to the North, undulating hills to the South and rising to the foothills of Kilungu hills to the East (Jaetzold *et al.,* 2006). The geology of the study area is characterized by relatively deep over-burden, with very few exposures of the underlying basement rock. The soils are highly varied, dominated by sandy soils punctuated with vertisols, acrisols and cambisols. These types of soils are developed on quartz – feldspar gneisses (Norconsult, 2003). The underlying geology has given rise to highly weathered leached soils ranging from sandy to the south and east, sandy clays to the south and sandy loams to the north (Kiarie, 2010).

2.1.4 Flora

The study area is predominantly open low-shrubs with 65-40% crown cover with patches of shrub savannah, rain fed herbaceous crop and open to closed herbaceous vegetation that grows on temporarily flooded plains (FAO,2000). The major grass type in the area is *Themeda triadra*, a tufted perennial with a height of 50-150 cm that is valuable for grazers. Other habitat types include *Themeda- Acacia* or *Themeda- Balanites* wooded grasslands. Controlled burning is used to prevent encroachment of woody plant species to allow some of the smaller and more palatable grasses to persist in competition with other taller species. Both the grass and browse (leaves of trees and shrubs) are important forage resources (Kinyua *et al.,* 2000).

2.1.5 Fauna

Various wildlife species found in the study area include herbivores like zebra *(Equus burchelli)*, eland *(Taurotragus oryx)*, giraffe *(Giraffa camelopardalis)*, cokes hartebeest *(Alcelaphus buselaphus)*, and Grant's gazelle *(Gazella granti)*. Carnivores include the endangered cheetah, spotted hyaena and black-backed jackal. Primates include yellow baboon *(Papio cynocephalus)* and vervet monkey *(Cercopithecus spygerrythrus)*. There are also game birds such as ostrich *(Struthio camelus massaicus)* and guinea fowls *(Numida meleagris)* in the area (Kinyua *et al.*, 2000; Wambua, 2008).

2.1.6 Socio-economic activities

The Akamba community, who practice mixed farming, primarily inhabit this area. The crops grown in this area include different varieties of fruits like mango, pawpaw, oranges and avocado. Staple crops include maize, beans, cowpeas, millet and sorghum (Wambua, 2008).

Commercial ranching based on beef production, solely or in combination with milk production is the major livestock enterprise. Ranches also keep mutton sheep and meat goats. They also practice wildlife conservation (Kinyua *et al.*, 2000).

2.2 Materials and Methods

2.2.1 Composition, density and distribution of potential cheetah prey

Data were collected from July 2013 to February 2014 in the morning (beginning 6:30 am) and night (beginning 7:30 pm). A vehicle was driven at an average speed of 15km/h along the road transects in each of the four ranches- Game Ranching, Machakos Ranching, Kapiti Estate and Lisa Ranch. When an animal of interest was sighted, the vehicle was stopped, the species identified, distance of the animal from transect determined with a range finder and the geographical location obtained using a hand held global positioning system (GPS). For the night counts, a strong spotlight was swept from side to side up to a 90-degree angle from the car to spot eye glare from an animal's eye (Wambua, 2008). The number and whenever possible the sex and age of the observed species were noted. The perpendicular distance from the point of observation to the animal was measured with a range finder, the angular bearing from the point of observation was measured using a hand-held compass and the general vegetation type recorded (Wambua, 2008).

Potential cheetah prey species were then recorded according to the general vegetation type they were observed in the study area during game counts to determine their distribution in relation to available habitats and their influence on cheetah distribution based on the spatial distribution of cheetah scats collected and positively identified in the study area.

2.2.2 Use of faecal examination and hair for prey examination

2.2.2.1 Faecal examination

Faecal or scat analysis is a non-invasive method used to determine dietary habits of carnivores. Quantification of undigested prey, especially through scat analyses has been widely used to determine food habits of carnivores (Bowland and Perrin, 1993; Wilson 2006; Lovari *et al.,* 2009; Ogara *et al.,* 2010; Shehzad *et al.,* 2012). Variable and sometimes large amounts of predator hair have been reported in carnivore faeces at a range of 18 - 48%, indicating the need for appropriate hair identification (Gamberg and Atkinson, 1988). The completeness of prey hair recovery from carnivore scat as reported by Gamberg and Atkinson (1988) indicates that prey hair identification provides a good basis for diet reconstruction.

Faecal examination represents the most readily available and easily collected source of diet information and it has been previously used to study diets of various carnivores, such as the snow leopard *(Unica unica)* in Mongolia (Shehzad *et al.,* 2012) and cheetahs in Namibia and South Africa (Wachter *et al.,* 2006; Wilson 2006). Such diet analysis requires the identification of undigested remains, bones, teeth or hair in faeces. However, there are problems relating to faeces examination of sympatric species of carnivores. The first relates to the accurate identification of carnivore faeces in the field as noted by Shehzad *et al.,* (2012) and Wilson (2006) and these identities have to be confirmed in the laboratory. Secondly, not all prey taxa are accurately identified and/ or detected (Shehzad *et al.,* 2012).

2.2.2.2 Basic hair structure

Hair can be classified into two main types, the long thick outer hairs (guard hairs) and fine short underfur (Keogh 1983). Guard hairs are further divided into primary and secondary types. Primary guard hairs which are larger in size and most species-specific are most useful in identification (Bahuguna *et al.,* 2010). With a few exceptions, hair consists of the cuticle, cortex and the medulla (Figure 4). Variations of these features are commonly used in hair identification (Keogh, 1983).

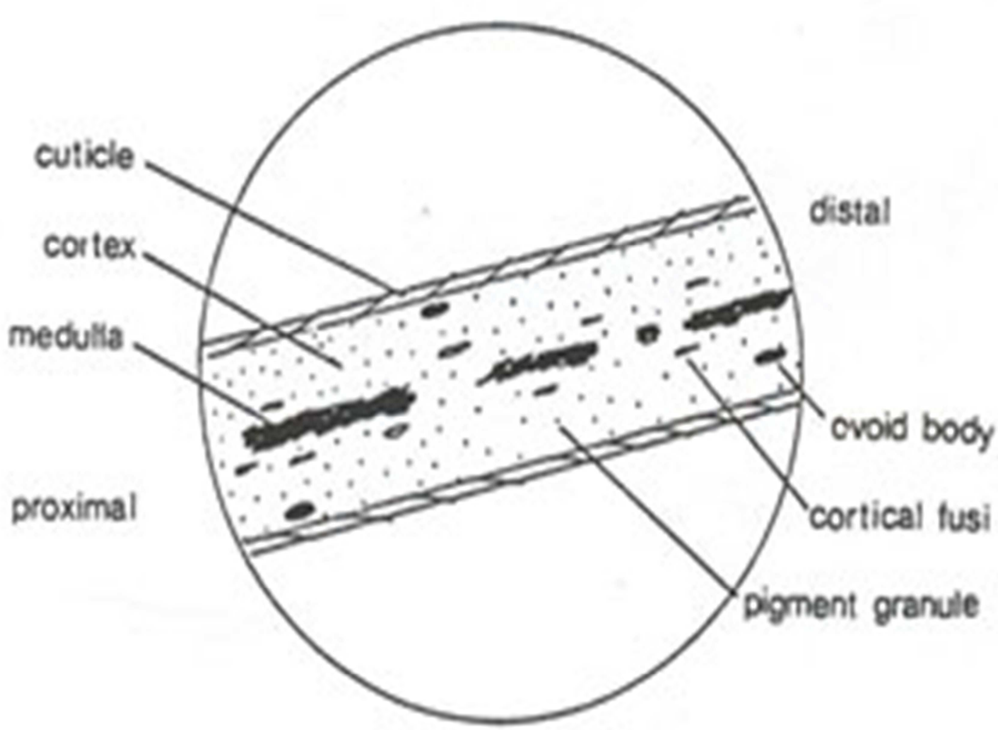


Figure 4: Basic structural features of mammalian hair
(Source: Deedrick and Koch, 2004)

2.2.2.3 Prey species identification

The cuticle consists of keratinized overlapping scales, which form patterns along the length of the hair (Figure 5). Their shapes, size and types of margins have been used for identification purposes (Keogh, 1983). Scale shapes and patterns for hair identification of various species have been used by the Cheetah Conservation Fund (CCF) in Namibia, Bahuguna *et al.*, (2010) and Bevridge and van den Hoogen (2013). However, it is not possible to develop a key for identification of species on the basis of one characteristic alone because of the variation of the cuticular pattern along the length of the hair and among hairs from different parts of the body (Bahuguna *et al.*, 2010). Apart from the scale patterns, other parameters such as the scale margin and scale distance can be used to describe the cuticle.

The cortex which is composed of non-nucleated cells is filled with alpha-keratin. According to Keogh (1983), the cortex is not often a diagnostic character but its size, relative to the medulla is used in prey species identification. The medulla can be seen in the whole mount of the hair. The air cavities within the medulla obstruct its detailed structure under a normal microscope making it to appear dark in structure (Bahuguna *et al.*, 2010). If air is expelled, various arrangements of the medulla can be seen. These arrangements have been classified and have been used as diagnostic criteria (Keogh, 1983).

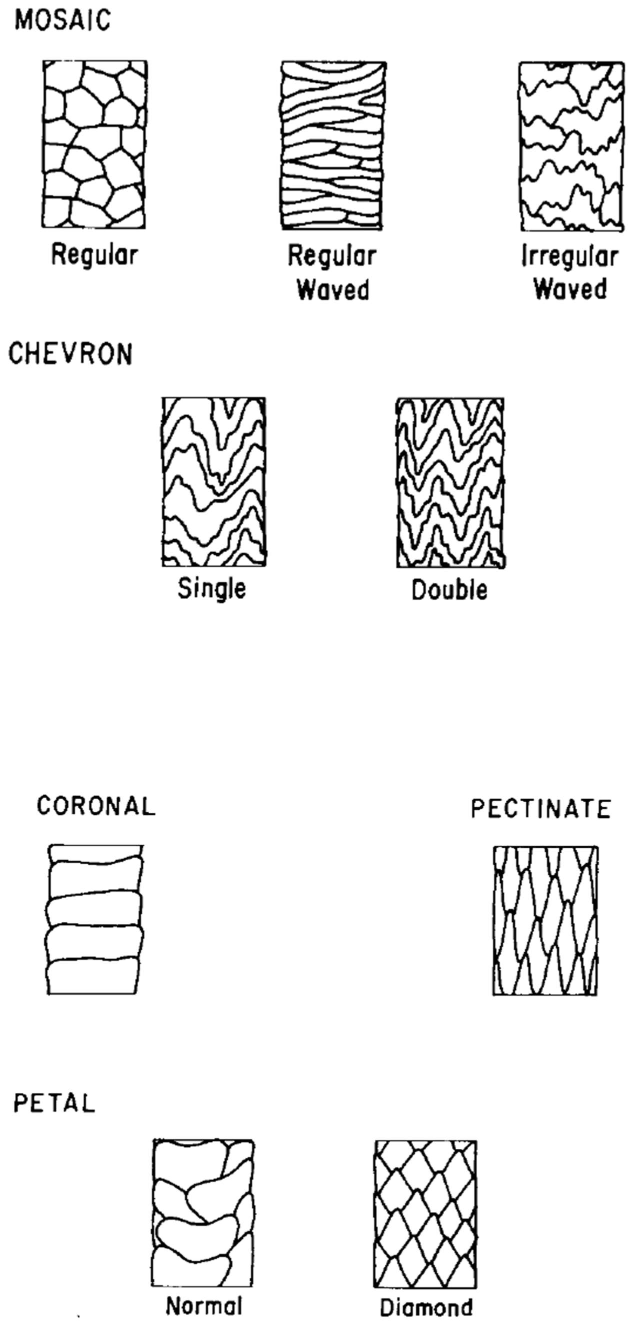


Figure 5: Cuticular hair scale patterns of mammals used in hair identification (Keogh, 1983)

Other hair details that can be established include the hair root appearance – dotted or clear, the appearance of the hair – medulla and cortex (i.e.) thin medulla and the size – medulla width, cortex width (Figure 6).

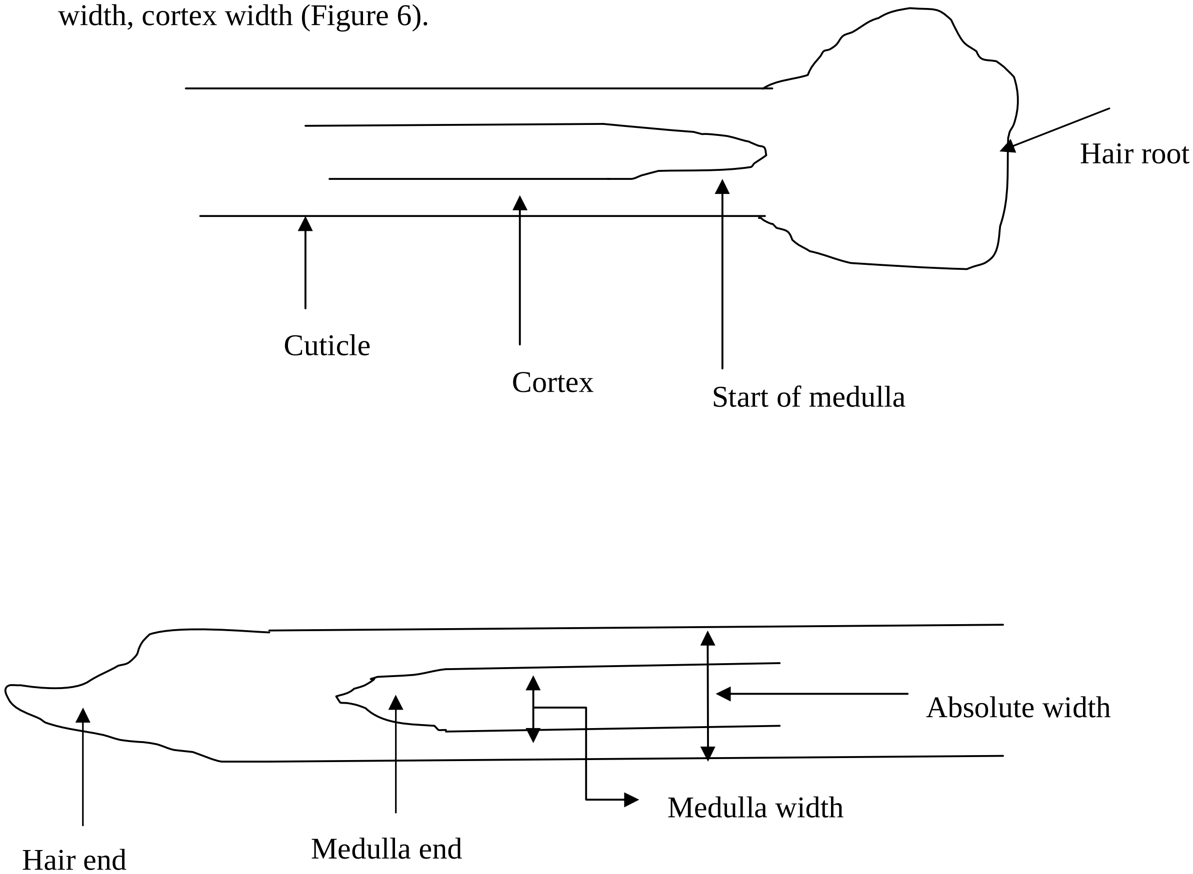


Figure 6: Hair characteristics used in mammal species identification
(Source: Bodendorfer, 2006)

Hair examination is commonly done through comparisons of reference specimens with salvaged hair mounts. However, this method is laborious and time-consuming. Hairs from the same animal may also vary in structure according to their location within its fur. Similarly, hair from several related species may possess similar characteristics. Finally, the lack of reference specimens can prohibit accurate diagnosis (Shehzad *et al.*, 2012).

2.2.3 Carnivore scat collection

Carnivore scats were opportunistically collected on foot in four private ranches in Kapiti area. Search efforts were mainly concentrated along Action for Cheetahs in Kenya (ACK) patrol areas where cheetahs had been sighted and from locations of previously collected scats in 2012. Each collected scat was individually placed in a polythene bag that was labelled with the date, name of the ranch, geo-reference, collector's name and species. To avoid cross contamination, the collectors used one hand glove per scat. The bags with the scats were later stored in a cool dry place (Wilson, 2006). The data was stored as a geo-reference to show points of collection and spatial distribution as described by Ogara *et al.*, (2010).

2.2.4 Cheetah scat analysis

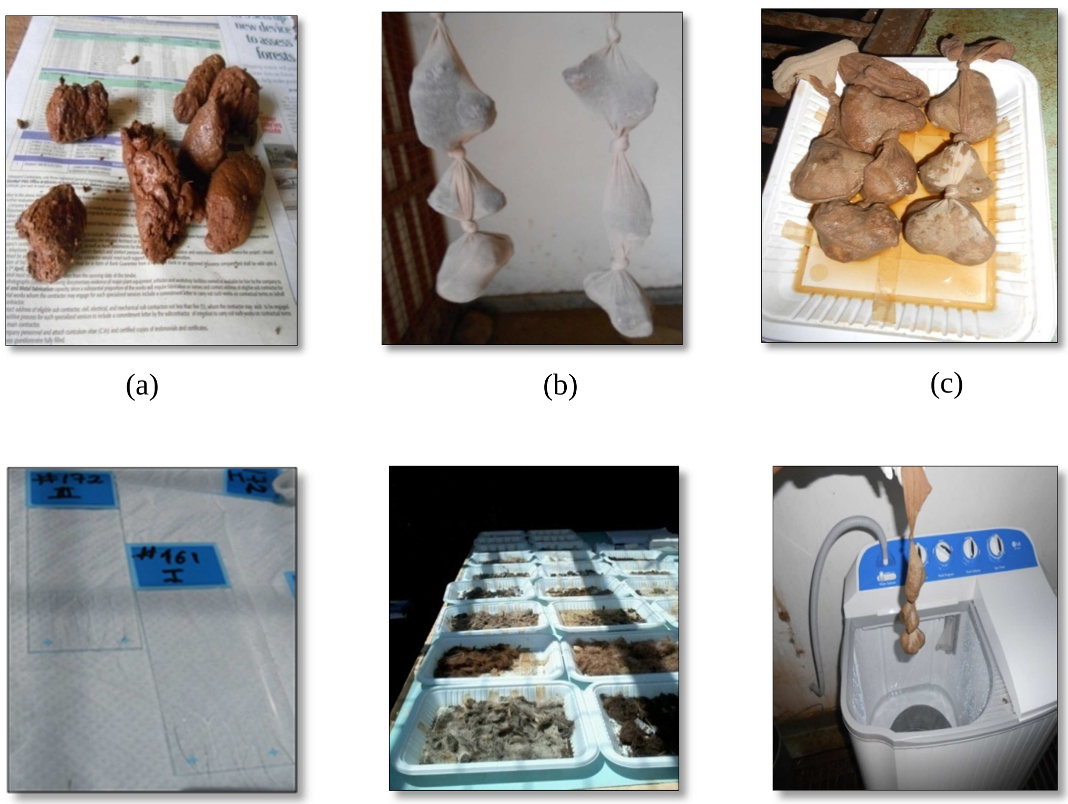
In the laboratory, scat samples were individually placed in nylon stockings with an identification label and soaked in water overnight. Using a conventional washing machine, the scats were washed through two complete regular cycles, each 15 minutes long, until they were soft and all the faecal matter washed out. All that remained in the nylon stocking was hair, teeth, bones and hoofs. No detergents or bleaches were used as they would damage the structure of the hair (Marker *et al.,* 2003). The stockings containing retrieved material were hung out to dry. Dried remains were spread evenly in a dissecting pan for insection and sorting out of material. They were later soaked in 70% ethanol for 15 minutes so as to relax the prey hair and remove irregular colouration (Figure 7).

According to Lovari *et al.,* (2009), the presence of hair in scats of felids is commonly used to identify cat species. Identification of cheetah scats was mainly based on the presence of cheetah hair in the scat. This is because cheetahs are known to ingest their own hair during grooming (Wachter *et al.,* 2006). From verified cheetah scats, dried remains were evenly spread on a dissecting pan with a grid of 10 equal squares and soaked in 70% ethanol for one hour. One hair was randomly selected from each square. The hair was carefully examined and mounted on microscopic glass slides using clear nail polish as mounting medium. A permanent mount of the same hair was made by mounting hair using gelatine, covering it with a cover slip and allowing it to dry overnight (Figure 7). Medullar and scale patterns of the hair were observed under a light microscope at x10 and x40 magnification. Microphotographs of the representative medulla and scale patterns of the hair were taken using Leica IC180 microscope. A reference hair catalogue developed was used to identify unknown hair in subsequent scat samples and prey consumed by cheetah (Shabbir *et al.*, 2013).

2.2.5 Establishment of a reference hair collection

According to Keogh (1983), hairs from fresh skin and preserved carcasses are identical. Reference hairs were obtained from specimens preserved at the National Museums of Kenya (NMK) mammal collection. More data on hair of different ungulate prey were obtained from the Kenya Wildlife Service Headquarters, Lewa Conservancy and Earthwatch Institute Kenya, following their previous work done on carnivore scatology. Additional reference hairs were established by processing hairs from all the domestic and wild animals' carcasses found in the study area or from preserved skins at KWS. Clean glass slides were thinly coated with clear nail polish, which was used as a mounting medium. Hairs from the belly, back, hip and shoulder of potential prey (Marker *et al.*, 2003) were mounted on to the glass slides using fine forceps. This is because cuticular scales under normal microscopy cannot be seen on the hair and instead imprints can be used to reveal scale patterns that can easily be studied (Keogh, 1983).The mounted hair was left overnight to dry before being removed for scale imprints. Only the hair scale patterns along the hair were established under x10 and x40 magnification.

Nomenclature of the scale pattern followed that of Keogh (1983) (Figure 5). Permanent mounts of the same hair were made using gelatine as a mounting solution. The ratio of the medulla and cortex, appearance of the cortex and medulla was also established microscopically using x10 and x40 magnification. Microphotographs of the scale and medulla patterns were taken using Leica IC180 microscope.



(a) (b) (c)

(f) (e) (d)

Figure 7: Scat processing and analysis from raw scat (a) through drying (b) placing in nylon stockings (c) soaking (d) washing (e) separation of dry samples and (f) mounting of hair on microscopic slides.

2.2.6 Assessment of available cheetah habitats and their vegetation characteristics

Four sites within the study area were identified to be frequently used or visited by the resident cheetahs. A ‘frequently used/visited site’ was considered to be an area where cheetahs had been repeatedly sighted either directly or on camera traps during the study period or indirectly based on spoors such as tracks and total number of scats collected and positively identified as belonging to cheetah. Each of the four sites within the four ranches was located on different habitat types namely; woodland bushed grassland and shrubland. Various sampling methods were used to determine vegetation characteristics in these sites. These methods included point quarter sampling method, wandering method and plot sampling method.

Point quarter sampling method was used to collect woody vegetation data in Kapiti Plains. Four- 100 metre long base line transects were established from the base of a rock outcrop, which had been identified to be frequently used by cheetahs as a vantage point, to mark the beginning of the transects. On each baseline, two points were determined at an interval of 50 meters. These points represented the centre of the four compass directions, which divided the sampling site into four quarters. In each quadrant, the nearest point-to-plant distance from the centre point to the centre of the rooted stem was measured. The species was recorded, height and diameter at breast height (DBH) of each woody plant (>10cm DBH) were determined and recorded. The height of the trees was estimated by sight and the DBH with a DBH tape measure (Cox, 1990). One by one meter square quadrants were placed along the baseline at an interval of 50 meters. Five points within the plots were sampled to determine the average grass height and dominant grass species.

In Game Ranching and Small World ranch (adjacent to Game Ranching), wandering quarter method was used due to the random distribution of scattered trees. A 200 meter long baseline was randomly established from the base of a water tank that had been previously used by cheetahs in the study area as a vantage point or for scent marking. This baseline cut across different vegetation types. A starting point was randomly selected near the beginning of the baseline. Using a compass, a quadrant which was bisected by the baseline was set up. Point-to-plant distance to the nearest plant in that quadrant was measured, plant identified and coverage estimated. This plant was then used as the apex of a new quadrant with a line running parallel to the baseline bisecting the quadrant. The point-to-plant distance to the nearest plant in that quadrant was measured, plant identified and coverage estimated. This procedure was repeated until the end of the baseline (Brown, 1990). One by one meter square quadrants were placed on the baseline at an interval of 40 meters. Five points within the plots were sampled to determine the average grass height and dominant grass species.

In Lisa Ranch where the vegetation mainly comprised of scattered trees which later transitioned to dense bushes, two-200 meter long baselines were established on opposite sides of the sampling area. A point which marked the centre of a 50 by 50 metre plot was selected after every 40 meter interval along the baseline. Once the plots had been marked out, species of woody vegetation were identified and the number of individuals within each plot recorded. Height and diameter at breast height (DBH) of each tree (>10cm DBH) was also determined and recorded. The height of the trees was estimated by sight to the nearest metre and the DBH with a DBH tape (Cox, 1990). A smaller quadrant measuring one by one square meters were nested within the 50 by 50 meter plot. Five points within the plots were sampled to determine the average grass height and dominant grass species.

In summarizing data from plot and plotless sampling methods, density (number of individuals per unit area), dominance (basal area per unit area) and frequency (fraction of sampling plots/ area containing species) of plant species was determined. For particular species, these values were then expressed in relative form to show the percentage that the species value is of the total for all species (Cox, 1990). Only the basal area covered by large woody plants was determined by measuring the diameter of the trunk and the basal area (cross-sectional area of the trunk) obtained from Cox (1990).

The results (variables) were comparable in all the four sites regardless of the method used. Vegetation in each site was classified according to Pratt and Gwynne (1977) physiognomic classification of East African rangelands.

2.3 Data Analysis

Data points from the animal counts with corresponding coordinates were overlaid on the map of the study area to map out the distribution of wild animals observed during the study period. Game count transects were overlaid on the map of the study area and their length per vegetation type in each farm calculated. Transects cutting across similar vegetation types were summed to come up with the total length for each individual vegetation type. The total area covered by each vegetation type was calculated using Arc Views' X-Tools extension.

Cheetah scat distribution in the study area was determined using the standard Land Cover Classification System (FAO, 2000). The area occupied by each vegetation type in the study area was obtained from (Wambua, 2008).

Mean density of each species of animal encountered in the different vegetation types during the game counts was calculated by dividing the total number of species of species *i* encountered by the area covered by that vegetation type on excel spreadsheet.

Independent sample t-test was used to test for differences between mean species density by season and time of day using SPSS vs.20 software.

Observed wildlife species were divided into three prey categories based on their body mass and their potential to resist attack from a cheetah. Male, female and sub-adult body masses of different prey species was obtained from Kingdon (2011). Prey mass of a species was obtained from three-quarters of the mean female body mass of that species in order to account for calves and sub-adults eaten by cheetah (Hayward *et al.*, 2006). Prey species categories included less than 23kilograms, between 23 and 56 kilograms and above 56 kilograms.

Prey items, such as bone fragments, food remains and hair from the scats were used together to identify carnivore species and assess prey types in the positively identified cheetah scats. Cheetah prey identified in the scat was qualitatively quantified using frequency of occurrence of prey per scat and percent occurrence. The percentage frequency of occurrence of a prey per scat was calculated based on the total number of scats analyzed to give an indication of the importance of the prey type in providing a regular food source (Bowland and Perrin, 1993). Relative percent occurrence was expressed as the number of individuals of each prey type over the total number of individuals (Bowland and Perrin, 1993).

Cheetah prey preference was computed using a preference ratio (P) where a prey species i was expressed as the frequency of occurrence of that species in the scat over its abundance in relation to the total species abundance.

CHAPTER THREE: RESULTS

3.1 Density and distribution of wild animals

Potential mammalian cheetah prey species were recorded in open grassland, bushed grassland and woodland habitats within the study area. Open grassland had the highest average density of potential mammalian cheetah prey species followed by woodland and bushed grassland. Wildebeest had the highest average densities in both bushed grassland and open grassland. However, giraffe had the highest average density per square kilometre in open grassland habitat. Of all the potential cheetah prey species recorded, wildebeest were the most abundant followed by zebra and kongoni (Table 1). Other species such as the Beisa oryx, lesser kudu and reedbuck were only recorded in bushed grassland habitat. Habitat type did not significantly influence cheetah prey species abundance in the three habitat types apart from the warthog ($\chi^2_{0.05, 2}$= 0.8).

3.1.1 Density of potential cheetah prey in woodland habitat

A total of 15 mammal species were recorded in this habitat. Wildebeest had the highest mean density of all species recorded followed by kongoni and zebra (Figure 8).

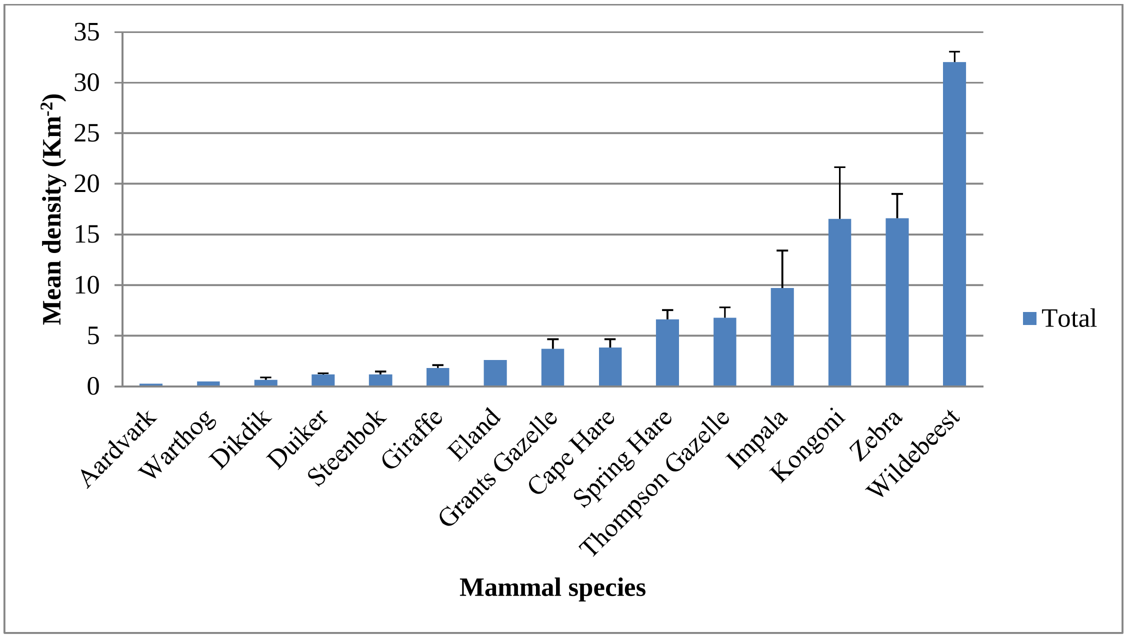


Figure 8: Mean density (± SE) of potential mammal cheetah prey species recorded in woodland habitat.

The highest mean density of potential mammalian cheetah prey in woodland habitat was recorded during the night. However, there was no significant difference in the mean density of species during the day and night in woodland habitat type (t=2.00; *df* =323; P>0.05). Wildebeest had the highest mean density of all species in both day and night counts (Figure 9).

Table 1: Average density (Km^{-2}) of potential mammalian cheetah prey species per habitat type

	Habitat type		
	Open grassland	**Bushed grassland**	**Woodland**
Species	**Average density (Km^{-2})**	**Average density (Km^{-2})**	**Average density (Km^{-2})**
Aardvark	-	0.50	0.25
Beisa oryx	-	1.95	-
Cape hare	8.94	2.15	3.82
Dik-dik	-	0.55	0.65
Duiker	-	0.67	1.16
Eland	-	2.28	2.61
Gerenuk	28.43	0.98	-
Giraffe	33.33	2.33	1.80
Grant's gazelle	11.31	6.11	3.71
Impala	-	8.55	9.71
Kongoni	15.75	7.73	16.52
Lesser Kudu	-	0.71	-
Reedbuck	-	0.32	-
Springhare	11.50	2.13	6.60
Steenbok	-	0.57	1.18
Thompson gazelle	11.39	4.18	6.75
Warthog	17.06	2.68	0.50
Wildebeest	30.29	16.66	32.02
Zebra	24.93	15.30	16.60

The aardvark was only encountered at night but in very low densities. Low densities of warthogs were also observed during the day counts only (Figure 9).

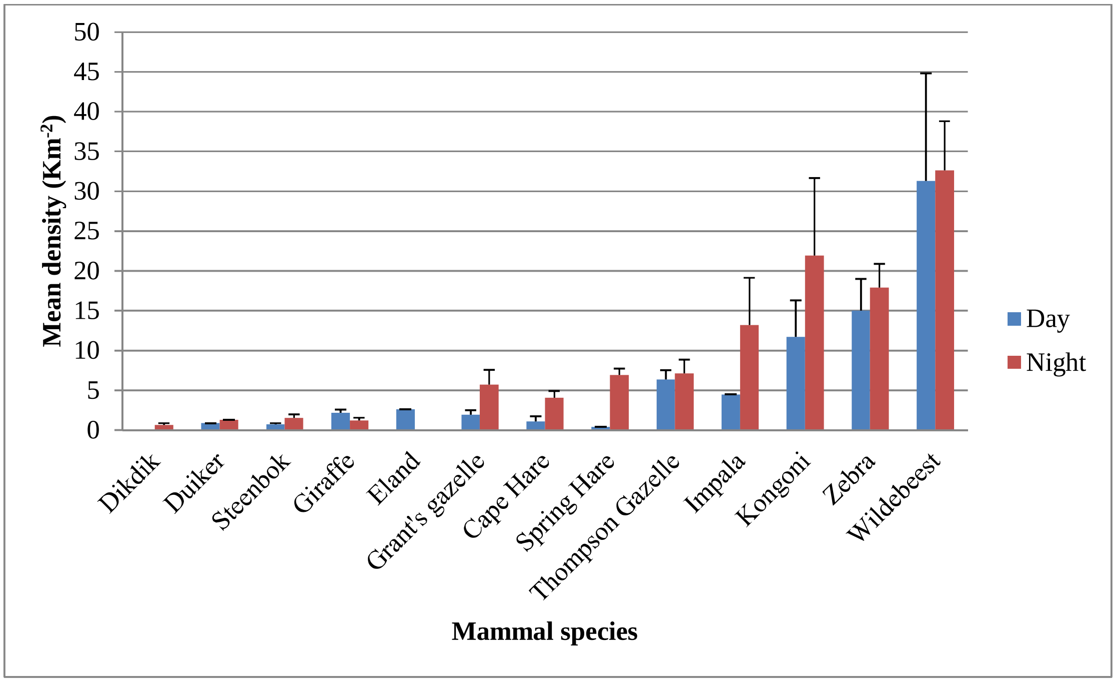


Figure 9: Mean density (± SE) of potential cheetah prey species recorded in woodland habitat type during day and night

The dry season had a higher mean density of potential cheetah mammalian prey species compared to the wet season. However, there was no significant difference in the mean density during the wet and dry season ($t=2.00$; $df=323$; $P>0.05$). Wildebeest had the highest mean density per square kilometre during the dry season followed by kongoni and zebra respectively (Figure 10). In the wet season, the wildebeest, zebra and impala had the highest mean densities of species recorded. Aardvark was only encountered during the wet season in low densities while the warthog was only encountered during the dry season (Figure 10).

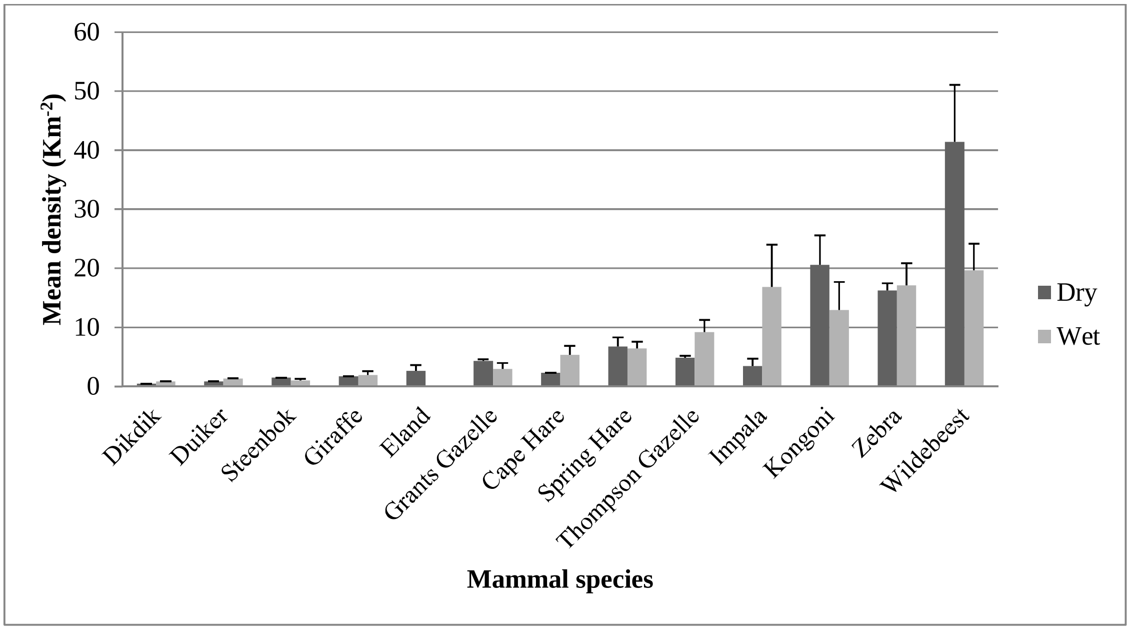


Figure 10: Mean density (± SE) of potential cheetah prey species recorded in woodland vegetation during the wet and dry season.

3.1.2 Density of potential cheetah prey in bushed grassland

A total of 19 mammalian wildlife species were recorded in bushed grassland habitat. The wildebeest had the highest mean density of 16.67 per square kilometre followed by the zebra and impala with 15.30 and 8.56 individuals per square kilometre respectively (Figure 11). Reedbuck had the least density of 0.33 individuals per square kilometre followed by the aardvark and dik-dik with 0.50 and 0.55 individuals per square kilometre respectively (Figure 11).

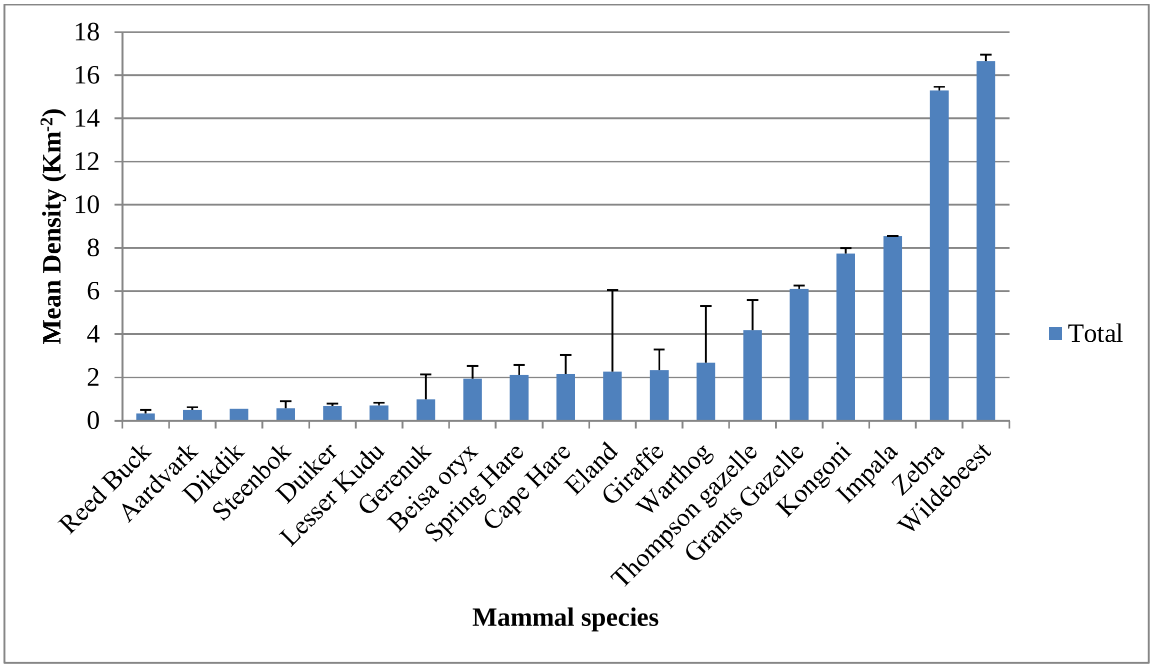


Figure 11: Mean density (± SE) of wildlife species recorded in bushed grassland habitat.

The mean species density significantly differed between day and night counts (t=2.00; *df* =364; $p<0.05$). Of all the species recorded, wildebeest, zebra and impala had the highest mean densities recorded during both day and night (Figure 12). Warthog was only observed during the day. Other species such as the aardvark, Beisa oryx, dik-dik, reedbuck and steenbok were encountered only at night (Figure 12).

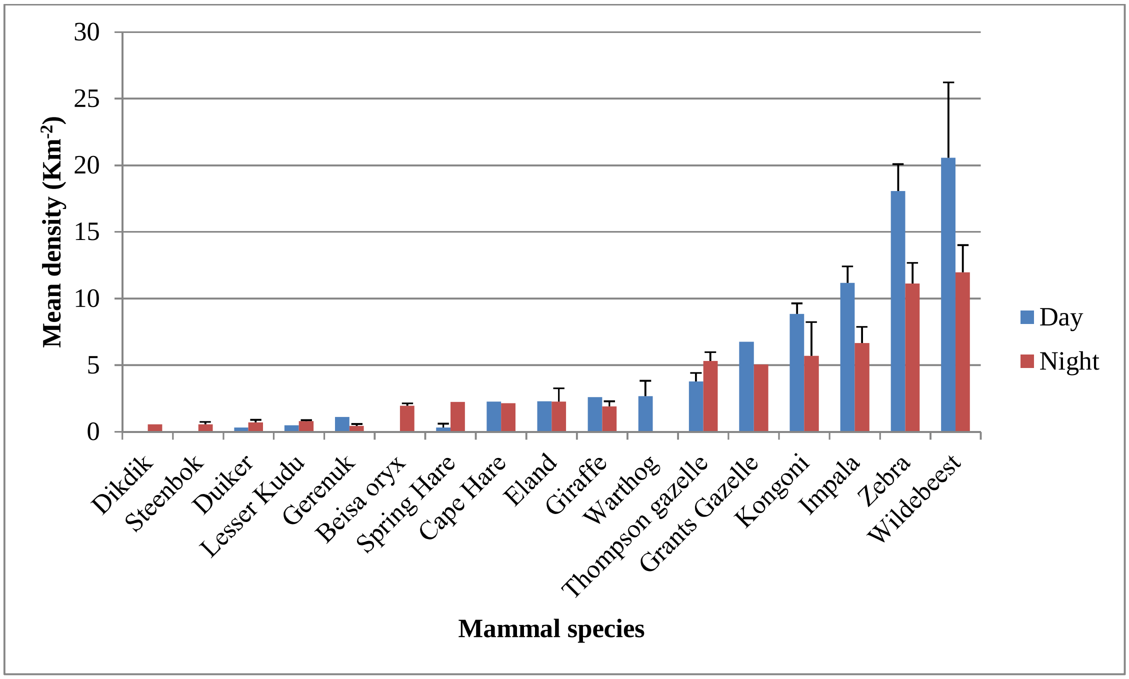


Figure 12: Mean density (± SE) of potential cheetah prey species recorded in bushed grassland habitat during day and night. Only single animals were recorded on transects where no SE are shown.

Highest mean density of potential cheetah prey species in bushed grassland habitat was recorded during the dry season. However, the mean density of species had no significant difference between the wet and dry season (t=2.00; *df* =364; P>0.05).During the dry season, wildebeest (20.6±3.8), zebra (17.5±4.8) and impala (2.92±6.1) had the highest mean densities respectively. In the wet season, wildebeest and zebra had the highest mean densities of all potential cheetah prey species recorded (Figure 13). Aardvark was only encountered during the dry season in the bushed grassland vegetation type while Beisa oryx and reedbuck were the only species encountered during the wet season (Figure 13).

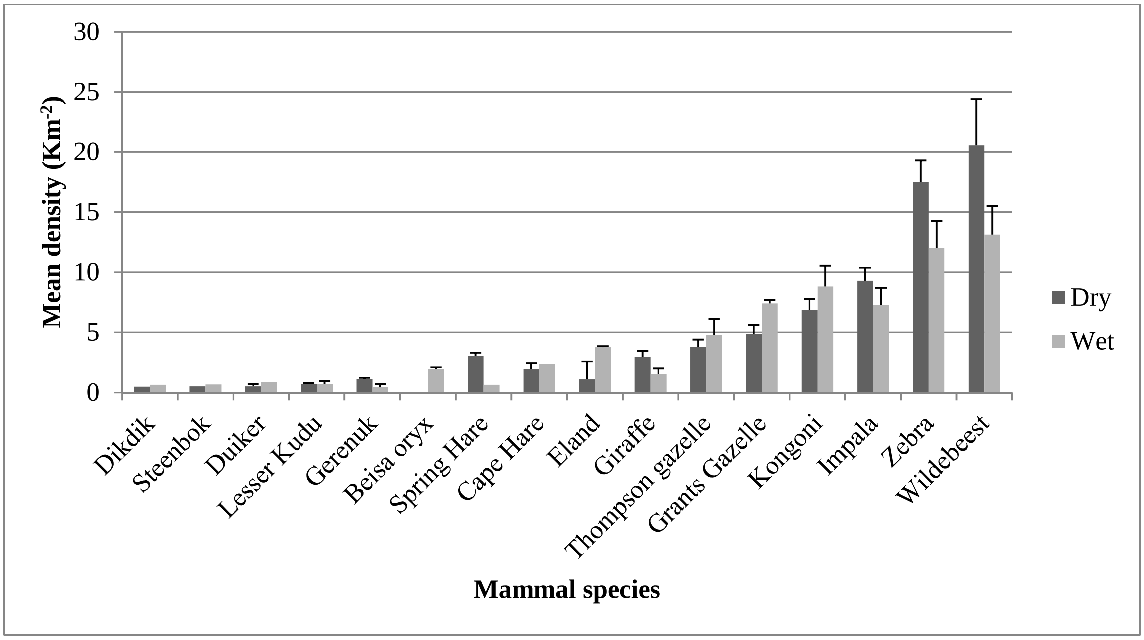


Figure 13: Mean density (± SE) of potential cheetah prey species recorded in bushed grassland habitat during the wet and dry season. Only single animals were recorded on transects where no SE are shown.

3.1.3 Density of potential cheetah prey in open grasslands

A total of 10 mammal species were recorded in open grassland vegetation type. Of all these species, giraffe had the highest mean density of 33.3 individuals per square kilometre followed by wildebeest and gerenuk at 30.29 and 28.43 individuals per square kilometre respectively (Figure 14). Cape hare had the least density with 8.94 individuals per square kilometre.

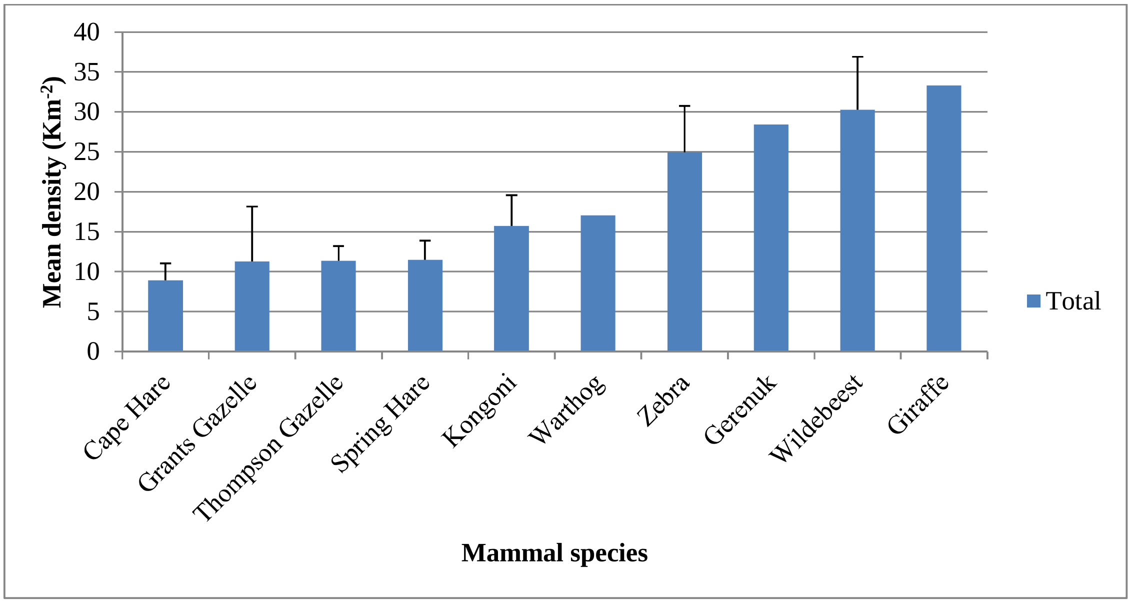


Figure 14: Mean density (± SE) of potential cheetah prey species recorded in open grassland habitat. Only single animals were recorded on transects where no SE are shown.

Highest mean density of potential cheetah prey species were recorded during the night counts compared to the day counts. However, there was no significant difference in the mean species density during the day and night ($t=0.588$; *df* $=100$; $P>0.05$). During the day counts, wildebeest had the highest mean density of species recorded while the giraffe had the highest mean density per square kilometres during the night counts. Apart from the giraffe, other species such as cape hare, gerenuk and spring hare were only encountered during the night while the warthog was only recorded during the day counts in the open grassland habitat (Figure 15).

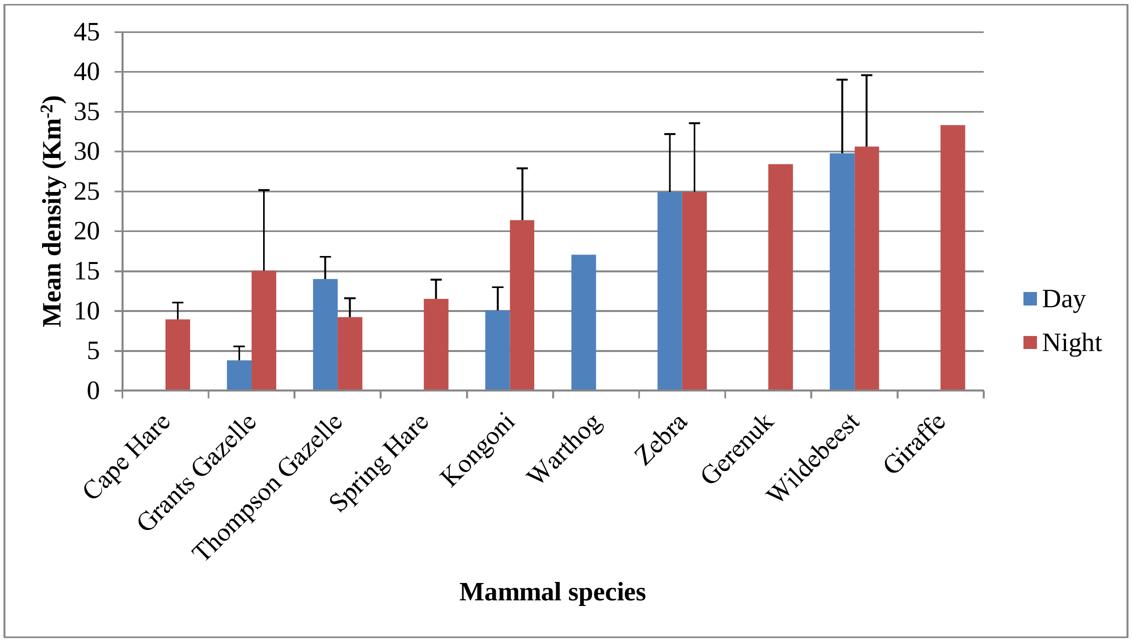


Figure 15: Mean density (± SE) of potential cheetah prey species recorded in open grassland habitat during day and night. Only single animals were recorded on transects where no SE are shown.

The wet season had the highest mean density of potential cheetah prey species recorded in open grassland habitat. However, there was no significant difference in the mean species density during the wet and dry season (t=0.582; *df* =100; P>0.05). In the dry season, gerenuk had the highest mean density of all species in the grassland vegetation type followed by wildebeest and zebra (Figure 16). Gerenuk was only encountered during the dry season while the giraffe and warthog were only encountered during the wet season. In the wet season, giraffe (33.33), wildebeest (26.87) and zebra (22.90) were observed to have the highest mean densities in the grassland vegetation type (Figure 16).

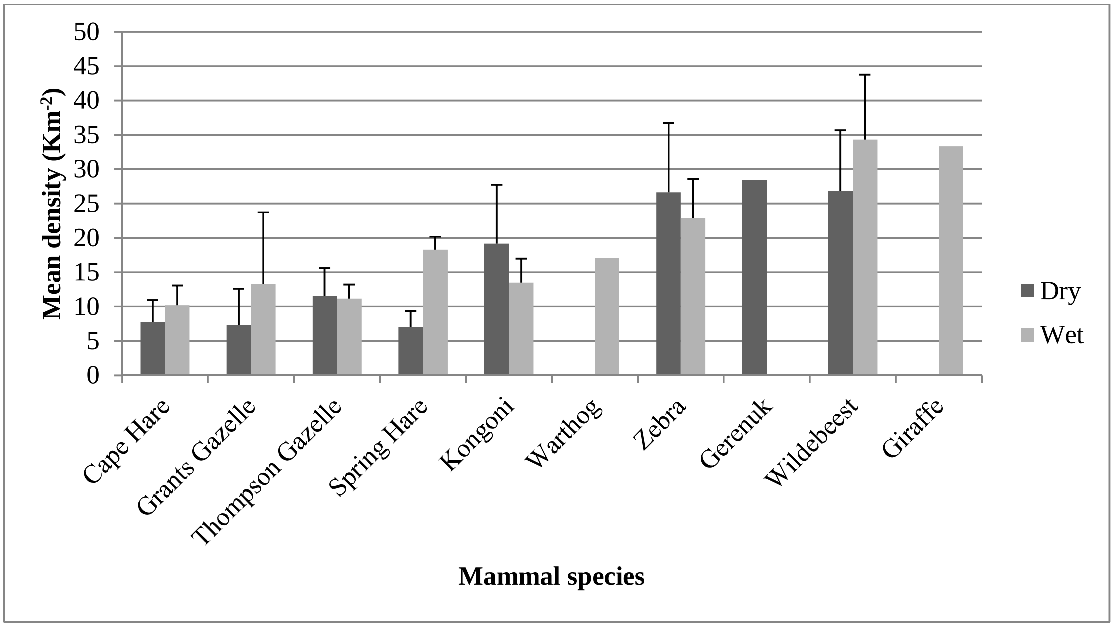


Figure 16: Mean density (± SE) of wild animals recorded in grassland habitat type during the wet and dry season. Only single animals were recorded on transects where no SE are shown.

Of all the three habitat types, open grassland habitat had the highest mean number of individuals Km^{-2} followed by woodland and bushed grassland. Wildebeest, zebra and kongoni had the highest mean density in the study area during the study period while aardvark, lesser kudu and reedbuck had the least mean density. In both woodland and bushed grassland habitat, wildebeest and zebra contributed the highest mean densities of all species while the giraffe contributed the highest mean density in the open grassland.

In all the three habitats, wildebeest had the highest mean density during the day counts. High mean densities of wildebeest were also recorded in bushed grassland and woodland during the night counts. However, giraffe had the highest mean density in the open grassland during the night counts. In the wet season, wildebeest had the highest mean density in all the three habitats. Nevertheless, wildebeest had the highest mean density in bushed grassland and woodland while the gerenuk contributed the highest mean density in open grassland habitat in the dry season.

3.2 Results of scat analysis

A total of 287 scat samples were collected and identified. Only 61 (21.25%) of the scats contained carnivore hairs which included that of cheetah (9.41%), African civet (2.79%), common genet (2.09%), caracal (2.09%), leopard (2.09%), jackal (0.7%), domestic dog (0.7%), lion (0.7%), serval cat (0.35%) and hyena (0.35%) (Table 2). The rest of the scat samples were either unidentified or only contained hair from prey species.

Table 2: Carnivore species identified from scat analysis

	Scats Identified	
Carnivore species	**n**	**%**
Cheetah	27	9.41
African Civet	8	2.79
Common genet	6	2.09
Caracal	6	2.09
Leopard	6	2.09
Jackal	2	0.7
Domestic dog	2	0.7
Lion	2	0.7
Serval	1	0.35
Hyena	1	0.35
Total	**61**	**21.27**

n= number of scats

3.3 Distribution of cheetah scat

Cheetah scats were collected in seven of the nine vegetation types classified under the Land Cover Classification System (FAO, 2000) in the study area (Figure 17). Majority of the cheetah scats (37%) were found in open low shrub with 65-40% canopy cover followed by shrub savannah (19%) and open shrubs (45-40% crown cover) (15%) (Table 3).

Table 3: Cheetah scat distribution in relation to vegetation types in the study area

Vegetation	**Habitat type**	**Area (km^2)**	**Cheetah scats collected (n)**	**% Cheetah scats collected**
Shrub savannah	Shrubland	178	5	19
Open shrubs (45-40% crown cover)	Shrubland	92.2	4	15
Open trees (65-40% crown cover)	Open woodland	10.3	1	4
Closed to open woody vegetation (thicket)	Closed woodland	19.7	-	-
Open low shrubs (65-40% crown cover)	Open woodland	23.6	10	37
Trees and shrub savannah	Bushed grassland	9.81	2	7
Open to closed herbaceous	Wooded grassland	2.15	-	-
Isolated herbaceous	Open grassland	38	4	15
Scattered herbaceous	Open grassland	4	1	4
Total Area		**378.56**	**27**	**100**

The least number of scats (4%) were collected in open trees (65-40% crown cover) and scattered herbaceous vegetation types (Table 3). No scats were collected in closed to open woody vegetation (thicket) and open to closed herbaceous.

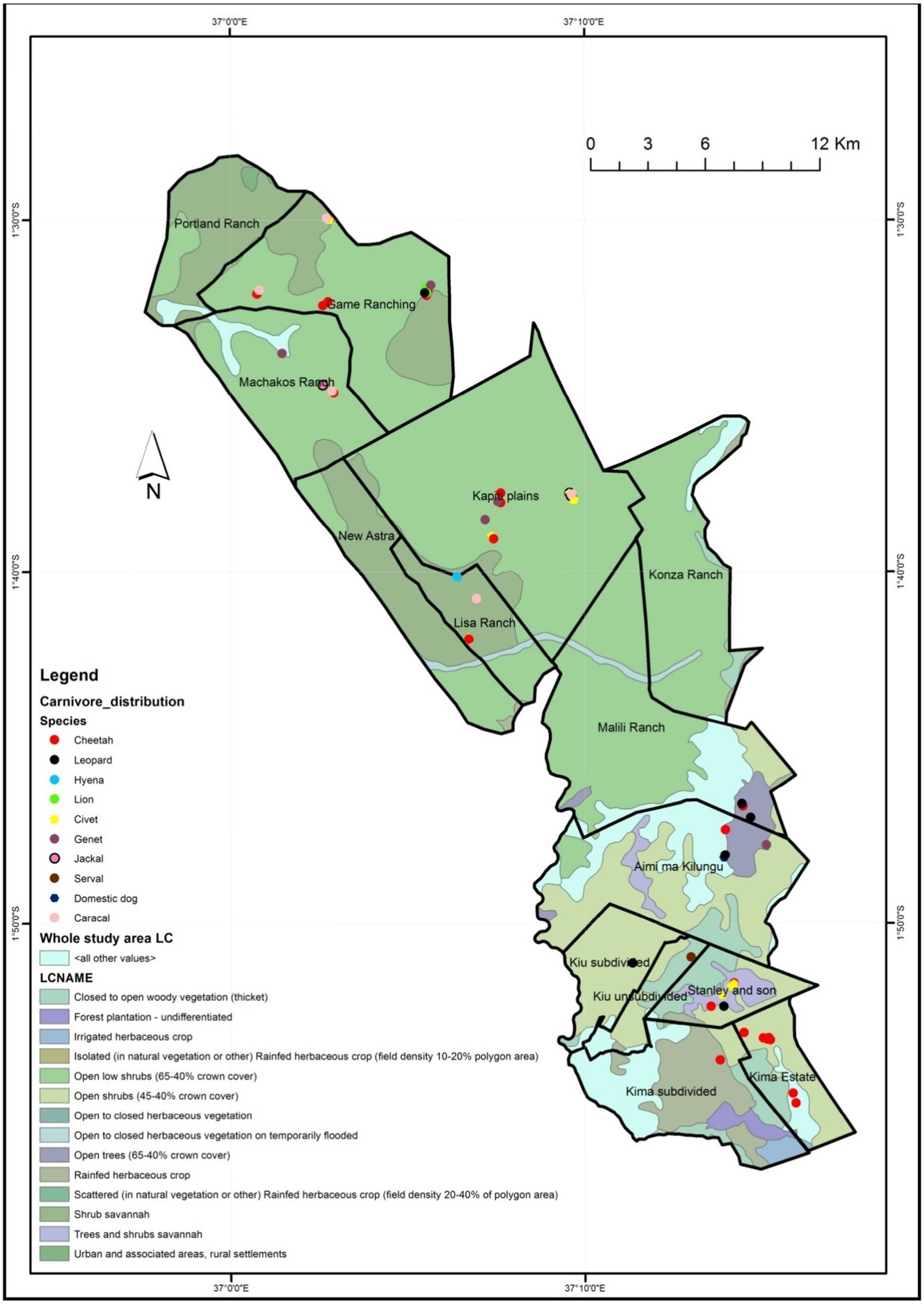


Figure 17: Carnivore scat distribution in livestock ranches in Salama and Kapiti

3.4 Prey species composition in the cheetah diet

Of the 61 faecal samples containing carnivore hair, 27 samples (9.41%) were identified as originating from the cheetah due to the presence of cheetah hair in the samples. The diet composition of cheetahs was diverse with a total of 106 prey items, mainly hairs; from 21 wildlife species.

On the basis of its occurrence in cheetah faeces, Grant's gazelle was observed to be the most frequent prey (25.9%) followed by cape hare (22.2%) and domestic goat (18.5%) (Table 4). Ungulates comprised the dominant part of the diet (51.85% of faeces) comprising of wild species (40.74% of faeces) and domestic livestock (11.11% of faeces).

Table 4: Contribution of various prey species to the cheetah diet in Salama/ Kapiti area

	Frequency of occurrence		**Percent occurrence**	
Prey type	**Actual (n)**	**%**	**Actual (n)**	**%**
Grant's gazelle	7	25.9	31	18.56
Cape hare	6	22.2	30	17.96
Goat	5	18.5	11	6.59
Bushbuck	5	18.5	6	3.59
Spring hare	4	14.8	7	4.19
Sheep	3	11.1	9	5.39
Zebra	3	11.1	6	3.59
Giraffe	2	7.4	2	1.2
Kongoni	2	7.4	5	2.99
Wildebeest	2	7.4	8	4.79
Baboon	2	7.4	8	4.79
Impala	2	7.4	7	4.19
Rock hyrax	2	7.4	4	2.40
Cow	1	3.7	1	0.6
Common duiker	1	3.7	3	1.8
Thompson gazelle	1	3.7	1	0.6
Warthog	1	3.7	5	2.99
Vervet monkey	1	3.7	7	4.19
Steenbok	1	3.7	8	4.79
Lesser kudu	1	3.7	6	3.59
Giant rat	1	3.7	2	1.2
Total	**27**	**196.1**	**167**	**100**

Among the three cheetah prey categories, prey with a mean mass of 23-56 kilograms had the highest frequency of occurrence (45%) with the Grant's gazelle (25.9%), goat (18.5%) and bushbuck (18.5%) being the most frequent prey observed in this category. Prey with a mean mass >56 kilograms occurred in 36% of the cheetah scats and were dominated by zebra (11.1%), wildebeest (7.4%) and kongoni (7.4%). Cape hare (22.2%), spring hare (14.8%) and baboon (7.4%) were observed to be the most frequent among prey with a mean mass <23 kilograms (Figure 18).

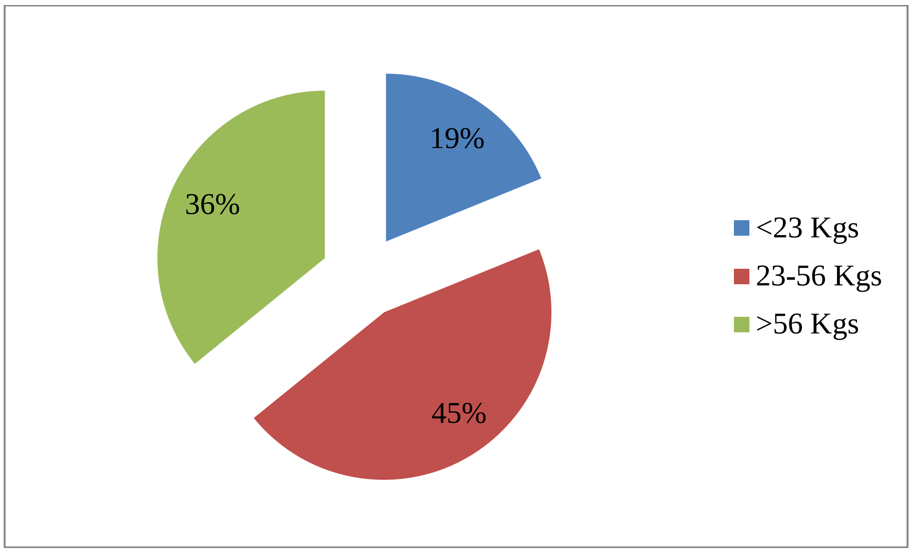


Figure 18: Frequency of occurrence of the three categories of prey body mass in the cheetah scat.

Of the wild ungulates, the lesser kudu was the most preferred prey species with a preference ratio of 30.8 followed by steenbok (20.6), common duiker (18.5) and warthog (18.5) (Table 5). The least preferred cheetah prey was kongoni (0.63), zebra (0.33) and wildebeest (0.20) respectively (Table 5).

Table 5: Preference ratio of cheetah prey

Prey	**Numbers recorded (A_i)**		**Frequency of occurrence (U_i)**		**Preference Ratio (P)**
Species	n_i	$n_i / \sum n_i$	f_i	$f_i / \sum f_i$	U_i / A_i
Lesser kudu	15	0.0012	1	0.037	30.83
Steenbok	22	0.0018	1	0.037	20.56
Common duiker	24	0.0020	1	0.037	18.5
Warthog	24	0.0020	1	0.037	18.5
Giraffe	185	0.0153	2	0.074	4.84
Cape hare	358	0.0296	6	0.222	7.5
Impala	533	0.0440	2	0.074	1.68
Spring hare	578	0.0478	4	0.148	3.1
Grant's gazelle	667	0.0551	7	0.259	4.7
Thompson gazelle	1092	0.0902	1	0.037	0.41
Kongoni	1414	0.1168	2	0.074	0.63
Zebra	2698	0.2229	2	0.074	0.33
Wildebeest	4493	0.3712	2	0.074	0.2

Where:

n_i- Mean abundance of species *i* in the study area

$\sum n_i$ –Total mean of prey species abundance recorded in the study area

A_i- Mean abundance of species *i*

f_i– Frequencyof occurrence of species *i* per cheetah scat

$\sum f_i$ -Total frequency of occurrence of all species

U_i-Frequencyof occurrence of species *i*

P- Frequency of occurrence of species *i* / abundance of species *i*

3.5 Habitat types

Four sites within the study area were observed to be frequently used or visited by cheetahs. Two of the sites were located in woodland vegetation type while the other two sites were located in bushed grassland and shrub land vegetation types.

3.5.1 Woodland habitat characteristics

Woodland vegetation type was characterised by scattered trees predominantly *Balanites aegyptica* and few bushes of *Comiphora lunati*. The trees whose canopy cover was less than 20% had a mean height of three metres. The ground cover was dominated by young *Themeda triandra* grass which had an average height of three centimetres (Figure 19).

Figure 19: *Balanites aegyptica* woodland (with *Themeda* ground cover) in a frequently used cheetah site (Photo: Noreen Mutoro: November 2014)

B. aegyptica had the highest number of individuals encountered and was the most dominant woody species (Table 6). It also had the highest tree density in the woodland vegetation type with 24,129 individuals per hectare and relative frequency of nearly 94% followed by *Commiphora lunati* whose relative density was 6% (Table 6).

Table 6: Vegetation characteristics of *Balanites aegyptica* woodland (with *Themeda* ground cover) in area frequently used cheetah site.

Species	**No. of individuals**	**Average dominance value**	**Density (Ha)**	**Relative density**	**Dominance**	**Relative dominance**	**Frequency**	**Relative frequency**
Ba	15	34.45	24129	93.75	831227.3	100	0.9375	93.75
Cl	1	0	1609	6.25	0	0	0.0625	6.25
Total	**16**			**100**	**831227.3**	**100**	**1**	**100**

Key: **Ba-** *Balanites aegyptica*, **Cl-** *Commiphora lunati*

The other woodland was a *Balanites aegyptica Acacia seyal* woodland (Figure 20). *Balanites aegyptica* was still the most dominant woody species encountered in this area with a dominance value of 6417.12, a relative frequency of 67%and density of 17158 individuals per hectare. The trees had an average height of three metres (Table 7).

Figure 20: *Balanites aegyptica Acacia seyal* woodland (with *Themeda* ground cover) in a frequently used cheetah site. (Photo: Noreen Mutoro: November 2014)

This woodland also comprised of two species of shrubs; *Acacia drepanolobium* and *Acacia seyal* which both had a density of 4290 individuals per hectare (Table 7). Compared to *Acacia drepanolobium, Acacia seyal* was the most dominant species of shrub with 857.90

(Table 7). This site was predominantly covered with *Themeda tiandra* which had a mean height of 10 centimetres.

Table 7: Vegetation characteristics of *Balanites aegyptica Acacia seyal* woodland (with *Themeda* ground cover) in a frequently used cheetah site

Species	No. of individuals	Average dominance value	Density (Ha)	Relative density	Dominance	Relative dominance	Frequency	Relative frequency
Ba	4	3.74	17158	66.67	64171.12	98.60	4.00	66.67
Ad	1	3.14	4290	16.67	52.33	0.08	1.00	16.67
As	1	0.2	4290	16.67	857.90	1.32	1.00	16.67
Total	**6**			**100**	**65081.36**	**100**	**6**	**100**

Key: **Ba-** *Balanites aegyptica***, Ad-** *Acacia drepanolobium*, **As-** *Acacia seyal*

3.5.2 Bushed grassland habitat characteristics

Bushed grassland habitat type comprised of an assemblage of trees and shrubs which were dominated by plants of shrubby habit mainly *Acacia drepanolobium, Cordiasinensis, Lycium europaeum, Solanum incanum* and *Hibiscus flavifolius.* Trees mainly *Balanites aegyptica* and *Commiphora lunati* were conspicuously scattered in close, dense stands of *Acacia drepanolobium* which formed thickets that were impassable (Figure 21). The ground was predominantly covered with short grass, mainly *Themeda tiandra* which had a height of three centimetres.

Commiphora lunati contributed to the highest number of trees in the bushed grassland. Compared to *Balanites aegyptica*, it had the highest tree density with 130 individuals per hectare while *Balanites aegyptica* had a tree density of eight individuals per hectare (Table 8). In relation to dominance, *Balanites aegyptica* was the most dominant tree with a value of 0.54 followed by *Commiphora lunati* with a dominance of 0.10 (Table 8).

Figure 21: *Balanites aegyptica*. *Acacia drepanolobium* bushed grassland in a frequently used cheetah site. (Photo: Noreen Mutoro: November 2014)

Majority of the shrubs in the bushed grassland comprised of *Acacia drepanolobium*, *Solanum incanum* and *Hibiscus flavifolius* (Table 8). They also contributed the highest density of shrubs with 365, 100 and 55 individuals per hectare respectively while *Lycium europaeum* had the least density of shrubs with 10 individuals per hectare (Table 8). *Hibiscus flavifolius* had the highest relative frequency of 22.22% followed by *Acacia drepanolobium*, *Solanum incanum* which both a relative frequency of 11.11% (Table 8).

Table 8: Vegetation characteristics of a bushed grassland in a frequently used cheetah site

Species	**No. of individuals**	**Density (Ha)**	**Relative density**	**Basal area**	**Dominance**	**Relative dominance**	**Frequency**	**Relative frequency**
Ad	146	365	49.66				0.30	11.11
Ba	8	20	2.72	2154.7	0.54	48.47	0.50	18.52
Am	1	2.5	0.34				0.10	3.70
Cl	52	130	17.69	385.63	0.10	8.68	0.50	18.52
Bg	14	35	4.76				0.10	3.70
Cs	1	2.5	0.34	226.98	0.06	5.11	0.10	3.70
Hf	22	55	7.48				0.60	22.22
Le	10	25	3.40	1677.8	0.42	37.74	0.20	7.41
Si	40	100	13.61				0.30	11.11
Total		**735**	**100.00**		**1.11**	**100.00**	**2.70**	**100.00**

Ad- Acacia drepanolobium**, Am-** Abutilon mauritianum, **Ba-** Balanites aegyptica**, Bg-** Balanite sgalbra, **Cl-** Commiphora lunati, **Cs-** Cordia sinensis**, Le-**Lycium europaeum, **Si-**Solanum incanum and **Hf**-Hibiscus flavifolius

3.5.3 Shrub land habitat characteristics

Shrubland habitat type consisted of stands of shrubs that were two metres high, which formed a canopy cover of less than 20%. The ground cover was almost bare with scattered tufts of grass which had an average height of two centimetres.

Figure 22: *Acacia seyal* shrub land in a frequently used cheetah site. (Photo: Noreen Mutoro: November 2014)

Acacia seyal was the only tree species recorded in this habitat with a density of 261 individuals per hectare and a relative frequency of 50% (Table 9). *Euclea* and *Flugea virosa* was the only shrub species identified. *Euclea* was the most dominant shrub with a relative frequency of 41% and density of 212.3 individuals per hectare (Table 9).

Table 9: Vegetation characteristics of a shrub land in a frequently used cheetah site

Species	**No. of individuals**	**Average dominance value**	**Density (Hectares)**	**Relative density**	**Dominance**	**Relative dominance**	**Frequency**	**Relative frequency**
As	16	30.07	261.29	50	7857.04	82.69	0.5	50
Es	13	7.57	212.3	40.625	1607.11	16.91	0.41	40.63
Fv	3	0.78	49	9.375	38.22	0.40	0.09	9.38
Total	**32**			**100**	**9502.36**	**100**	**1**	**100**

As-*Acacia seyal,* **Es-** *Euclea sp,* **Fv**-*Fluggea virosa*

CHAPTER FOUR: DISCUSSION, CONCLUSION AND RECOMENDATIONS

4.1 Discussion

4.1.1 Influence of habitat type on distribution of potential cheetah prey

Optimality theory predicts that an animal will select and settle in a place where it would perform as well as a strong competitor living in a prime habitat (Fretwell and Lucas, 1970). Cheetahs living outside the protected areas should select habitats where they can meet the critical needs for food, concealment from enemies and competitors, and reproductive success. In Salama-Kapiti area, it was found that the composition and distribution of potential cheetah prey species varied with habitat type. The potential prey mammal species were most diverse and most abundant in bushed grassland, which covered about 31% of the study area.

The woodland and open grassland habitat types supported relatively moderate diversity and low abundance of mammal species. This uneven distribution of wildlife species in the study area, however, changed within habitats with some species being restricted to certain sub-habitats only. For instance, the reedbuck, lesser kudu and beisa oryx showed high preference for bushed grassland habitat type. Other potential prey species, such as cape hare, spring hare, Grant's and Thompson gazelle occurred in all habitats but were most abundant in areas with short open grassland. Large herbivores including the wildebeest, zebra and kongoni showed no significant preference for any habitat type but often occurred in high densities in the grassland with isolated trees or scattered bushes.

4.1.2 Cheetah diet based on scat analysis

This study found that cheetahs preferentially preyed upon medium-sized ungulates weighing between 23-56 kilograms. These findings were in general agreement with previous studies, especially by Hayward *et al.*, (2006). Both studies indicated that cheetahs preferentially preyed upon medium-sized ungulates weighing between 23-56 kilograms. The prey ranged from hares (Schaller, 1973; Marker *et al.*, 2003; Wachter *et al.,* 2006) to juvenile wildebeest (Eaton (1974). Wild mammalian species contributed a large portion (57.05%) of the cheetah diet compared to domestic livestock which only contributed (14.09%). The results were similar to those of previous studies that determined cheetah diet in the Namibian farmlands (Wachter *et al.,* 2006). In that study, the main cheetah prey was found to consist of wild mammalian species while domestic livestock (goat) comprised only a small portion (4%) of the diet.

Grant's gazelles contributed the highest proportion to the cheetah diet though they were not the most abundant species within the preferred cheetah prey weight range of 23-56 Kg. Previous research by Eaton (1974) in the Nairobi National Park also revealed cheetah preference for Grant's gazelles and impalas over Thompson gazelles. This, according to Hayward *et al.,* (2006) was as result of increased vegetation density in the area that provided cheetah stalking cover which allowed them to capture larger prey. In Salama- Kapiti areas, presence of dense vegetation in bushed grasslands may have provided cheetah stalking cover to hunt Grant's gazelles. Thompson gazelles were more abundant than the Grant's gazelles but they contributed a small portion to the cheetah diet. This is because Grant's gazelle is a larger and more profitable prey item compared to Thompson gazelle (Hayward *et al.,* 2006). However, in Serengeti National park, most cheetah kills were Thomson's gazelles as they were the most abundant species (Schaller, 1973).

Cheetah diet in the Salama-Kapiti area also consisted of large animals above 56 kilograms, such as the giraffe, common zebra, kongoni, wildebeest and lesser kudu (Table 4). Previous studies have shown that cheetahs can hunt and kill large animal prey (Eaton, 1974, Bisset and

Bernard, 2006, Hayward *et al.,* 2006) while in a hunting coalition. They may also hunt and kill the juveniles of large herbivores (Wachter *et al.,* 2006). However, as has been reported in previous studies, hunting cheetahs form coalitions of several sub-adult males which enables them to kill larger prey to meet the increased nutritional demands of the group. Only in a rare occasion were single females seen to kill an adult kudu (Bisset and Bernard, 2006).

As noted in previous studies, presence of nocturnal prey (Cape and spring hares) in the scats in the study area showed a shift in cheetah activity patterns towards a more nocturnal foraging strategy (Wachter *et al.,* 2006). However, in Nairobi National Park, cheetahs were never reported to hunt or kill hares and other small mammalian prey (Eaton, 1974). These observations suggest that cheetahs can adjust their foraging strategy according to available prey outside the protected areas.

4.1.3 Cheetah prey selection in relation to wild animal density and abundance

Large herbivores, such as wildebeest, zebra and kongoni, had the highest densities of all cheetah prey in the study area. However, findings of this study show that though they were the most abundant, they were the least preferred prey for cheetah in the study area. Studies by Hayward *et al.,* (2006) reveal that even though cheetahs select prey based on abundance, they avoid hunting large herbivores due to morphological limitations. In addition, avoidance of large prey minimizes risk of injury and reduces loss of kill to kleptoparasites as they are able to quickly consume small to medium size prey unlike large prey. The findings of this study also showed that cheetahs hunted the most available prey present at site within a body mass range of 23-56 kilograms. Although the Impala was the most abundant cheetah prey within the preferred weight class, Grant’s gazelle formed the bulk of the cheetah diet in the study area.

These findings were similar to those of Hayward *et al.,* (2006), which confirmed cheetahs to preferentially prey upon medium-sized prey (23-56 kg) and significantly prefers Grant's gazelle, impala and Thompson gazelle.

4.1.4 Use of scat analysis to assess cheetah prey

Quantification of undigested prey through scat analysis has previously been used in the study of dietary habits of cheetahs (Marker *et al.,* 2003; Wachter *et al.,* 2006; Wilson, 2006; Lovari *et al.,* 2009). Previous studies reveal that scat analysis is preferred to direct and opportunistic observations in assessing cheetah diet because of the cheetahs' large home ranges, extremely shy behaviour and minimal chances of finding fresh prey carcasses. However, the use of scat analysis to determine cheetah prey has its own challenges.

The cheetah is an opportunistic predator whose prey varies in size from rodents to adult ungulates (Table 4). This great variation in prey size makes interpretation of scat analysis quite complicated (Marker *et al.,* 2003). Collection of scats by walking is time consuming. Other factors such as large home ranges, low cheetah densities and rapid disintegration of scats in arid environments makes it difficult to find fresh scats during the monthly field visits. Similar studies previously done also noted the same challenges (Marker *et al.,* 2003; Wilson, 2006). Identification of carnivore scats has to be confirmed in the laboratory as opposed to the field as faeces of sympatric carnivores are similar in morphology and not always easy to differentiate (Wilson, 2006; Shehzad *et al.,* 2012). Presence of predator hair in scats can be used in the identification of carnivores. However, where the predator hair is not found in the scats then, the identity of the predator cannot be determined in most cases. This reduces the sample size because the scats cannot be assigned to cheetahs with certainty. Accurate identification of prey taxa is also difficult, especially because large bones and teeth are generally fragmented and therefore difficult to piece together and identify the prey consumed (Shehzad *et al.*, 2012).

4.1.5 Potential uses of the reference hair collection

Reference hair collections are important for identification of prey species. Although there are hair keys and other published materials, they may not provide conclusive results in hair identification as noted by Wilson (2006). This makes a reference collection of all the possible prey items in a study area for comparative purposes essential. Reference specimens should not only consist of morphological hair characteristics but also cuticular imprints with clear medullary patterns in order to simplify the identification process. The reference hairs should include hairs from various parts of the species' body (back, belly, hip, shoulder) since hairs from the same animal may vary in structure according to their position on the body (Marker *et al.*, 2003). Furthermore, hair from several related species may possess similar characteristics (Shehzad *et al.*, 2012). Nevertheless, a hair collection of potential prey can serve as a useful tool for evaluating prey consumed by cheetahs and other predators in a particular area.

4.1.6 Habitat selection by cheetahs living outside protected areas

National parks and other protected areas in the savannah regions of Africa host relatively high densities of herbivores and carnivores of different sizes. The protected areas also offer a wide range of habitats and ecological niches for the resident wild animal species. These natural areas constitute prime habitats where the abundance of critical resources and levels of competition influence the local density and distribution of individuals. The animals that occupy these natural areas, however, have innate mechanisms of finding safe and productive living places in which to settle (Alcock, 1979).

In contrast, habitats in community grazing lands and livestock ranches are often fragmented and modified through livestock grazing, harvesting, burning and even cultivation. There is also significant disturbance by people and livestock as well as conflict over pasture and water, destruction of infrastructure, crop raiding and predation of livestock by wild carnivores. Animals living in such sub-optimal habitats should be able to select good living places that can provide breeding sites, foraging sites and safety from enemies and inclement weather.

Salama-Kapiti area in southern Kenya comprises community grazing lands and livestock ranches covered by three main vegetation types: woodlands found along shallow valleys and topographic depressions, bushed grassland and shrub land vegetation found on the plains. Cheetah scats were found in all habitat types, which indicated that the carnivores utilized all the three habitat types. Eaton, (1974), Bisset and Bernard, (2006), and Broekhuis *et al.,* (2007) reported that cheetahs require a mosaic of open habitats, particularly grassland and open wooded habitats. In Salama-Kapiti area, resident cheetahs did not show any preference for any of the three habitat types.

In neighbouring Nairobi National Park, Eaton, (1974) found that resident cheetahs used for hunting open woodlands more often than dense woodlands. In Serengeti National Park in northern Tanzania, Eaton, (1974); Caro, (1994);suggested that resident cheetahs were specialised hunters of the open savannas as they were observed to prefer to hunt in the open plains with short or medium height grass. However, studies by Hamilton, 1986; Gros and Rejmánek, 1999; Mills *et al.,* 2004 and Muntifering 2004 indicate that cheetahs use heterogeneous habitats which play a critical role in their survival. Broekhuis *et al.,* (2007) also found that woodlands interspersed with bushes were important habitat because the vegetation provided cover to hunting cheetah from other predators and decreased kleptoparasitism. In open plains with short grass, cheetahs had difficulties catching prey as they were detected early by potential predators and had difficulties hiding their prey when feeding (Broekhuis *et al.*, 2007). During the current study, a female cheetah with four one week old cubs was found hiding her cubs in a thicket. Similar studies on cheetahs in the neighbouring Kiu area of southern Kenya also found a female cheetah with cubs hiding in thick bushes (Wykstra, 2012).

The results of this study indicated that cheetahs in the Salama-Kapiti area used non-preferentially all the available habitats. Habitat selection and use among cheetahs were influenced by sex, parental status and levels of disturbance by herders and their livestock. Bisset and Bernard (2006) noted that cheetah females with weaned cubs established home ranges in open grasslands with dense bushes while a coalition of hunting male cheetahs primarily occupied open habitats. Laurenson (1994) stated that vegetation cover provides safe denning sites for cubs and increases their chances of survival to adulthood.

4.2 Conclusion and Recommendations

4.2.1 Conclusion

This study provides information on available cheetah habitat types, actual and potential cheetah prey and their contribution to the diet of cheetahs living in livestock ranches in the study area. A clear and unambiguous understanding of an endangered carnivore's habitat preference and diet is crucial for conservation planning for the species.

Cheetahs outside protected areas can adapt to the reduced habitat diversity and fragmentation. They can utilise more than one habitat type each with different vegetation characteristics.

Bushed grassland was used to establish denning sites for their cubs to enhance their survival to adulthood. Open grassland with short to medium height grass was selected so as to improve hunting success and to reduce loss of prey through kleptoparasitism. Habitat selection by cheetahs is also dependant on landscape features such as rock kopjes, ant hills, and slanting trees (play/scent marking trees) and man-made structures such as water tanks. These features and structures provide vantage points for scanning the habitat for potential prey and competitors.

Preferred cheetah prey outside protected areas, mainly comprises of wild animals that range in size from small mammals to large ungulate prey. Cheetahs selected the most abundant ungulate prey in the area (Grant’s gazelle) whose mean mass ranged between 23 to 56 kilograms. Presence of nocturnal prey in the cheetah scats also indicated a shift in the cheetah’s foraging strategy from early mornings or afternoons to twilight hours or night. This might be a strategy adopted by cheetahs in the study area to reduce interactions with humans and livestock during the day. This strategy also enabled cheetahs to decrease competition from large carnivores, such as spotted hyenas and leopards.

The use of a tracker dog in searching and identifying cheetah scats in the field was found to be very successful as it reduced the amount of time spent in the field and laboratory; hence offering immense potential for use in future studies.

Scat analysis is a reliable method for positive identification of cheetah scats and its prey. However, it is time consuming and laborious. It also gives basic dietary habits of the cheetah based on a small sample size of the scats collected. It can compliment molecular and DNA studies of carnivore prey by providing the baseline information or a credible starting point.

In conclusion, cheetah survival outside protected areas is dependent on habitat type and quality. This in turn influences the type of prey available for the cheetah, its hunting success and its ability to protect its off-springs as well as its kill from other competing predators. However, they are less selective of habitats as shown by the findings of this study. Cheetah diet outside protected areas shifted from large to small prey but they showed preference for wild ungulates whose weight range between 23-56 kilograms. However, they killed domestic stock thereby generating conflict with the local community. Consultation between conservation authorities and local communities is absolutely important for survival of cheetah outside protected areas.

4.2.2 Recommendations

Based on the results of this study and previous works, the following recommendations are made.

4.2.2.1 Further study

- Further research should be conducted in order to gain a more accurate estimate of cheetah density in the Salama- Kapiti areas. This is necessary so as to assess the extent of stock loss that cheetahs may be responsible for.
- This study only gives a basic insight in to the dietary habits of cheetahs outside protected areas and the results were based on a small sample size. Further study on the cheetah dietary habits should be carried out by using larger scat samples so as to provide a more accurate assessment of foraging behaviour and habitat utilisation of cheetahs outside protected the areas.
- Detection dogs trained to locate the cheetah scats can be used during scat collection so as to differentiate the cheetah faeces from those of sympatric carnivores found in the same area. This strategy should be tried in other cheetah ranges.

- Scats collected in the field can be validated by genetic analysis for accurate identification of cheetah scats and then classical approaches can be used to determine the prey consumed.
- Reference hair catalogues for East African mammals should be developed to make hair examination studies less laborious. They should include all mammalian species especially small mammals which are likely not to be identified during hair examination studies.
- Correction factors for differences in prey digestibility should be developed and used for accurate estimates of composition of cheetah diet. This is because consumption of smaller prey gives a higher number of field-collectable scats relative to the mass of prey consumed, because they are composed of relatively more indigestible matter.

4.2.2.2 Conservation and management action

- Strategies that encourage conservation of natural habitats in community and private lands should be adopted. This will help in the survival of carnivores as well as their wild prey.
- Education and awareness programmes should be introduced to local communities living in landscapes shared with cheetahs and other carnivores. Through such initiatives, land owners can learn how to protect and sustainably utilize the environment and how to build predator-proof bomas.
- Conservation planning and compensation schemes should be introduced in the area to promote co-existence between the local community and wild animals in shared landscapes. This would help increase tolerance from local communities especially where livestock predation is prevalent.
- Collaboration between local communities and conservation authorities should be encouraged in managing wildlife resources. This would help improve livelihoods

through tourism/ecotourism and research. It would also assist in sustainable use and protection of natural resources.

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APPENDICES

Appendix I: Some characteristics and conservation status of African carnivores

Scientific Name	**Common Name**	**Family**	**Body Weight (Kg)**	**Conservation status**
Lutra maculicollis	Spotted- necked Otter	Mustelidae	4-7	Least concern
Canis mesomelas	Black- backed Jackal	Canidae	6-10	Least concern
Canis aureus	Golden Jackal	Canidae	7-10	Least concern
Proteles cristatus	Aardwolf	Felidae	8-10	Least concern
Canisa dustus	Side- striped Jackal	Canidae	8-12	Least concern
Mellivora capensis	Honey Badger	Mustelidae	7-16	Least concern
Leptailurus serval	Serval cat	Felidae	11-13	Least concern
Profelis aurata	African Golden Cat	Felidae	11-14	Near threatened
Civetticti scivetta	African Civet	Viverridae	10-17	Least concern
Canis simensis	Ethiopian Wolf	Canidae	11-16	Endangered
Caracal caracal	Caracal	Felidae	10-18	Least concern
Aonyx capensis	Cape clawless Otter	Mustelidae	13-34	Least concern
Aonyx congicus	Congo-clawless Otter	Mustelidae	13-34	Least concern
Lycaon pictus	African Wild Dog	Canidae	20-34	Endangered
Hyaena hyaena	Striped Hyena	Hyaenidae	26-41	Near threatened
Hyaena brunnea	Brown Hyena	Hyaenidae	28-47	Vulnerable
Panthera pardus	Leopard	Felidae	30-60	Near threatened
Acinonyx jubatus	Cheetah	Felidae	35-65	Vulnerable
Crocuta crocuta	Spotted Hyena	Hyaenidae	46-70	Least concern
Panthera leo	African Lion	Felidae	120-180	Vulnerable

Appendix II: Farms within the study area and their land uses.

Name	Approximate Coverage (Acres)	Land use type
Kapiti Plains Estate	33,000	Beef, sheep, Livestock Research
Lisa Ranch	6,000	Livestock, conservation, environmental education, research, tourism
Game Ranching	11,000	Wildlife conservation, tourism, hay harvesting, livestock
Machakos Ranching	3,500	Ranching- Beef cattle, Doper sheep, Wildlife Conservation
Kima Ranch	5,500	Dairy, Sheep and Goats
Stanley & Son Ltd.	5,000	Dairy, Beef, Camels and Semen production
Malili	22,500	Partly settled
Kiu Ranch	3,000	Dairy (<100cows)/ partly settled

Appendix III: Common name, scientific name and order of all animal species recorded in the study area

Common name	Scientific Name	Order
Aardvark	*Orycteropus afer*	Tubulidentata
Beisa oryx	*Oryx beisa beisa*	Artiodactyla
Bat-eared fox	*Otocyon melagotis*	Carnivora
Cape hare	*Lepus capensis*	Largomorpha
Duiker	*Sylvicapra grimmia*	Artiodactyla
Dik-dik	*Madoqua kirkii*	Artiodactyla
Eland	*Tragelaphus oryx*	Artiodactyla
Gerenuk	*Litocranius walleri*	Artiodactyla
Giraffe	*Giraffa camelopardalis*	Artiodactyla
Grant's gazelle	*Gazella granti*	Artiodactyla
Guinea fowl	*Numida meleagris*	Aves
Spotted hyena	*Crocuta crocuta*	Carnivora
Impala	*Aepyceros melampus*	Artiodactyla
Kongoni	*Alcephalus busephalus*	Artiodactyla
Lesser kudu	*Tragelaphus imberbis*	Artiodactyla
Ostrich	*Struthio camelus massaicus*	Aves
Reedbuck	*Redunca redunca*	Artiodactyla
Serval	*Leptailurus serval*	Carnivora
Silver-backed jackal	*Canis mesomelas*	Carnivora
Spring hare	*Pedetes surdaster*	Rodentia
Steenbok	*Raphicerus campestris*	Artiodactyla
Thompson gazelle	*Gazella thomsoni*	Artiodactyla

Common name	**Scientific Name**	**Order**
Warthog	*Phacochoerus africanus*	Artiodactyla
Wildebeest	*Connochaetes taurinus*	Artiodactyla
Yellow-necked spurfowl	*Francolinus leucoscepus*	Aves
Wildebeest	*Connochaetes taurinus*	Artiodactyla
Zebra	*Equus burchellii*	Perisodactyla

Appendix IV: Animal species from the study area included in the reference hair catalogue

Common name	**Scientific name**
Dik-dik	*Madoqua kirkii*
Impala	*Aepyceros melampus*
Warthog	*Phacochoerus africanus*
Common duiker	*Sylvicapra grimmia*
Thompson gazelle	*Gazella thomsoni*
Grant's gazelle	*Gazella granti*
Steenbok	*Raphicerus campestris*
Spring hare	*Pedetes surdaster*
Cape hare	*Lepus capensis*
Tree hyrax	*Dendrohyrax arboreus*
Rock hyrax	*Procavia capensis*
Giant rat	*Crycetomis emini*
Domestic goat	*Capra hircus*
Sheep	*Ovis aries*
Wildebeest	*Connochaetes taurinus*
Lesser kudu	*Tragelaphus imberbis*
Giraffe	*Giraffa camelopardalis*
Eland	*Tragelaphus oryx*
Kongoni	*Alcephalus busephalus*
Cheetah	*Acinonyx jubatus*
Lion	*Panthera leo*
Leopard	*Panthera pardus*

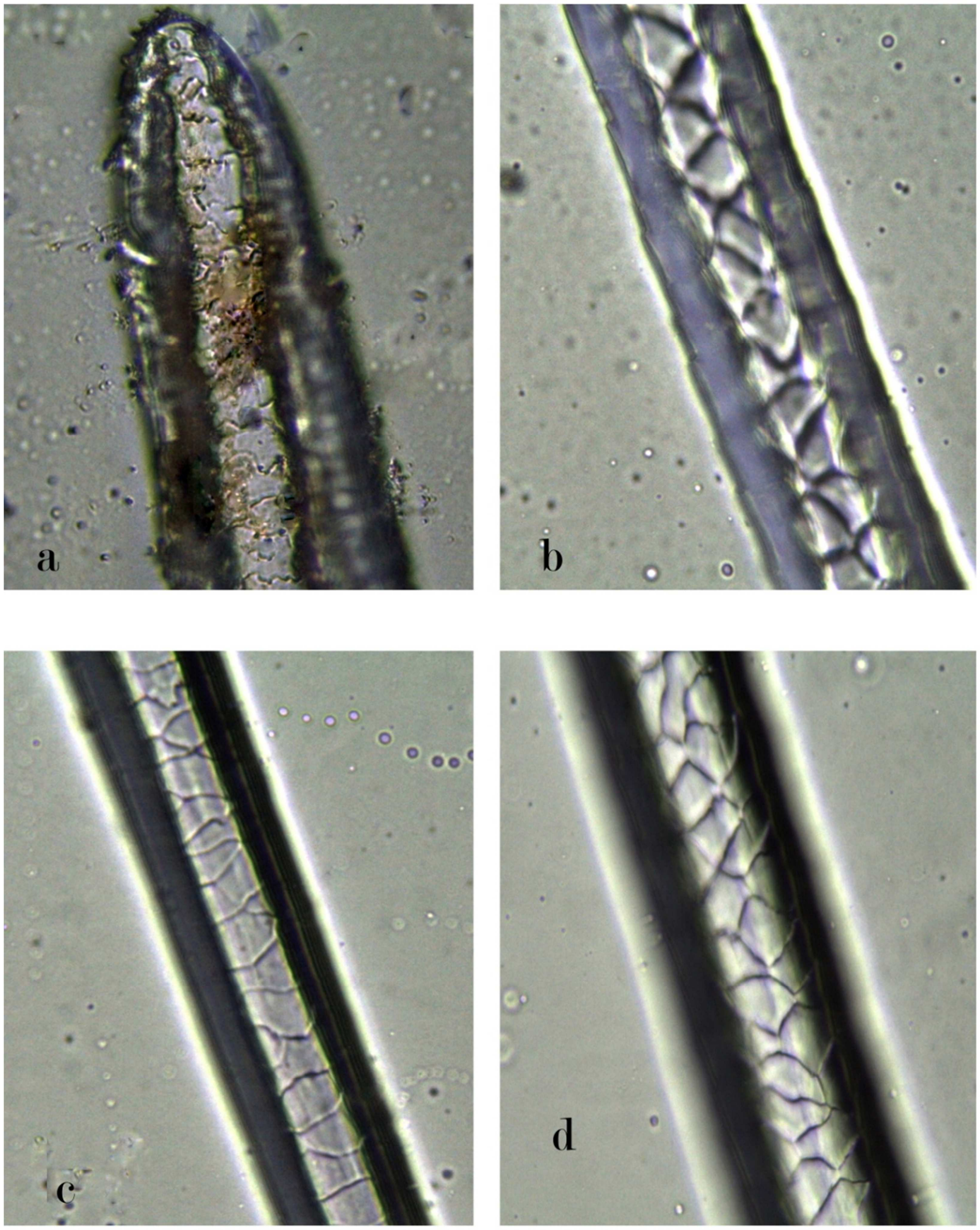
Common name	**Scientific name**
Domestic dog	*Canis familiaris*
Spotted hyena	*Crocuta crocuta*
White-tailed mongoose	*Ichneumia albicauda*
Black-backed jackal	*Canis mesomelas*
African civet	*Civettictis civetta*
Common genet	*Genneta genetta*
Serval	*Leptailurus serval*

Appendix V: Cheetah reference hair scales collection

A) Description

	Back Hair	**Belly Hair**	**Hip Hair**	**Shoulder Hair**
Tip	Irregular waved mosaic	Regular waved mosaic	Irregular waved mosaic	Irregular waved mosaic
Shaft	Diamond petal/ Regular mosaic	Regular waved mosaic	Regular waved mosaic	Regular mosaic
Root/ Base	Regular waved mosaic	Irregular waved mosaic	Regular waved mosaic	Regular mosaic

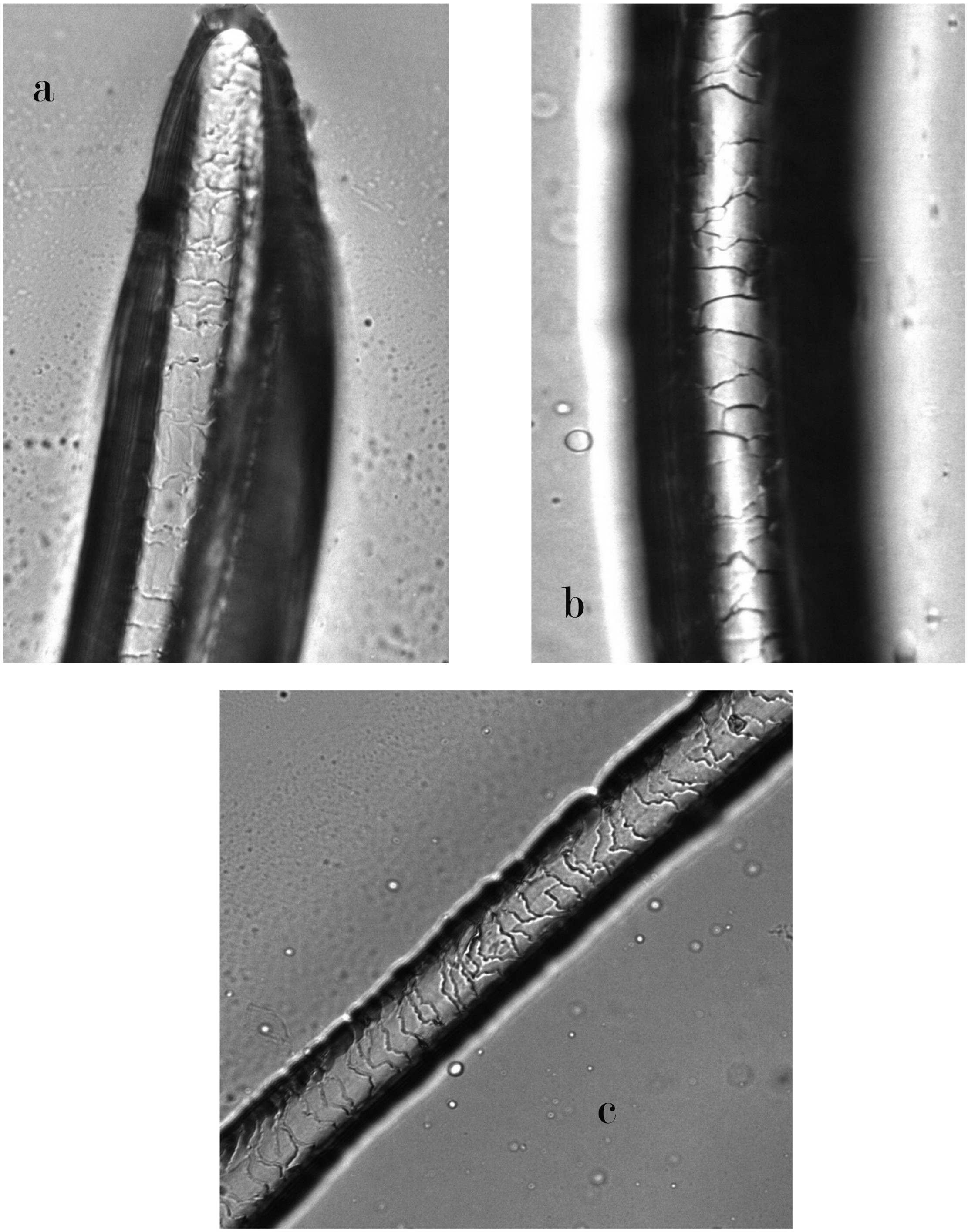
B) Cheetah back hair scale



a) Tip- Irregular-waved mosaic **b)** Tip- Regular mosaic/ Diamond petal

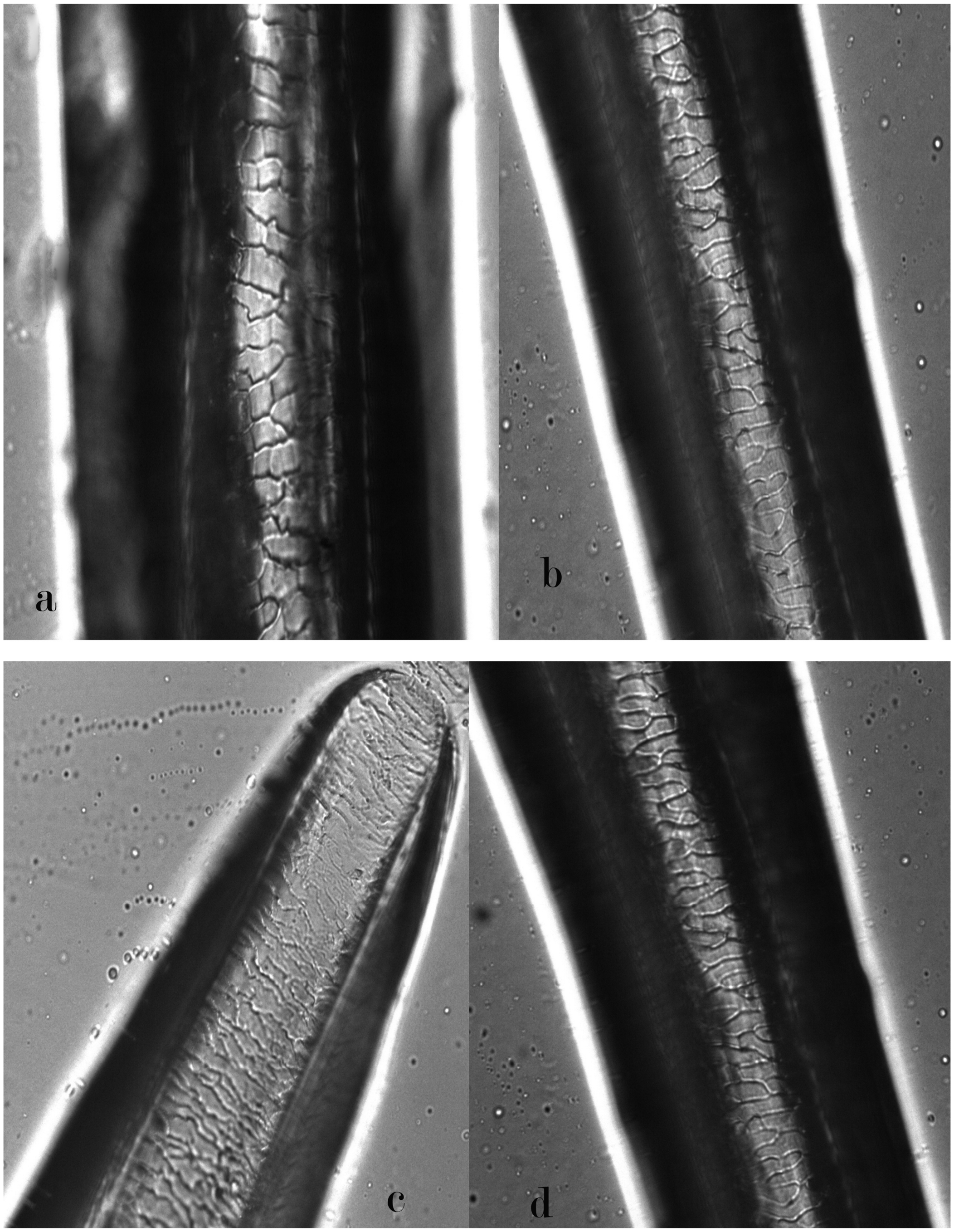
c) Root- Regular waved mosaic **d)** Shaft- Diamond petal

C) Cheetah belly hair scale



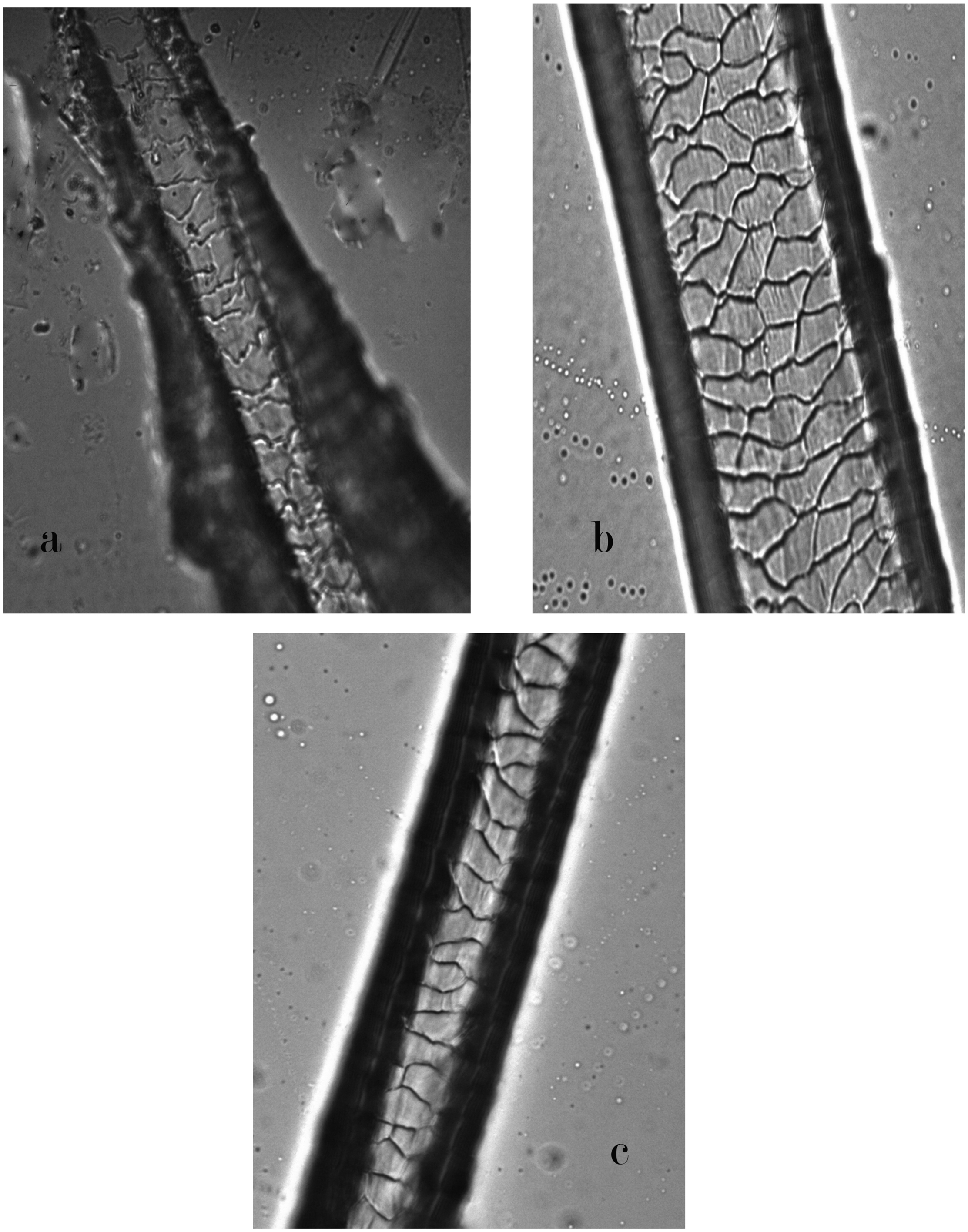
- **a)** Tip- transitional (Regular waved- Irregular waved mosaic)
- **b)** Shaft- Regular waved mosaic
- **c)** Root- Irregular waved mosaic

D) Cheetah hip hair scale



a) Shaft- Regular mosaic/ regular waved mosaic
b) Shaft- Regular waved mosaic
c) Tip- Irregular waved mosaic
d) Root- Regular waved mosaic

E) Cheetah shoulder hair scale



- **a)** Tip- Irregular waved mosaic
- **b)** Shaft- Regular mosaic/ regular waved mosaic
- **c)** Root- Regular waved mosaic