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Spatio-temporal overlap between leopard and potential prey

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Declaration

I hereby declare that I have done this thesis entitled Spatio-temporal overlap between leopard and potential prey independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to Citation rules of the FTA.

In Prague 26.4.2019

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Karolina Mikslová

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Abstract

Predator – prey interactions in space and time are fundamental in understanding the ecology of species in given environment. Leopard *Panthera pardus* plays the role of apex predator in the KumKum Farm located in Nama-Karoo biome in south-eastern Namibia. Leopards living in these dry mountainous areas are known to hunt mainly klipspringers and rock hyraxes from studies conducted in South Africa.

First aim of this survey was to evaluate availability of potential prey species and their spatial distribution within the study area. Secondly, we evaluated habitat use and spatio-temporal interactions between leopards and the potential prey species.

We assessed spatial distribution and temporal activity pattern of leopard and potential prey species in the area of 225 km^2 through 20 camera trap stations. To increase our data sample for more spatial and habitat data we conducted 20 transects in the surroundings of camera traps and recorded direct and indirect observations in Cyber Tracker. Data were collected for two months in the dry winter season and were further analyzed in ZSL Camera Trap Analyses Tool and ArcGIS Software.

Our results suggest that klipspringers and hyraxes are the main potential prey species of leopard in the area. They were the most abundant potential prey species of leopards on the KumKum Farm and both species showed highest spatial overlap with the leopard than other species. Klipspringers and hyraxes occurred mostly in rocky plains and slopes habitat as well as leopards did.

Leopards in the Karoo and especially along Orange River are still poorly studied. Studying their specific ecology and interactions with prey are important for future wildlife management decisions and also in the broader context of the leopard-farmers conflict which extent in the region has yet not been evaluated.

Key words: *Panthera pardus*, camera trap survey, cyber tracker, predator-prey space race, habitat use

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CTS – Camera Trap Station

TR - Transect

1. Introduction and literature review

Predator – prey interactions are fundamental issue in ecology (Hammond et al. 2007) and it has been of interest of behavioural ecologists for about half a century (Kie 1999). From number of experimental studies about predator – prey interactions it is known that prey strategically adjust their behaviour and spatial distribution according to the actual predation risk (Kie 1999; Sih 2005). These studies were mainly realized among various groups of species like insects, amphibians, fishes or small mammals in conditions with constrained predator or prey. However, interactions between free ranging predators and their prey in natural conditions remain understudied mainly due to the difficulty of realizing such studies (Sih 2005; Laundré 2010; Hammond et al. 2007; Myers 2015).

Spatial distribution of predators and their prey, and in large mammalian systems especially (Ripple & Beschta 2004), has a wide impact in terms of evolution, species population dynamics, resource depletion, ecosystem health but also in terms of the level of potential wildlife human conflict and decisions about relevant management practices (Hammond et al. 2007; Myers 2015; Marker & Dickman 2005). Although it is often overlooked approach, it is important to focus on the mutual joint of predator and prey in space and time because that is what represents the resulting outcome of the behavioural responses between both (Sih 2005). Together with determining the relative abundance of prey, spatio-temporal overlap studies offer useful information for predicting encounter probabilities and potential preferred diet of opportunistic predators (Weckel et al. 2006).

1.1. Predator – prey space race

Predator – prey "space race" or "games" are one of the many terms occurring among studies focused on behavioural responses and spatial distribution of the two (Hammond et al. 2007; Laundré 2010; Muhly et al. 2011; Sih 2005). Principally, in this game predators are trying to maximize their overlap while prey attempts for the right opposite (Muhly et al. 2011). Spatial distribution of animals depends on the type of their activity and it may differ also according to many factors (see subchapter 1.1.1.) but usually the habitat selection is predominantly influenced by food resources distribution (Belotti et al. 2013). Carnivores use space in accordance to prey abundance and hunting success (Belotti et al. 2013; Laundré 2010; Karanth et al. 2006) while prey must consider the variations of the habitat in predation risk and forage quality (Kie 1999; Muhly et al. 2011; Myers 2015; Suhonen 1993) as well as variation of predation risk over time of the day (Laundré et al. 2001). Both aim to benefit from their decisions and the resulted energy gain must worth the effort and ensure the future survival success (Kie 1999). Predators do not threaten their prey only by direct killing but the predators' presence and ever-present risk of predation especially is forcing the prey to constantly choose between safe and risky patches and balance their needs for food and safety (Preisser et al. 2005; Laundré et al. 2001; Sih 2005). When predators follow areas with rich resources as cues for promising abundance of prey, these patches become also the most risky ones (Lima & Dill 1990, Muhly et al. 2011; Suhonen 1993).

For example, study on elk (*Cervus canadensis*) in Yellowstone showed, that after reintroduction of wolfs in the area, elks modified their feeding behaviour to avoid predation risk and spend more time hidden in woodlands rather than feeding in exposed meadows. This change of behaviour also resulted in lower reproduction of elks as well as decreased survival of the born calves (Creel 2008). Dugongs (*Dugong dugon*) in Australia spent less time in the ocean bottom with sea grass when the probability of predation risk from tiger shark (*Galeocerdo cuvier*) was higher (Wirsing et al. 2007). Pygmy owls (*Glaucidium passerinum*) in Finland influence the use of foraging sites in coniferous forests by tits, their main prey during the winter season, and the predation pressure forces the tits to move into the inner parts of coniferous trees (Suhonen 1993).

Above mentioned principles and examples are related to optimal foraging theory which predicts that in risky areas, prey sacrifice feeding effort to reduce predation risk. To avoid predation they reduce the time spent feeding and they increase the level of vigilance behaviour (Brown 1999; Kie 1999).

To increase the chances of success, predators and prey use various predatory and anti-predatory strategies which also correlate to particular habitat type. In predators, cryptic coloration is often common characteristic which improves their hunting success (Hayward et al. 2006; Preisser et al. 2005). Prey species are known to adjust their social structure in relation to predation risk. For example, forming larger herds in open areas is one of the strategies common in large species of ungulates (Hayward et al. 2006). Individuals inside the herd benefit from this cooperation trough shared vigilance, which allows them to spend more time feeding while the overall vigilance do not decrease and more eyes increases the chance of detecting predator in the opened landscape. Moreover, for particular individuals the chance of being caught by predator decreases with the herd size (Kie 1999). On the other hand, small species of antelopes rather prefer dense vegetation cover where they adjusted their behaviour to solitary and inconspicuous life and they are also more vigilant (Hayward et al. 2006; Kie 1999).

The final result of the predator – prey game can be predicted from their spatio – temporal overlap. Both actors can be associated positively, negatively or randomly. When positive association between predators and prey occurs, predators are predicted to win the race. In case of negative associations, when prey occurs mainly in areas where predation risk is lower, it likely wins the race. Lastly, there does not have to be any winner in case when the interaction does not exist or it has cancelling effects. In short terms, losing the game does not have to create fatal impact for the individual or population. But in longer terms, predator which keeps losing the race and does not catch a proper prey item in longer time will face fatal consequences (Sih 2005). Likewise, if prey will hide in low risky areas but with poor food intake, in the longer term it negatively influences their fitness, reproductive rate and eventually leads to higher mortality rate (Preisser et al. 2005) like in the previously mentioned example with elks.

1.1.1. Other factors influencing spatial distribution

As mentioned before, not always are the food resources the main element which leads animals to choose particular habitat and their choice highly depends on the actual animal needs or activity they perform. Breeding season, for example, forces animals to seek for habitats which serve also as suitable site for mating or rearing young (Belotti et al. 2013). Felids which spend most of the day time resting are especially affected by presence of suitable resting sites (Kolowski & Woolf 2002). In areas with more predator species or higher predator densities the competition must be taken in account by predators as well (Laundré 2010). In human populated areas can be the distribution of predators and prey influenced by landscape fragmentation, persecution and other human activities. Sometimes prey is using areas close to human settlements as safe refuges while predators are rather avoiding these areas to mitigate the direct encounter with human which can be fatal especially in wildlife-human conflict areas. Thus human activities may sometimes help prey species to win the predator prey space race (Muhly et al. 2011). The health state plays an important role in animal's decision. Laundré (2010) discuss that injured animal or animal in poorer nutritional state probably takes more risk and chooses foraging areas with higher risk along the forest edges which are more valuable in resources. Nevertheless, any environmental factor like temperature, light levels, seasonality and so on, influences the distribution of species across space.

1.2. Predator – African leopard (*Panthera pardus pardus*)

African leopard (*Panthera pardus pardus*) population is widely distributed across Africa (presented in Figure 1). It occurs more or less consistently in over 40 countries across the continent (Marker & Dickman 2005). It is usually considered as the biggest subspecies of the nine subspecies of leopards (Catsg 2019) but the individuals of the south-African populations are particularly small (Stuart & Stuart 2017; Martins & Martins 2006)**.** Generally, female weight span from 17-48 kg while male can weigh up to 90 kg. The tail with white tip is up to 110 cm long and that is almost half of the total leopard's maximum length. Wide palette of colour variations depends on habitat. Individuals living in forest habitats are darker, in arid environments they possess pale cream to yellow-brown colour and those occupying cooler regions are almost grey (Stuart & Stuart 2017; Nowell & Jackson 1996). The rosettes are small and spare in light-coloured leopards found in dry areas (Gerdel 2008).

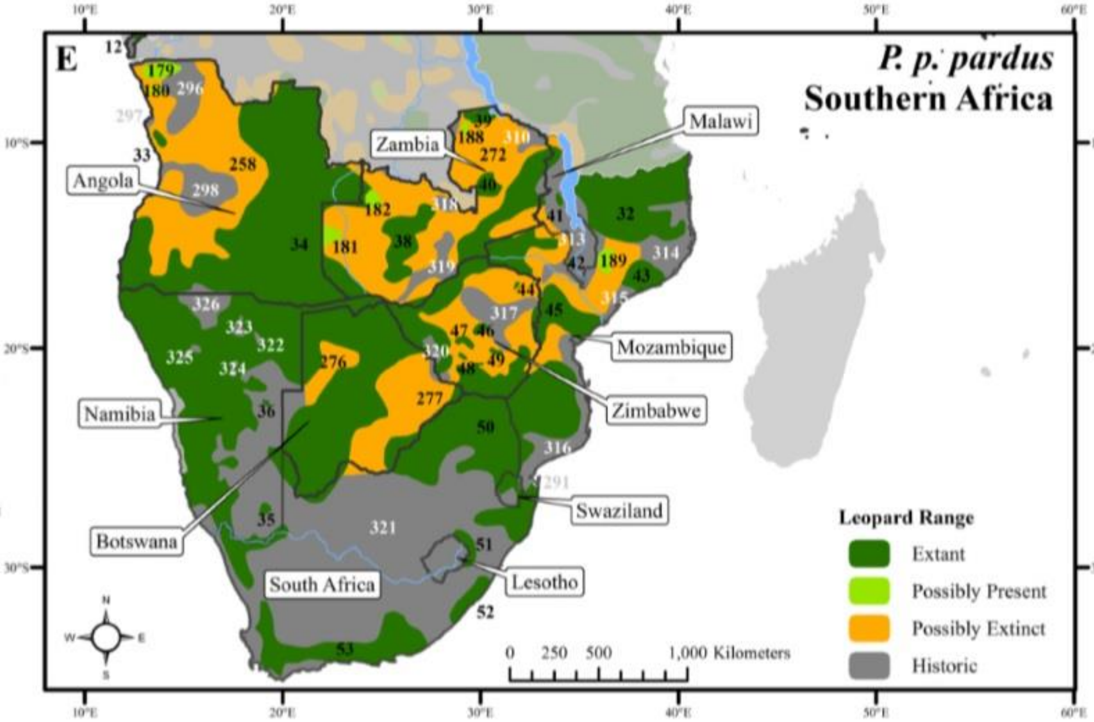

Figure 1. Distribution of African leopard (*Panthera pardus pardus*) in southern part of Africa by Jacobson et al. (2016)

As most of the cat species, they live solitary except the mating season and when a female has cubs. There is no fixed breeding season and usually she gives birth to 1-3 cubs. Even though they are known for being active mainly at night, in some areas where they are not disturbed, they can be observed also during the cooler daylight hours (Stuart & Stuart 2017). Also Norton et al. (1986) refused the common belief that leopards in the mountains are active solely at night.

One of the well-known characteristic about leopards is that they are the most adaptable of large felids and inhabit various habitats including tropical rainforests, arid savannas, grasslands, shrublands, urban areas (Fox 1995) or isolated rocky areas and mountains (Norton et al. 1986; Stein et al. 2016) which is the case of leopards within our study area. They are able to survive even in areas close to watercourses in the Namib Desert where there is sufficient vegetation cover (Mills & Hes 1997). Size of territories of the leopard varies between particular areas. They can be smaller than 6km^2 or several hundred square kilometres large (Stuart & Stuart 2017). In dry areas leopards have much bigger home range and in Namibia are reported the largest territories compared to elsewhere. It is attributed to lower prey abundance, loss of habitat diversity, lower leopard population densities and by other factors such as persecution (Stuart & Stuart 2017; Marker & Dickman 2005).

Leopards are listed as vulnerable species in the IUCN Redlist (Stein et al. 2016). They have vanished from almost half of its historic range in Africa (Panthera 2019; Ray et al. 2005) and their populaiton trend is constantly decreasing. They are percieved as symbol of power among many African tribes and leopards skin is often used for the ceremonials (Panthera 2019; Stein et al. 2016). In Namibia the leopard population is currently under detailed research and from the last comprehensive leopard census in 2012 together with previous studies, it has been suggested that Namibia has the highest density of leopards in all of Africa (AgriForum 2018). Leopards have shown large activity on farmlands outside conservation areas and that commonly results in leopard-farmers conflict (Swanepoel 2008; Stein et al 2011; AgriForum 2018). Namibia is known for its positive conservation attitude and successful management practices, still local farmers suffer great losses due to leopards and other predators and their respond can often lead to eradication of the predators from farmlands. Habitat loss, reduction of natural prey, direct killing, poor trophy hunting management and monitoring pose possibly the biggest threat to Namibian leopards. Moreover, in 2015 and 2017 Namibia was hit by severe tough dry season and some parts of the country are still recovering (AgriForum 2018; Martins & Martins 2006).

Isolated population of leopards oppressed by human activities into the remote mountainous areas unsuitable for agriculture may also face another potential threat such as decreasing genetic diversity.

1.2.1. Leopards in southern Namibia

Although the human population density in Namibia is not high at all (3.20ind./km²) (World Population Review, 2019), the human activities such as transformation of the landscape to cattle ranches, oppressed rest of the survivor leopards in to the surrounding inhospitable remote mountains inaccessible for shepherds. Here the species successfully breeds mainly thanks to its great adaptation to almost any kind of environment and opportunistic diet (Norton et al. 1986). Other species of big mammals including large predators such as lions (*Panthera leo*), cheetahs (*Acinoyx* *jubatus*) and spotted hyenas (*Crocuta crocuta*) have been extirpated from the area in the past (Skead 1980; Marker & Dickman 2005) and the leopard become the top predator.

At the moment, the most related and helpful materials dealing with leopards living in similar habitat condition like the leopards on KumKum Farm, are publications from South African areas, mainly from the Cedarberg Mountains in the Little Karoo biome (Norton et al. 1986; Martins & Martins 2006; Patterson 2008). Little mention about the presence of leopard population along the Orange River basin (concretely in Richtersveld National Park in South Africa) was found in studies of Stuart & Stuart (1989), Nowell & Jackson (1996) or Friedmann & Traylor- Holzer (2008).

Figure 2. African leopard (*Panthera pardus pardus*)

1.2.2. Prey species of leopards in southern part of Africa

Leopards take a wide variety of prey from insects, reptiles, fish, birds and small mammals up to large herbivores more than twice their size (Stuart & Stuart 2017; Norton et al. 1986; Macdonald & Loveridge 2010). Known mainly as opportunistic feeders with over one hundred prey species, yet they have shown prey preferences in their diet among studies. In places where some prey species may be regularly hunted, it may be avoided in other areas. Leopard diet is affected by many different variables. It can be the habitat type, local prey species assemblages, temporal availability of prey, individual preferences or presence of competitors (Macdonald & Loveridge 2010; Hayward et al. 2006; Karanth & Nichols 1998). Above that, leopard's diet seems to be the more interesting due to the significant differences between male and female body size and skull morphology (Hayward et al. 2006). For that males may be able to tear down larger prey and pose different food habits than females even within the same area.

Generally, prey weight varies between 10 and 40kg, with an optimum weight of 23kg which corresponds to medium sized mammals and smaller antelopes (Hayward et al. 2006; Macdonald & Loveridge 2010). Studies by Norton et al. (1986) and Martins (2010) in the south-western Cape Province in South Africa stated that leopards showed preference for small to medium-sized mammals (<20kg). As well as other studies realized within the semi-arid Karoo biome it highlights klipspringers (*Oreotragus oreotragus*) and rock hyraxes (*Procavia capensis*) as principle prey species of leopards in the mountains (Norton et al. 1986; Druce et al. 2009; Brashares & & Arcese 2002; Gerdel 2008; Martins & Martins 2006; Sale 1966; Martins 2010). In Cederberg mountains in South Africa klipspringers and hyraxes constituted 78% of leopards diet (Martins 2010). Juvenile and sub-adult individuals of greater kudu (*Tragelaphus strepsiceros*) also possess important component of leopards' diet in the Karoo biome (Mann 2014) and in the Waterberg mountains in South Africa they are reported as one of the most important prey species of leopards (Swanepoel 2008; Mann 2014). However, study conducted in the same area focused on female leopards identified kudu as rather avoided prey species (Pitman et al. 2013).

The rest of the leopards' diet consists of a wide range of other species of animals including rodents, several bird species or crickets. Rodents are mostly represented by various species of rats and lagomorphs but scat analysis showed that also for example porcupine (*Hystrix africaeaustralis*) is sometimes taken by leopard (Norton et al. 1986; Hayward et al. 2006; Mann 2014) and in dry mountainous areas in Cederberg mountains in South Africa porcupine formed 9% of leopards' diet (Martins 2010).

Primates, specifically baboons are often mentioned among studies of leopards' diet. Hayward et al. (2006), Norton et al. (1986) and several other authors denied the common belief that baboons represent leopards major prey species. Results from Limpopo province in South Africa reported by Pitman et al. (2013) showed that female leopards prey on baboons in accordance with their availability in mixed closed woodlands within the study area. Anyway, leopards do have an effect on the movements and spatial activity patterns of baboon troops (Smithers 1983).

Leopards are commonly known to regularly kill other carnivores such as cheetahs (*Acinonyx jubatus*), black-backed jackals (*Canis mesomelas*), genets (*Genetta spp.*), mongooses (*Herpestidae spp.*), African golden cats (*Caracal aurata*), bat-eared foxes (*Otocyon megalotis*) or caracals (*Caracal caracal*) (Macdonald & Loveridge 2010; Stuart & Stuart 2017; Hayward et al. 2006). However, scat analysis from mountain leopards in south-western Cape Province showed that no small carnivores like mongooses, genets or wild cats were taken despite their abundance within the study areas (Norton et al. 1986) and in further studies aardwolf (*Proteles cristatus*) and three species of mongooses were identified from scat but their formed only very little amount of leopards' diet (Martins 2010).

Leopards strategically avoid large armed animals like gemsbok (*Oryx gazella*) which present high injury risk for the solitary predator (Hayward et al. 2006; Mann 2014). The red hartebeest (*Alcelaphus buselaphus kaama*) has been also cited mostly as avoided species (Hayward et al. 2006; Pitman et al. 2013, Mann 2014).

Eventually, some species were simply never reported to be preyed upon by leopard. From those present also in our study area Hayward et al. (2006) named honey badger (*Mellivora capensis*), mountain zebra (*Equus zebra*) and springhares (*Pedetes capensis*).

1.2.3. Predatory behaviour and habitat use of leopards

Leopard use wide range of hunting techniques. It adjusts its methods due to the prey species and especially due to the habitat limitations, namely the vegetation cover. As a solitary hunter, it aims to avoid the risk of injury which could seriously influence its future hunting success and therefore usually does not seek for large prey like for example lions (Balme et al. 2007; Hayward et al). It relies on its' camouflage and inconspicuous approach in to the closest proximity of the prey followed by quick attack. For that leopard almost always depends on some amount of vegetation cover but it should not be too dense as it might mitigate the chance of stalking predator to clearly target the prey and approach it without too making much noise. Even vegetation not higher than 2cm was sufficient for leopard to successfully approach to the prey (Bothma & Le Riche 1984).

In the Cederberg Mountains in South Africa leopards avoided open and flat habitats even in areas where this habitat is dominant. Leopards preferred rocky mid-steep slopes in proximity to perennial and non-perennial rivers while areas distanced from the rivers more than 150m were significantly avoided. Rocky areas with sufficient vegetation cover provide leopard suitable habitat to observe and stalk potential prey (Martins 2010).

Behaviour of leopards from rugged remote mountains is still understudied and it might be quite specific because leopard happened to be the apex predators after the removal of their larger competitors in the past (Martins 2010). Coexistence with other predators in other areas across their range influences leopards hunting techniques in many ways. They adjust their temporal activity pattern, size of selected prey and habitat preferences due to the presence of other predators like lions in Africa or tigers in India (Karanth & Nichols 1998; Martins 2010). On the other hand, leopards are able to survive on very small prey items and benefit in areas where both large and medium-sized prey suitable for larger carnivores is scarce (Karanth & Nichols 1998). Also due to their smaller body size, leopards inhabiting the rugged mountainous area show preference for smaller prey items compared to larger individuals across Africa which hunt larger prey (Mann 2014).

Martins (2010) rejected assumptions that leopards are more active during the day in the mountains because of their selection of diurnal prey species such as klipspringers and rock hyraxes. Conversely he concludes that leopards in rocky areas are taking advantage from their perfect night vision and hunt mainly during the darkest nights. Klipspringers and hyraxes which are vigilant during the day are disadvantaged during the night. Martins (2010) further suggests that leopards are excavating hyraxes directly from their crevices which makes them even more vulnerable as they spent the night in their crevices and cannot detect approaching predator in time.

Leopards hide their kills amongst vegetation or rocks (Stuart & Stuart 2017) and in rugged mountains leopards are known to hide their catch under the bushes or rocky overhangs (Martins 2010).

1.3. Potential prey species

This chapter introduces more in detail two main potential prey species of leopards in southern Namibia highlighted in previous chapter. Following text includes the general information about the species with focus on their habitat and vigilance behaviour description. According to the literature research klipspringer (*Oreotragus oreotragus*) and rock hyraxes (*Procavia capensis*) were chosen as most important potential prey items of leopards in our study area.

1.3.1. Klipspringer (*Oreotragus Oreotragus*)

Klipspringer *(Oreotragus oreutragus)* is a small and stocky antelope distributed in southern and eastern Africa and north to the Red Sea. About one-quarter of the population occurs in protected areas and private Namibian farmlands are home to very large numbers of individuals (IUCN 2016).

Klipspringer means 'cliff-jumper' in Afrikaans (IUCN 2016) which explains their strict habitat-bound on rugged, rocky habitat and extreme agility performed on their little hooves. They spend a majority of the diurnal time on opened and steep rocky mountain slopes and granite outcrops.

They occur in pairs or small family parties with one to two juvenile or subadult individuals. Female gives birth to a single lamb at any time of the year. In the study area in southern Namibia only the ram has horns but not in all part of Africa is this the rule – for example in East African klipspringer (*Oreotragus oreutragus schillingsi*) the horns are common also in females (Estes 1974). Sometimes during the monitoring in the field it is difficult to distinguish the male from female because the male's horns begin to develop at about six months. In these situations it may lead to the wrong impression that the group is composed of more than two breeding females (Tilson 1980). In some cases, klipspringers may be also seen in groups of up to even 6 individuals aggregated at preferred feeding sites. But these are only temporary associations, which split into pairs when disturbed (Druce et al. 2009).

Klipspringers are almost exclusively browsers, but grass is also taken occasionally. They feed mainly on growing shoots, flowers, and fruits of a wide variety of shrubs and herbs as well as on stems from a large proportion of the shrub and herb species available (Norton 1984). Study made by Druce et al. (2009) demonstrated that klipspringers can forage efficiently without water and that their water-independent way of life allows them to occupy a wider range than would be possible if they were limited by access to free water. Being water-independent is big advantage for such small antelope living in semi-arid areas for which it would be always a big risk to travel in search for water source. Also in our study area there are no camera traps records of klipspringers using the artificial water source and therefore they probably depend mainly on natural sources of water.

Klipspringers are listed as least concerned on Redlist (IUCN 2016) and are considered common throughout much of their range (Stuart & Stuart 2017). However more research about their taxonomy, distribution population size and dynamics is needed. Some certain isolated populations with small areas of suitable habitat are under threat due to hunting for food (local and national level), sport hunting and competition with goats (IUCN 2016). Authors point out that in terms of management in small, enclosed reserves klipspringers may be threatened by adding artifical water points through increased competition by water-dependant species which may be benefited by the detriment of animals that are adapted to the more extreme conditions (Druce et al. 2009).

Figure 3. Pair of klipspringers (*Oreotragus oreotragus*)

1.3.1.1. Vigilance behaviour and habitat use of klipspringers

Klipspringers are often cited as preferred diet not only of leopards (Hayward et al. 2006; Druce et al. 2009; Brashares & & Arcese 2002; Gerdel 2008; Martins & Martins 2006) but also other species present at the KumKum Farm like caracals (Druce et al. 2009), brown hyenas (*Hyaena brunnea*), chacma baboons (*Papio ursinus*), black-backed jackals or some birds of prey like black eagles (*Aquila verreauxii*) are considered as common klipspringer predators (Tilson 1980).

Klipspringers spend most of their time on the rocky slopes which they are perfectly adapted to and from where they have clear vision on the surrounding area. From these sites they have better chance to detect danger and can choose among flight routes. As they lack defensive weapons, the rapid flight over steep rocky terrain is the only way they can fight for life in direct encounters with predators. Therefore they become most vulnerable when they need to leave the rocky slopes and climb down to the sandy riverbeds to feed on plants or to move to another hill because their specialised hoofs sink into the sandy river-bed substrate and slow their ability to flee from danger (Tilson 1980). Klipspringers perceive an increasing predation risk with increasing distance from rocks but they can travel even up to 10 kilometres between rocky outcrops in search for feeding sites (Druce et al. 2009). In areas with vegetation cover it is much more difficult for them to detect predators. When the group moves from one feeding or resting site to another or when the group flights from potential danger female usually leads the group with the adult male last (Tilson 1980).

The surveillance of the surrounding terrain from a prominent site is characteristic vigilance behaviour for klipspringers (Stuart & Stuart 2017). Their habitat provides them to keep the source of danger continuously in view but for a price of being very conspicuous all the time as well. The patrolling is mostly done by an individual standing in a higher position while the rest of the group feeds or rests nearby. All mature group members share the vigilance but mostly it is done by the adult male (Tilson 1980). When disturbed, klipspringers give characteristic nasal alarm whistles which are often delivered as a duet between the adult pair. After the group runs 30 to 50m higher up the slope they often stop to look back to the source of danger and may resume their calling. When escaping they aim to boulder or rocky ledge prominent for terrestrial predators (Tilson & Norton 1981; Tilson 1980).

The trends in klipspringer vigilance behaviour and social structure distinguish them from other small antelopes (*Antilopinae: Neotragini*). Usually small antelopes seek for dense vegetation which also serves as hiding place in case of danger. Permanent pair-bond in klipspringers brings large benefit for female attained through male vigilance. But if detecting predators was the only reason for creating social groups, the group size should increase beyond the family unit and with more eyes to make the detection of predator more reliable as well as reduce chances of being hunted as an individual (Hamilton 1971). Wittenberger (1979) explains: “Klipspringer should benefit from co-operative vigilance, but the advantages must exceed the costs of competition for critical resources on a territory before groups beyond the monogamous pair can evolve”.

1.3.2. Rock hyrax (*Procavia capensis*)

Rock hyraxes (*Procavia capensis*), also commonly called rock dassies, are small social mammals from the Procavia genus with five species and 17 described subspecies. They are tailless, stoutly built weighting up to 5 kg and are characteristic with their very short legs and ears (Stuart & Stuart 2017). They are widespread and common throughout Africa and the Middle East (Sale 1966). They are gregarious, living in polygamous family units consisting of single territorial male, up to 17 females and youngs of both sexes (Davies 1994) but size of the group varies according to habitat condition and can consist from only 4-8 individuals up to 80. In favourable habitats the densities can be very high. Their birth season varies from region to region. Female gives birth to usually 1-3 young which are well developed and soon move around (Stuart & Stuart 2017).

They are very adaptive and may occupy a wide range of habitats including human areas where they can even become pests but they are typically associated with kopjes (rocky outcrops), cliffs, or piles of boulders in mountains and on open plains (Stuart & Stuart 2017). They do not burrow but seek for any type of rock providing suitable cavities where the inside temperature never reaches the extremes of the outside air temperature. (Sale 1966). They usually live at the same sites and share the same crevices where they overnight and seek shelter from predators but some move between locations (Davies 1994). They often share their habitat with another species commonly occuring on KumKum Farm - red rock rabbits (*Pronolagus spp.*) (Stuart & Stuart 2017).

Dassies are diurnal and their day starts with frequently observed behaviour especially during winter - sunbasking in the early morning hours. After extended period of time they move off to feed. Under certain conditions they may feed also at night (Brown & Downs 2007; Stuart & Stuart 2017). They are herbivores with a very diverse diet and take a lot of grass and forbs mainly during the intensive midmorning and late afternoon sessions (Sale 1965; Turner and Watson 1965; Stuart & Stuart 2017). Although they don't need much water because they get most of it from their food (San Diego Zoo Global 2019) it has been proofed in one research that the groups tend to distribute toward the episodic water courses and that rock outcrops in the vicinity of water sources were usually occupied (Davies 1994).

Hyraxes are hunted locally for local consumption and skin and sometimes a population in smaller localities can become extirpated (Butynski et al. 2015). Visser (2013) mentioned that "gene-flow between populations is influenced by the polygynous social system of hyraxes in addition to the landscape connectivity between isolates in a specific region." Besides that, there are no major threats to this species and according to IUCN (2015) their population is stable and least concern. More often mentioned is the problematic with their growing numbers leading to crops and garden damage in human settlements which results in involvement of control measure (Butynski et al. 2015). High population densities of hyraxes can be caused by eradication of predators and in these areas the reintroduction of predators is recommended as management strategy. However, dassies occur in many large protected areas across much of its range and at the moment there is no specific conservation actions needed (Visser & Wimberger 2016; IUCN 2015).

1.3.2.1. Vigilance behaviour and habitat use by rock hyraxes

Leopards are considered hyraxes' main enemy (Sale 1966) but dassies are often victims to many other predators. One of the most important and also commonly present on the KumKum Farm is black eagle which is highly prey-specific to hyrax (Davies 1994). Another predators to hyrax is caracal, brown hyena and marital eagle but that one is not certainly present on the farm. Juvenile hyraxes are especially vulnerable to a variety of numerus smaller predators like mongooses, african wildcat (*Felis silvestris*), jackals or cape cobra (*Naja nivea*) (Davies 1994).

Their anti-predatory behaviour varies among the nature of the predators. First of all, their warning calls and guarding functions play an important role. Usually the oldest female is responsible for guarding from nearest highest point but when the danger is near (for example flying eagle) all adult individuals watch. When potential predator approaches, short squeak warns the rest of the group which usually sits motionless ("freezes") for few minutes. Whether the group will flee to their shelters depends on the intensity of following auditory signals. In some cases it was observed that while the rest of the group escaped in to the shelter, the guards stayed outside and tried to chase away the predator (Fourie 1983).

Hyraxes rarely move more than a few hundred metres from their crevices where they hide from predators (Stuart & Stuart 2017). They become most vulnerable during feeding and basking. Group feeding is done in pairs while one of the individuals acts as a sentinel from a viewpoint (Sale 1965; Turner and Watson 1965; Kotler et al. 1999). When feeding too far from their shelter, they can hide in thick vegetation from raptors but not from attacks by felids. The only time they might be a bit safer while feeding further from their holes is during the midday period when the cats are less active (Davies 1994). During basking it has been observed that dassies orientate themselves so that they are facing away from their neighbours. It has been explained as a strategy to mitigate common aggressive behaviour between individuals but another function is early predator detection (Sale 1970).

Interestingly, there is probably a relationship between local predators and the maximum size of hole entrance regularly used by members of a colony. Except for a few temporary exceptions, holes that allow entrance to a large cat are never used by the colony (Sale 1966).

Studies on captive hyraxes have also shown that they can distinguish when they are safe even when the danger is very close and so they can stay calm in their shelter or become even curious (Sale 1966; Fourie 1983).

Except their intelligence they are very brave and aggressive too. They are for example known to successfully chase of mongoose, vervet monkey (*Chlorocebus pygerythrus*) or even black-backed jackal (Fourie 1983).

Figure 4**.** Rock hyrax (*Procavia capensis*)

2. Aims of the thesis

First aim of this thesis was to determine potential prey species availability in the study area and to show spatial spatial distribution of both the leopard and potential prey. The second aim was to eavulate habitat use and spatio-temporal overlap of leopard and its potential prey species.

2.1. Hypotheses

According to the literature review we predict that klipspringer and rock hyraxes will be abundant in the KumKum Farm and thus will be the main potential prey species of leopard.

3. Methods

3.1. Study area

Research is conducted in a private fenced KumKum Farm reservation located in south-eastern Namibia on the border with South Africa formed by Orange River (28°39'57.8"S 18°59'40.6"E). Administratively lays this area in Karas region. The total area of 450km^2 is covered by dry mountainous Nama-Karoo biome and surrounding areas are covered mostly by pastures. This survey is conducted in the first half (black line on Figure 2) of the farm.

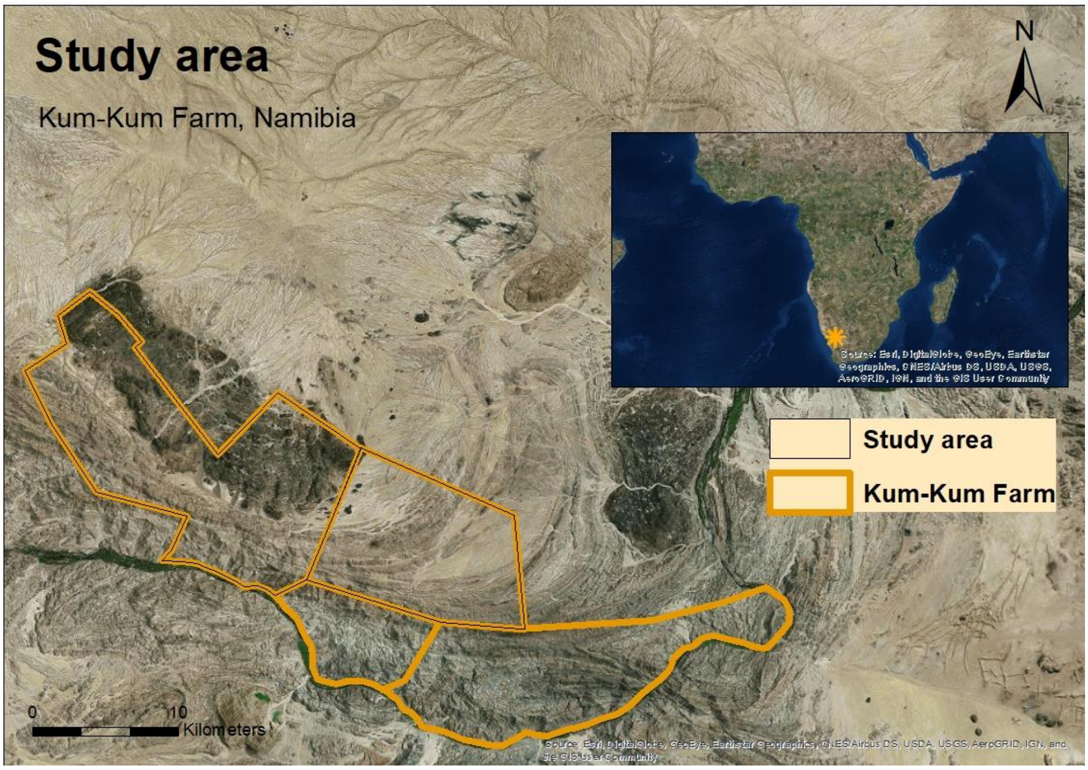

Figure 5. KumKum Farm and study area

The Nama-Karoo is a large region on the central plateau of around 248 000 km^2 in the western half of South Africa and extends into south-eastern Namibia which is known as Bushmanland subregion of Nama-Karoo (Cowling 1986). It is a complex low hills, mountains and plains, dominated by dwarf shrubs intermixed with grasses, succulents, geophytes and annual forbs. Trees are scattered and often found on rocky outcrops. The name of the biome is derived from the Khoi San word *kuru* meaning ‘dry’ (Mucina et al. 2006). The estimate terrain elevation above sea varies around 617 metres at the KumKum Farm.

The geological underlain consist by highly deformed and metamorphosed rocks dominated by granitic gneisses. Pedologically the landscape is young containing weakly structured soils and as is typical in the more arid areas of South Africa upper soil layer lacks organic and humic topsoil. The most common soils of the region are red and yellow soils reflecting the weathering of the granitic parent material in a well-drained and oxidizing environment. Steep mountainous slopes with shallow soils and exposed rocks consist of a quartzite, schists and amphibolites and granitic gneiss at the base. The highly siliceous quartzites are infertile, whereas the schists and amphibolites contain important major elements such as potassium, calcium and magnesium with variable amounts of copper and zinc. The granitic gneisses have lower concentration of these elements (Dean & Milton 1999).

The climate in Karoo is essentially continental. Summers are hot with mean temperature above 40°C and in cold winters the temperature can drop below zero. Temperature extremes range from –5°C in winter to 43°C in summer. Most rain falls in late summer (December to April) with peaks in March and annual mean precipitation is less than 100 mm in Bushmanland. The low rainfall is unreliable and droughts are unpredictable and sometimes prolonged. The rivers are nonperennial apart from the Orange River (Mucina et al. 2006; Dean & Milton 1999).

Figure 6. Characteristic landscape of the KumKum Farm

Previously the land on KumKum Farm served as game ranch and was busy with frequent trophy hunting events. Hunting had a great impact also on the local ecosystem due to the intense fencing within the area for cumulating herbivores on smaller area and simplifying the spotting of hunted animals. In 2012 the land was bought by Dr. Peter van der Byl Morkel and Ian Craig and is now run as nature reserve. Current management of the farm strives for restoring of the ecosystem through removal of the redundant fences and opening the space which allows animals to migrate freely through the reserve in its entire range and mitigate the pressure of grazing on damaged areas. Other daily management activities in the reserve include building and controlling artificial water places, cutting of invasive *Acacia* stands, monitoring of predators and prey species within the area as well as monitoring and dealing with illegal pasture activity. Nowadays also small amount of ecotourism activities are supported through educational camp hosting volunteers.

3.1.2. Biodiversity of the KumKum Farm

Vegetation is studied well in many regions of Namibia, however Karas region where our study area lies, is completely neglected as well as in other farmlands in Namibia (Burke & Strohbach 2000). In general, the Nama-Karoo flora is not particularly rich and the local endemism is very low, but it has high diversity in plant life forms. According to Mucina (2006) lies our study area in the Bushmandland and West Griqualand vegetation unit. Sparse vegetation dominates by deciduous or semi-deciduous shrubs and dwarf shrubs, with annual and perennial grasses and herbs conspicuous especially in spring. Typical and most common representative tree species *Aloe dichotoma* (Aloaceae) is usually found as separate individuals on rocky slopes. Other scattered tree species or small woodlands composed mostly by Acacia species grow usually on sandy soils along dry riverbeds. Dominant plant families are represented mainly by *Asteraceae*, *Fabaceae* and *Poaceae*. Other species from succulent genera of the families *Crassulaceae Euphorbiaceae* and *Apocynaceae* are also commonly found in the reserve (Mucina et al. 2006).

Figure 7. Typical tree species *Aloe dichotoma*

Orange River area was a primary entry point to Namibia for first settlers and populations of big mammals like elephants, rhinos, hippos, lions and cheetahs as well as other animal species had been decimated by early 1800s (Skead 1980). Now the only top predators roaming the area are leopards (*Panthera pardus*). Other members from Felidae family living in the reserve are caracal (*Caracal caracal)* and African wild cat (*Felis silvestris*). Significant representatives of the Hyaenidae family are brown hyena (*Hyanea hyanea*) and aardwolf (*Proteles cristatus*) and Canidae family is represented by bat-eared fox (*Otocyon megalotis*) and black-backed jackal (*Canis mesomelas*). Striped polecat (*Ictonyx striatus*), small spotted genet (*Genetta genetta*), honey badger (*Mellivora capensis*), rock hyrax (*Procavia capensis*) and mongooses (*Herpestidae spp.*) belong to common species of small mammals in the area. Especially at night the large plains are crowded with numbers of Southern African springhares (*Pedetes capensis*), red rock rabbits (*Pronolagus rupestris*), Cape porcupines (*Hystrix africaeaustralis*) and the only representative of the order Tubulidentata – aardvark (*Orycteropus afer*). Herds of antelope species are found all across the reserve. Steep rocky slopes are home to abundant klipspringer (*Oreotragus oreotragus*) – very specific small antelope species. Similar sized antelope (around 50-60cm shoulder height) found in opened grasslands is Steenbok (*Raphicerus campestris*) typical for its large ears and larger Springbok (*Antidorcas marsupialis*) (Stuart & Stuart 2017). Large herbivores move on grasslands as well as in the rugged mountainous terrain. Mountain zebras (*Equus zebra*), common elands (*Taurotragus oryx*), greater kudus (*Tragelaphus strepsiceros*), gemsboks (*Oryx gazella*) and red hartebeests (*Alcelaphus buselaphus*) are still found in numerous herds across the area, however it is not easy to find them due to their high vigilance probably related to the frequent hunting events in the past.

Most of the bird species reside near the Orange River at the very border of the reserve. From those the most common include species of herons (*Ardeidae*), kingfishers (*Alcedinidae*), ibises (*Threskiornithinae*) and eagles (*Accipitriformes*). Further in the reserve various species of weavers (*Ploceidae*), doves (*Columbidae*), bee-eaters (*Meropidae*), bustards (*Otididae*), martins (*Hirundinidae*) and many others are found.

Though breeding of cattle inside the reserve is strictly prohibited, illegal shepherds accumulate near the Orange River, therefore domestic animals such as sheep (*Ovis aries*), goats (*Capra hircus*), cattle (*Bos Taurus*) and dogs are also small but influential part of the local ecosystem. Fortunately the rest of the reserve is not easily accessible thanks to rugged rocky terrain so it prevents from spreading grazing herds of domestic animals further inside the reserve.

The animal species diversity of the reserve is not explored in detail yet. For example the presence of the black-footed cat (*Felis nigripes*) or meerkat (*Suricata suricatta*) is far from being confirmed at the KumKum Farm though they are both mentioned as common species of these areas in field guides (Stuart 2013; Stuart & Stuart 2017).

Figure 8. Greater kudu (*Tragelaphus strepsiceros*)

3.2. Data collection

Data collection for this thesis took place on one half of the KumKum Farm (225 km^2). Data for this survey were collected by camera traps and accompanied by transects. Through camera traps we accessed spatial distribution of species, prey species diversity, availability and temporal activity patterns of both the predator and potential prey. Transects data served as comparison sample with camera trap data and through them we also enlarged sample area and gained more data about habitat and species distribution in the surrounding of the camera traps.

Data collection lasted from 26th of July 2018 until 30th of September 2018. Collected data sample correspond to one dry winter season.

3.2.1. Camera array

According to the pilot study made in the spring 2018, 20 camera trap stations including 40 camera traps were set in suitable places with highest leopard track occurrence. Camera models used were UOVision Panda UV 535, Bushnell TrophyCam HD and Browning Strike Force Mini HD.

All 40 cameras were installed for 60 days. Each day was considered as one sampling occasion. In each trap station 2 opposed camera traps were installed for leopard individual identification due to ongoing research about local leopard population. Probability of detection of animals was maximized by placing the stations in narrow riverbed paths between rocky walls where most mammal species are likely to travel. Cameras were positioned on rock piles supported by wooden sticks where needed. No bait was used to attract animals to the target area. See camera array on Figure 3.

The whole camera trap design and data collection was realized by Ing. Viktor Neštický. This survey is part of his PhD research on local leopard population.

Data from camera traps were inserted in ZSL Camera trap analysis tool which calculates the trapping rates, occupancy and provides various useful outputs including activity plots and distribution maps easily saved as Google Earth file, ArcGIS shapefiles and other.

3.2.2. Transects

For transect data collection Cyber Tracker application was used. It is an efficient method for wildlife monitoring and serves as GPS device at the same time (Cyber Tracker Conservation 2013). We customized our application for collection of habitat data and direct and indirect signs of species. We used range finder for measuring the distance of the observed object and other helpful tools like binoculars and filed guides with African mammals of southern Africa (Stuart 2013; Stuart & Stuart 2017).

Twelve walking transects and four day and four night car transects were made. Habitat types were noted in below mentioned categories. Number, activity and vigilance of directly observed animals were recorded and where possible also the population structure with numbers of males, females and juveniles. Habitat signs like footprints, dung and other (feeding sights, active burrows, carcasses) were recorded and identified with field guides books (Stuart & Stuart 2000; Stuart & Stuart 2017). White coloured dung was ignored completely as it can remain in the dry environment for years. Vigilance was measured by range finder as the distance from the observer at which animal escaped after detecting him. Distance and angle of observation was measured through range finder as well.

Transects on foot with average length of **7** kilometres covered the surrounding area of camera trap stations. On foot we accessed various habitats, especially rocky slope and mountain areas inaccessible for vehicle. Significant part of the foot transects led through dry river beds with sandy soil because animals use these river beds as corridors between rocky slopes where the sandy soil provided best condition possible for tracking of animals. Day and night car transects served opportunity to monitor remote and large areas and increased the chance for direct sighting observation both of diurnal and nocturnal animal species in various habitats.

Obtained data were exported from Cyber Tracker application in excel and shape files for further analyses.

Table 1. Overview of length and number of each type of transect

Type of transect	Lenght	Number of transects
Walking	7 km	12
Car	30 km	4
Night	15 km	4

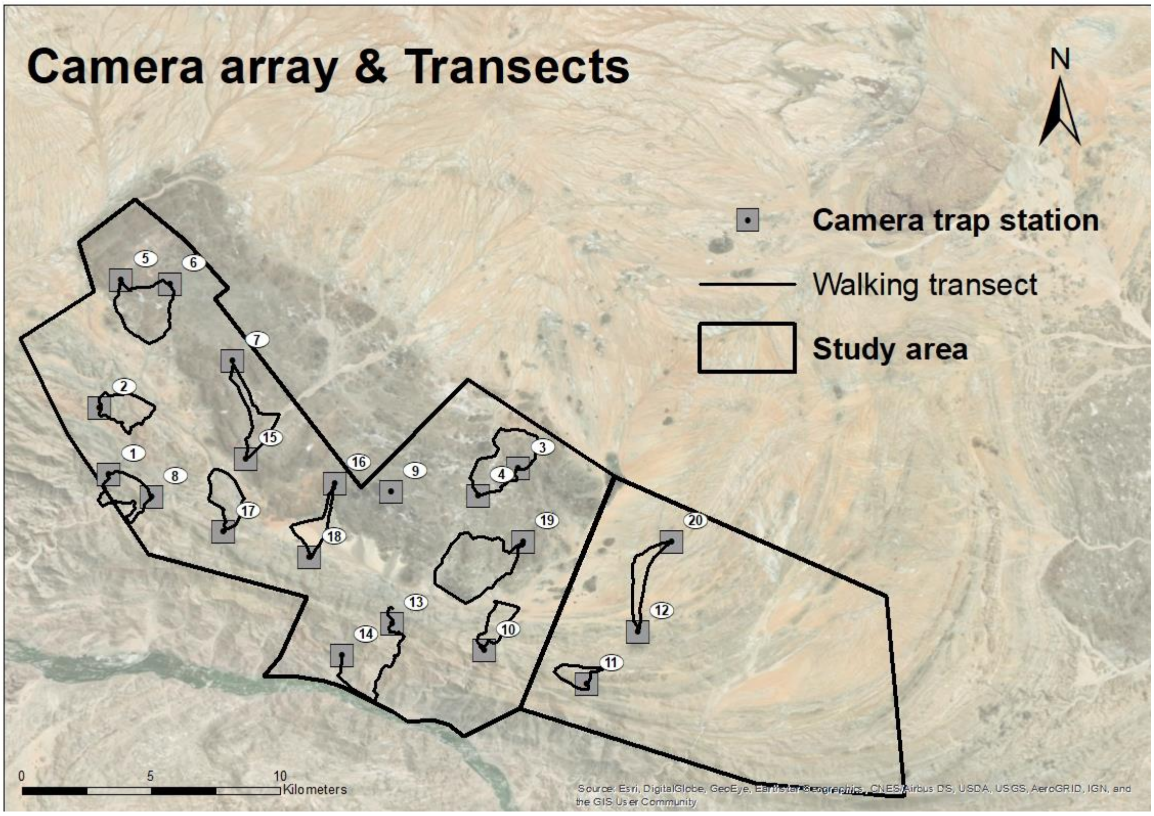

Figure 9. Camera trap stations with identification numbers and walking transects

3.2.3. Potential prey species availability

All detected species from camera traps and transects were arranged in two tables (one for cameras and other for transects) including number of camera trap stations/transects where each species occurred, percentage representation of each species camera/transect occupancy, total number of each species events/observations, percentage of all wildlife events. Occupancy is the probability that certain place is occupied by a target species and it is an alternative technique for determining occurrence over space of species that cannot be individually identified (Bailey et al. 2014). Moreover, from camera trap data species specific trapping rate (number of independent photographic events per trap day times 100) was calculated by ZSL CTAT Analysis Tool. From transects data we calculated index of abundance for each species as:

Index of abundance = N of D + N of IND observations / total number of transects (20)

We compared the camera trapping rates and transect abundance indexes between species to determine the most detected and thus the probably most abundant potential prey species.

3.2.4. Spatial distribution and overlap

GPS position of camera traps and transect observations served as data sample for spatial distribution of each species. Spatial data of the leopard and selected main potential prey species were processed in ArcGIS and graphically presented in maps.

Co-occurrence of leopard and each prey species was accessed through sampling history report in the ZSL Camera Trap Analysis Tool and number of equal camera traps locations shared with both the leopard and each prey species was summarized. Resulting numbers express the percentage of all camera traps where the leopard co-occurred with each of the potential prey species.

3.2.5. Habitat use of leopard and potential prey

We monitored habitat on three levels (primary, secondary and tertiary) and in three basic categories– rocky plains and outcrops, shrublands and grasslands. Primary habitat type corresponds to the habitat at the certain point where the camera trap is installed. Secondary habitat type is the one that dominates in the surrounding area according to the Cyber Tracker records and Google Earth view. We set up our Cyber Tracker application for multiple choices of habitat in case that various habitats were overlapping at the locality. Tertiary habitat combines them both and creates the resulting habitat variable at each of the twenty camera trap station. Besides, as mentioned before, all camera traps were installed in dry riverbeds.

Each camera trap station and each transect observation record holds information about the habitat type at the locality and thus also about the number of events/observations of each species in the given habitat. The results from camera traps correspond to percentage of number of events and results from transects correspond to percentage of number of observations of each species in each habitat type. From these results the habitat use by each species was evaluated and finally, results from camera traps and transects were compared.

We also tested the differences in habitat use by klipspringer, leopard and hyrax using chi-square tests in Statistica STAT Software.

3.2.6. Temporal activity pattern and overlap

Temporal pattern is based on the time of the photo capture. Captures were classified into three categories: diurnal, nocturnal and crepuscular (Table 2). Numbers of events in each category for each species were summarized and recalculated to percentage. Temporal activity radial plots were created for each selected species in ZSL Camera Trap Analysis Tool to demonstrate the activity pattern of leopard and the main potential prey species. Interaction between leopard and potential prey species was graphically displayed on chart exported from ZSL Camera Trap Analysis Tool.

Table 2. Time classification

Time category	Hour of the day
Diurnal	7:01 – 17:30
Nocturnal	19:31 – 5:30
Crepuscular	17:31 – 19:30 and 19:30 – 7:00

4. Results

During two month camera trap sampling period 10 548 camera trap pictures were captured by twenty camera trap stations while 2 506 pictures were identified as wildlife records corresponding to the total number of 882 individual wildlife events. After excluding events of 1 reptile, 103 birds and 6 mice from the collection, the number dropped to the final number of 772 mammal events.

From twenty transects the resulting Cyber Tracker database contained total number of 892 observations including 57 direct sightings and 835 records of indirect signs.

Complete list from both data sets holds 24 detected mammal species from 14 families and 8 orders. Most diverse group was family Bovidae represented by 7 species of antelopes. The rest of the families were all represented by two or one species belonging to groups of Canidae, Cercopithecidae, Equidae, Eupleridae, Felidae, Hyaenidae, Hystricidae, Leporidae, Mustelidae, Orycteropodidae, Pedetidae, Procaviidiae and Viverridae. Full list of expected and detected species by camera traps and during transects in the area is in the Appendix 1.

4.1. Potential prey availability

The most detected species by camera traps were mongooses which occupied 95% of camera trap stations (Table 3). Rock hyrax and klipspringer took the second and third place behind the mongooses. There was total number of 159 events of hyraxes within 16 camera trap stations and 90 events of klipspringers which occupied 17 camera trap stations. Red rock rabbits also had one of the highest high trapping rate values and they occupied 70% of all camera trap stations. Trapping rate of following species significantly decreased and the rest of the first ten most detected species is represented by gemsbok, honey badger, mountain zebra, chacma baboon, porcupine and greater kudu. Cape hare was present repeatedly only on one camera trap station. African wild cat is the third most detected small carnivore species after mongoose and honey badger. Detection of other small carnivores such as black backed jackal, small-spotted genet, striped polecat and aardwolf were only rare (usually 1-3 events). Other the least recorded potential prey species were common elands, red hartebeest, steenbok and aardvark with only 1 or 2 recorded events. See list of the ten most detected potential prey species by camera traps in Table 3 and full list in Appendix 2.

Table 3. List of the ten most detected potential prey species by camera traps organized by highest trapping rate value

Species	Number of stations	% of all stations	Number of events	% of all wildlife events	Trapping rate
Mongoose	19	95%	210	27,2%	16,86
Rock hyrax	**16**	**80%**	**159**	**20,6%**	**12,04**
Klipspringer	**17**	**85%**	**90**	**11,7 %**	**7,1**
Red rock rabbit	14	70%	70	9 %	5,37
Gemsbok	8	40%	28	3,6 %	2,32
Honey badger	11	55%	31	3,9%	2,21
Mountain zebra	9	45%	27	3,5 %	2,19
Chacma Baboon	8	40%	29	3,7%	2,09
Porcupine	11	55%	25	3,2 %	2,05
Greater kudu	7	35%	24	3,1 %	1,81

***** *Trapping rate = Number of independent photographic events per trap day times 100*

Within transects, large ungulate species hold the highest value of abundance index (Table 4). Those were gemsbok, mountain zebra and greater kudu occurring on 65-70% of all transects. Rock hyrax followed large ungulates with abundance index of half of the previous values of ungulate species but with twice higher number of direct observations than gemsbok. After common eland, klipspringer took the 6th place according to the index of abundance. The rest of the first ten most detected species was represented by baboons, cape hare and springbok. Springhare had one of the lowest abundance indexes but had 12 direct observation within the night car transects which made him together with klipspringer the most directly observed animal. Aardvark and porcupine held abundance index value with similar height to previous species. Lower values from 0,5 down to 0,05 belonged to steenbok, mongoose, African wild cat, striped polecat, honey badger, aardwolf and red hartebeest which was the least detected species during transect data collection. See the list of the ten most detected potential prey species during transects in Table 4 and full list in Appendix 3.

Rock hyraxes and klipspringers were one of the most detected potential prey species. Rock hyraxes had second highest number of events in camera traps (159) and occupied 80% of all camera traps. Within transects they were the 4th species according to the index of abundance value, they were detected on more than half of transects (55%) and they were the second species with the highest number of sightings (8). Klipspringers were after hyraxes the third most detected species by camera traps with the total number of 90 events and had higher occupancy than hyraxes (85%). In transects they were the most directly observed animals (20% of all direct species observation) and had the highest transect occupancy (80%).

Table 4. List of the ten most detected potential prey species during transects organized by highest index of abundance

Species	**Number of transects**	**% of all transects**	**N of D OBS**	**% of all D OBS**	**N of IND OBS.**	**% of all IND OBS**	**Index of abundance**
Gemsbok	14	70%	4	6,6%	218	56,9%	11,1
Mountain zebra	13	65%	2	3,3%	194	23,2%	9,8
Greater kudu	13	65%	4	6,6%	128	15,3%	6,6
Rock hyrax	**11**	**55%**	**8**	**13,3%**	**52**	**6,2%**	**3**
Common eland	9	45%	1	1,6%	46	5,4%	2,25
Klipspringer	**16**	**80%**	**12**	**20%**	**24**	**2,86%**	**1,8**
Chacma Baboon	9	45%	0	0%	31	3,7%	1,55
Cape hare	11	55%	7	11,6%	20	2,4%	1,35
Springbok	3	15%	3	5%	20	2,3%	1,15
Springhare	5	25%	12	20%	8	0,9%	1

***** *Index of abundance = N of D + N of IND observations / total number of transects (20)*

4.2. Spatial distribution and overlap between leopard and potential prey

Leopard was successfully captured on 70% of the installed camera traps. Total number of individual events was 41 and within individual stations the number of events varied from 1 to 5 events. There were 44 indirect signs recorded and no direct observation. Leopard track and dung occurred on more than a half of the conducted transects.

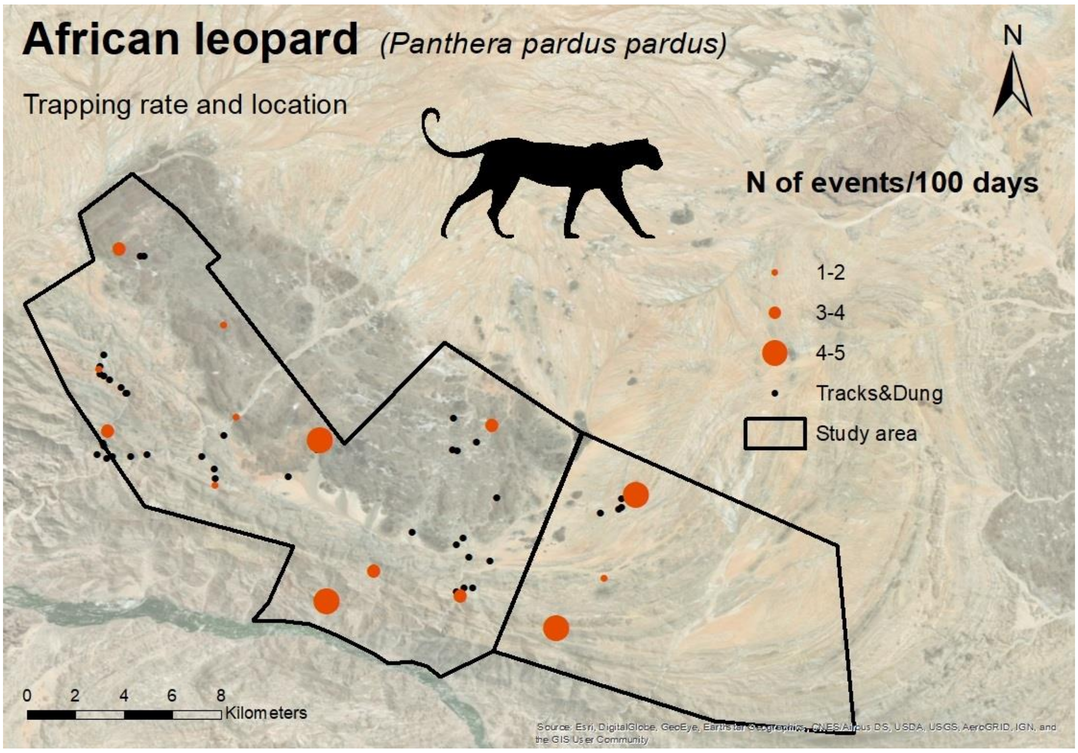

Figure 10. Distribution of leopard within the study area

Klipspringers occurred on 85% of all camera trap stations. Number of events within visited stations varies from 1 to 20 individual events. Direct and indirect observations often detected presence of klipspringers in close proximity of the fenced border of the farm (Figure 11).

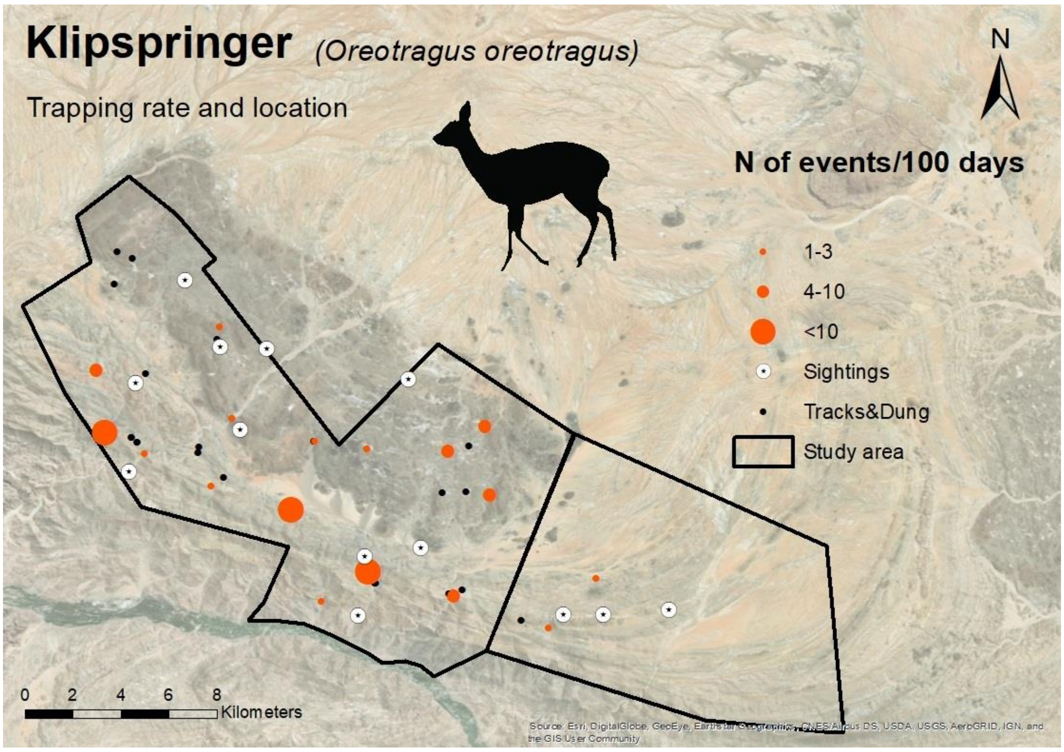

Figure 11. Distribution of klipspringer within the study area

Klipspringers co-occurred on 12 camera trap stations with the leopard and on 5 locations only the klipspringer showed presence. Three remaining stations did not record any event with klipspringer (Figure 12).

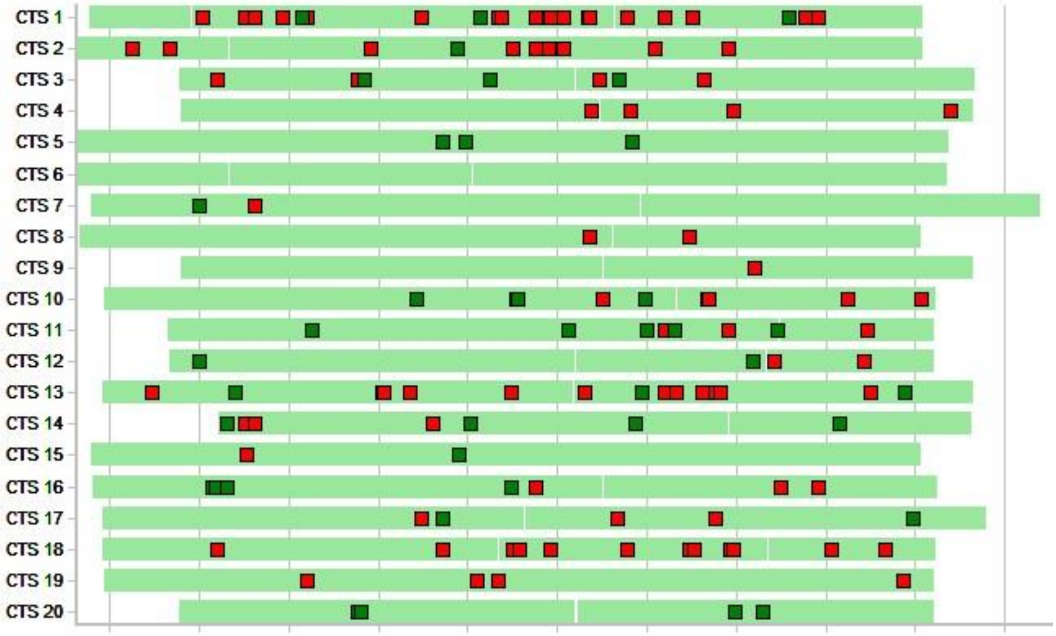

Figure 12. Co-occurrence of leopard (green squares) and klipspringer (red squares) within camera trap stations

Rock hyraxes were recorded on 16 camera traps with total number of 159 events (Figure 13).

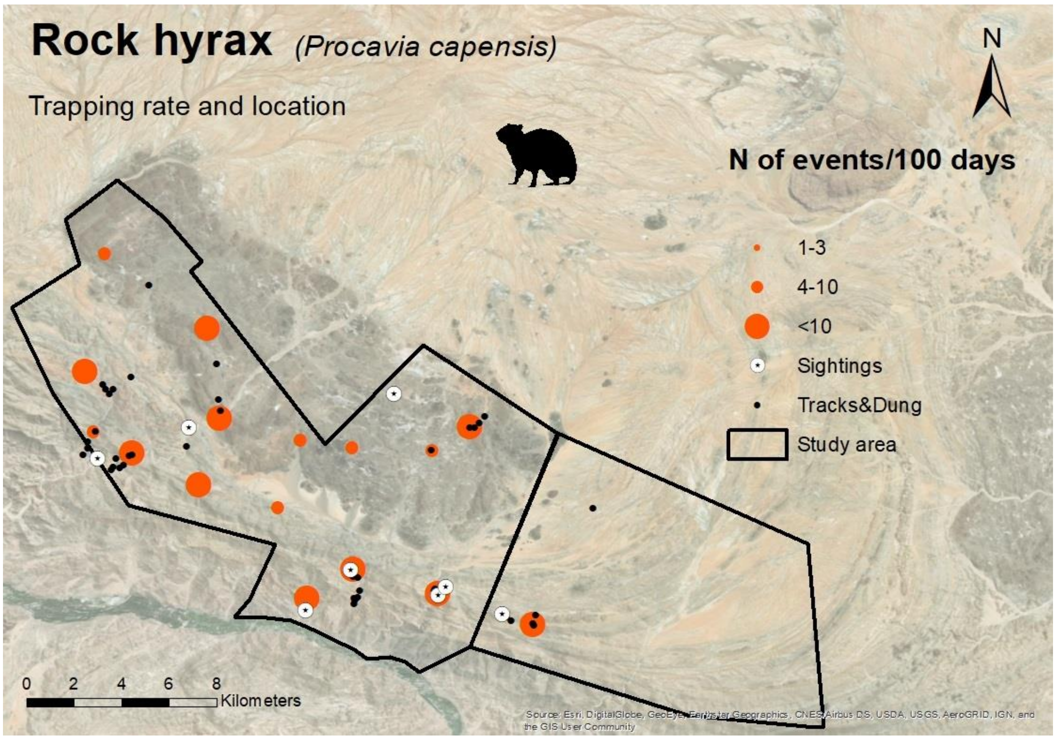

Figure 13. Distribution of rock hyrax within the study area

They co-occurred with leopard on 12 stations and on 4 stations were the hyraxes present alone. Remaining 4 camera traps did not show presence of hyraxes (Figure 14).

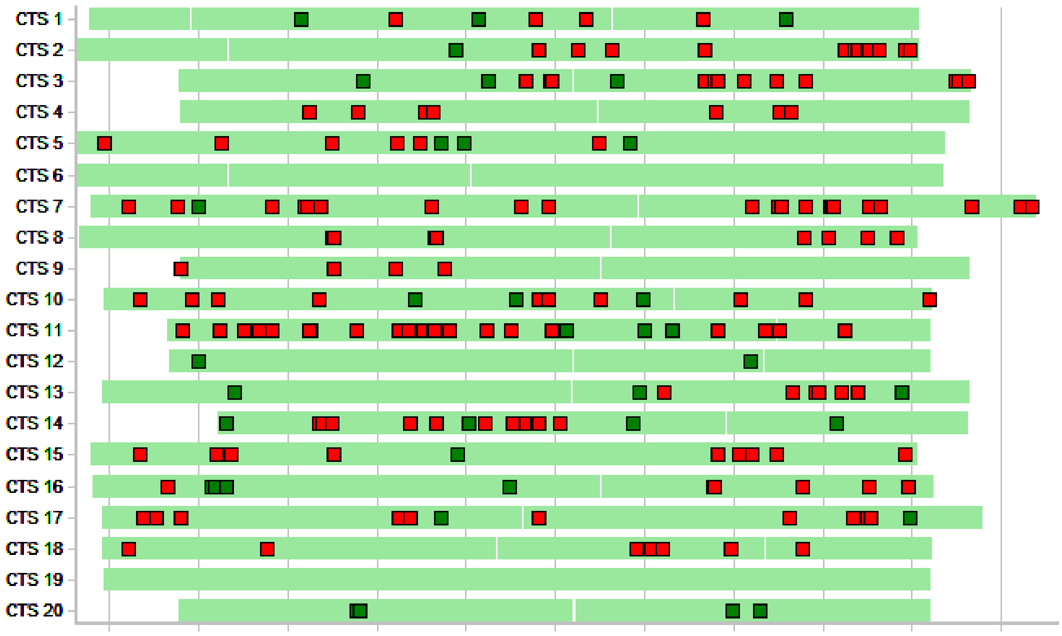

Figure 14. Co-occurrence of leopard (green squares) and rock hyraxes (red squares) within camera trap stations

Leopard overlapped on 60% of all camera trap stations equally with both the klipspringers and the rock hyraxes. Those were the second highest overlap measures. The highest overlap with leopard is performed with mongooses on 70% of camera trap stations.

Most significant overlap results between leopard and other species are presented in Table 5 below and complete overview is in Appendix 4.

Table 5. Spatial overlap between leopard and first ten potential prey species

Species	Overlap with leopard
Mongoose	70%
Klipspringer	**60%**
Rock hyrax	**60%**
Red rock rabbit	45%
Honey badger	45%
Baboon	35%
Porcupine	30%
Mountain zebra	30%
Gemsbok	30%
Greater kudu	20%

4.3. Habitat use of leopard and potential prey species

From the habitat data collected we identified 5 following habitat types within camera traps and transects: RP (rocky plains), RPGR (rocky plains + grassland), RPSH (rocky plains + shrubland), SH (shrubland), GR (grassland). Table 3 shows how many of the twenty camera trap stations and transects each habitat type covered.

Table 6. Distribution of habitats across camera trap stations and transects

N of CTS and Transects / Habitat	RP	RPGR	RPSH	SH	GR
Camera Traps	10	2	8	0	0
Transects	11	0	8	14	9

From both the camera traps and transect data follows that leopard occurred mainly in rocky plains and slopes habitat. In smaller amount it also occurred within rocky plains covered by vegetation. Low number of dung and track records within the grassland suggest that leopard avoided these open landscapes.

Klipspringers and hyraxes showed similar habitat use pattern like the leopard. They predominantly occurred in rocky plains and slopes. In significantly smaller amounts they showed presence also in places with shrublands in proximity to rocks. Both did not occur in grasslands at all and hyraxes did not occur in habitats without presence rocky outcrops (Figure 15). Differences in habitat use by klipspringer, leopard and hyrax tested by chi-square test did not show any significant results. See the results of habitat use for all other species in separate tables in Appendix 5 and Appendix 6.

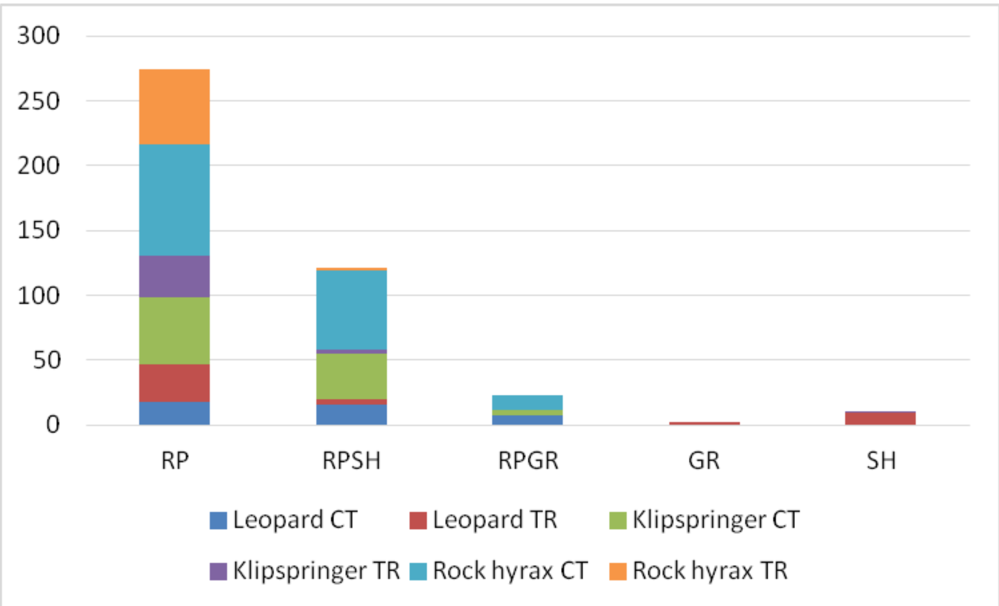

Figure 15. Habitat use by leopards, klipspringers and rock hyraxes within camera trap stations (CT) and transects (TR) based on N of camera trap events and transect observations per habitat type

4.4. Temporal activity and overlap

Leopards were active predominantly at night and showed significant activity during dawn and dusk. Activity peaks around 8pm, midnight and then around 6am. Daily activity occurred rarely (Figure 16).

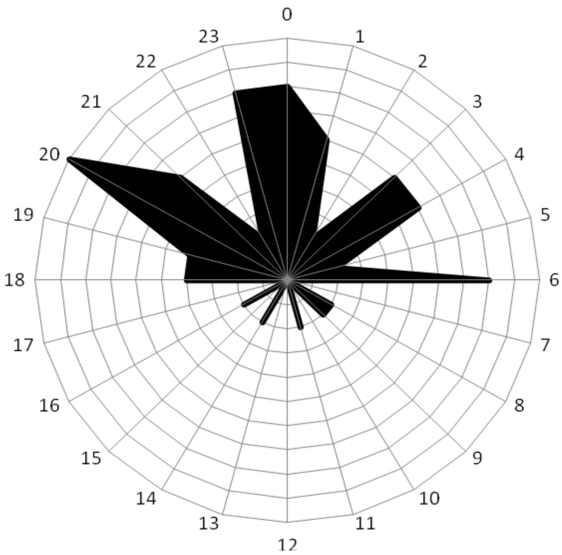

Figure 16. Temporal activity pattern of leopards

Klipspringers were active continuously from early morning with highest activity between 8-10am and then again between 5-6pm (Figure 17). Occasional events were recorded at night not only by camera traps but also by direct observations during night car transects.

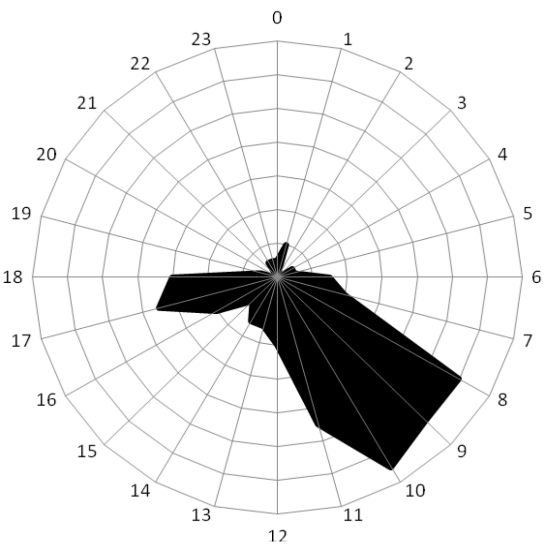

Figure 17. Temporal activity pattern of klipspringers

Growning and declining line of klipspringers activity traces the decreasing and growning patter of leopards (Figure 18). Activity of klipspringers peaks the most after 7am where the sharp decrease of leopard activity occurs and decreases significantly around 6pm simultaneously with the growing activity of leopards. Temporal overlap between leopard and klipspringer occurs mainly early in the morning between 6-7am and then again before nightfall around 7-8pm.

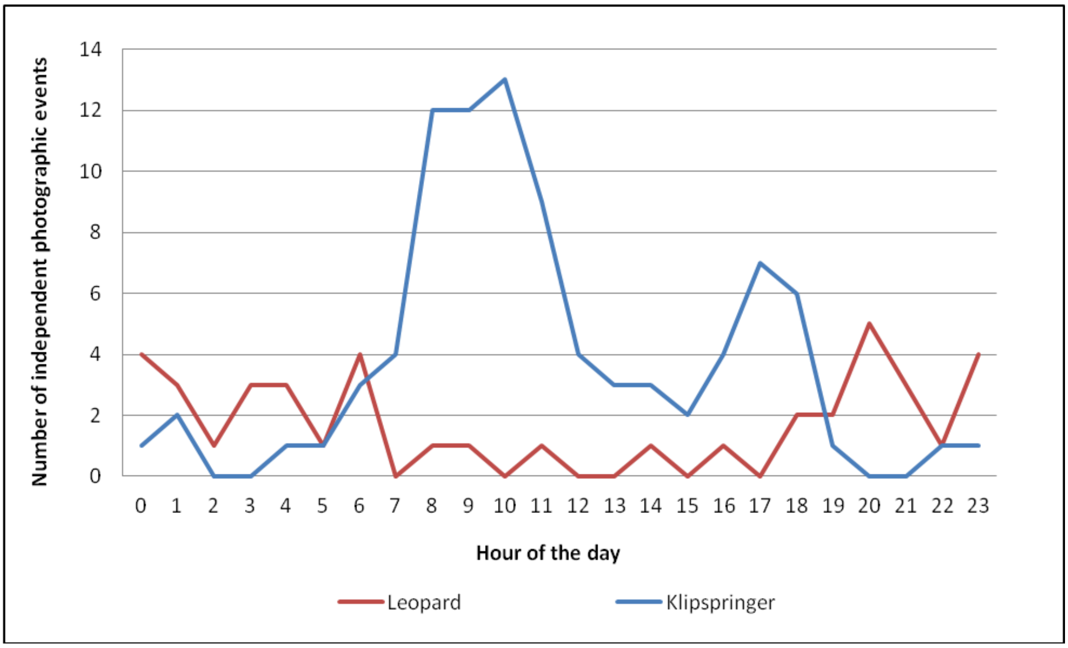

Figure 18. Visualization of activity interactions between leopards and klipspringers

Rock hyraxes showed strict diurnal activity starting and at the same time culminating at around 10am. From that point the activity lasted more or less constantly until dusk and between 5-6pm rapid considerable downturn occurred. After 6pm, the activity stopped completely (Figure 19).

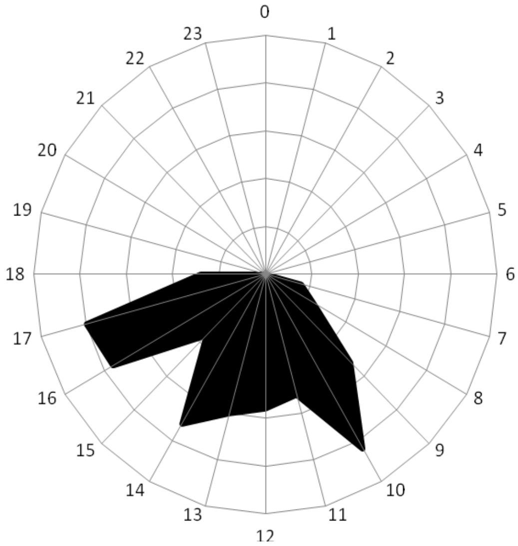

Figure 19. Temporal activity pattern of hyraxes

Activity of hyraxes started slowly increasing after the sharp decline of leopard activity (around 7am) and than again the activity of hyraxes decreased sharply around 5-6pm while the activity of leopards started to increase significantly. Activity pattern between leopard and hyraxes overlaped between 7-8am and again around 6pm (Figure 20).

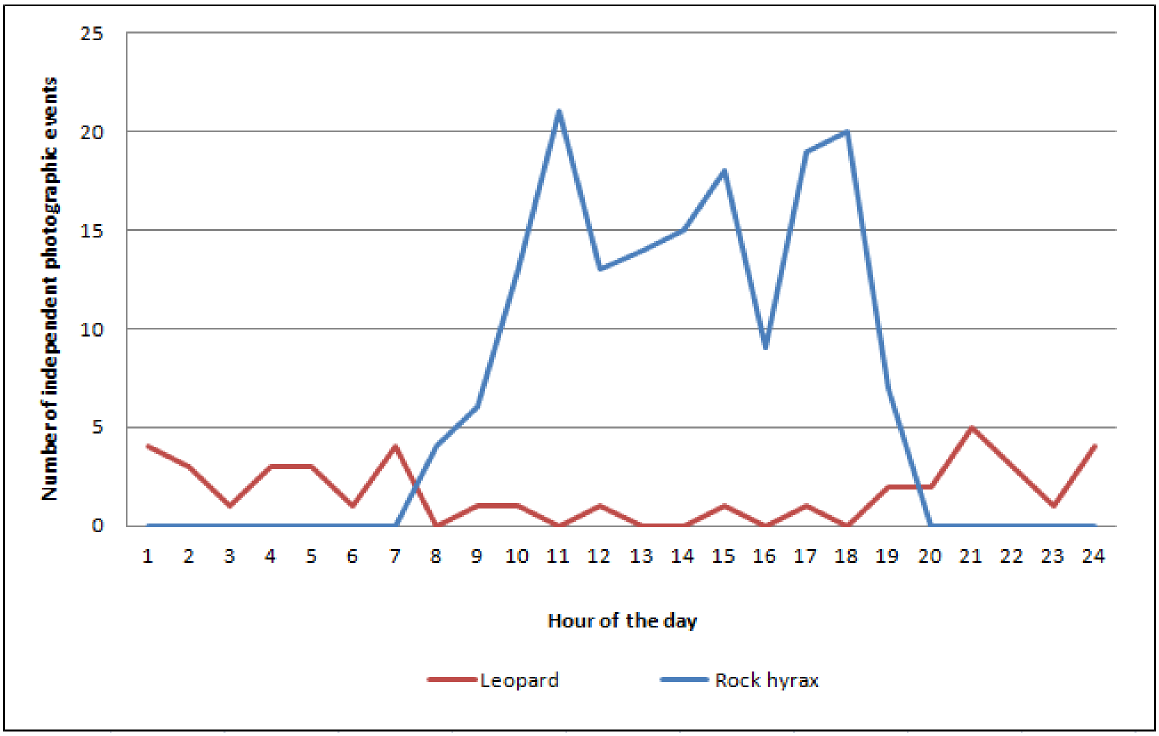

Figure 20. Visualization of activity interactions between leopards and hyraxes

Detailed overview of activity pattern of leopard and ten most detected species is in Table 7. Other species which were active mainly during the day were mongooses and chacma baboons. Greater kudus were recorded largely during the day but also at night in significant extent. Red rock rabbit and porcupine were active mainly at night. Honey badgers and large ungulates such as mountain zebras and gemsboks showed activity in similar degree at any time with no significant peak in particular part of the day.

Table 7. Activity of leopard and ten most detected species based on time of photographic capture

Species	**N of events**	**Crepuscular (%)**	**Diurnal (%)**	**Nocturnal (%)**
Leopard	**41**	**22%**	**12%**	**66%**
Mongoose	210	2%	98%	0%
Rock hyrax	**159**	**4%**	**96%**	**0%**
Klipspringer	**90**	**12%**	**81%**	**7%**
Red rock rabbit	70	37%	6%	57%
Gemsbok	28	32%	29%	39%
Honey badger	31	29%	39%	32%
Mountain zebra	27	33%	19%	48%
Chacma baboon	29	10%	90%	0%
Porcupine	25	24%	0%	76%
Greater kudu	24	13%	58%	29%

5. Discussion

Within two months data collection, camera traps and transects revealed presence of majority of the species which we expected to occur in the area according to the literature review (Griffin 1998) and field guides (Stuart 2013; Stuart & Stuart 2017). Camera traps were especially helpful in capturing elusive, nocturnal and solitary mammals which were difficult to observe during transects due to the mentioned behavioural characteristics, difficult tracking conditions (dry sandy soil, rocky outcrops) and limited tracking skills of our team. Although in small quantities, camera traps revealed presence of brown hyenas, black-backed jackals and small spotted genets, whose presence was not recorded during transects. On the other hand, camera traps did not collect evidence about the presence of springboks and springhares which were often observed especially during day and night car transects.

Final list of the 24 detected species does not contain bat-eared fox, caracal and vervet monkey but these are generally known to live on the farm. Species which are also potentially present in the KumKum Farm but with no evidence yet recorded are meerkats, cape fox and black-footed cat (Stuart 2013; Stuart & Stuart 2017).

Monitoring in the dry Karoo biome was very challenging and all the obstacles and future possibilities are discussed in following chapters. Nevertheless, both the camera traps and transects proved to be effective non-invasive methods in accessing the species diversity in the study area.

5.1. Prey Availability

Calculating prey abundance from transect observations data was not possible due to the lack of direct sightings of animals including large ungulates. That is caused by very low densities of species in the area and high vigilance behaviour which might be caused by the recent hunting history on the land and generally low habituation to movement of groups of people like tourists. Also the above mentioned ecology of other species including nocturnal, elusive and solitary behaviour influenced the low numbers of direct sightings.

Comparing trapping rates and occupancy between species captured by camera traps proved to be an alternative method in estimating relative potential prey abundance where the individuals could not be identified individually (Bailey et al. 2014, Stein et al. 2008). We assessed relative prey availability by comparing trapping rates between species captured by camera traps, abundance indexes values between species observed during transects and occupancy of camera trap stations and transects of each species (Martins 2010).

Mongooses were the most captured species by camera traps. That testifies to their great abundance in the rocky plain and slopes habitat where all the cameras were placed. Besides that, high number of events with mongooses was caused by their repeated visits and great interest in investigating the cameras. Conversely, due to the lack of direct and indirect observations of mongooses they appeared to be one of the least detected species within transects.

Tracking of large ungulates, which dominate the data sample from transects, was especially tricky in the Karoo biome because indirect signs of these species can remain in the dry environment for very long time and even though we avoided recordings of clearly old dung, it is taken in to consideration that part of the collected records might not have an actual corresponding value anymore. Numbers of species with highest indirect records like gemsboks and mountain zebras might be also overestimated due to the gaps in our tracking skills and causing biases by counting the same path as more individual records (Silveira et al.2003). However, according to the camera trap data gemsboks and mountain zebras also occur in the first ten of recorded species and belong to the most abundant species in the area. From negligible number of direct sightings and low number of camera trap events of common elands we assumed that their high position rank in transect data sample may be biased due to the high number of indirect signs records.

Unlike the previous species, klipspringer and hyraxes were clearly dominant in both of the data sets. High detectability by camera traps might be influenced similarly like with mongooses by placing the stations in the rocky habitat which is where these species mostly occur (Norton 1980; Sale 1966). Nevertheless, results from transects agreed with the camera traps results. Both klipspringers and hyraxes were also the most directly observed species during walking and car transects, besides springhares which will be discussed further. The risk of creating biases during indirect signs recordings was limited because tracks of both species always led as an individual path created across the riverbed from one side of the rocky slopes to the other when the animal needed to cross the riverbed. Moreover, klipspringers are using common latrines, so their dung was always found at one spot which prevented us from creating potential biases as well (Stuart & Stuart 2017). Almost no hyrax dung was recorded and most of the indirect signs correspond to the individual path tracks. Considering these factors, we assumed that the abundance evaluation of klipspringers and hyraxes was one of the most accurate comparing to the other potential prey species.

Camera traps and transects data served for comparison of relative species abundance but not for more detailed analysis. In the near future implementing animal census by modern UAV methods are expected to bring more accurate information about the availability and abundance of potential prey species on the KumKum Farm.

5.2. Spatial distribution and habitat use

Camera trap data collection was limited in terms of species distribution among various habitats because of the intentional placement of cameras in the riverbeds and rocky habitats. The primary aim of the camera trap survey on KumKum Farm was to gain information about the size of the local leopard population which is the focus of the on-going leopard project in the study area. Thus the camera plot was not designed to cover various habitats but to increase the probability of detection of leopards. For that reason transects were very useful for this study and they contributed largely with data about species distribution across the study area and in different habitats, especially grasslands and shrublands.

Resulting data from both sources are in mutual agreement. Most importantly, from both data sets clearly followed that leopards, klipspringer and hyraxes depended largely on the same habitat type – rocky plains and slopes. Klipspringers also used the shrublands and hyraxes proved to be strictly dependent on the rocks and crevices. Besides them, mongooses, porcupines and baboons showed prevailing distribution pattern within rocky habitats. Springhares which were mentioned as one of the most directly detected species did not occur in habitats adjacent to the rocky outcrops and concentrated all of their activity in shrublands and opened grassland. Other species present mainly in these habitats were springbok, steenbok and aardvark. These species, considering their size, could be a suitable prey item of leopard (Hayward et al. 2006). However, signs of leopard rarely occurred in open grasslands which goes in hand with other studies (Pitman et al. 2013; Balme et al. 2007).

The rocky plains and slopes are dominant habitat type in the area and in ongoing studies it would be useful to consider this factor in future attempts of categorizing the habitat. At first glance this rocky habitat seems to be uniform but taking in to account factors like slope angle, position of the rocks to the sun and altitude may bring valuable information for understanding the way that species living in these conditions distribute themselves among this specific habitat (Sale 1966).

As this study was conducted only during the winter season it was not needed to consider the seasonality. During the dry winter season when most of the vegetation was not visible, it was especially difficult to distinguish areas with considerable vegetation cover and important feeding grounds. Moreover, the ecosystem of KumKum Farm is currently still recovering after significant grazing pressure caused by intensive fencing from the recent times when the land used to be a hunting farm. During the data collection for this study, remaining fences had been removed and in a few years the landscape, vegetation mosaic and the associated spatial distribution of majority of species may change significantly.

However, data about animal distribution and their habitat use collected through Cyber Tracker provided meaningful information for this particular study. For future studies it is planned to use already mentioned UAV, which will bring more precise information about animal habitat preferences. In terms of leopards, efforts for collaring the first leopard with GPS collar are already in process and future data will hopefully bring more accurate and interesting information about the habitat use of leopard on the KumKum Farm.

5.3. Spatial overlap

Mongooses, klipspringers and rock hyraxes were species with which the leopard overlapped in space the most. Mongooses and small carnivores in general, are often mentioned as only secondary prey species of leopard and they only account for less than 1% of prey biomass (Martins 2010). Norton et al. (1986) concluded from scat analysis of leopards in Cederberg mountains in Cape Province that leopards did not hunt mongooses even when they were abundant in the area. Baboons were also overlapping in great amount with leopards but the evidence of predation of leopards on baboons in these regions are uncommon (Norton et al. 1986; Martins 2010) and leopards are known to hunt baboons mainly when other prey species are scarce (Hayward et al. 2006). Considering these previous findings from areas with similar habitat conditions, we suggested that even though mongooses were the most abundant species within the rocky habitat and had the highest overlap with leopards, they are probably not the preferred prey item of leopard. Other species which greatly overlapped with the leopard (honey badger, mountain zebra and gemsbok) are cited among studies as avoided species or species which were never hunted by leopard because they already present high injury risk for the leopard (Hayward et al. 2006). From that we suggested that these species do not need to consider the predation risk and that explains the high spatial overlap.

On the other hand, high spatial overlap with klipspringers and rock hyraxes clearly supports the prediction that these two species present the most important potential prey item within the study area. Moreover, during the pilot study one camera trap recorded picture of a leopard carrying dead klipspringer in his mounth. As already explained in literature review, studies conducted in the Karoo biome name these two species as the most important prey item of leopards (Norton et al. 1986; Druce et al. 2009; Brashares & & Arcese 2002; Gerdel 2008; Martins & Martins 2006; Sale 1966; Martins 2010). Red rock rabbits and porcupines are also known to be hunted by leopards in the Karoo and our spatial overlap results agree with that (Martins 2010; Norton et al. 1986).

Implementing scat analysis method for identification of the prey that leopard actually used would bring valuable information for comparison and continuation of this study. This approach was originally planned for this study but finding fresh scat suitable for analysis is extremely challenging in the given environment (Martins 2010; Weckel et al. 2006). Such data collection and analysis would need a lot of commitment and using effective methods for finding scats like for example detection dogs (Long et al. 2012). Finding fresh kill sites are also extremely difficult to locate. Future tracking of leopard with the GPS collar will significantly ease these tasks.

5.4. Temporal Activity

Leopards are generally known to be nocturnal, except those who live in forest ecosystems. However, in southern Africa females were found to be largely active during the day which was explained mainly by the presence and competition with other predators (Pitman et al. 2013). Norton et al. (1986) suggested that leopards in the mountainous areas in the Cape Province should hunt during daylight hours because of the entirely diurnal activity pattern of klipspringers and hyraxes. That was rejected by Martins (2010) who did a study on leopards in Cederberg mountains and concluded that leopards are mainly nocturnal and that they are hunting diurnal prey most actively during the darkest nights when the leopards take advantage of their perfect night vision. Our results confirm the latter conclusion as the leopards were active mainly during the night.

Activity pattern of rock hyraxes and klipspringer agreed with their description in the literature review. Rock hyraxes started to be largely active later in the morning after their basking routine (around 10am). That is when they spend time searching for food in the surrounding crevices and rocky slopes (Brown & Downs 2007). They continued to be active for the following hours and before dusk (between 5-6pm) their activity decreased significantly. Their activity pattern seemed to be perfectly adapted to the activity of the leopard. From the resulting temporal interaction between leopard and hyrax we suggested that hyraxes are intensively hunted by leopards on the KumKum Farm. Predatory behaviour of leopards on hyraxes in the Karoo is described more in detail in the literature review (Chapter 1.2.3). Klipspringers showed occasional activity during the night but similarly to hyraxes they seemed to largely adjust their activity to the presence of predators.

Activity of species which we already mentioned in the previous text as species avoided by leopards (springhares, zebras, gemsboks and honey badgers) were commonly active during the night which again contributes to the assumption that these species are not threatened by leopard.

Unfortunately our camera traps did not have the function of recording the lunar activity which could be an influential factor on the temporal activity pattern and behaviour of predators and prey (Kie 1999, Martins 2010).

6. Conclusion

Presented results brought the first basic insight about the interactions in space and time between leopard and its main potential prey species in the first half of the KumKum Farm in south-eastern Namibia. Spatial overlap and temporal activity evaluation based on camera traps with the contribution of transect survey proved to be useful tools in determining the most important potential prey species of leopards in the area and their habitat use. According to the literature review and our results we confirmed our prediction that the main potential prey species of leopard on the KumKum Farm are klipspringers and hyraxes. Both species proved to be abundant in the reserve, occurred solely in the rocky plains and slopes habitat that the leopards used predominantly as well, and both spatially overlapped with the leopards significantly.

This study gave a basic overview of potential prey availability in the first half of the area and future studies will deepen our knowledge with data collection by UAV drones and GPS collars. To access prey species that leopards actually used would be useful to implement leopard scat analysis although it would be a very challenging task due to the monitoring conditions in the Karoo biome. Future results from an ongoing survey focused on leopard-farmer conflict will reveal other important information about the leopard prey preferences on the farm and surrounding areas.

This thesis was conducted in the broader context of the leopard project realised by Ing. Viktor Neštický under the supervision of Dr. Karolína Brandlová. Initial interest for starting the leopard research on the KumKum Farm came from Dr. Peter van der Byl Morkel, one of the owners of the property. This thesis with attached map outputs and graphic representations of the distribution of the apex predator and main potential prey species can serve as helpful material for the future wildlife management on the KumKum Farm. On a broader scale this survey contributed to the overall research of leopard ecology living in the specific Karoo biome and to leopard research in general.

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Appendices

Appendix 1: Species list of expected and detected mammal species within the study area

Appendix 2: Full list of species detected by camera traps organized by highest trapping rate value

Appendix 3: Full list of species detected during transects organized by highest index of abundance value

Appendix 4: Spatial overlap between leopard and all species detected by camera traps

Appendix 5: Habitat use of species detected by camera traps, N of events per habitat type (%)

Appendix 6: Habitat use of species detected within transects, N of observations per habitat type (%)

Appendix 1: Species list of expected and detected mammal species within the study area

Common name	Latin name	Family	Camera traps	Transects
Aardvark	*(Orycteropus afer)*	Orycteropodidae	✓	✓
Aardwolf	*(Proteles cristatus)*	Hyaenidae	✓	✓
African wild cat	*(Felis silvestris lybica)*	Felidae	✓	✓
Bat-eared fox	*(Otocyon megalotis)*	Canidae	x	x
Black-backed jackal	*(Canis mesonelas)*	Canidae	✓	x
Black-footed cat	*(Felis nigripes)*	Felidae	x	x
Brown hyena	*(Hyaena brunnea)*	Hyaenidae	✓	x
Cape fox	*(Vulpes chama)*	Canidae	x	x
Cape hare	*(Lepus capensis)*	Leporidae	✓	✓
Cape porcupine	*(Hystrixafricaeaustralis)*	Hystricidae	✓	✓
Caracal	*(Caracal caracal)*	Felidae	x	x
Chacma baboon	*(Papio ursinus)*	Cercopithecidae	✓	✓

Common eland	*(Tautotragus oryx)*	Bovidae	✓	✓
Gemsbok	*(Oryx gazella)*	Bovidae	✓	✓
Greater kudu	*(Tragelaphus strepsiceros)*	Bovidae	✓	✓
Honey badger	*(Mellivora capensis)*	Mustelidae	✓	✓
Klipspringer	*(Oreotragus oreotragus)*	Bovidae	✓	✓
Leopard	*(Panthera pardus)*	Felidae	✓	✓
Meerkat	*(Suricata suricatta)*	Herpestidae	x	x
Mongoose	*(Herpestes spp.)*	Eupleridae	✓	✓
Mountain zebra	*(Equus zebra hartmannae)*	Equidae	✓	✓
Red hartebeest	*(Alcelaphus buselaphus caama)*	Bovidae	✓	✓
Red rock rabbit	*(Pronolagus rupestris)*	Leporidae	✓	✓
Rock hyrax	*(Procavia capensis)*	Procaviidiae	✓	✓
Small-spotted genet	(Genetta genetta)	Viverridae	✓	x
South African springhare	*(Pedetes capensis)*	Pedetidae	x	✓

Springbok	*(Antidorcas marsupialis)*	Bovidae	x	✓
Steenbok	*(Raphicerus campestris)*	Bovidae	✓	✓
Striped polecat	*(Ictonyx striatus*)	Mustelidae	✓	✓
Vervet monkey	*(Chlorocebus pygerythrus)*	Cercopithecidae	x	x

Appendix 2: Full list of species detected by camera traps organized by highest trapping rate value

Species	Number of statinons	% of all stations	Number of events	% of all wildlife events	Trapping rate
Mongoose	19	95%	210	27,2%	16,86
Rock hyrax	16	80%	159	20,6%	12,04
Klipspringer	17	85%	90	11,7 %	7,1
Red rock rabbit	14	70%	70	9 %	5,37
Leopard	14	70%	41	5,3 %	3,37
Gemsbok	8	40%	28	3,6 %	2,32
Honey badger	11	55%	31	3,9%	2,21
Mountain zebra	9	45%	27	3,5 %	2,19
Chacma Baboon	8	40%	29	3,7%	2,09
Porcupine	11	55%	25	3,2 %	2,05
Greater kudu	7	35%	24	3,1 %	1,81
Cape hare	1	5%	8	1%	0,66
African wild cat	6	30%	7	0,9%	0,49
Small spotted genet	2	10%	5	0,6%	0,41

Striped polecat	3	15%	4	0,5%	0,33
Black backed jackal	2	10%	3	0,4%	0,25
Brown hyena	3	15%	3	0,4%	0,25
Common eland	2	10%	3	0,4%	0,25
Aardvark	1	5%	2	0,3%	0,17
Aardwolf	1	5%	1	0,1%	0,08
Red Hartebeest	1	5%	1	0,1%	0,08
Steenbok	1	5%	1	0,1%	0,08

Appendix 3: Full list of species detected during transects organized by highest index of abundance value

Species	Number of transects	% of all transects	N of D OBS.	% of all D observation	N of IND OBS.	% of all IND observation	Index of abundance
Gemsbok	14	70%	4	6,6%	218	56,9%	11,1
Mountain zebra	13	65%	2	3,3%	194	23,2%	9,8
Greater kudu	13	65%	4	6,6%	128	15,3%	6,6
Rock hyrax	11	55%	8	13,3%	52	6,2%	3
Common eland	9	45%	1	1,6%	46	5,4%	2,25
Leopard	11	55%	0	0%	44	5,3%	2,2
Klipspringer	16	80%	12	20%	24	2,86%	1,8
Chacma Baboon	9	45%	0	0%	31	3,7%	1,55
Cape hare	11	55%	7	11,6%	20	2,4%	1,35
Springbok	3	15%	3	5%	20	2,3%	1,15
Springhare	5	25%	2	20%	8	0,9%	1
Aardvark	5	25%	0	0%	17	2%	0,85
Porcupine	3	15%	0	0%	13	1,5%	0,65
Steenbok	5	25%	1	1,6%	9	1,1%	0,5
Mongoose	2	10%	0	0%	4	0,4%	0,2
Red rock rabbit	3	15%	2	3,3%	1	0,12%	0,15

African wild cat	2	10%	1	1,6%	1	0,1%	0,1
Striped polecat	2	10%	0	0%	2	0,2%	0,1
Honey badger	1	5%	0	0%	1	0,1%	0,05
Aardwolf	1	5%	0	0%	1	0,1%	0,05
Red Hartebeest	1	5%	0	0%	1	0,1%	0,05

Appendix 4: Spatial overlap between leopard and all species detected by camera traps

Species	Overlap with leopard
Mongoose	70%
Klipspringer	60%
Rock hyrax	60%
Red rock rabbit	45%
Honey badger	45%
Baboon	35%
Porcupine	30%
Mountain zebra	30%
Gemsbok	30%
Greater kudu	20%
African wild cat	10%
Small spotted genet	10%
Striped polecat	5%
Black – backed jackal	5%
Common eland	5%
Aardvark	5%
Cape hare	5%
Red hartebeest	5%
Steenbok	5%

Aardwolf	0%
Brown hyena	5%

Appendix 5: Habitat use of species detected by camera traps, N of events per habitat type (%)

RP (rocky plains and slopes), RPGR (rocky plains + grasslands), RPSH (rocky plains + shrublands)

Species / Habiat	RP	RPGR	RPSH
Aardvark	0%	0%	100%
Aardwolf	0%	0%	100%
Black backed jackal	0%	0%	100%
Brown hyena	0%	0%	100%
Cape hare	0%	100%	0%
Common eland	0%	33%	67%
Red hartebeest	0%	100%	0%
Steenbok	0%	0%	100%
Porcupine	16%	56%	28%
Small spotted genet	20%	80%	0%
Chacma baboon	24%	10%	66%

Honey badger	32%	23%	45%
Gemsbok	32%	21%	47%
Mountain zebra	37%	4%	59%
Mongoose	39%	28%	33%
Red rock rabbit	40%	13%	47%
African Wild Cat	43%	28%	29%
Leopard	44%	22%	34%
Striped polecat	50%	0%	50%
Rock hyrax	54%	8%	38%
Klipspringer	56%	7%	37%
Greater kudu	57%	37%	13%

Appendix 6: Habitat use of species detected within transects, N of observations per habitat type (%)

RG (rocky plains + grassland), SH (shrubland), RP (rocky plains and slopes), RPSH (rocky plains + shrublands)

Species / Habitat	RG	SH	RP	RPSH
Aardvark	8%	77%	15%	0%
Aardwolf	0%	100%	0%	0%
African Wild Cat	0%	0%	100%	0%
Black backed jackal	0%	0%	0%	0%
Cape hare	14%	50%	29%	7%
Common eland	13%	41%	46%	0%
Greater kudu	13%	67%	0%	20%
Honey badger	0%	0%	100%	0%
Chacma baboon	0%	26%	58%	16%
Klipspringer	0%	13%	67%	20%

Leopard	6%	30%	52%	12%
Mongoose	0%	0%	100%	0%
Mountain zebra	8%	41%	48%	3%
Gemsbok	4%	25%	65%	6%
Porcupine	0%	22%	78%	0%
Red hartebeest	0%	0%	100%	0%
Red rock rabbit	0%	50%	50%	0%
Rock hyrax	0%	0%	92%	8%
Small spotted genet	0%	0%	0%	0%
Springare	37%	63%	0%	0%
Springbok	20%	75%	5%	0%
Steenbok	30%	70%	0%	0%
Striped polecat	0%	100%	0%	0%