Sveriges lantbruksuniversitet
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Animal Sciences

Activity patterns and livestock depredation by cheetahs (*Acinonyx jubatus*), leopards (*Panthera pardus*) and jackals (*Canis mesomelas*) within Ol Pejeta Conservancy – where, why and when?

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Abstract

The widespread and severe conflict between humans and wildlife is one of the most critical threats for the survival of many wildlife species today. The increasing human population growth have along with habitat loss, fragmentation, prey depletion and persecution led to extensive declines in many large carnivores. Further are many carnivores considered as great threats to human interests and security and it is therefore urgent to identify suitable mitigation strategies taking both human interests and carnivore survival into account. This can be obtained by studying carnivore behaviour to gain valuable knowledge regarding activity and depredation patterns to better understand crucial periods when carnivore activity is higher. The main objective in this study was to examine general activity patterns in a fenced reserve by three carnivores of importance: cheetahs (*Acinonyx jubatus*), leopards (*Panthera pardus*) and black-backed jackals (*Canis mesomelas*), due to their repeated involvement in human-wildlife conflicts. Potential relationships between three environmental variables (moon phase, temperature and rainfall) and activity patterns were also examined. Lastly was depredation by these predators mapped and interviews were performed with concerned herders. The study was conducted in the private reserve Ol Pejeta Conservancy, Laikipia district, Kenya. Activity and movement patterns were analyzed using camera traps at two out of three wildlife corridors placed along the northern boundary while depredation was mapped using available data on site. Interviews were performed in field during a fieldtrip in November 2016. The results revealed a low presence of both cheetahs and leopards as for why statistical analysis were only performed on the environmental variables in relation to jackal activity. Activity patterns revealed an overlap between cheetah and jackal activity but with an exclusively nocturnal activity in leopards. Moon phase and temperature were found not to have any effect on jackal activity but a significant negative relationship could be seen between jackal activity and rainfall. Increased activity during dry periods could potentially derive from competition or predator avoidance by black-backed jackals but presumably is activity patterns more regulated by prey availability and perhaps mate search. Results from depredation analysis indicated that depredation is unaffected by environmental factors and that attacks presumably occurs randomly in an opportunistic way, especially when prey availability is low. Despite low sample size did the results also reveal a high percentage of attacks occurring both in proximity to water, during night and in the Sirrima-area, referred to as predator free. My results therefore implies that the human-carnivore conflict can be mitigated at Ol Pejeta by being extra cautious when grazing cattle in the Sirrima area or other areas near water, especially at night during dry seasons when there is a high abundance of calves in the herds.

Sammanfattning

Den omfattande och svåra konflikten mellan människor och vilda djur är ett av de allvarligaste hoten för många arters överlevnad idag. Den växande mänskliga populationen tillsammans med habitatförlust, fragmentering, minskad bytestillgång och förföljelse har lett till en omfattande minskning av många stora rovdjur idag. Många rovdjur anses utgöra ett stort hot mot mänskliga intressen och säkerhet och det är därför brådskande att finna lämpliga lösningar som tar både mänskliga intressen och rovdjurens överlevnad i beräkning. Det kan uppnås genom att studera rovdjurens beteende för att erhålla viktig information om när rovdjuren uppvisar högre aktivitet eller när risken för boskapsattacker är större. Målet med studien var att i ett stängslat reservat undersöka generella aktivitetsmönster hos tre viktiga rovdjur: gepard (*Acinonyx jubatus*), leopard (*Panthera pardus*) och schabrakschakal (*Canis mesomelas*) på grund av deras upprepade konflikter med människor. I studien undersöktes också ifall tre olika miljöfaktorer (månfas, temperatur och nederbörd) kunde kopplas till dessa aktivitetsmönster. Slutligen var attacker av dessa rovdjur kartlagda och intervjuer med berörda herdar utfördes. Studien utfördes i privatreservatet Ol Pejeta i Laikipia distriktet, Kenya. Aktivitets- och rörelsemönster analyserades med hjälp av kamerafällor från två av tre korridorer placerade längs reservatets norra gräns medan attacker kartlades genom att använda tillgänglig data på plats. Intervjuer utfördes i fält under en fältresa i november 2016. Resultatet visade på en låg närvaro av både gepard och leopard varför miljöfaktorerna endast testades i relation till aktiviteten hos schakaler. Analyserna avslöjade ett överlappande aktivitetsmönster mellan gepard och schakal men med en uteslutande nattlig aktivitet hos leopard. Ingen effekt av månfas eller temperatur på schakalernas aktivitet kunde hittas men ett signifikant negativt samband kunde ses mellan nederbörd och aktivitet. Ökad aktivitet under torra perioder kan härstamma från konkurrens eller undvikandet av andra rovdjur men troligen är mönstret till större delen reglerat av bytestillgång eller partnersök. Resultat från analys av rovdjursattacker indikerade att boskapsattacker är oberoende av väder och att attackerna förmodligen sker slumpvis ur en opportunistisk synvinkel, framförallt när bytestillgången är låg. Även om datamängden var bristfällig indikerade mönstret att attackerna sker både i närheten till vatten, på natten samt i Sirrima området, vidare hänvisat som rovdjursfritt. Mina resultat visar därför att konflikten mellan rovdjur och människor på Ol Pejeta kan förmildras genom att vara extra uppmärksam när boskapen betar inom Sirrima området, i närheten av vatten, under natten - framförallt under torrperioder och när det finns en stor tillgång på kalvar i hjordarna.

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1. Introduction

1.1. Human-wildlife conflict

The widespread and severe conflict between people and wildlife is one of the most critical threats to the survival of many wildlife species today (Dickman 2010). The increasing human population growth brings pressure on the remaining natural habitats and their resources through habitat conversion and commercial exploitation (Kolowski & Holekamp 2006), with more conflicts between humans and wildlife as a consequence (Bulte & Rondeau 2005, McCleery 2009). The conflict has had fundamental impacts on natural ecosystems and continues to have. These impacts reach beyond the extent of ecosystem reconstructions to extermination of local populations, habitat destruction and even extinction of species (Woodroffe *et al*. 2005). Carnivores in particular are greatly exposed to conflicts due to their dietary requirements (Inskip & Zimmermann 2009) and can be seen as great threats to human interests and security (Treves & Karanth 2003). Globally, many large predators are seen as flagship species and are of great conservation concern and efforts are made to maintain viable populations in the wild. At a lower and more local level they are however not as popular and not desirable in proximity to human settlements (Woodroffe *et al*. 2005). Large carnivores furthermore show low reproductive rates and usually occur at low densities (Purvis *et al*. 2000) and protected areas are seldom large enough to maintain viable carnivore populations (Linnell *et al*. 2001). Non-protected areas are therefore of great importance for large carnivore conservation (Funston *et al*. 2013), but human-carnivore conflicts frequently occur and retaliatory killing is common (Swanepoel *et al*. 2014). Lately, an increasing amount of research on human-wildlife conflicts has been conducted to better understand the underlying factors of these occurrences and to find suitable mitigation strategies (Dickman 2012). Even though research is in progress, solutions that benefits both humans and wildlife are rare (Ripple *et al.* 2014) and many large carnivores keep declining throughout the world despite the actions taken.

1.2. Conservation of cheetah, leopard and black-backed jackal

The African continent is widely known for its immense biodiversity and is home to approximately a quarter of the world's mammals (UNEP 2016). The last intact carnivore guild can only be found here (Dalerum *et al*. 2009) but many carnivores keep declining throughout Africa, largely due to human actions (Koziarski *et al*. 2016) and the need for successful conservation strategies is urgent.

Two large carnivores of great conservation concern are the African cheetah (*Acinonyx jubatus*) and the African leopard (*Panthera pardus*). The species show declining populations, partly caused by their repeated involvement in conflicts with humans. Magnitude of conflict can furthermore increase with felid body mass, showed by Inskip & Zimmermann (2009), where 37 felids were categorized based on their conflict status in relation to size. Cheetahs were categorized to cause 'moderate' conflicts while leopards caused 'severe' conflicts. Both species are declining across their range similar to other large predators due to habitat loss and fragmentation, prey depletion, poaching, trophy hunting and other anthropogenic threats (Jacobson *et al.* 2016). Cheetahs furthermore suffer from low genetic diversity which is believed to derive from one or several bottleneck effects from the Pleistocene epoch (Dobrynin *et al*. 2015). Cheetahs are also victims of high cub mortality, which can be as high as 90 percent, due to predation by other predators (Durant 2000, Mills & Mills 2014) and they are highly exposed to the illegal pet trade (IUCN 2014a). Both species are today listed on the IUCN Red List of Endangered Species where cheetahs are classified as Vulnerable (VU) and leopards as Near Threatened (NT), although all global leopard populations are declining (IUCN 2015, 2014a).

Another carnivore of interest is the black-backed jackal (*Canis mesomelas*), not for its great conservation concern but due to the conflict status with humans. The species is not considered threatened and is classified as Least Concern (LC) by the IUCN Red List of Endangered Species. However, black-backed jackals are highly exposed to persecution due to depredation on livestock and their image as rabies vectors (Loveridge & Macdonald 2001) but the population trend is stable and without severely fragmented populations (IUCN 2014b). Despite the importance of mesopredator surpression by apex predators (Prugh *et al.* 2009, Ripple *et al*. 2014, Ritchie & Johnson 2009) they still fill an important function within their ecosystems and it remains vital to keep the species under monitoring in order to preserve a healthy population.

1.3. Wildlife activity patterns and predator-prey interactions

All wildlife species constantly move between areas or even different habitats in response to intrinsic physiological factors and specific requirements such as exploiting patchy resources (e.g. food availability, potential mates or water supply) or to avoid constraints such as predation (Baker 1996) or competition (Durant 2000). Prey response to these requirements can furthermore influence carnivore activity since predators can move in search of patchy prey resources (Lima 2002). Activity and movement patterns among predators can thereby differ greatly depending on prey availability. Seasonal migrations are a common pattern for many terrestrial herbivores, including wildebeests (*Connochaetes taurinus*), zebras (*Equus burchelli*) and Thomson's gazelles (*Eudorcas thomsonii*) (Strauch 2013), due to limited grazing opportunities and nutritional quality. Seasonal migrations and other movements can thereby locally reduce prey availability (Allen *et al*. 2014) which can lead to greater carnivore movement or predation on other prey (Bissett *et al.* 2012) However, not all ungulates migrate in order to find new grazing grounds and several species such as Grant's gazelle (*Nanger granti*) and impala (*Aepyceros melampus*) can switch from grazing to browsing locally rather than migrating (Schuette *et al.* 2016). These adaptions can further influence carnivore behaviour due to prey availability. The activity pattern of cheetahs, leopards and black-backed jackals are therefore greatly depending on available prey and specific prey species. Especially for cheetahs which do not show as wide ranged diets as leopards (Hayward *et al.* 2006) and jackals (Van de Ven *et al*. 2013). Interspecific competition (Caro & Stoner 2003), human activity and persecution (Belton *et al.* 2016, Ordiz *et al.* 2014) are other factors that can affect carnivore activity. Environmental variables such as moonlight (Broekhuis *et al*. 2014, Heurich *et al*. 2014, Prugh & Golden 2014), rainfall (Durant *et al.* 2004, Marker & Dickman 2005), seasons (Manfredi *et al*. 2011), vegetation cover (Cooper *et al*. 2007, Schuette *et al*. 2016), wind orientation and time of day (Funston *et al.* 2001) can have impact on carnivore behaviour and carnivore hunting success. Cheetahs have also shown to be greatly influenced by reproductive status (Cooper *et al*. 2007).

1.4. Activity patterns of cheetahs, leopards and black-back jackals

Both cheetahs and leopards are wide-ranging species but differ greatly in adaptation abilities. Cheetahs are a subordinate species to larger predators, especially lions and spotted hyenas due to competition over similar prey resources (Broekhuis *et al*. 2014). Cheetahs further have the competitive disadvantage of being both smaller and predominantly solitary which makes them avoid larger competitors such as lions, hyenas and even leopards (Durant 1998). Many cheetahs therefore tend to inhabit areas with lower densities of larger predators, which usually lie outside protected areas and they frequently fall inside agricultural land (Winterbach *et al*. 2014). The widespread lack of larger carnivores and provision of artificial waterholes in combination with high abundance of prey make commercial farmland a preferred refuge for cheetahs (Marker *et al*. 2008) which can lead to a greater activity in areas with high predator densities. Cheetahs are also predominantly diurnal (Cozzi *et al.* 2012) opposite many of the larger, nocturnal felids (Broekhuis *et al.* 2014). Leopards on the other hand are more highly adaptive felids and not as subordinate against other large predators (de Ruiter & Berger 2001, Stein *et al*. 2015). This allows them to persist in a great variety of habitats from areas with high predator densities to areas where other large predators have been excluded due to human activity (Jacobson *et al*. 2016). Due to this ability they often tend to inhabit areas greatly modified by humans or in close contact with human settlements (Pitman *et al*. 2013) where they might attack livestock (Constant *et al*. 2015, Kissui 2008, Rust & Marker 2014).

Jackals, opposite to cheetahs and leopards, are mesopredators (Potgieter *et al*. 2016) and are often described as highly adaptive (IUCN 2014b) and opportunistic mesopredators (Kaunda & Skinner 2003). Jackals have expanded their range in agricultural areas where other mesopredators have perished due to human expansion (Kaunda & Skinner 2003). In these areas can they influence livestock and game farming by depredation (Plessis *et al.* 2015) and are thus considered as a problem species for many farmers (Humphries *et al*. 2016). Since both cheetahs and leopards show declining populations together with a high exposure to human-carnivore conflicts for all three species is there a need to further examine activity patterns by these predators. This in order to gain valuable knowledge regarding when the predators exhibit greater activity.

1.5. Study background

This study took take place at Ol Pejeta Conservancy in Laikipia, Kenya, and focused on the activity and movement patterns of cheetahs, leopards and black-backed jackals and furthermore mapped depredation within Ol Pejeta by these predators. Cheetahs, leopards and jackals together with the remaining large predators are seen as “problem species” within Africa due to depredation on livestock (Woodroffe *et al*. 2006). Kenya is furthermore a region with several global biodiversity hotspots (Habel *et al*. 2016) but an increasing amount of rangeland is converted into farmland and an increasing population of approximately 47 million people (World Population Review 2016) threatens the remaining wildlife. The need for suitable conservation strategies is therefore urgent and studying carnivore behaviour is important to gain knowledge valuable for mitigating the severe human-wildlife conflict. Furthermore does the Laikipia county benefit from tourism due to a large proportion of wildlife conservancies and ranches with numerous and diverse large mammals. This makes Laikipia considered one of Kenya’s best regions for safaris which also indicates the importance of preserving wildlife within this area. Ol Pejeta Conservancy in particular is convenient for studying carnivore behaviour due to high mammal density, great species diversity and large proportions of the larger carnivores (e.g. lions, spotted hyenas, leopards, cheetahs and African wild dogs (*Lycaon pictus*). The reserve is maintained by a 120 km electric fence as protection against poaching but also for reducing depredation in surrounding villages (Ol Pejeta Conservancy 2016). Three openings in the fence, referred to as “wildlife corridors”, are placed along the northern boundary which allow wide-ranging species, such as elephants (*Loxodonta africana*) and African wild dogs, to migrate to neighboring ranches and other conservancies. These corridors are furthermore equipped with motion detection cameras which allow studies of animal movement across the northern border. The high number of predators and herders with domestic cattle within the reserve in combination with the camera traps allow great opportunities for studying carnivore behaviour within this region.

1.6. Aim and objectives

The general objective of this study was to examine activity patterns and depredation by the African cheetah, African leopard and black backed-jackal within the Ol Pejeta Conservancy. The aim of this study was to examine when activity was higher and if this could be correlated with time of day or any environmental variable (i.e. moon phase, rainfall, temperature) and furthermore if the activity could be linked to specific individuals. Another aim of the study was also to map depredation by the focal species within Ol Pejeta. Lastly was it of interest to interview herders with livestock attacks during the study period.

I asked the following questions:
i) Is there a difference between the corridors in the amount of passages?
ii) When is there an increased activity and can this be correlated to any environmental variables (i.e. moon phase, rainfall and temperature) or time of day?
iii) Are some individuals more present in the corridors than others (i.e. cheetahs, leopards)
iv) Is there any correlation between depredation and the same environmental variables?

2. Methods

2.1. Study site

The study was conducted in Ol Pejeta Conservancy (0º00 N, 37º00 E), a 360 km^2 (90,000 acre) non-profit wildlife conservancy in Laikipia County, Kenya (figure 1).The study site is divided into five types of habitat with open bush land as the dominating habitat (Ol Pejeta Conservancy 2016) with low annual rainfall. Two rain seasons occur throughout the year with a longer rain season reaching from late April to the beginning of June and a shorter season in October to December. The Ol Pejeta Conservancy is furthermore located on the equator which allow sunrise and sunset to differ insignificantly throughout the year. Sunrise usually occurs between 06:10-06:40 and sunset between 18:20-18:50 which gives approximately 12 hours of daylight and an equal amount of darkness. The conservancy is maintained by a 120 km electric fence with the exception of three corridors along the northern boundary which allows connection to the greater Laikipia-Samburu ecosystem. These corridors (figure 2) allow all animals except highly exposed rhinoceros to move in and out of the reserve, especially important for migrating species. The corridors differ in size, with corridor 1 being 183 m while the other two being 34 m each, and consist of several posts reaching almost a meter above ground and are placed with an interval of 55 cm. These corridors are furthermore equipped with in total 10 motion detection cameras which were used in this study. The conservancy has current population of around 28 cheetahs, 20 elusive leopards and a numerous amount of black backed jackals (Ol Pejeta Conservancy 2016)

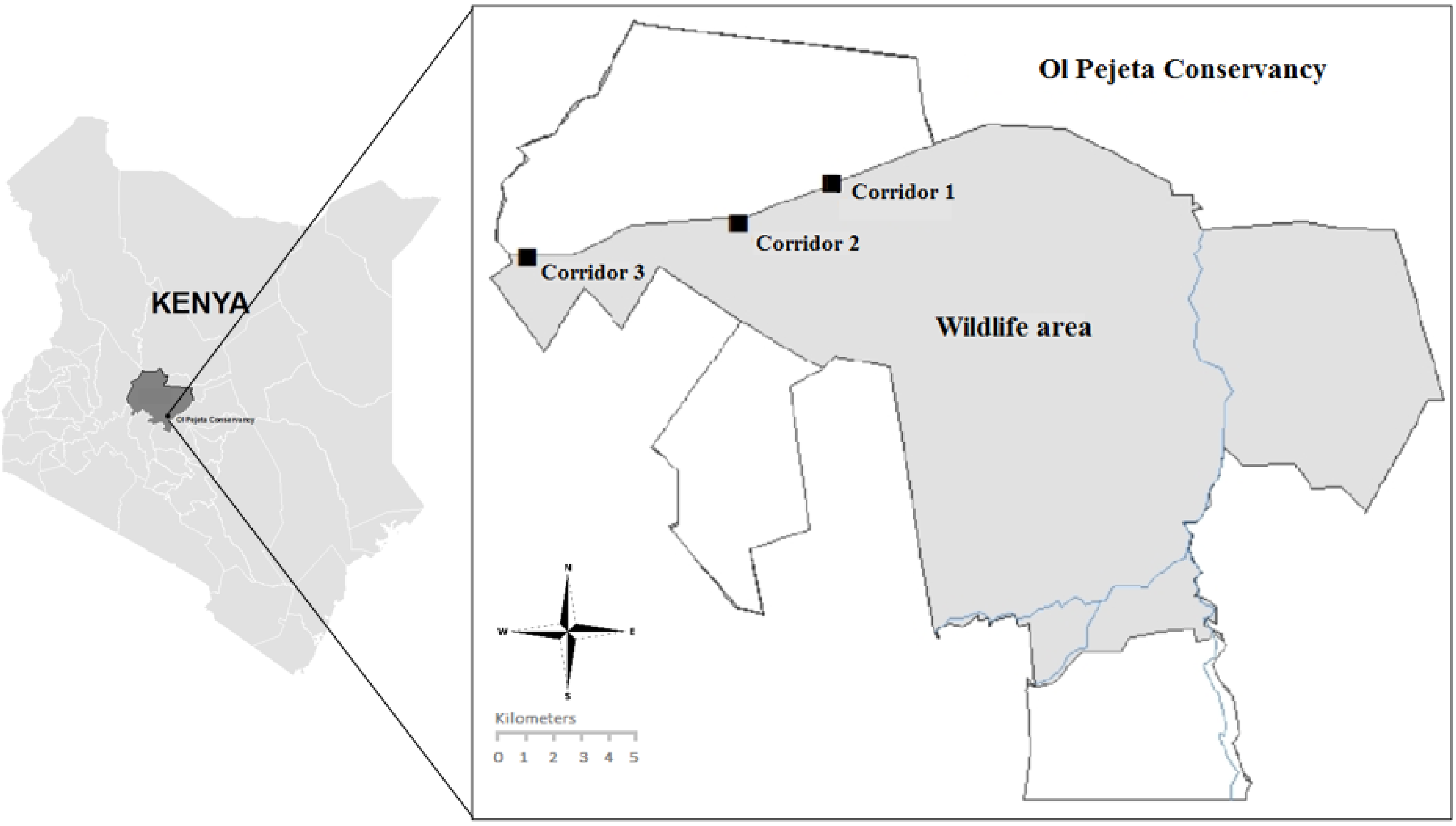

Figure 1: Map over Kenya with Laikipia district highlighted in dark grey and Ol Pejeta Conservancy. All three wildlife corridors are marked along the northern boundary of the reserve.

2.2. Data collection

2.2.1. *Camera traps*

Three different methods were used in this study (i.e. camera traps, mapping depredation and field interviews) for which the camera traps represented the main method. The data collection from the camera traps consisted of collecting images of the focal species taken by the motion detection cameras previously set up at the three wildlife corridors. Images were taken with Reconyx HC600 Hyperfire cameras which allow a detection range up to 24 m at daytime but are limited by a flash range of 18 m during night. The cameras are active 24 hours a day and take between 3-5 pictures per session and with 1-5 seconds between sessions when an animal, or human, approaches the corridor. The cameras furthermore register date, time of day, temperature and moon phase. Corridor 2 and 3 each have three camera traps set up (A, B and C) (figure 3) while corridor 1 have four (A, B, C & D) due to its extensive size. Further was a Maasai village located directly north-east of corridor 3. Available local records on weather data (i.e. temperature) and moon data were collected from Weather Underground (2017) for the nearest city, Nanyuki, and were assumed to be representative for the study area. Rainfall data from two rain stations (Loirugrugu and Kamok) at Ol Pejeta were provided directly by the conservancy.

Data collection in field was performed by Nick Ndiema with colleagues at Ol Pejeta and images were supposedly collected every week, every 8th day or at maximum every second week. Along with data collection were also camera condition and battery levels checked to ensure camera quality. For this study were images in total collected from 1st of June 2015 to 31st of May 2016.

Only corridor 2 and 3 were used in this study due to higher carnivore activity and lack of data on my species of interest in corridor 1.

Figure 2: One of three wildlife corridors (2) along the northern boundary with two out of three visible camera traps attached to the far left and to the right (Photo: Nike Nylander)

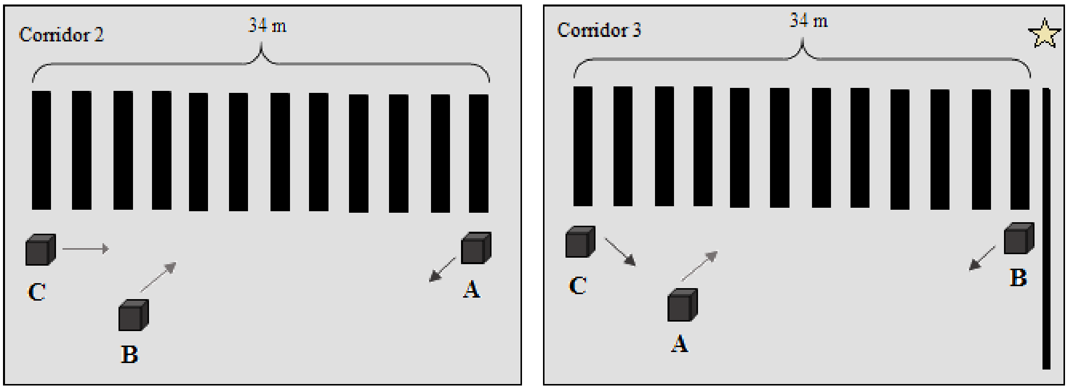

Figure 3: Illustration of the two corridors in question and their different camera positions. The star at corridor 3 highlights the position of the Maasai village close to the border. (Illustration: Nike Nylander)

2.2.2. *Depredation mapping and interviews*

Depredation data and further data on livestock mortality and injuries over the past 10 years were provided on site in Kenya by Richard van Aardt, head of livestock and thus manager of all cattle at Ol Pejeta. All data were presented in excel sheets with information regarding date, name of herder, type of cattle, type of predator (if known), death cause/injuries, location and other remarks. The results from the period overlapping with the camera images (01/06/15 to 31/05/16) were further mapped using ESRI ArcGIS (ArcMap 10.4.1). Only leopards and jackals were mapped since there were no known attacks on cattle by cheetahs.

Based on the information provided in the excel sheets, field interviews were conducted with herders who had been exposed to attacks on their herds during 2016. The interviews were performed in field during a two week period from 14th to 27th of November 2016 using an interpreter of Swahili and Maa which are two of the most local languages around Ol Pejeta. The herders were during the interviews asked to recall their experiences of recent attacks. The interviews were based on a few questions as for when the attack occurred, type and amount of predators, approximate time of day, if they saw the attack, any deaths or injuries, type of vegetation, in what area and if the cattle were within bomas (temporary, fenced enclosures during night) or not. The herders were not allowed to talk to each other before or during the interviews in order to keep their testimony as trustworthy as possible. This was ensured to a certain extent by not forewarn the herders before our arrival about the purpose of our visit.

The interviews were compiled in a notebook after finished interviews and then compared to the excel sheets provided with depredation information to examine if the interviews conformed to the depredation data.

2.3 Data analysis

Digital pictures were sorted in two steps. The preliminary sorting was made in Kenya by Nick Ndiema with colleagues. During the preliminary sorting the raw data was sorted into separate species folders. Already sorted folders containing my three focal species were obtained directly at Ol Pejeta during a part of the field trip to Kenya (14/11/16 to 27/11/16) but the remaining data was received on Dropbox for further sorting continuously until I had 12 months of data. The second sorting included a more detailed evaluation of the images as for examine activity patterns, determine group size, sex or indentify specific individuals together with any further notification of interest. The second sorting was furthermore performed using Microsoft Office Excel 2013 where I summarized the total number of passages based on the pictures. For each passage were several attributes recorded: movement direction (in/out/unknown/along), corridor number (1 or 2), camera name (A, B or C), date, month, time, hour, species, sex (if possible), age (cub/subadult/adult) and group size. Group size was determined as individuals caught together or directly after eachother within a 5 min period.

Movement was determined by studying the direction of the animal present. Animals moving past the cameras set up in close proximity to the posts facing ‘inside’ were designated as moving ‘out’ while the animals following the opposite pattern were designated as moving ‘in’. If unsure about direction I recorded the movementas ‘unknown’, especially if an animal only was present in very few pictures or additionally only present between the wooden posts but never crossing the border.Some animals, clearly only passing by were assigned ‘along’. Individuals were also recorded (1/0) for every passage and camera per day which allowed me to identify periods with less activity.

Animal identification was added for cheetahs and leopards where all identified individuals were assigned a specific ID-number (ID_XXXc or ID_XXXl). The identification was based on the unique patterns of the different individuals according to characteristic spot patterns or other very specific characters. Jackals were excluded from the identification analysis since individuals are much harder to identify on individual level based on camera trap images since they lack spots or other unique characters.

2.4 Statistical analysis

All statistical analysis, including the descriptive analsyis, were conducted in R Studio 1.0.143 (2009-2016). Statistical testing was mainly performed on black-backed jackals due to lack of data on the larger predators. The activity was measured in number of passages and was tested in relation to time of day, temperature, moon phase and rainfall. To evalute activity patterns, I divided the day into a 24-hour cycle ranging from 0-23 with no division between day and night. For the environmental variables were temperature measured as mean temperature per day and was divided into three groups of low (10-18 □C), medium (19-20 □C) and high (21-25 □C) average temperature. The three groups were divided as fair as possible according to number of days for each temperature which resulted in 103 (low), 171 (medium) and 71 (high) days recorded. Days without available temperature data were excluded from the analysis. Moon phase was measured from 0-100 % moon light but was further divided into a range from 1-3: 0-33 % (1), 34-66 % (2) and 67-100 % (3), which were used when performing the statistical analysis. Lastly, rainfall was measured as total rainfall per day, during the previous 7-, 30- and 90 days. Descriptive analysis were conducted on activity per month to visualize the differences in activity per month over the whole year. Descriptive statistics were also used to see the relationship between the activity and most used corridor and camera. Further was this method also applied on activity per time of day to understand when activity in general is higher over a 24 hour span. Lastly this was also applied on movement direction for in and out per hour to evalute if there is a greater difference between when the animals choose to leave or enter the reserve.

Descriptive analysis were also used for the environmental variables but were also tested for by performing an ANOVA analysis for each environmental factor. ANOVAs were used to test for differences in activity over 1) the temperature groups and 2) moon phases. Additionally, Pearson's correlation tests were used to evalute for any relationship between activity and rainfall. The level of significance was $P \leq 0.05$ for all statistical analysis.

3. Results

3.1. Camera trap analysis

3.1.1. *General activity patterns and other attributes*

The camera traps generated 639 passages of black-backed jackals, 23 cheetahs and 23 leopards over 366 days from 1 June 2015 to 31 May 2016. Black-backed jackals were found to be active at all recorded months in contrast to cheetahs and leopards that were present at very few occasions over the year. August to October followed by May showed the highest activity by black-backed jackals (figure 4). October followed by May and June showed the highest abundance of all species together. Jackals were in total present at approximately 58 % of the days throughout the whole year.

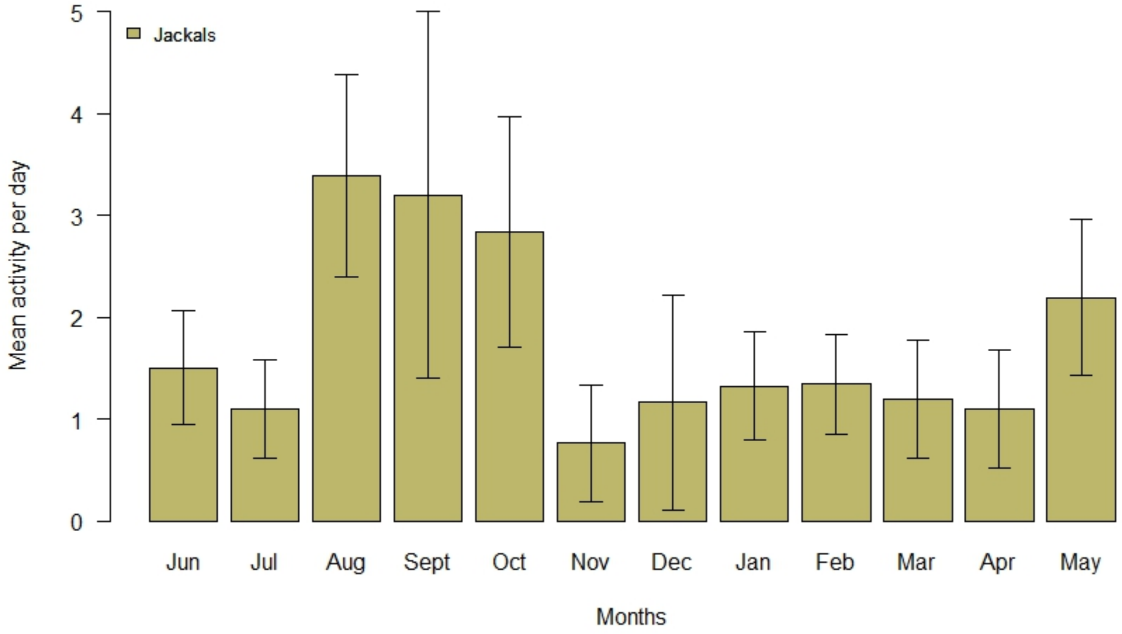

Figure 4: Bar plot showing differences in mean number of passages ±SE per month for jackals over the whole study period.

Corridor 2 was overrepresented as in number of passages of black-backed jackals compared to corridor 3 (450 vs 189). Similar patterns were found for cheetahs (14 vs 9) but the opposite for leopards (4 vs 19). As for the cameras did camera A and C represent close to a 100 % of the collected images for my focal species in corridor 2 while camera C represented almost a 100 % in corridor 3. In corridor 2, were all species caught on camera A and C but jackals were the only species caught on camera B (middle camera facing out). Similar patterns were found for the analogy in corridor 3 where only jackals were caught. Camera C in corridor 3 was further almost solely the only camera used in this corridor. No animals were present at camera B (the analogy to camera A in corridor 2), which was located to the right and in proximity to the Maasai village.

Analysis of movement pattern showed a great uncertainty in estimation of movement direction. Of the 639 passages by black-backed jackals 39.4 % were recorded as “unknown” while almost an equal amount of “in” and “out”-passages were recorded (25 vs 28.9 %). A small fraction (6.5 %) was noted as “along”. A comparison between movement direction (in and out) (figure 5) however revealed that jackals tended to leave the reserve at almost all hours but that the amount of animals entering the reserve decreased during evening and later increased during early morning.

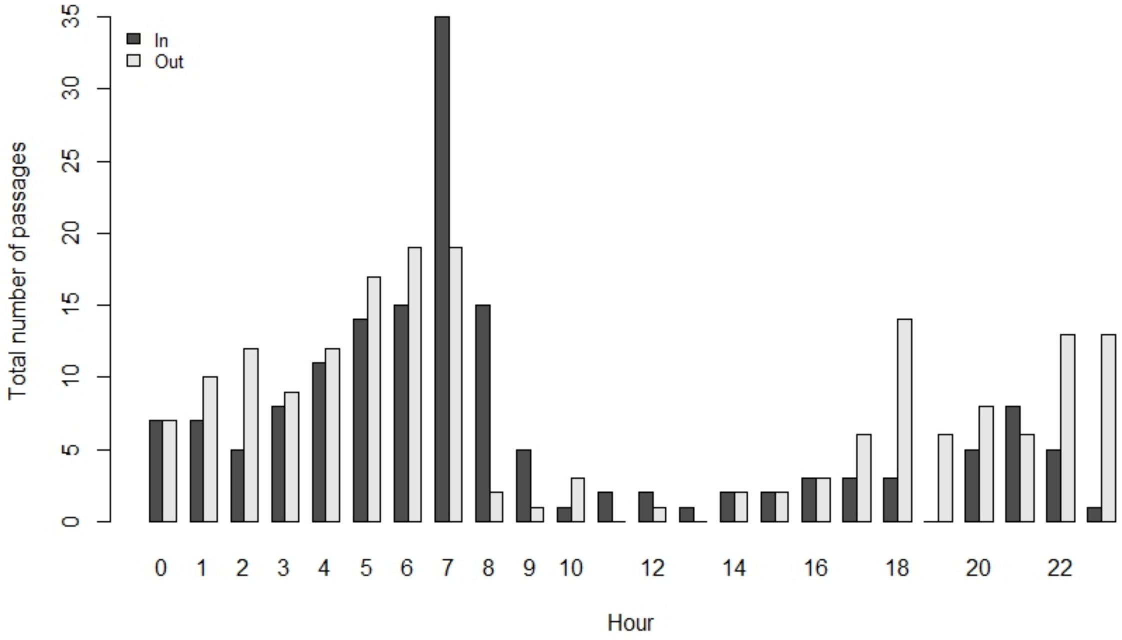

Figure 5: Bar plot showing differences in total number of passages for recorded black-backed jackals entering or leaving the reserve. A high proportion of the recorded animals leaving the reserve could be found at almost all hours but a high proportion of animals entered the reserve during early morning.

A total of 55.5 % of recorded passages by jackals were solitary individuals. An additional 30.8 % of the jackals were recorded in pairs. In 4.2 % of the cases were three individuals found and in the remaining 9.4 % passages were four or more individuals found with a maximum amount of 8 individuals together. With the exception of one jackal cub were only adult individuals caught on the camera traps. The same went for cheetahs and leopards where only solitary adults were present at the corridors. Cheetahs were the only species where I was able to sex determine two individuals (one male and one assumed pregnant female). Sex determination of leopards proved to be impossible due to low image quality at night and due to difficult angles. The same went for jackals and I thereby noted almost all individuals as unknown even though pairs probably consisted of one male and one female.

Activity patterns for black-backed jackals showed activity at every hour but with an increasing activity from early afternoon (2 pm) to late morning (9 am) (figure 6). The activity peaked between 5-8 am with the highest peak at 7 am. Cheetahs were shown to exhibit similar activity patterns and greatest activity was presented between 6 and 8 pm. These hours did however only consist of 3 passages each. A more distinct pattern was found for leopards that only showed nocturnal activity (7 pm to 6 am) with an activity peak at 10 pm and 4 am, however, as for cheetahs these peaks only consisted of 5 passages each.

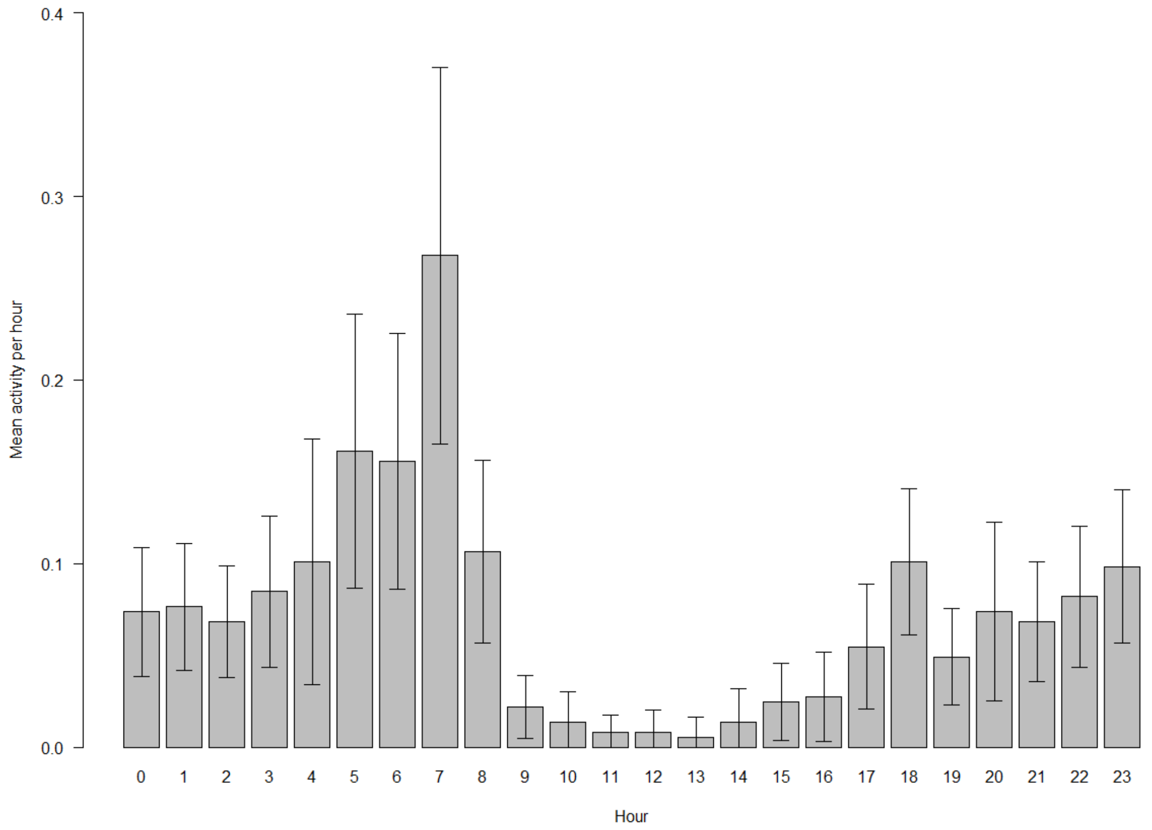

Figure 6: Bar plot showing differences in mean activity ± SE per hour of black-backed jackal. Higher mean activity can be found from late evening to early morning with a peak at 7 am (0.26) and further a lower mean activity during daytime. Lowest mean activity (0.005) was found at 1 pm.

Mean activity per day differed greatly between jackals and the other two predators (figure 7) due to more recorded passages by jackals. I found a higher daily mean activity for jackal (1.76) than for cheetahs and leopards (0.063).

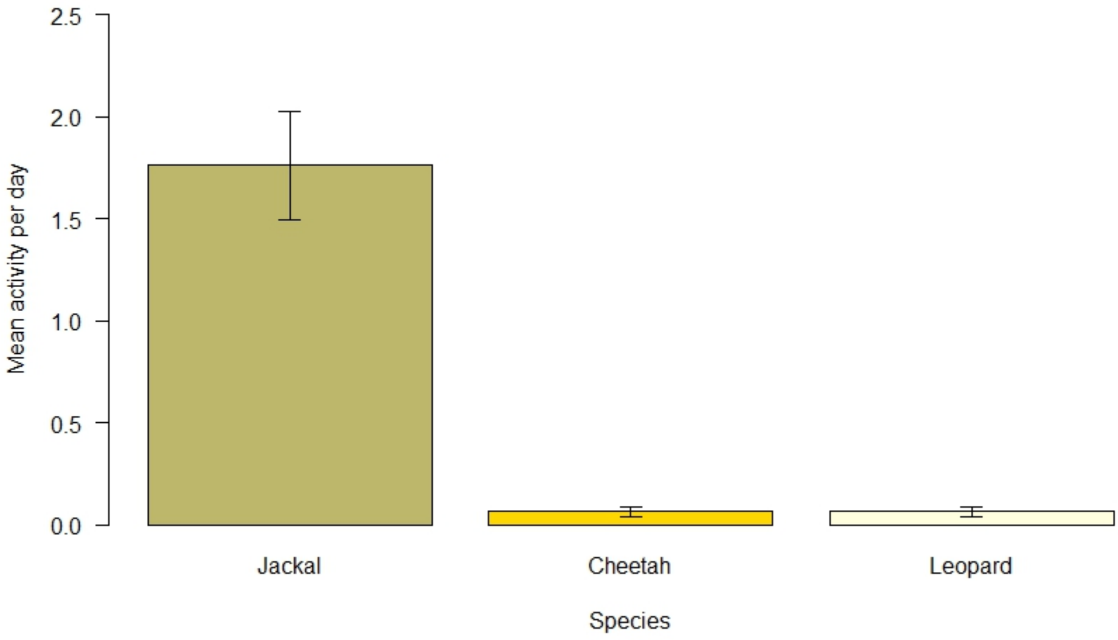

Figure 7: Bar plot showing mean activity per day presented per species ± SE.

3.1.2. *Environmental correlations*

Statistical analysis on activity patterns in relation to the environmental variables could only be performed on jackals due to a too small sample size on cheetahs and leopards.

The temperature varied throughout the year with a range in mean temperature from 10 □C to 25 □C. The temperature average was 19.5 but with an average of measured as mean temperature over the whole 24-hour cycle. However, a total of 20 days of temperature data were not available which might have slightly contributed to a different average. Rainfall ranged from no rainfall (0 mm/day) to a maximum of 39.25 mm/day with an average of 1.82 mm/day. This calculated as mean for each day over the 366 days represented. Most rainfall fell in April 2016 (117 mm) followed by November and January (103 mm each). The driest period occurred from July to September 2015 with the lowest amount of rain in September (4 mm).

Average daily temperature revealed the highest amount of activity of jackals (n = 15, 16 and 17) at 19 □C, 21 □C and 22□C. However, the division of temperature range between low, medium and high temperature revealed a slightly greater activity (measured as mean activity) for the group with the highest temperature (figure 8). Although, no significant results could be found between the different groups (ANOVA, df=2, p=0.139).

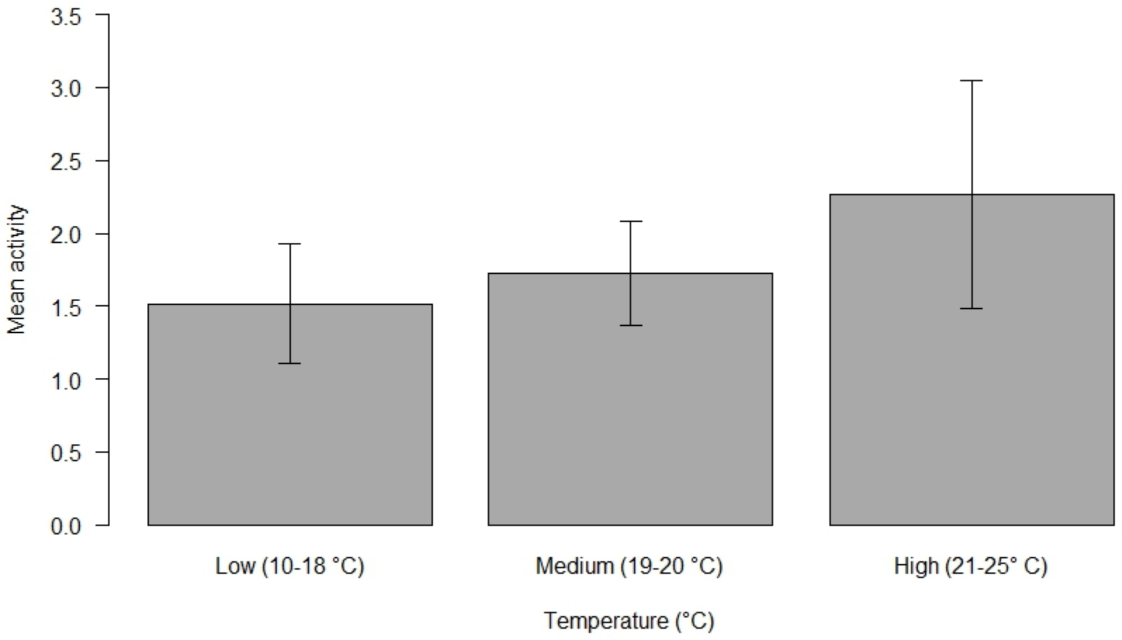

Figure 8: Mean activity per day (jackal) in both corridors in relation to average temperature divided by low, medium and high temperature ± SE. No significant difference between the groups ($p>0.05$).

No relationships were found between activity and moon phase in jackals (figure 9) (ANOVA, df=2, $p=0.889$).

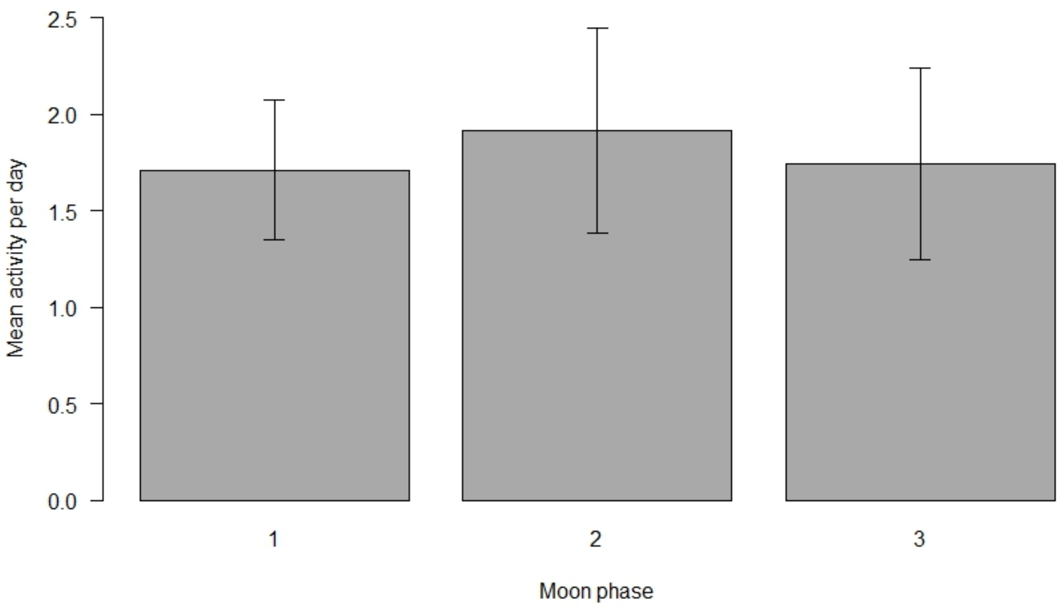

Figure 9: Mean activity per day (jackal) in both corridors in relation to moon phase 1, 2 and 3 ±SE. No significant difference between the three groups ($p>0.05$).

Rainfall was the only environmental variable that revealed to have any significant impact on activity in black-backed jackal although only weak negative relationships could be found. The greatest correlation was found for total rainfall during the previous 90 days (-0.14), followed by the previous 30 days (-0.13), during the previous 7 days (-0.09) and lastly on the actual day (-0.11). Pearson's correlation tests showed a significant relationship between activity and rainfall for total rain per day (Pearson's, df=364, p=0.031, 95 % CI [-0.213, -0.010]), during the previous 30 days (Pearson's, df=364, p=0.013, 95 % CI [-0.229, -0.028]) (figure 10) and during the previous 90 days (Pearson's, df=364, p=0.004]) 95 % CI [-0.249, -0.048]). There was a statistical tendency towards a significant relationship between activity and total rainfall during the previous 7 days (Pearson's, df=364, p=0.05773, 95 % CI [-0.199, 0.003]).

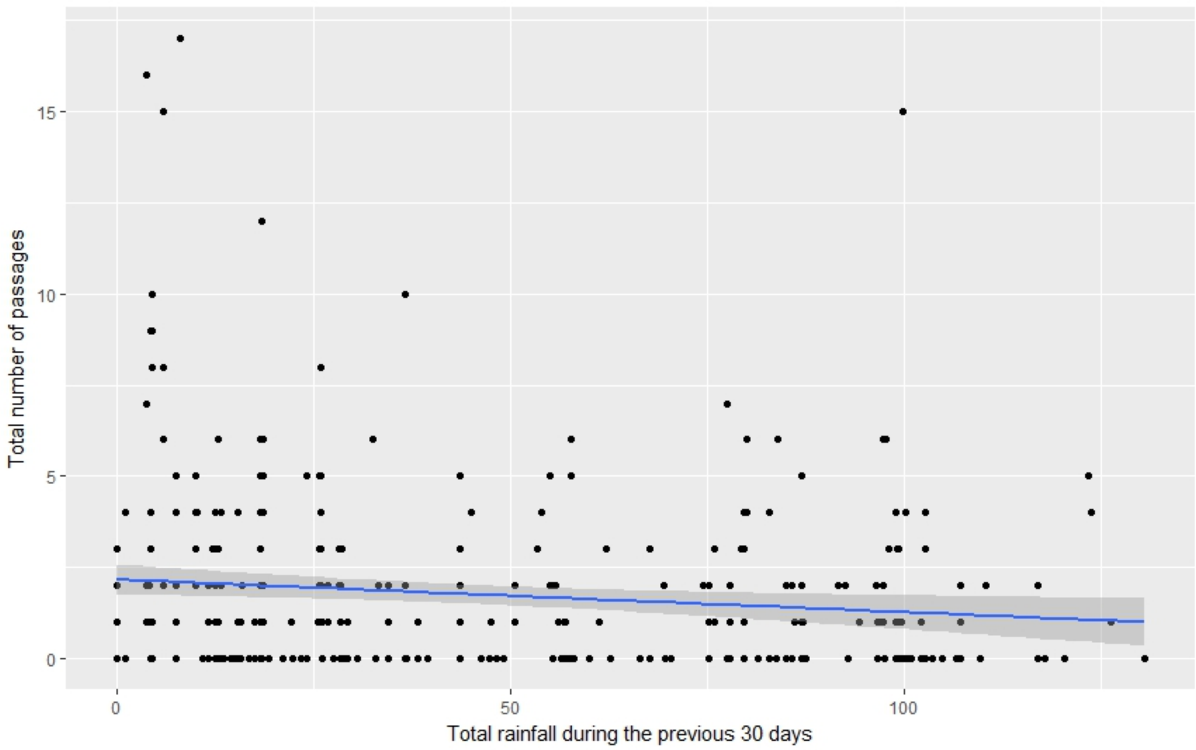

Figure 10: Scatterplot visualizing the relationship between total activity and total rainfall during the previous 30 days with a significant (p<0.05) but weak correlation of -0.13 where the amount of passages increase with decreased rainfall.

3.2. Depredation & interviews

A total of 17 attacks by leopards and jackals occurred at Ol Pejeta during the 366 days between 1st of June 2015 and 31st of May 2016. Leopards represented a majority of these two species in relation to number of attacks (12) while jackals were responsible for the additional five. The attacks varied throughout the period with most attacks in June 2015 (4 leopard attacks) and two months without any attacks (March and April 2016). Locations with depredation by jackals and leopards during the period varied greatly over the area (figure 11). Most attacks occurred at the Sirrima-area with three leopard attacks at Sirrima 1 and four attacks (two of each species) at Sirrima 2. Furthermore attacks also occurred at G6 and Gatarakwa which lies in proximity to Sirrima 1 and 2. Only one attack occurred at daytime while nine others were noted as attacks during night but 6 out of 17 lacked further notes on time of attack. A majority of the attacks were predation on calves (11 out of 17), one heifer and five steer where all were killed. In four cases did jackals fatally attack calves but one steer under treatment was also killed. Leopards mainly attacked calves but attacks on steers and heifers also occurred. None of the predators attacked full-grown adult cattle.

I did not test the depredation statistically due to too low sampling size but no general depredation patterns could be seen in relation to the environmental variables. Depredation by leopards occurred during all three moon phases (ranging from 1-99 % moon light) and during moon phase 1 and 2 for jackals (ranging from 1-37 % moon light). The average temperature only varied between 17 and 21 □C with a relatively even distribution of attacks during the different temperatures with the highest number of attacks at 20 □C (n = 7). Depredation did not seem to correlate with rain either since months with the greatest total amount of rain, November 2015 (103 mm), January 2016 (103 mm) and April 2016 (117 mm) contained attacks as well as months with low or intermediate amounts of rain.

Interviews were performed with herders experiencing attacks during January to May 2016. Interviews regarding attacks in 2015 were excluded due to the time span since the attacks occurred. Only four attacks (2 leopard and 2 jackal) with three different herders occurred during the period of interest (January to May 2016). Two of these three herders implied that they had not experiences any attacks during 2016 and the third one denied any attack but changed his mind and described the only leopard attack that he had been exposed to.

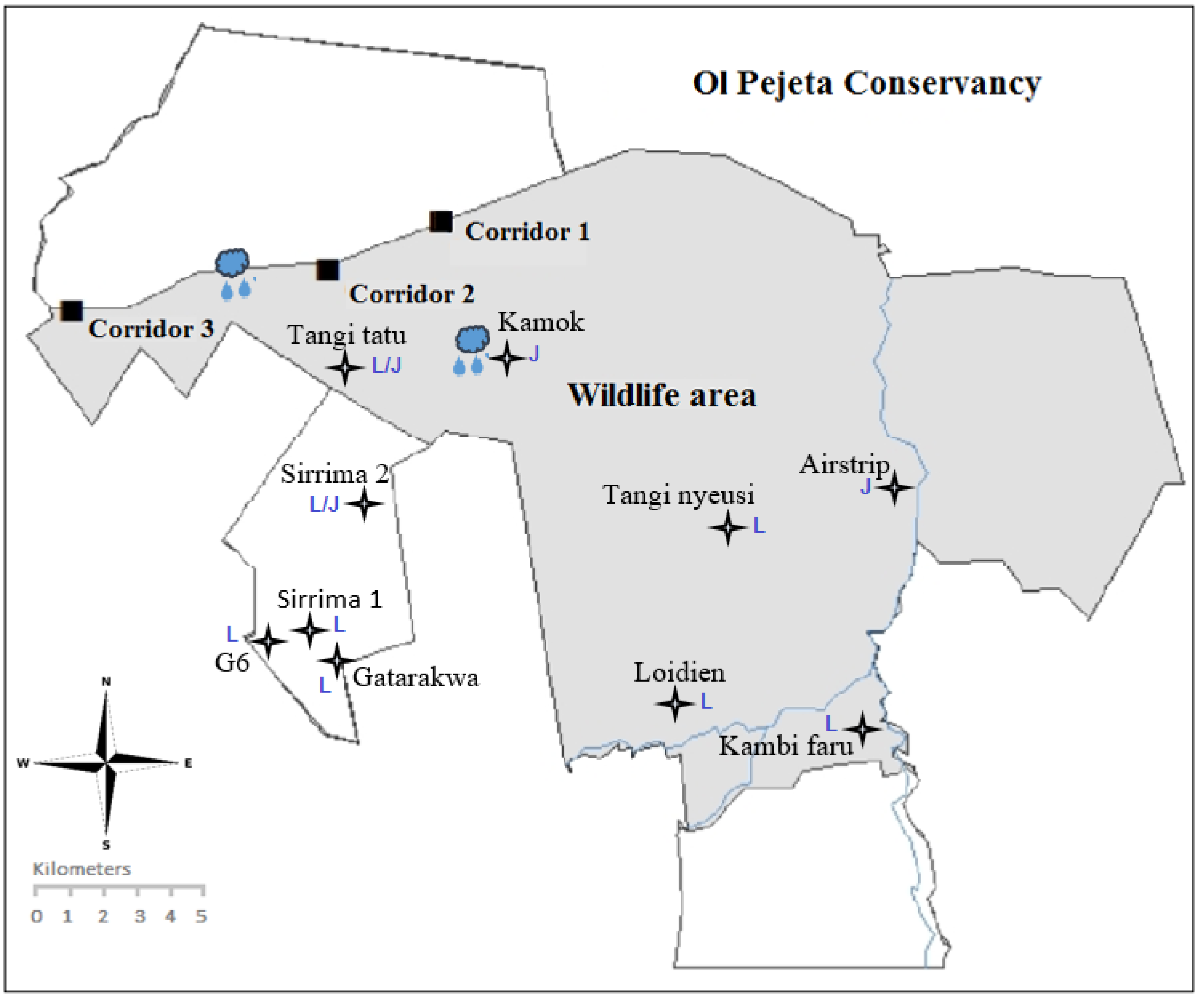

Figure 11: Marked locations of the 17 livestock attacks by jackals (J) and leopards (L) between 01/06/15 and 31/05/16 together with the position of the two rain stations Loirugrugu (left) and Kamok (right).

3.3. Individual identification of cheetahs and leopards

A total of 23 cheetahs and 23 leopards were caught on the camera traps from 01/06/15 to 31/05/16. In total were 3 cheetahs (i.e. ID_001c to ID_003c) and 3 leopards (i.e. ID_001l to ID_003l) identified (appendices I to V). Some images were not of sufficient quality for identification due to low image quality or difficult angles. These were categorised as ‘unknown’. Cheetahs were in general more easily identified (figure 12) due to their presence at the corridors during daytime compared to the strictly nocturnal leopards.

The recorded individuals showed a difference in activity pattern between each other. For cheetahs individual ID_001c (the most present male) was found to be active at both morning, mid day and evening. No nocturnal preferences could be found in contrast to the second individual (ID_002c) that was found to be active only during early to late evening. The last cheetah (ID_003c) were present during midday and early evening to late night but never during morning. The first two cheetahs were found to be active at the corridors from the beginning of this study until winter but then disappeared and were not found on the camera traps during 2016. During autumn 2015 did the third cheetah appear and was the only cheetah active at the corridors during 2016.

All leopards were recorded as nocturnal individuals with little difference between the three identified individuals. The first (ID_001l) and second (ID_002l) individuals were found to be active from late evening to late night in comparison to the third individual (ID_003l) which was found only to be active during late evening. The first and second leopard were found to be active at the corridors from the beginning of the study but the first individual disappeard in November. During 2016 did the last leopard (ID_003l) appear and this leopard, together with the second, were the only two present at the corridors during the rest of the study period. However, the third individual were only recorded during 2 occasions.

Figure 12: Camera images visualizing the difference in image quality between cheetahs (left) and leopards (right) for identifiable individuals (ID_001c and ID_002l).

4. Discussion

My results show an overall greater activity by black-backed jackals compared to the larger predators. My results further showed similar activity patterns between jackals and cheetahs but an exclusively nocturnal activity by leopards and a great difference in preference of corridor. For both cheetahs and leopards I did not obtain enough data to test the activity statistically for any parameter. It is therefore of great importance to address the limitations of data on the two larger predators why these results should be interpreted with care and is not representative enough for cheetah and leopard activity patterns. For this reason were the environmental variables only tested for in relation to jackal activity. Of the three environmental variables tested, I found that rainfall was the only parameter that had an effect on jackal activity but not moon phase or temperature.

Depredation proved to be difficult to evaluate due to the low amount of attacks during the overlapping study periods but my results showed no pattern towards an influence of the environmental variables on increased depredation. Lastly, the interviews were also of low value since only a few interviews could be performed. My results revealed however that the interviews did not agree to a greater extent with the obtained data on depredation.

4.1. Diurnal activity patterns

General activity patterns between the three predators were revealed to differ over the 24-hour span where jackals and cheetahs were found to have overlapping activity patterns. Both species were found to be active during almost every hour with a peak in early morning (jackals) and early evening (jackals and cheetahs) in contrast to the exclusively nocturnal leopards. These results conforms to previous studies on cheetahs (Broekhuis *et al*. 2014, Hayward 2009), black-backed jackals (Fuller *et al*. 1989, Kaunda 2000, Kaunda 2001) and partly conforms to studies on leopards where leopards have shown to be predominantly nocturnal but camera traps have caught activity also during daytime (Quinton *et al*. 2013, Hayward 2009). However, the activity peaks for cheetahs and leopards only consisted of five passages each and cannot therefore be considered representative for cheetah and leopard activity.

A majority of available studies on activity patterns exhibited by all three predators are overall conducted in the most southern African countries (i.e. Namibia, South Africa, Botswana and Zimbabwe) and many studies on leopards are performed in Asia. There is a low number of available studies conducted on my focal species from East Africa. This is especially true for black-backed jackals were data in general is scarce all over Africa. Due to this, it might be of importance for caution in interpreting the activity patterns found in this study when comparing with other articles. Mainly since animal ecology and behavioural patterns may differ in different parts of Africa.

Cheetahs were found to be moving out of the reserve to a greater extent during early evening and night and exclusively moving in during morning. Since cheetahs have the competitive disadvantage of being both smaller and predominantly solitary they often face strong interspecific competition (Durant 1998) and fenced reserves are often too small to house a great proportion of large carnivores (Bissett *et al*. 2015). It might thereby be a possibility that the revealed activity patterns actually reflects avoidance of competition by larger nocturnal predators within the reserve. Cheetah activity have further been shown to be greatly influenced by reproductive status (Cooper *et al*. 2007). However, this study did not focus on intra-guild competition or reproductive status and obtained data were not sufficient enough to either test or provide evidence for their effect on cheetah activity. Leopard activity patterns were not as clear as for cheetahs and jackals but in general did animals move out during late evening and night and came back during early morning.

Although, since movement direction varied a lot more for leopards it might reflect less competition between leopards and the other nocturnal predators within Ol Pejeta Conservancy. Since leopards show the greatest dietary niche of all the large predators and is claimed to prefer smaller prey than the other species, they are less affected by interspecific competition (Hayward & Kerley 2008). They can furthermore avoid kleptoparasitism by arboreal caching (Stein *et al*. 2015). The technique allows leopards with great climbing skills to kill and drag prey up into trees where larger predators cannot reach them. The leopard can thereafter eat their catch in peace without interference or loss of prey to other carnivores. The varying movement patterns of leopards in the corridors might therefore reflect something else than interspecific competition within the conservancy, such as different foraging strategies or mate search. For jackals did the results on the other hand show a quite even distribution between animals moving in and out. However, the amount of animals leaving the reserve were quite even during almost all hours but the amount of animals entering the reserve dropped during evening and increased during early morning. These results might be explained by a higher degree of foraging outside the reserve during evening/night but also avoidance of interspecific competition or predation by larger predators. However, the latter two is not in line with findings by Yarnell (2013) and Brassine & Parker (2012) where presence of apex predators did not cause a significant difference in foraging strategies by black-backed jackals. Although, these findings (Brassine & Parker 2012, Yarnell 2013) were from South Africa and may not be fully applicable on the situation in eastern Africa.

Monthly activity patterns were also found to differ greatly between the three species and only jackals were found to be active at the corridors every month. Only 5 out of 12 months had an overlap between cheetahs and leopards while several months lacked data on the larger predators. The reason for low carnivore activity might be explained by the low numbers of cheetahs and leopards within the conservancy itself. Both cheetahs and leopards furthermore show extensive home ranges (Houser *et al*. 2009, Mizutani & Jewell 1998), especially for non-territorial cheetahs (Broomhall *et al.* 2003) and transient leopards (Mizutani & Jewell 1998) which possibly can have reduced their presence at the corridors if they spend time in other areas belonging to their home ranges. This may also be applicable on territorial individuals that hold territories within Ol Pejeta further away from the corridors and thus never cross the territorial boundaries of other individuals. Further might potential mate search outside the reserve also affect the presence of the carnivores within the reserve together with avoidance of other large predators. Jackals showed a great activity over the whole study period but with a peak in August to October followed by May. These results may be explained by several factors, beside the environmental ones. First of all, these results coincide with mating (May to August) and further breeding season (July to October) of black-backed jackals (IUCN 2004) which may result in greater activity in the corridors due to mate search or increased foraging during this period. Even though jackals are considered opportunistic omnivores feeding on a great variety of prey (Van de Ven *et al.* 2013) a large proportion of conducted studies show a high abundance of ungulates in jackal diets (Klare *et al*. 2010, Loveridge 2003, Kamler & MacDonald 2012). The high activity in the corridors during these months may therefore also reflect increased activity during ungulate breeding seasons or even during cattle breeding seasons. Even though jackals are not considered to predate on cattle, they may attack cows giving birth (prey on calves) (Joly & Walton 2003) or mainly sheep and goats (Potgeiter *et al*. 2016, Yirga *et al*. 2013). This study did not focus on prey abundance and its effect on carnivore activity but the depredation data from Ol Pejeta revealed that jackals do attack cattle and especially calves. A high abundance of sheep and goats were also noticed around the conservancy which may have increased jackal activity during periods with low prey availability. Low prey availability could potentially also increase the scavenging behaviour of black-backed jackals on carcasses and human refuse. This could also be an explanation for high activity during night when human activity in general is low.

Evaluation of activity patterns in relation to corridor did also reveal a great difference in activity between the two options. The results showed a far greater activity in corridor 2 compared to corridor 3 for jackals and cheetahs with a preference for corridor 3 by leopards. Both corridors are of equal size but differ both in location and in habitat. Corridor 2 is dominated by open grassland while corridor 3 is located in an area with more dense vegetation. Since both jackals and cheetahs are considered to prefer open habitats to a higher degree (IUCN 2014, IUCN 2014b) are these results expected. The Maasai village, located close to corridor 3 further had sheep and goats which probably attract some potential predators but might also scare others. Even though the reason for high leopard activity in corridor 3 is not clear it might be partly explained by the high plasticity in leopards. All three species are known to predate on sheep and goats (Potgeiter *et al*. 2016, Patterson *et al*. 2004, Kissui 2008) but leopards in particular are famous for their highly adaptive abilities. For this reason do leopards often tend to inhabit areas greatly modified by humans or in close contact with human settlements (Pitman *et al*. 2013). And thus may the higher activity in corridor 3 be explained both by habitat preferences and plastic abilities in leopards. Furthermore did camera set up differ greatly between the corridors. Camera A (right) was overrepresented in amount of collected images in relation to camera C (left) in corridor 2.

The opposite pattern was found in corridor 3 where camera C (left) was over overrepresented. The camera position also differed between the corridors where camera A and B (corridor 3) had switched positions in relation to their positions in corridor 2. Overall were there few images collected on both cameras facing outside (i.e. camera B in corridor 2 and camera A in corridor 3). I found this a bit surprising since a large proportion of the corridors are covered on these cameras. The reason remains unknown but it may be a possibility that most animals prefer the edges (which also could be seen on most images) and thereby never got caught on the cameras positioned in the middle. Although, this might not be the full explanations since at least cheetahs and leopards are large enough to get caught on these cameras despite positioning.

Jackals did overall show a greater solitary appearance than expected with 55.5 % of the passages registered as solitary individuals. Jackals are monogamous and mated pairs seem to bond for life and this behaviour form the basis of social structure (IUCN 2004, Minnie *et al*. 2016). Mated pairs typically hunt together or can even form smaller 'packs' when hunting larger prey (IUCN 2004, Klare *et al*. 2010) for which the number of solitary individuals is a bit surprising. One explanation for this could be that jackals are relatively small mammals and individuals may therefore go undetected through the corridors. Hence, there might be a higher activity of pairs than my results revealed. Another explanation could be that a high proportion of the solitary individuals were solitary animals searching for a potential mate. Age determination of jackals proved to be difficult and I therefore recorded all individuals, except one obvious cub, as unknown. A high proportion of the solitary individuals might be sub-adults searching for new territories or potential mates. For this reason, it would have been interesting to evaluate both age and sex ratio more thoroughly for the solitary individuals. However, sex determination of jackals by only evaluating camera traps showed to be an impossible task. Especially since a great share of the pictures were taken during darkness and thus reduce image quality further. The same problem with sex determination proved to be impossible also for leopards due to low image quality during night and difficult angles. For cheetahs I did manage to sex determine one male (also the most present individual) and one, assumed pregnant, female. All cheetahs and leopards were adults. However, these results are not useable as an estimation of differences in activity between sexes in the three specie since sex determination proved to be too difficult for jackals and leopards. The amount of sex determined cheetahs was also too low.

4.2. Environmental correlations

Statistical analysis were only performed on jackal activity in relation to the environmental variables since data obtained on the larger predators were too scarce. Although, the patterns for cheetahs revealed an almost exclusively higher activity during moon phase 1 and 2. This was not the case for leopards were activity seemed to be independent of moon phase. The temperature varied greatly for all recorded passages and no evidence for influence of temperature on activity could be found for any of the species. Rainfall was the only variable proved to have any effect on jackal activity where activity increased with less rain. Cheetah and leopard activity increased however during months with more average precipitation. These results may not be useable due to the low sampling size but gives an indication that moon phase and rainfall may affect cheetah and leopard behaviour.

Moon light does not seem to be a prerequisite for jackal activity in this study. In general, few studies have been conducted on environmental factors driving jackal activity and thus even less on how moon light may affect their behaviour. The findings in this study although conforms to similar results found in a study by Bothma (2015) where no relationship could be found between moon light and any of the four moon phases. This is interesting since many of the larger carnivores rely greatly on their eye sight when hunting and many carnivores have been found to be affected by the amount of visual moon light (Broekhuis *et al*. 2014, Cozzi *et al.* 2012, Heurich *et al*. 2014). Increased illumination may enhance predator activity since it enables predators to detect prey more easily (Prugh & Golden 2013). However, not all studies support this and studies performed on lions and spotted hyenas found the animals to be unaffected by moon light. However, other studies conducted on other mesopredators, such as the red fox (*Vulpes Vulpes*) have also revealed similar results where the effect of moon cycle on red fox behaviour was weak, only revealing a slight increase of probability of being active around new moon (Penteriani *et al*. 2013). The results from this study, supported by results from Penteriani *et al*. (2013) and Bothma (2015), indicates that the difference in jackal activity might be explained by other factors moon light. It is furthermore important to address that I did not take cloud cover into account in this study. Cloud cover may be of importance since it can reduce the amount of available moon light during cloudy nights. This leaves the probability that the study may have showed a different outcome if taking cloud cover into account. Although, since previous studies (despite the low number) have revealed no or very weak relationships between moon light and mesopredator activity is there a strong possibility that jackals, as opportunistic mesopredators, are less affected by moon light than some of the larger and more specialized predators. I did not find any evidence for a difference in activity in relation to temperature either and temperature does therefore not seem to be a prerequisite for jackal activity at Ol Pejeta. As a conservancy located on the equator, average daily temperature does not vary greatly between days or seasons. For this reason it may not be surprising that jackals do not seem to be affected by differences in average temperature. This in contrast to mesopredators on other continents or even in other parts of Africa where the temperature varies more. Few studies have been conducted on the relationship between temperature and carnivore activity and thus even less on temperature effects on carnivore behaviour around the equator. Studies on cheetahs have presented the possibility of high nocturnal activity as a response to more favourable conditions during lower temperatures at night (Broekhuis *et al*. 2014). This might also explain the low activity by jackals (and the other predators) during daytime. However, since I used average daily temperature instead of actual temperature at active hours, is the data not sufficient enough to prove that temperature actually has an effect on increased animal activity. The results can therefore only prove that average daily temperature does not have any effect on jackal activity.

Rainfall was the only environmental variable that I found to have a significant effect on jackal activity at the corridors. Rainfall increases vegetation growth and thus increase grazing opportunities for many ungulates within the conservancy and can thus affect prey availability. Rainfall has previously been found to affect large carnivore behaviour, in particular influences by changes in prey biomass (Durant *et al*. 2004, Marker & Dickman 2005). Low rainfall may further indirectly benefit less competitive species such as cheetahs, since it forces water-dependent lions to remain near water sources (Durant *et al*. 2004). This may also be applied on jackals. My results showed a significant increase in activity during low rainfall. One explanation for these findings may be explained by low prey availability during drier periods and thus force jackals to hunt more outside Ol Pejeta which increase the activity at the corridors. Low prey availability may also lead to less scavenging opportunities of carcasses killed by larger predators due to interspecific competition and might increase scavenging behaviour closer to human settlements outside the conservancy. Although, an activity peak could be seen in May directly after the heavy rainfall in April 2016. The reasons for the greater activity here remains unknown but may be explained by the start of the jackal mating season, rather than amount of rainfall.

4.3. Depredation and interviews

Evaluation of depredation patterns proved to be difficult to draw conclusions from due to the low amount of attacks during the study period. Only 17 attacks by leopards and jackals occurred during this time where leopards were responsible for 12 attacks and jackals for the additional 5. A majority of the attacks were conducted on calves but leopards managed to kill steers and heifers as well. Only one jackal attack was performed on a steer which is a quite large prey for a small jackal. However, this individual was under treatment which probably lowered its ability to defend itself. The excel sheets do not reveal the number of jackals performing the attacks but jackals have been found to occasionally form ‘packs’ when hunting larger prey species (IUCN 2004) which might be an explanation in this case. No statistical analysis were performed on depredation due to the low amount of data but the results are still valuable and give an indication regarding depredation risk at Ol Pejeta. However, the results should be interpreted with care and more data is required to actually draw any statistical conclusions. As for the environmental variables did not moon phase or temperature seem to affect depredation. Attacks occurred during all three moon phases for leopard (1-99 % moon light) and during moon phase 1 and 3 for jackals (1-37 % moon light), with a slightly higher total number of attacks during moon phase 2 for both species in total. These findings furthermore conforms to the results from the activity patterns analysis. Average daily temperature differed by 4 °C (17-21 °C), this may imply that attacks occur at an intermediate temperature but more data is needed to actually evaluate these patterns more thoroughly. Depredation did not seem to correlate with rain either although months with the highest number of attacks (2-4) had an intermediate total rainfall (12-78 mm per month). Similar patterns have been found for depredation by leopards and lions in Tsavo National Park, Kenya (Patterson *et al.* 2004) where attacks are scattered over months varying in rainfall. Although, in their study could a slightly greater activity be found during months with higher total rainfall. Due to these findings and low amount of data is it not possible to claim that depredation is particularly affected by any of the environmental factors but rather that some patterns might suggest that depredation occurs randomly in an opportunistic way than under specific environmental conditions. A reasonable explanation for high depredation attacks could also be low prey availability, even though prey availability is not evaluated in this study, several other studies put emphasis on low prey availability as an important reason for increased depredation rates (Ogata *et al*. 2003, Woodroffe *et al*. 2006). The risk of predation by leopards is also greatly influenced by distance to water, something that has been proved by (Constant & Hill 2015), where risk of attacks increased closer to water and especially within 1 km from the water resource. This is of interest since a high proportion of the attacks at Ol Pejeta during the study period occurred in proximity to either the water holes in the Sirrima area or in proximity to the river system running through the reserve. Sirrima is further considered as a predator free area which does not conform to the results from this evaluation. A majority of the attacks also occurred during night. These findings emphasize the importance of protecting livestock during night time in closed bomas, something already practiced at Ol Pejeta, further away from water or in closer proximity to human settlements. It is also of great importance to keep livestock in the Sirrima area under strict monitoring during presence to prevent attacks by leopards. The importance of guard dogs have also been claimed as of great importance for reducing livestock attacks (Ogada *et al*. 2003) and could further be implemented in the future under controlled circumstances in particularly highly predated areas.

Evaluation of interviews did not give any further input of value to the human-carnivore conflict. A majority of the 17 attacks occurred during 2015 but only herders with attacks from January to May 2016 could be interviewed. This resulted in only 3 interviews with 4 different herders. Surprisingly though, did herders' experiences not agree with the reported attacks. The reason for this remains unknown but could possibly derive from cultural differences and/or be due to herders feeling ashamed or scared of being accused for not doing their work properly, although we tried to minimize these errors by telling them that the answers were for study purposes only. It is important to also emphasize our ability to remember events and that herders simply did not remember the attacks. This might be especially true during event where cattle were attacked but not killed. Lastly could it be possible that herders remember attacks performed by other carnivores, such as a pack of lions, to a greater extent than a single leopard and jackal and thereby give another explanation. If this is a common pattern for other, similar studies, also remain unknown but there might be a great need to interpret results from other studies (based on interviews) with great care. We were also not allowed to perform interviews in the Sirrima area ("predator free") although this might have been of more value since a majority of the attacks actually occurred at or in proximity to Sirrima.

4.4. Future studies and perspective

There are several factors that potentially could have influenced the outcome of this study and also its reliability. First, provision of reliable data proved to be partly uncertain due to missing values in the data set. At several occasions were there missing dates on the memory cards resulting in less pictures than in reality. If these pictures contained images of my focal species I will never know but there is a high probability of missing data on these dates. This happened at several occasions which might have skewed the results both in relation to total amount of passages per month and hour, movement direction, group size and total amount of individuals. Although daily activity rhythms were probably not as affected due to very prominent peaks during morning and early evening. The most reasonable explanation for the missing data is that the batteries died after a few days on some cameras. This is further justified since we detected that all cameras had low batteries (0 or close to 0) during our field trip to Kenya in 2016. Furthermore was also at least one week missing completely in December 2015 and was never found which might have affected the results to a great extent. This week probably disappeared due to failed downloading to a computer or some other technical issue.

Second, at the beginning of the study period were only one image per session collected for each animal which made it difficult to predict movement direction in many cases. This resulted in a high proportion of passages registered as unknown, even though this may have been prevented if the total session would have been provided from the beginning.

Third, apart from problems with accurate data provision was weather data (moon and temperature data) obtained from the nearest city, Nanyuki, representative for conditions at Ol Pejeta. Although this might be true for moon data, local temperatures may have varied more. Several days further lacked available data on average temperature which resulted in exclusion of these passages in the temperature analysis.

Lastly, it is a possibility that animals were affected by the camera traps, especially during night when animals can be scared by the camera flash. The cameras may further have failed to cover all passages and that individuals were missed during sorting, especially during night when flash range is limited. Additionally, even if identification of cheetahs and leopards were not a major part of this study is it worth to note that identification only by camera traps is a difficult task. Animals are not only photographed occasionally during low light conditions but also from different angles. If an animal furthermore also runs through the corridor, identification is even harder. This was very frequently occurring in leopards whereas cheetahs usually walked calmly through the corridors.

For future research would it be of great value to also take other factors into consideration, such as prey availability, vegetation- and cloud cover when evaluating activity patterns. Furthermore is there a great amount of research conducted on the larger carnivores but little is known about black-backed jackals, especially in eastern Africa. Most conducted studies on black-backed jackals take diet preferences, home-range and activity (time of day) into account but very few studies have been conducted on the effect of environmental variables. Most articles are further dated, also claimed by Plessis *et al*. (2015), for which there is a need for more recent studies on mesopredator behaviour in eastern Africa. Furthermore have also few studies been conducted on the diet of black-backed jackals within livestock dominated areas (Kamler *et al.* 2012). Since almost all large carnivore species are decreasing is there of great value to examine jackal activity in relation to environment and depredation. As for the camera traps is it important to also evaluate camera positions. The camera traps are good at capturing present animals but examination of movement pattern is hard, especially for the fairly small jackals compared to the larger predators as for why it is a good idea to change the set ups to reduce the total amount of passages registered as unknown.

4.5. Conclusion

In this study I investigated activity patterns by cheetahs, leopards and black-backed jackals and potential relationships with attributes such as time of day, month and environmental variables in a fenced conservancy in Laikipia, Kenya. Furthermore were depredation patterns within the reserve examined and interviews were performed with livestock herders that had experienced attacks on their herds during the study period. Lastly were leopards and cheetahs identified to evaluate differences in activity between individuals active at the corridors.

- My results revealed overlapping activity patterns between jackals and cheetahs over the 24-hour span with increased activity during dusk and dawn. Both species were found to be moving out to a greater extent during evening and came back during early morning. However, many jackals also showed a preference for leaving the reserve in the morning. Leopards were found to be exclusively nocturnal. The differences in activity patterns can derive from interspecific competition. However, it is likely that all three species are affected by other factors such as prey availability, mate or territory search and environmental factors.

- Statistical analysis on the environmental variables (moon phase, temperature and rainfall) could only be performed on black-backed jackals due to too low sample size on the larger predators. No significant results could be found for moon phase and temperature and these factors therefore does not seem to influence jackal activity. Rainfall was the only environmental factor that proved to have an effect on jackal activity as activity decreased with increased rainfall. The environmental factors may work directly or indirectly on black-backed jackals. Due to their appearances as mesopredators may environmental variables not affect them to as great extent as the larger predators. Similar patterns between the environmental factors and activity were found for the larger carnivores although it could not be tested statistically and cannot therefore be proved in any way.

• Identification of cheetahs and leopards proved to be hard only relying on camera traps images. In total were three individual of each species identified and evaluated. These individuals differed greatly in activity patterns which might be explained by inter- and intraspecific competition.

• Evaluation of depredation patterns did not reveal any clear relationship between attacks and the environmental factors. No statistical analysis could be performed due to the low sample size but the results give an important indication on when there is a greater depredation risk. My results from the camera trap analysis however revealed a greater jackal activity during drier periods independent of moon phase and temperature. This implies a greater need for extra carefulness during calving season, especially during drier periods. There is also a need for extra caution during night and especially in areas in proximity to water. My findings also revealed that the Sirrima area is more exposed to predation than any other area and this implies a need for extended monitoring when livestock is present in this area, despite considered as a predator free location.

Even though information on activity rhythms of the larger predators and additionally also other mesopredators exist are data on black-backed jackal very scarce and largely dated. For this reason is there a great need for additional and updated research on this species to completely explain the activity patterns and potential relationship with environmental factors.

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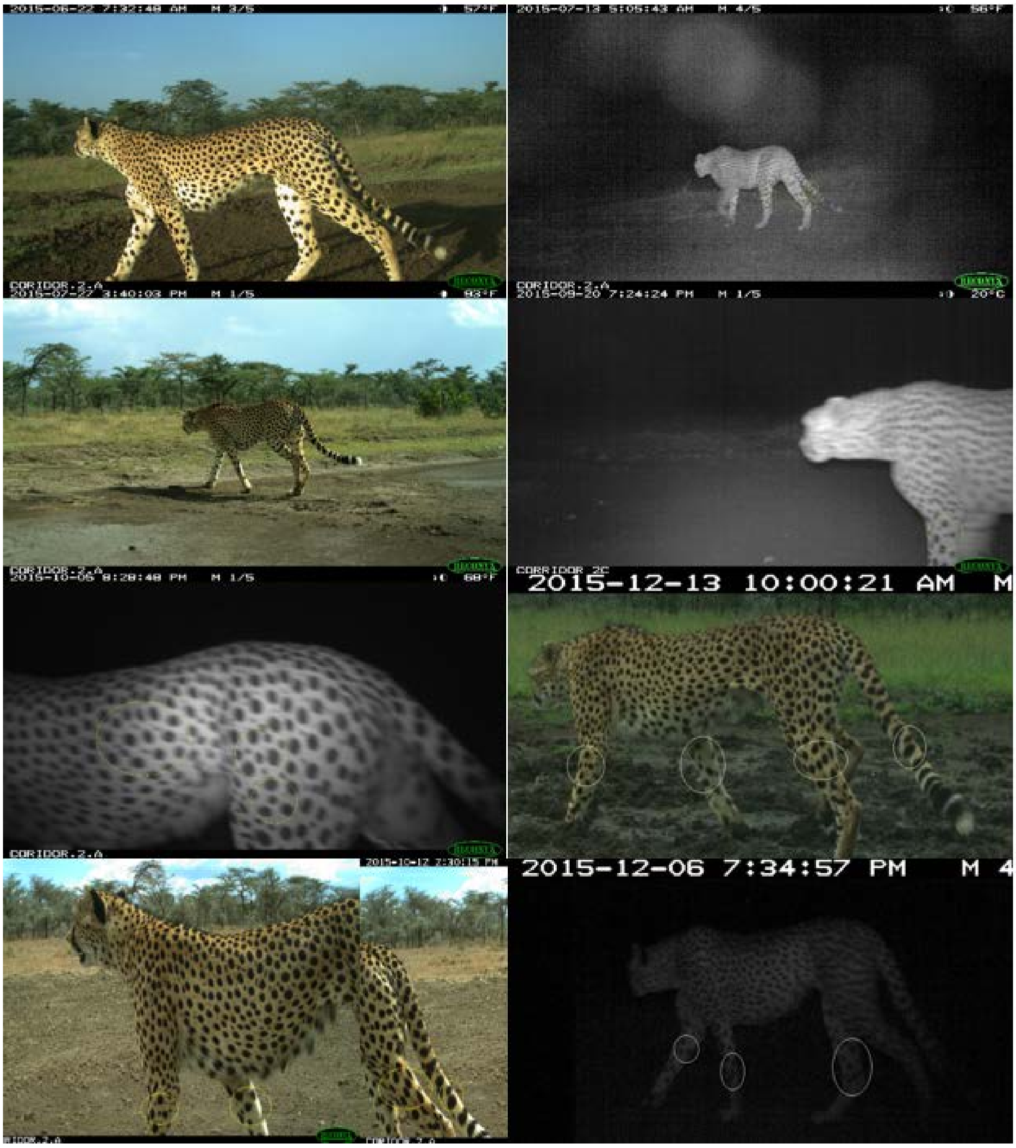
Appendix I
Identification of cheetahs and leopards

SPECIES	ID NUMBER	SEX	PRESENCE (DAYS)	PRESENCE (DATES)
CHEETAH	ID_001c	Male	8	2015-06-22, 2015-07-13, 2015-07-27, 2015-09-20, 2015-10-05, 2015-12-06, 2015-12-13
CHEETAH	ID_002c	Probably female (pregnant during June 2015)	3	2015-06-11, 2015-06-23, 2015-10-06
CHEETAH	ID_003c	Unknown	4	2015-10-04, 2016-01-09, 2016-05-01, 2016-05-30
LEOPARD	ID_001l	Unknown	4	2015-06-04, 2015-09-05, 2015-10-24, 2015-11-11
LEOPARD	ID_002l	Unknown	2	2015-06-02, 2016-05-19
LEOPARD	ID_003l	Unknown	2	2016-02-27, 2016-03-27

Appendix II

Identification of individual ID_001c

8 passages



Appendix III

Identification of individual ID_002c
3 passages

Identification of individual ID_003c
4 passages

Appendix IV

Identification of individual ID_001l
4 passages

Identification of individual ID_002l
2 passages

Appendix V

Identification of individual ID_003l

2 passages