Migration and activity of the eastern black-backed jackal (*Canis mesomelas schmidtii*) in Ol Pejeta, Kenya

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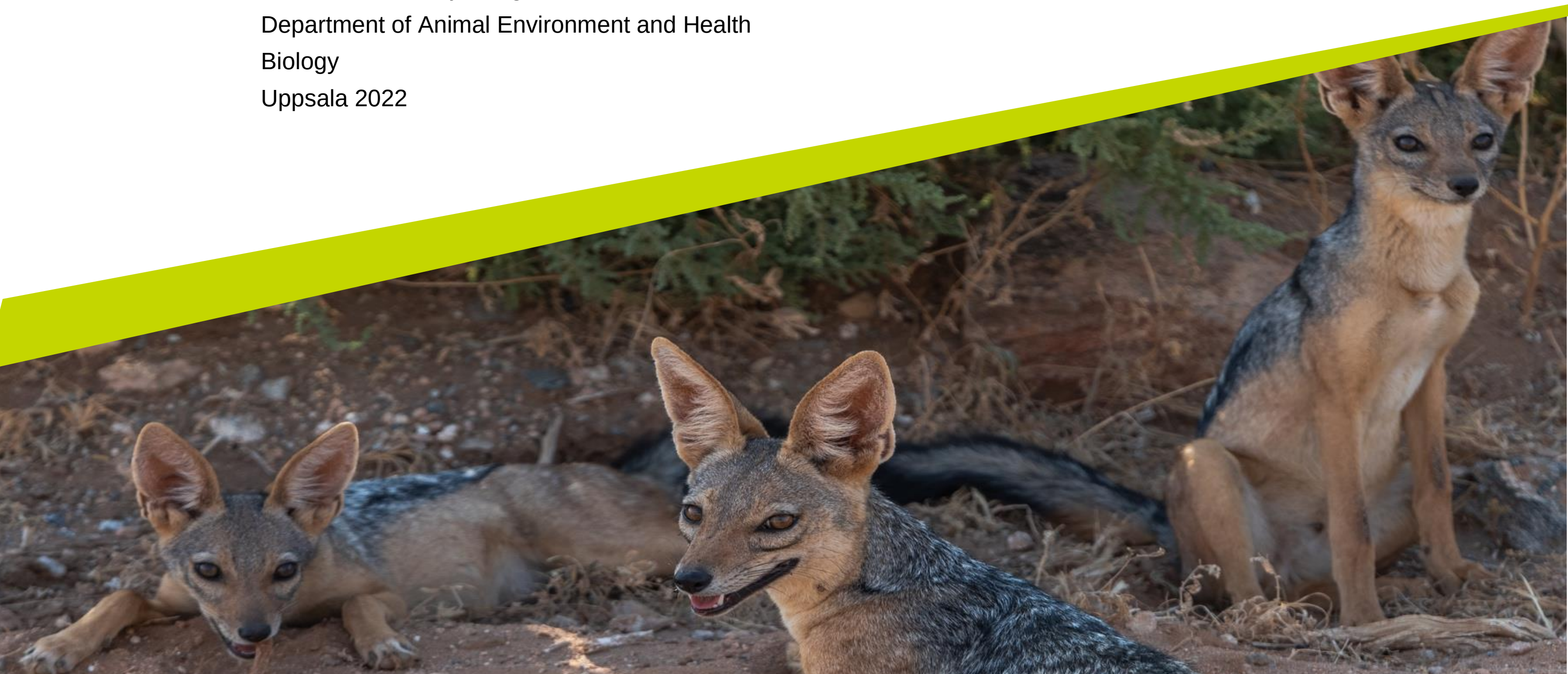

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Migration och aktivitet hos den östra svartryggade schakalen (Canis mesomelas schmidtii) i Ol Pejeta Conservancy, Kenya

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Abstract

This study examined the effects of weather during the day and illumination at night on the migration activity of the eastern black-backed jackals (Canis mesomelas schmidtii) in Ol Pejeta, a wildlife conservancy in Kenya, from October 2015 to December 2019. Jackal ecology is an understudied subject where focus has been directed to a sub-specie of black-backed jackals in southern Africa, with different animals, seasons, and habitats than to those in Ol Pejeta and eastern Africa. Black-backed jackals are important mesopredator in areas they live in and can even be beneficial to livestock farmers due to their ability to supress certain herbivore populations.

Migration activity was investigated by using camera trap footage from three wildlife corridors along the northern conservancy boarder. Jackals were found active between 19:00 to 06:00 with two activity peaks, and observations found jackals to be active inside the conservancy during low activity hours at the corridors. Daily average temperature, cloud cover and rainfall were ranked into 3 categories from low, medium to high and were found to be significant together for corridor activity ($p = 0.016$, $p = 0.009$ and $p < 0.001$). Temperature as a factor alone did not show any significance activity changes between the 3 ranks ($p = 0.124$) but activity increased slightly percentwise with increased temperatures. However, both cloud cover and rainfall significantly ($p < 0.001$ & $p < 0.001$) decreased activity with higher amount of cloud cover and rainfall. Illumination from the moon at nights did have a significant effect ($p = 0.024$) on jackal activity where activity was significant ($p = 0.021$) between 5 ranks, while cloud cover did not ($p = 0.756$), Only the ranks between new moon and full moon showed a significant ($p = 0.008$) activity increase. These results provide a much needed and updated insight into jackal ecology, as well as to increase the already lacking research on the eastern black-backed jackal.

Keywords: black-backed jackals, Kenya, activity, weather, moon, illumination

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1. Background

Kenya is situated in East Africa, with its eastern coastline to the Indian Ocean and has a population of around 54 million people. Roughly 85% of the population of sub-Saharan Africa use agriculture as their main source of livelihood and the agriculture sector contributes up to 55% to the continent's gross domestic product (Kogo *et al*. 2021). Tourism in Kenya brings in 25% of gross domestic product, whereas wildlife-based tourism contributes to 70% of the total tourism earning (Akama *et al*. 2011).

Around 8% of Kenya's landmass is designated for wildlife conservation, with 23 terrestrial National Parks, 28 terrestrial National Reserves, 4 marine National Parks, 6 marine National Reserves, and 4 national sanctuaries (*Kenya Wildlife Service*, 2021). Kenya's population grows by ca 3% per year and is putting pressure on the land available and its resources (Okello & Kiringe 2004; Sha & Ayiemba 2019). There has been an increased agricultural land and settlement demand throughout Kenya, which has led to human-wildlife conflicts and environmental degradation (Okello & Kiringe 2004). In all 50 reserves in Kenya, researchers found that human-wildlife conflict is the second-largest threat to wildlife, occurring in 82% of the reserves, after illegal bushmeat hunting.

1.1 Black-backed Jackals

One of the predators residing in Ol Pejeta, a wildlife conservancy in Kenya, is the mesopredator black-backed jackal (*Canis mesomelas*). Black-backed jackals are named after their distinct black and white specked saddle covering their upper backs (Walton & Joly, 2003). Endemic to Africa, black-backed jackals live in either eastern or southern Africa because they are two recognised isolated and separate subspecies with the last common ancestor existing over 6 million years ago (Van Valkenburgh & Wayne 1994; Hoffmann, 2014). The eastern black-backed jackal (*Canis mesomelas schmidtii*) can be found in Kenya, Tanzania and the United Republic of Congo up to Eritrea, and the southern black-backed jackal (*Canis mesomelas mesomelas*) in South Africa up to Angola and Zimbabwe (Walton & Joly, 2003; Hoffmann, 2014). Van Valkenburgh & Wayne (1994) studied both subspecies and found that the southern jackal is significantly larger than the eastern and that the eastern jackal has developed a more carnivorous diet because of their wider skulls, deeper jaws, and smaller dental grinding areas that would otherwise aid in digesting insects and plant-based foods.

1.1.1 Activity

Foraging and reproduction are two reasons for animals to be active and are also most likely to influence the activity of an animal (Theuerkauf *et al.* 2003). Previous studies have shown that black-backed jackals are active during the night and less during the day, with two activity peaks at sunrise and sunset (Rowe-Rowe, 1983; Loveridge & Macdonald, 2003). Fuller *et al*. (2008) showed in their study that the East African black-backed jackal is more active during early mornings and that this could be due to two other sympatric jackals' activity patterns; the side-striped jackal (*Canis adustus*) and the golden jackal (*Canis aureus*) and that coexistence affects the activity. However, black-backed jackals are the only jackal species in Ol Pejeta and cannot be affected by sympatric jackals. Considering their ability to change their circadian rhythm to fit the habitat situation they live in, as well as the prey that is preferred and available, it is difficult to know whether the jackals in Ol Pejeta follow similar activity patterns due to the lack of research.

1.1.2 Family and territory

Black-backed jackals live either as mated pairs or as a family group (Kamler *et al.* 2019). The dominant pair will patrol along territory boundaries sniffing the area and using scent markings like urination, scratching, and rubbing, by both male and female (Jenner *et al*. 2011). They are facultative cooperative breeders (Jenner *et al.* 2011) meaning they are capable of rearing offspring without the support or help of others. There is evidence of alloparental behaviour among younger jackals (also known as betas or helpers in some publications) who suppress their own reproduction to help care for their younger siblings (Bingham & Purchase, 2002; Kamler *et al*. 2019) creating these family groups. This kind of philopatry has its benefits; it increases pup survival, gives experience rearing pups, and allows for territory inherence (Kamler *et al.* 2019).

Group or family size can also vary depending on the food source. Jenner *et al*. (2011) study on black-backed jackals near a clumped abundant food source (Cape fur seals, *Arctocephalus pusillus*) found group sizes of 2-8 individuals where the group size significantly increased the further away they get from the food source, as well as territory size (ranging from 0.2 to 11.1 km^2). The same trend is observed by Ferguson *et al.* (1988) study, in which the size of the jackals' territory decreased as they approached an abundant prey source. According to Jenner *et al*. (2011), jackals are willing to travel up to 20 km to get to the seal colony, which indicates they are willing to have smaller territories and tolerate the presence of other jackals. This could harm farmers living near the area because of the increase in jackals (Nattrass *et al*. 2020b). If they find farmers' livestock to be an abundant food source, jackals will tolerate other jackals in the area, thereby increasing the population in the area.

1.1.3 Foraging

Black-backed jackals use different foraging techniques depending on the family group size and prey availability. They can either hunt alone, cooperatively in pairs, or in groups (Jenner *et al*. 2011; Temu *et al*. 2016; Hayward *et al.* 2017; Nattrass *et al*. 2020b). They cooperatively hunt down typically injured or old impala *(Aepyceros melampus)*, gazelle *(Gazella spp)* and springbok *(Antidorcas marsupialis)* (Loveridge & Macdonald 2003; Kamler *et al*. 2012). However, Kamler *et al*. (2009) observed a single black-backed jackal hunt and kill a seemingly healthy adult impala.

The diet of black-backed jackals varies both regionally and temporally (Avery *et al*. 1987; Walton & Joly, 2003; Nattrass *et al*. 2020b). They are generally considered opportunistic generalists (Van de Ven *et al*. 2013; Temu *et al*. 2016; Hayward *et al*. 2017). However, a recent study by Hayward *et al*. (2017) found that it might not be that simple. The authors found 20 articles related to the southern black-backed jackal, unfortunately, no record of the East African sub-specie was found to match their criteria for the study. Still, with the studies on the southern black-backed jackal they could conclude that the most frequently consumed animals in relation to the percentage of their diet were many species of different birds, sheep *(Ovis aries)*, and impala (Hayward *et al*. 2017). Yet, when counting the frequency of consumed animals at the different sites; kudu (*Tragelaphus strepsiceros*), bushbuck (*Tragelaphus scriptus*), and warthog (*Phacochoerus africanus*) were the most frequently consumed in that order. This research seems to suggest that jackals do not preferentially prey on sheep in South Africa but instead consistently select small mammals (Kamler *et al.* 2012), preferably prey with a weight range of 14–26kg (Hayward *et al*. 2017). Their results showed that black-backed jackals do exhibit preferences for small ungulate species with body masses between 17 to 30kg over other species of prey (Hayward *et al*. 2017). These preferences are further explained due to the type of prey (springbok, duiker *Sylvicapra grimmia*, and bushbuck) hiding their young as an anti-predator strategy instead of following the herd (Klare *et al*. 2010; Hayward *et al*. 2017). In Tanzania, jackals rely on scavenging carcasses during the dry season for food, but this increases their vulnerability to larger predators and conflict with other scavenging jackals (Temu *et al.* 2016). However, jackals nearly double their consumption of lamb during the lambing season (Kamler *et al.* 2012) making it harder on farmers since they have to compensate for the loss of each lambing season. Black-backed jackals are still an important mesopredator in areas they live in and can even be beneficial to livestock farmers due to their ability to supress certain herbivore populations, leaving less grazing competition for livestock (Kamler *et al*. 2012; Bagniewska & Kamler, 2014; Nattrass *et al.* 2020b, 2020a).

1.2 Aim

The limitations of academic research on jackals are evident, most studies are outdated or conducted in countries with completely different seasons. There is a need to study the activity patterns of jackals, to further understand their activity and role in the ecosystem they live in. This is especially true for the eastern sub-specie since most studies have been conducted in the south of Africa and on the southern sub-specie. The general aim of this study is to further investigate the ecology and behaviour of this species and environmental factors will also be considered as they relate to jackal behaviour and activity.

1.2.1 Research questions

Question 1: When does migration activity of black-backed jackals take place during the day?

Question 2: Is there any effect of weather (temperature, cloud cover, rainfall) on the migration activity of black-backed jackals?

Question 3: Does visibility at night (cloud cover, moon phase) influence the migration activity of black-backed jackals?

2. Material and Methods

2.1 Study site

Ol Pejeta Conservancy (OPC) is a not-for-profit wildlife conservancy in Kenya, covering an area of 360 km^2 in Laikipia County. The border of the conservancy is fenced with an electric fence except for three wildlife corridors along the northern border of the conservancy (Figure 1) These corridors provide a unique opportunity for studying migration and diurnal rhythm of a number of species and the corridors are hence monitored closely by cameras. The fences and corridors are in place to ensure that wild animals only leave the conservancy towards other conservancies in the north due to farms in other directions, as well as to keep rhinos (norther white *Ceratotherium simum cottoni*, southern white *C. s. simum* and black rhino *Diceros bicornis*) inside the conservancy for protection. OPC, which used to be an old cattle ranch in colonial times and that still have cattle grazing inside to this day, is now said to have one of the highest predator densities in Kenya according to their own website (*Ol Pejeta Conservancy, 2021*).

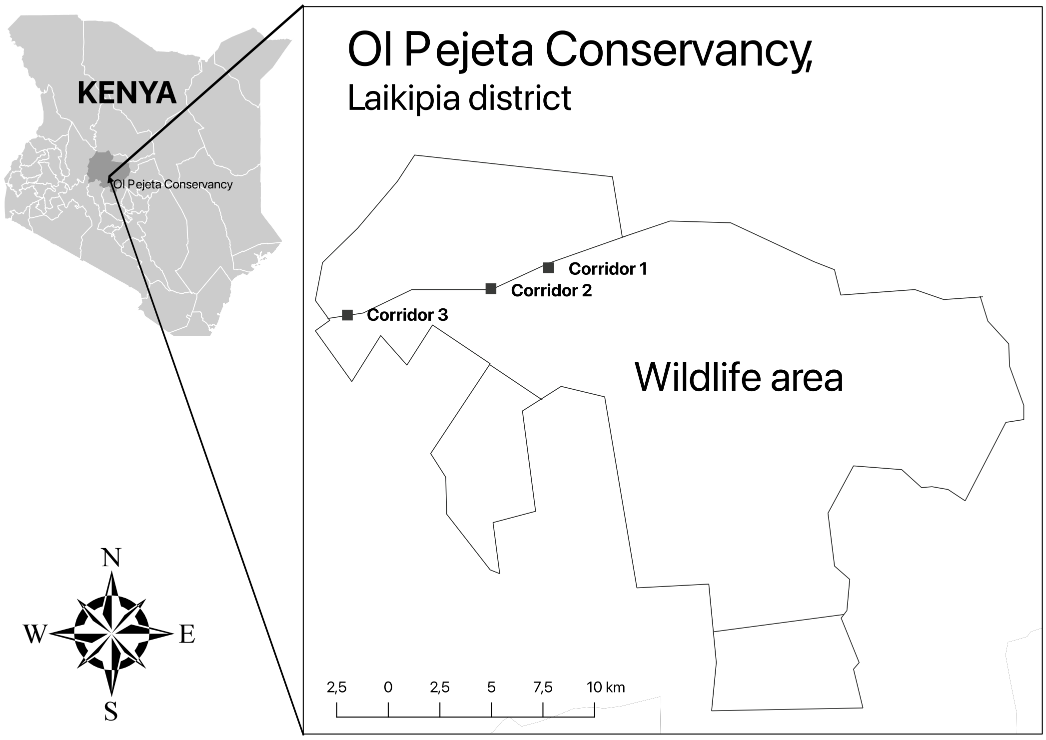

Figure 1. Map of Kenya, Laikipia district highlighted in dark grey with a schematic of Ol Pejeta Conservancy. The three wildlife corridors marked out along the northern border. (Illustration: Julia Wallin)

2.1.1 Corridors

To investigate the jackals' activity, cameras along the northern wildlife corridors were used to capture their movements. The corridors are comprised of a long 'wall' of stones that separates the inside and outside of OPC and follows the line of the electric fence. There is a raked dirt area between the line of stones to where the cameras were placed and wooden poles in between (Figure 2 & Figure 3).

The study used pictures from 1st of October 2015 to 21st of December 2019. Between the 21st of April 2017 and the 24th of April 2017 all corridors were shut down for 2 weeks. After the 2 weeks, corridors 1 and 2 reopened, while corridor 3 remained closed to date due to farming activity outside OPC. Two cameras were moved from corridor 3 to corridor 1, hence why corridor 1 has cameras A to F. Therefore, corridor 1 only had 4 cameras (A-D) before the 21st-24th of April 2017. Moving the cameras was done to cover some blind spots at corridor 1.

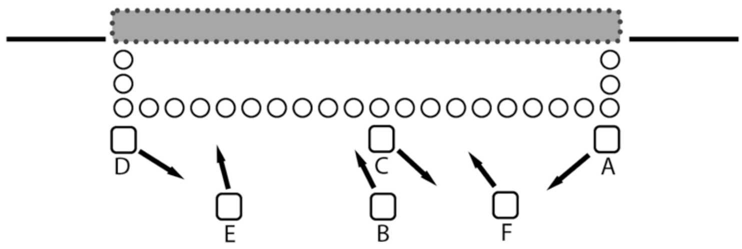

Figure 2. Illustration of corridor 1 with a length of 183 meters and 6 cameras (A-F) inside OPC pointing to different directions. Not to scale. (Illustration: Julia Wallin)

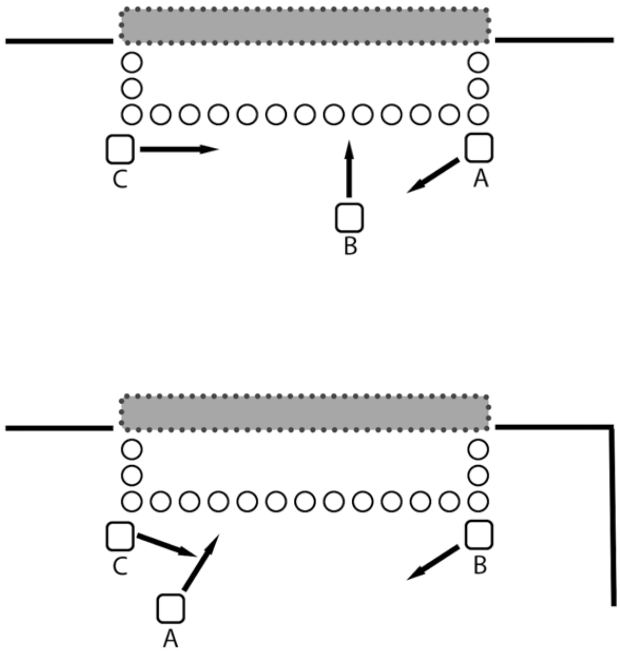

Figure 3. Illustration of corridor 2 (top) and 3 (bottom) with a length of 34 meters and 3 cameras (A-C) each inside OPC pointing to different directions. Not to scale. (Illustration: Julia Wallin)

2.1.2 Cameras

To capture black-backed jackals and other migrating animals on camera, infrared motion activated Reconyx HC600 Hyperfire cameras were used for the study (*Reconyx* n.d.). When triggered, the camera takes 3-5 pictures with a 0-5 second intervals and a silent period of 0-5 seconds (depending on the camera settings and the year). The cameras were secured on metal rods in boxes 80 cm above the ground. The cameras had a detection range of 24 meters during the day and 18 meters with flash and infrared illuminators during the night. Each camera had its own internal information such as label (camera A, B, C or D [E & F] and which corridor it was stationed in [1-3]), time, and date.

Every Friday, a local field assistant changed the batteries and memory cards in the cameras to ensure that the cameras were working continuously. The memory cards were then uploaded to a computer as the personnel on site sorted the pictures into different species, dated them, and upload the pictures into Dropbox.

To determine when the different cameras were operational (taking pictures), ExifTool (Harvey 2021) was used to extract metadata from all folders with unsorted pictures from October 2015 to December 2019 into an excel file. This resulted in several metadata tags (time, date, corridor, flash trigger, etc), time, date and the corridor of where each picture was taken from was selected. The data was then imported into RStudio (*RStudio* 2021). In total, for this thesis, there were 1547 days where at least one of the 10-9 cameras was active, and 52 days where no cameras worked, or files were missing (between October 2015- December 2019).

2.1.3 Registrations

Camelot (Hendry & Mann 2020, which is a desktop software for sorting and tagging pictures from camera traps was utilised to decrease the risk of human errors in the results by generating necessary data automatically, instead of the user doing so manually for each picture. That also made it possible to browse through a larger set of pictures for a shorter period of time. In Camelot, the independent sighting was set to 10 minutes (Palmer *et al.* 2017); if two jackals move in and out of frame within the 10-minute limit the assumption was that they were the same jackal. If the time between the sightings were ≥ 10 minutes, the assumption that they were two different individuals was made.

An animal was registered once for one picture in each series (series of pictures varied from 3 to 5) and the 'group' number was adjusted. This meant that two jackals had one individual registration each and the 'group' number was adjusted to the number of jackals within the series (e.g., two individuals less than 10 minutes apart would both have a group size of 2).

Jackals inside the conservancy area, whose heads and bodies were pointed toward the corridor and appeared as if they were moving toward the corridor in one or more pictures were registered as OUT. The assumption was that they were most likely traveling toward the gate leading out of the conservancy. Jackals with one or more pictures with their body, head and traveling direction turned towards the inside of the conservancy was registered as IN. This indicated they were most likely turning away from gates into the conservancy.

Jackals that moved along the grass and raked area (about one meter on either side of the grass/raked line) inside of the conservancy were recorded as STAYING INSIDE. Jackals that moved along the grass then left the conservancy and returned to the inside within 10 minutes were also recorded as STAYING INSIDE, since they either did not leave the conservancy at all or left for a too short time period to be considered two independent sightings. Similarly, animals who entered the conservancy and then went or walked towards the corridor again within 10 minutes, were subjected to the same rule. They were registered as *STAYING OUTSIDE* since they did not remain inside the conservancy.

Series where the animal showed up in only 1 picture, whose direction/movement did not fit the above categories or stood still were disregarded as *UNCERTAIN*. Animals that passed the camera or raked area in a horizontal line were also registered as *UNCERTAIN* since the direction of the body or movement pattern did not fit with the above criteria, as well as not following the usual patrol line (2 meter wide grass/raked line being used the most).

2.2 Environmental effects

2.2.1 Weather data

Temperature and cloud cover were downloaded from the weather site OpenWeather (*OpenWeatherMap* 2022), where environmental records were documented every hour between 2015-2019. The average temperature and cloud cover could therefore be calculated for each day. These were then divided into 3 ranks of roughly the same number of days from small to large weather effect quantities. Access to OPC's weather stations was gained to compare the 2 stations closest to the corridors with the data from OpenWeather. The stations and OpenWeather followed similar trends but with some differences in the amount of rainfall. Ultimately, rainfall data from the two stations at OPC was used instead and daily average was calculated for this study. Rainfall was measured manually every day at about 07:00. Due to the large number of days with no rainfall, it was not possible to rank these equally into 3 ranks. Therefore, rank 1 had 1084 days of no rainfall and ranks 2 & 3 had 199 days each.

2.2.2 Astronomical data

Since OPC is located right on the equator, sunrise and sunset only differ by about 30 minutes throughout the months, 06:11-06:41 & 18:20-18:50, therefore, the average for both was used in this study. This resulted in sunrise being classified at 06:26 and sunset at 18:35. However, there will still be some light in the sky before or after the sun reaches the horizon, commonly referred to as dusk and dawn. There is little light in the sky from the sun when it sinks 6 degrees below the horizon, also referred to as civil twilight (Palmer *et al*. 2017; Nakamura-Garcia & Ríos-Chelén, 2021). Civil twilight is the point when light from the sun reaching the sky, meaning it would no longer be the moon that illuminates the sky (Palmer *et al*. 2017). This happened about 20 minutes before sunrise and 20 minutes after sunset. The sun illuminates the sky between 06:06 and 18:55 for this study, therefor the time between18:55 and 06:06 was classified as night.

Since the moon's position where moonrise and moon fall change every day, it was not possible to do the same with the moon as the sun. The moon was therefore only accounted for when it was at the horizon instead of at civil twilight. This means that there was a period before the moonrise and time after the moon sets where the moon is still illuminating the sky which is not accounted for in this study. Moonrise, moonset and moon illumination was found on the website timeanddate (*timeanddate* 2022) to complement the other websites used in the study since it was difficult to find one source that included everything needed.

There was no scientific consensus on which method was best used for behaviour changes corresponding to the moon's phases (Orsdol 1984; Daly *et al.* 1992; Griffin *et al.* 2005; Sábato *et al.* 2006; Ciechanowski *et al.* 2007). The moon was therefore categorised into 5 periods according to the percentage of the moon disk illuminated. This was done to maintain the extremes of light from the full moon and darkness from the new moon. The periods were as follows; 1 = 0%–20% (new moon), 2 = 20.1%–40% (waxing/waning crescent), 3 = 40.1%–60% (half-moon), 4 = 60.1%–80% (waxing/waning gibbous) and 5 = 80.1%–100% (full moon). The data set was limited to night-time sightings when the moon was at or above the horizon, since the aim was to compare the moon's effect on jackals and not necessarily the differences when the moon was present or not.

2.3 Pilot study - observations

Sporadic and opportunistic direct observations were conducted by me from a safari vehicle driving along random designated roads in OPC for a total of 9 half-days. Two of these started in the afternoon (around 14:00-16:30), seven in the early morning (around 06:40-13:00) and two of those continued until the afternoon (around 07:00-16:00 with a break between around 09:15-14:00). When spotting jackals, the number of individuals, group size, behaviour (Table 1), other animals nearby, and habitat-type (dense bush, open bush, grassland) was described. The behaviours were based on previous sightings during normal safari drives in OPC days before the observations took place. Groups were defined as being within 20 meters of each other and photographs were taken to record the time and habitat.

Table 1. Ethogram of the different black-backed jackal behaviours observed by me in OPC and their respective descriptions.

Behaviour	**Description**
Standing	Four feet on the ground head horizontal or higher to the body
Sitting	Behind on ground
Walking	Moving forward at a slow pace with two to three feet on ground at all times (Ghaskadbi *et al.* 2016)
Trotting	Moving with a rhythmic two beat diagonal gait in any direction (Ghaskadbi *et al.* 2016)
Running	Moving forward at a faster pace than trotting
Laying down	Body on ground
Feeding	Head in direct contact with feed
Nose to ground standing	Four feet on the ground with nose pointed close to the ground

Habitat was divided into 3 categories; Grassland (Figure 4), Open Bush (Figure 5), and Dense Bush (Figure 6), and were based on the habitat around the jackals within a 20-meter radius. Grassland was described as covering 22% of OPC and dominated by grasstypes *Themeda triandra, Penisetum stramineum* and *Penisetum mezianum*, while Open Bush covers most of OPC (53%) and was dominated by *Acacia drepanolobium* (*Habitats* 2015). The densest habitat was Dense Bush, occupying 27% of OPC and was dominated by bushtype *Euclea divinorum* (*Habitats* 2015). The rest of OPC was covered by Riverine (5%) with some Swamp/Marsh areas (*Habitats* 2015). If one habitat were to overlap with another during my observations, the one with the most percentage within the 20-meter radius was chosen. In total, 58 jackal observations were made during the time-period.

Figure 4. Grassland

Figure 5. Open Bush

Figure 6. Dense Bush

2.4 Statistics

The data from the pictures were sorted in Excel (Microsoft Excel 2022) by date and time. The data contained both jackal presence and non-presence by the corridors and were used to summarise jackal migration activity per hour and per day. This allowed for analysation of the weather effects temperature, cloud cover and rainfall since they were analysed as mean per day (sum of data points divided by data points) after they were downloaded as hourly values. Each weather effect was then sorted in order from small to large values and ranked into three equal rankings based on the number of days of this study. The mean weather value for each ranking was calculated by adding the values and dividing them by the number of days in the respective rank. The mean number of jackals for each ranking was also calculated based on the sum of movement activities for each rank divided by the number of days in the rank.

As for the effects of visibility at night, cloud cover was also analysed as mean per day and illumination percentages were already downloaded as such, however, migration activity registrations during the day were discarded as well as registrations when the moon was below the horizon. This study therefore only analysed the presence in the corridor during the specific conditions mentioned above and not at nights when the requirements were not met. Mean cloud cover values at night were also ranked into three categories the same way as the other weather effects for the day, mean jackal activity too. However, mean illumination values were ranked into five ranks based on the five moon phases, and the same method as the other weather effects was used. The five mean illumination value ranks, therefore, had a corresponding five mean jackal migration activity value as well.

Since this study tested the frequency of jackals by the corridors a Shapiro-Wilk test was done to investigate the normality in the data. The results from the test revealed a non-normal distribution ($p \leq 0.05$) in the dataset. Based on the Shapiro-Wilk test, a Generalized Linear Model (GLM) with Poisson regression was chosen to test whether the ranked weather effects together influenced jackal movement activity. The same test was used for visibility at night effect where cloud cover or illumination might influence jackal movement activity. Where significance was found from the Poisson GLM-test, a Kruskal-Wallis test would be applied, this was done to test if a ranked weather or visibility effect by itself could influence jackal activity. If the test significantly affected activity, a subsequent PostHoc Wilcoxon rank sum test, with a p-value adjustment to Holm, would be tried. The test was applied to compare the influence between the ranked values of the chosen effect on jackal activity. A Dunn's test was used for illumination periods because of ties in the Wilcoxon test. Ties happened when there are two identical values in the data which does not make the ranks unique to each other and can therefore not calculate exact p-values. The p-value was adjusted to Holms in the Dunn's test and the p-value was set to $\leq \alpha/2$ ($\alpha = 0.05$).

Changes in jackal migration activity were calculated with the mean number of jackals for each rank (1, 2 or 3) based on an effect increasing mean value (small to medium to large value). The significance level for the Poisson GLM-test, Kruskal-Wallis test and Wilcoxon rank sum tests was set to $p \leq 0.05$.

Data from the direct observations were gathered in excel and a pivot table was used to compare the number of individuals to behaviour, group size or habitat. Only percentages were used for the observational data.

RStudio (Allaire 2021) and Excel were used for the statistical analyses.

3. Results

3.1 General

The material consisted of 9796 pictures from the 1st of October 2015 to the 27th of December 2019. After sorting out incomplete dates, before and after camera check-ins and missing dates where no camera was working, a total of 1618 unique registrations (individuals) and 1482 camera trap days were used in this study. About 58% (n=857) of the 1482 days had no pictures of jackals, leaving 625 days with pictures of jackals to test migration activity for this study. However, due to their faster and more erratic walking patterns it was difficult for the cameras to detect them. Therefore, only assumptions could be made on their migratory direction at the corridors.

Among the 1618 registrations of jackals, 66.5% contained one jackal, 15.8% contained 2 jackals, 0.6% contained 3, and 0.1% contained 5 jackals. Corridor 2 had the most registrations followed by corridor 1 and 3 (n=1098, n=297 & n=224, respectively) (Figure 1). Camera A in corridor 2, camera A in corridor 1 and camera C in corridor 3 had the most pictures in their respective corridors (88.5%, 88.8% & 39.1% respectively) (Figure 2 & Figure 3).

There were 25 pictures that included other animals with the jackals; spotted hyenas *(Crocuta Crocuta)* were found on 10 separate occasions with jackals where the jackals either followed a lonely hyena or tried to steal the prey the hyena was carrying. A jackal turned from its straight path forward at night after a hare *(Lepus victoriae)* went from sitting to running when the jackal passed it. African elephants *(Loxodonta africana)* were seen 2 times, plains zebras *(Equus quagga)* 6 times, reticulated giraffes *(Giraffa reticulata)* 4 times, Thompson gazelle *(Eudorcas thomsonii)* once, impala once and olive baboons *(Papio cynocephalus anubis)* once.

Of the pictures 16 included jackals holding what looks like prey in its mouth. Four of these pictures were of legs from brown even-toed ungulates (most likely from gazelles residing in the conservancy) and 1 of a zebra leg. The rest (n=11) were of uncertain origin but were typically larger than a jackals' head in size and were covered with fur.

3.2 Activity

Analysis of the movement pattern of jackals showed that In and Out registrations were almost the same (532 vs 493 individuals) throughout the study period. However, more jackals were registered as having an unknown direction (311) than those jackals registered as either staying inside or outside (270 vs 13) the conservancy.

Jackals were more active during the night than during the day (Figure 7). The activity increased from about 17:00 and decreased around 07:00. There was a fairly large drop in activity at 03:00. In and Out registrations showed similar activity trends, but more jackals ventured into the conservancy between 05:00 and 09:00, while at night, more jackals ventured out between 16:00-22:00.

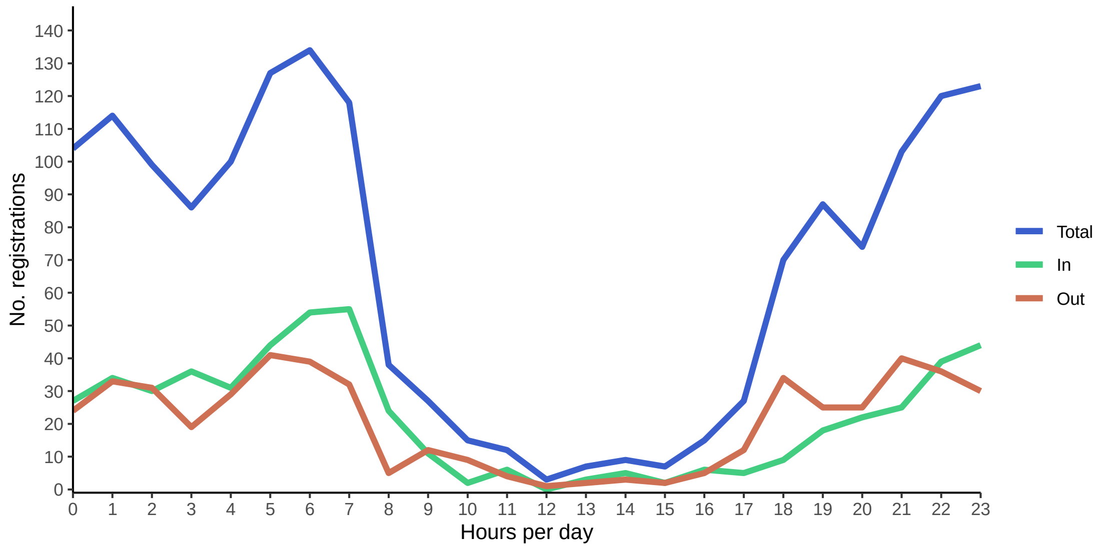

Figure 7. Circadian rhythms of jackals with total sum of registrations (individuals) for each hour during the entire study period as well as for migration in and out of the conservancy.

3.2.1 Pilot study - Observations

The observations resulted in 116 individual registrations of jackals between the hours of 06:00-11:00 and 13:00-16:00. There were 27 jackals observed as being solitary, 21 pairs (n=42), one group of 3 individuals, four groups of 4 individuals (n=16), two groups of 5 (n=10) and three groups of 6 individuals (n=18). The most common behaviours observed were trotting (n=38), lying down (n=35), and standing (n=21).

Out of the individual registrations (N=116) observed in OPC, Grassland (70.7%) was the most common habitat type to find jackals followed by Open Bush (20.7%) and Dense Bush (8.6%). One jackal was observed feeding on buffalo carrion, taken down by lions (*Panthera leo*) in dense bush habitat. A jackal pair was seen feeding on an ungulate fawn, the hunt itself missed, in grassland habitat. Another jackal found something small in the tufts of grass in a grassland habitat, jumped up in the air, landed with the front paws first and ate it. While one lion guarded a buffalo carrion, six jackals were then seen in the surrounding.

3.3 Weather effects on activity

The Poisson GLM revealed significant results for how daily average temperature (SE = 0.03070, z = 2.409, CI = 1.01 – 1.14, p = 0.016), cloud cover (SE = 0.03177, z = -2.618, CI = 0.86 – 0.98, p = 0.009), and rainfall (SE = 0.04341, z = 6.922, CI = 0.68 – 0.81, p<0.001) affect the activity of jackals.

Kruskal-Wallis test found no significant difference in activity between the ranks of daily average temperature (x^2 = 4.1738, df = 2, p = 0.124). However, there were still average jackal activity changes between the average temperature of 17.0°C & 18.3°C (ranks 1 & 2; Table 2), resulting in a 9.0% average activity increase. That activity only increased between average temperatures 17.0°C & 19.6°C (ranks 1 & 3; Table 2) to 18.0% and 8.26% between 18.3°C & 19.6°C (ranks 2 & 3; Table 2).

Both average daily cloud cover and rainfall ranks showed significant differences in jackal activity in the Kruskal-Wallis test (x^2 = 16.411, df = 2, p < 0.001 & x^2 = 28.955, df = 2, p < 0.001).

As a result of the Wilcoxon PostHoc test, there was a significant decrease in average jackal activity (18.0%) between 38.4% & 67.1% of average cloud cover (ranks 1 & 2; Table 2 [p = 0.0026]). Between 38.4% & 88.6% (ranks 1 & 3; Table 2 [p < 0.001]), a significant 25.78% average activity decrease was also registered. No significant activity change was recorded while the average cloud cover was 67.1% & 88.6% (ranks 2 & 3; Table 2 [p = 0.685]) but a 9.52% decrease in average jackal activity was still recorded.

There were also significant differences between rainfall ranks in the PostHoc test where 0mm & 15.4mm of average daily rainfall (ranks 1 & 3; Table 2 [p < 0.001]), decreased average jackal activity by 52.50%. Whereas 2.8mm & 15.4mm of average daily rainfall (ranks 2 & 3; Table 2 [p = 0.020]) resulted in a 42.42% activity decrease. The average daily rainfall of 0mm & 2.8mm demonstrated weak differences (ranks 1 & 2; Table 2 [p = 0.055]) where the average jackal activity decreased 17.5% at the corridors.

Table 2. Table showing mean environmental effect (temperature, cloud cover and rainfall), each with 3 ranks corresponding to the number of days within each rank, mean value of intervals as well

as the intervals (°C, % and mm), mean number of jackals per day and its corresponding standard errors (±SE).

Environmental factor	Rank	Days	Mean	Interval	Jackals	SE
Average temperature per day			*°C*	*°C*		
	1	484	17.0	14.3-17.8	1.00	0.07
	2	484	18.3	17.9-18.7	1.09	0.07
	3	514	19.6	18.8-21.8	1.18	0.08
Average cloud cover per day			*%*	*%*		
	1	499	38.4	10.0-55.8	1.28	0.08
	2	487	67.1	56.0-77.5	1.05	0.08
	3	496	88.6	77.7-100.0	0.95	0.07
Average rainfall per day			*mm*	*mm*		
	1	1084	0	0.0	1.20	0.05
	2	199	2.8	0.15-6.4	0.99	0.11
	3	199	15.4	6.5-52.5	0.57	0.08

3.4 Visibility at night

After removing registrations that did not fall into the night category (the period between 6:05 and 18:55), N=1155 nightly registrations were left. Approximately 45% (n=521) of the night registrations had a "non-visible" moon, where the moon was under the horizon. To assess whether the moon phase or illumination affected jackal activity, data from the "non-visible" moon registrations was discarded. As a result, 636 (55%) registrations had a moon at or above the horizon, which corresponded to a total of 357 nights with illumination periods of 1 to 5 (Table 3).

Poisson GLM was used to analyse the average cloud cover and illumination during night periods. No effect of average cloud cover at night (SE = 0.04828, z =

0.311, CI = 0.92 – 1.12, p = 0.756) on jackal activity was found, with little change in the average nightly activity either, while illumination showed significant (SE = 0.03076, z = 2.259, CI = 1.01 – 1.14, p = 0.024) effect on nightly jackal activity. The Kruskal-Wallis test for average cloud cover did therefore not yield any significant results (x^2 = 0.22276, df = 2, p = 0.8946) between the ranks on nightly jackal activity. An average cloud cover of 32.9% & 61.2% (periods 1 & 2; Table 3) and 32.9% & 86.6% (ranks 1 & 3; Table 3) resulted in a 3.45% increase in average jackal activity, while cloud cover averages 61.2% & 86.6% (ranks 2 & 3; Table 3) had no effect.

Table 3. Table showing mean visibility effects (cloud cover and illumination period) during nighttime. Cloud cover with 3 ranks and illumination period with 5, corresponding to the number of days within each rank, mean value of intervals as well as the interval (%), mean number of jackals per day and and its corresponding standard errors (±SE).

Illumination factors	Rank	Days	Mean	Interval	Jackals	SE
Average cloud cover			%	%		
	1	121	32.9	10.2-49.8	1.74	0.10
	2	117	61.2	50.1-72.5	1.80	0.12
	3	119	86.6	73.1-100.0	1.80	0.12
Illumination periods			%	%		
	1	28	12.0	0.7-19.5	1.21	0.08
	2	45	31.4	20.9-39.7	1.68	0.18
	3	54	50.5	40.3-59.9	1.85	0.18
	4	64	70.7	60.1-80.0	1.66	0.13
	5	166	93.9	80.1-96.5	1.93	0.10

Illumination periods showed significant (x^2 = 11.556, df = 4, p = 0.021) activity changes between the ranks when the Kruskal-Wallis test was used. The PostHoc Dunn's test for the different illumination ranks showed only a significant average activity increase (Table 4) between 12.0% & 93.9% of average illumination (ranks 1 & 5; Table 3), where the activity also increased the most across all pairwise comparisons. There were no significant differences between any other illumination period (Table 4). There was a high average jackal activity increase (Table 4) between new moon & waning crescent (rank 1 & 2; Table 3) and a smaller average increase in activity between waning crescent and half-moon (rank 2 & 3; Table 3). Interestingly there was a decrease in average activity (Table 4) between half-moon and waning gibbous (rank 3 & 4; Table 3) where the average jackal activity then increased again between waning gibbous to a full moon (rank 4 & 5; Table 3).

Table 4. Dunn's test between the different illumination periods with p-values ≤ $\alpha/2$ ($\alpha = 0.05$) and percentage of average jackal activity increase between periods 1 = new moon, 2 = waxing/waning crescent, 3 = half-moon, 4 = waxing/waning gibbous and 5 = full moon.

	Dunn's test			
Rank	1	2	3	4
2	p = 0.251 % = 38.84			
3	p = 0.036 % = 52.9	p = 0.541 % = 10.12		
4	p = 0.235 % = 37.2	p = 0.490 % = -1.2	p = 0.610 % = -10.27	
5	p = **0.008** % = 59.5	p = 0.519 % = 14.88	p = 0.861 % = 4.42	p = 0.421 % = 16.27

4. Discussion

The results of this study indicate that jackals were active between 19:00 and 06:00 where activity started by sunset and continued until sunrise to then decreased with low levels of activity between 08:00 and 17:00. Observations inside OPC indicate that jackals were active during the hours when they were not visible in the corridors. From the data collected by the corridors, jackal activity was affected by temperature, cloud cover and rainfall analysed together. However, temperature as a factor alone was not enough to change jackal activity. Cloud cover and rainfall significantly decreased activity by up to 25.78% and 52.50%, respectively. Cloud cover did not yield any significant changes in activity during nights when the moon was at or above the horizon. Instead, illumination did, with 12.0% to 93.9% of average illumination providing the highest activity increase (59.5%).

4.1 Activity

In this study, jackals at OPC follow a bigeminus activity pattern, where the activity has two distinct peaks, previously reported by Ferguson *et al*. (1988) and Loveridge & Macdonald (2003). However, this study used the total sum of jackals per hour instead of measuring the average distance moved or radio signal pulses over time. Radio-tracking study by Rowe-Rowe (1983) in the Giant's Castle Game Reserve, South Africa, reported no jackal activity between 9:00 and 14:59. Loveridge & Macdonald (2003) reported that black-backed jackals in Zimbabwe were more active between 16:00 and 07:00 rather than during the day. Similar results were found in this study with lowest jackal activity occurring between 08:00 and 17:00. The activity in Rowe-Rowe (1983) study started an hour before sunset and ended an hour before sunrise, this study found activity to decrease at sunrise (06:31) and increase an hour before sunset (18:35). Loveridge & Macdonald (2003) also found low activity levels between 01:00 and 03:00 that would increase until sunrise, to then decrease throughout the early morning, similarly to this study which had an activity drop at 03:00. Although these studies (Rowe-Rowe 1983; Ferguson *et al*. 1988; Loveridge & Macdonald 2003) are fairly old and uses different methods between their studies and to this study, they all show similar results. One clould thefore conclude that due to the similar results, using the corridors to measure activity pattern is a faily reliable method and also provides validity to the results shown in this study.

Ehlers Smith *et al*. (2019) suggested that the distribution of preferred prey in the area may cause a shift in activity patterns from nocturnal to crepuscular, as well as parallel activity peaks. Ferguson *et al*. (1988) also suggested that this bigeminus activity pattern is due to prey preference and the prey's activity pattern. Since there have not been any studies on jackals in OPC and few in East Africa overall, it is difficult to conclude if they have a specific preference in OPC that would affect their circadian rhythm, or if this is a general pattern.

The reason for the activity pattern could also be due to human activity outside OPC during daytime. Research shows that jackals can change their circadian rhythm; colonies in protected wildlife reserves are shown to be diurnal while those on farmland adapt to being nocturnal because of the presence and prosecution by farmers (McKenzie 1993). This proposed explanation is strengthened by the fact that more jackals entered the conservancy during the morning hours, while more jackals went out during the night. The observations confirmed jackal activity within OPC during the low activity period between 08:00 and 17:00 at the corridors. Prosecution and activity by farmers, people or cars outside the conservancy could explain why they are still active, just not at the corridors during these hours. The data presented here, however, is insufficient to support any prey preference or human activity theory. Additional research on prey preference with faecal diet composition, denning and sleeping hours is needed to fill this gap as well as satellite images to survey human activity in the area.

4.1.1 Individuals

Jackals typically live as mated pairs or family groups of 2-8 members (Jenner *et al*. 2011; Kamler *et al.* 2019). In 66.5% of the pictures, only one jackal is registered, which is surprising. Especially surprising since my observations found jackals to be alone for only 46.6% of the direct observations (N=58), meaning jackals are seen in pairs or more 53.4% of the observations. However, my observations are few and limited to the daytime within the conservancy. The results could be different if more observations had been done in other places and at different times of the day.

One explanation for the large number of single jackals in the pictures could be that the independence interval set for this study was too short. If jackal pairs crossed the corridor with more than 10 minutes apart, they are automatically registered as two individuals instead of a pair. Kamler *et al.* (2019) found both alphas (parents) and betas (children) to travel past their home ranges on excursions, with betas travelling further distances and for longer durations than alphas (2–8km 2–20% of the time and 2–3km 0–3% of the time, respectively). This is most likely so that betas can familiarise themselves with their surroundings, and search for future mates and territories (Kamler *et al.* 2019). Jackal do this since they are a disperal species, meaning when the betas grow out of their natal then they disperse and migrate to new areas to establish their own territories and families (Humphries *et al.* 2015). Juvenile male black-backed jackals can disperse to areas over 40 to 116km (Humphries *et al.* 2015) and could be a reason why many solitary jackals were passing the corridor. It is, to my knowledge, not studied whether betas or alphas travelling in pairs or groups can travel with a greater distance of ≥1km from each other.

4.2 Weather effects

With increasing global temperatures, measuring temperature's effects on animal behaviour will be crucial in the future, to understand its effect on both predator and prey behaviour. This study did find that daily average temperature affected jackal activity when analysing all the weather effects. However, temperature alone did not affect jackal activity. A study on African wild dogs (*Lycaon pictus*) found five packs to benefit from higher temperatures (Creel *et al.* 2016). Higher temperatures are of a larger disadvantage to their prey, impala and wildebeest (*Connochaetes taurine*), rather than the dogs themselves, resulting in increased hunting success and shorter pursuits of the prey (Creel *et al.* 2016). However, wild dogs typically seek to cooperatively take down their prey and during dusk & dawn to avoid nocturnal lions and spotted hyaenas. This study demonstrated that activity increased but cannot conclude if the activity increase is due to increase of kill rate or hunting success.

One way to improve a study on the effects of temperature, instead of using a daily average temperature, can be to use the averaging minimum and maximum temperatures throughout the day or even use the exact temperature when the jackals were registered in the pictures by the corridors. Using more precise temperature during active hours would perhaps be more beneficial than using a daily average, especially since jackals are more active during colder hours: around sunset, night and sunrise.

Cloud cover is seen to negatively affect jackal activity. While Harmsen *et al.* (2011) study did not use cloud coverage in their analyses, they do stress the importance of its relationship with activity. Yet, few studies have researched cloud cover's effect on daily activity, since most studies focus on cloud cover with moon illumination and activity at night (Rockhill *et al.* 2013; Schuttler *et al.* 2017; Preston *et al.* 2019; Botts *et al.* 2020).

Due to an increase in rainfall during wet seasons in OPC, the accumulation of cloud cover during that period should therefore be larger. It is difficult to determine whether there is a significant causation between the two factors since they were not analysed in this thesis since the two weather effects originated from different sources and could be a source of error in this study. Cloud cover was retrieved from weather stations outside OPC, closer to Mount Kenya and could not be measured at camera locations, while rainfall was measured within OPC close to the corridors. There were days where rainfall was found in OPC but no clouds were registered at the weather website. Since this study used a daily average of cloud cover instead of the percentage at the specific time a jackal movement was registered in the pictures, this could have affected the results. Perhaps there was no cloud cover during the day but was during the night. This means that the average would have some cloud cover regardless of when the jackal was active and could have led to a bias in this study.

Daily average rainfall also had a negative effect on the activity of jackals and the effect was significant between 0mm & 15.4mm and 2.8mm & 15.4mm of average rainfall. Activity decreased with the amount of rainfall making it clear from the results of this study that jackals prefer dry days or days with little rain rather than those with heavy rain. Few studies have studied the rain's effect on carnivore behaviour, and those that are available seem to point out that the effect on carnivore behaviour is due to indirect prey abundance and dispersion (Loveridge & Macdonald 2003; Dickman & Marker 2005; Ogutu *et al.* 2005). As this study did not compare wet and dry seasons or prey behaviour in relation to rainfall, no further insights into this question were found.

4.3 Visibility at night

There was no effect on jackal activity from average cloud cover during nights when the moon was at or above the horizon. Harmsen *et al.* (2011) study assumed that cloud cover would weaken the relationship between moon phase and activity due to the inability to measure its effect on illumination at the camera stations. However, other researchers have shown that moon illumination can also vary according to the type of cloud cover and cloud type (Rockhill *et al.* 2013). High and thin clouds could amplify illumination, at least in cities where light pollution is common (Kyba *et al.* 2011). Assuming that cloud cover alone would decrease illumination would introduce bias to the analysis. Due to inadequate cloud illumination during the night, there is also an underestimation of cloud coverage at night (Hahn *et al.* 1995). Not including cloud cover in this analysis could have been beneficial since it would not introduce bias to the data.

Illumination did influence jackal behaviour where jackal activity increased with brighter moon illumination, and it was significant between new moon (0-20%, rank 1) and full moon (80.1-100%, rank 5) illumination. This study showed that jackals are significantly more active during full moons rather than new moons when the moon is at or above the horizon. An older study on radio-tracked black-backed jackals in South Africa showed that they were most active during intermediate moonlight but decreased their activity during high illumination (Ferguson *et al.* 1988). This study found larger number of average jackal activity during full moon followed by halfmoon, crescent, gibbous and new moon. Activity increased from new moon to halfmoon and then decreased between halfmoon and gibbous to then increase again to full moon. The 10.27% decrease in activity between halfmoon and gibbous is unexplainable in this study since the activity otherwise increase between the moon phases between new moon to full moon. Ferguson *et al.* (1988) suggested in their study that low activity during moon lit nights could be due to prey easily detecting jackals during full moon periods, which would decrease hunting efficiency and success, causing jackals to be inactive during these periods. Light has been found to affect vigilance in deer (*Odocoileus virginianus*). Deer in areas without apex predators like wolves (*Canis lupus*) and cougars (*Puma concolor*), that contained mesopredators like coyotes (*Canis latrans*), are significantly less vigilant at night, especially during nights with heavy cloud cover or no moon present (Schuttler *et al.* 2017). Although the deer became less visually vigilant in these conditions when their vision are less effective, they instead increased their auditory vigilance. Furthermore, an increase in group size also decrease individual vigilance in deer (Schuttler *et al.* 2017). Lions favour hunting during moonless nights or when heavy clouds obscure the moon due to an increase in hunting success (Orsdol 1984; Preston *et al.* 2019). Funston *et al.* (2001) study on lions revealed that successfully hunting medium-sized prey and buffalo significantly increased during dark or no moon conditions, but no significance was found in the hunting success rates of impala, and small-sized prey. Since studies on jackals have shown that they feed on gazelles, such as impala, and other small-sized prey (Kamler *et al.* 2009, 2012; Hayward *et al.* 2017), it could therefore be assumed that there would not be any differences in their hunting success during night. However, as seen in Rafiq *et al.* (2020) study, although lions favour hunting during low illumination due to an increase in hunting success, their activity pattern was not affected by the moonlight illumination. If jackals favoured scavenging in OPC than hunting specific prey per their preference, one would assume that there would be activity increases around dark illumination periods in relation to lions hunting success. No such relation was investigated in this study and due to the uncertainty in prey preference and hunting success rates in relation to moonlight, more research is needed, and the use of better methods that can be validated should be used.

Spotted hyaenas do not seem either lunar phobic or -philic (Cozzi *et al.* 2012), and jackals were seen with hyaenas in pictures from the corridors on multiple occasions in this study, but never with lions. Jackal activity during the full moon could be a way to avoid encounters with other larger predators (Beltrán & Delibes 1994), in this case lions. However, there was still registrations (45%) of jackals where the moon was below the horizon meaning that the assumption that jackals avoid activity during moonless nights while favouring nights with a lot of illumination to avoid hunting lions might not be entirely true.

Activity and moon phases are an area that has not been studied on black-backed jackals and caution should be taken in the interpretation. However previous studies on mesopredators like the Iberian lynx *(Lynx pardinus)* and red fox *(Vulpes vulpes)*, have reported weak or no impact of moon phase/light at night on activity (Penteriani *et al.* 2013) and it is suggested that there are other more substantial factors at play, rather than just the moon. Still, the red foxes in Penteriani *et al.* (2013) study were more active during the darkest nights, possibly due to increased rabbit *(Oryctolagus cuniculus*) hunting success and decreased lynx activity. One jackal was seen passing a hare at night (01:18), during a moonless night where the moon phase was reaching a new moon at corridor 2 and did not notice its presence until the hare ran away. Since it seemingly did not visually see the hare before its movement, one could assume the jackal either smelled it but could not locate it or it did not see nor smell it and located it with sound first. There is, to my knowledge, no recent studies on auditory, visual, or olfactory preference on jackal behaviour. It is difficult to determine whether jackals favour hunting using one or all senses and especially during nights. More basic research into jackal biology and behaviour is therefore needed to draw a definitive conclusion.

Deciding on which method to use for measuring illumination and moon phase was very difficult since there is no scientific consensus on what is most optimal. A combination of different studies was used to make a new ranking for this study. Ciechanowski *et al.* (2007) used a scale of 0-15 with 0 being a new moon, 7 being the first or third quarter (halfmoon) and 15 being a full moon. Hecker & Bringham (1999) also used a scale of 0 (no light) to 50 (full moon directly overhead, no clouds). Daly *et al.* (1992) used a 7 day period to centre new and full moon (3 days before new/full moon, day of new/full moon and 3 days after new/full moon) with the rest of the days counting as either waning or waxing moon, Griffin *et al.* (2005) divided the lunar cycle into the full moon (14-days) and new moon (15.5-days) with a 5 day period centred around the two phases. Centring a new and full moon in a 5-7-day window leaves roughly 0%-15% and 80%-100% of the moon illuminated, which is similar to this study. Lang *et al.* (2006) divided illumination from the moon into 4 periods with 0–25% (new moon), 26–50%, 51–75% and 76–100% (full moon), which was an alternative option for this study. However, for the new moon and full moon to be as dark and light as possible, with the half-moon in the middle, dividing illumination into 5 periods based on the % of moonlight allowed that. Finding a more standardised method for measuring moonlights effect on behaviour is therefore needed for future studies since the different methods might offer different results.

4.4 Methods for studying black-backed jackals

4.4.1 Camera traps

If at least one camera had been working across all corridors throughout the entire study period, it should have left me with 1549 days. However, folders were deleted and not recovered on a computer, all corridors closed, and batteries died when the cameras were out in the field. 1482 days were left which was about 95% of the entire study period. Since more than half (58%) of those 1482 days did not show any jackals crossing any corridors, including more years or months could be beneficial for further studies.

One of the biggest challenges with this study was to accurately describe the direction the jackals were moving. During the observations from the car, it became evident that jackals prefer to trot, rather than walk when moving from point A to B. The faster walking pace along with darkness at night made it difficult for the cameras to pick up jackals moving. This created blurry pictures and uncertainty in the reliability of in and out movements. Even during the day, there were sometimes pictures of jackals that had already passed a camera, where only one out of two got caught on picture (shadow on the ground provided evidence of another individual).

Even though the cameras used for this study are motion-triggered, they are still dependant on temperature fluctuations (the difference between the animal's temperature in relation to the ambient air temperature). However, even with a trigger speed of 0.2 seconds, it was not fast enough to capture jackals' movements. Another reason why the pictures made it hard to determine movements could be because of the camera's own internal limitations in detection fields (*Reconyx* n.d.). Jackals that did not walk within the detection fields were therefore not photographed, or wind caused disturbances for the motion detector or changes in the temperature of the animal matching ambient temperatures. The cameras also work less efficiently when animals walk towards the cameras, rather than when they pass in a side-to-side movement (*Reconyx* n.d.). This limitation became evident when reviewing footage where the cameras faced out of the conservancy. Jackals would appear headfirst 3 meters in front of the camera but their walk towards the camera was not captured.

Determining the age and sex of jackals was not possible from the pictures alone. Only one picture featured an adult and a small juvenile. In one instance, it was only possible due to the juvenile's small size and not specific age. It was equally impossible to determine the sex of the individuals from the pictures. A study by Van Valkenburgh & Wayne (1994) found eastern jackals to display less variation in sexual dimorphism compared to their southern counterpart, making the sex determination even harder for the observer.

Alternative method

Camera-trap data is useful for gathering data on a big number of individuals with little effort, making them extremely useful for wildlife monitoring (Sollmann *et al.* 2013). Telemetry data is more precise and detailed than camera-trap data, allowing it to uncover details about individual behaviour over large areas (Harmsen *et al.* 2011). However, compared with non-invasive camera traps, telemetry data (GPS [Global Positioning System] or VHF [Very High Frequency]) require the capture, restraint and physical handling of the animal that is studied (Proulx *et al.* 2012). This is very stressful for the animals and can also be painful (Proulx *et al.* 2012) and it is generally considered a less ethical method in comparison to camera traps. It has also been reported to be fairly difficult to trap jackals because of their behaviour-plasticity, where they change their behaviour as a result of previous experience and are therefore fairly good at avoiding traps (Nattrass *et al.* 2020b, 2020a). This could lead to biases in age and gender where typically younger males are collared more often which would skew results and introduce bias (Nattrass *et al.* 2020b). While GPS collars give a more precise picture of where the animals go, when and why, they are expensive and take a lot of energy. In contrast, VFS collars are less costly and have a longer lifespan but require manual labour to track the animals. Still, the data from both types of collars are limited to the individuals researched on and due to high cost, they cannot be used on many individuals or many different species. Doing an additional telemetry study on some individuals in OPC would be a good complement to this study.

4.4.2 Pilot study - Direct observations

There were certain limitations to observing jackals in OPC. For starters where one could observe jackals, partly because there were designated roads and partly due to different landscapes offering different levels of visibility. For example, there were very few instances of jackal sightings in dense bush habitats. Most were seen in open grassland, even though they seem to prefer laying down in tall tufts of grass (Loveridge & Macdonald 2003), and the only times they were spotted in dense bush habitats were when there was a buffalo carcass taken down by lions. The reason for this may be because of predator vigilance or simply because they disguise themselves better from observers, which has yet to be fully explored. Loveridge & Macdonald (2002) used radiotelemetry to track jackals and found that black-backed jackals preferred grasslands more than other habitats even though grasslands only made up 18% of the study site. This was seen in southern Africa and in areas where there were no other jackal species in the area (Loveridge & Macdonald, 2002). This is to my knowledge the latest study on black-backed jackal habitat preference, but it does follow a similar trend to this study. During the direct observations jackals were observed more in grasslands (70.7%) compared to the other habitats even though grasslands cover the least percentage in OPC (22%). Still, more research on habitat preference for jackals in East Africa is needed since there is a serious knowledge gap on how their habitat preference affects other animals or how jackals themselves are affected by living in different habitats.

There was a limitation for how long the safari car could be used since rainfall started at around 13:00 while the observations remained in place. It became impossible to find jackals, therefore data on jackals from days where there was no rainfall in the afternoon was used. Due to the results of rainfall, negatively affecting when jackals are active, there would possibly be few jackals active to observe either way. There were also no observations of jackals at 12:00 in this study, which is due to lunch occurring at that time. It was not possible to continuously drive for an entire day in OPC, therefore only half days were recorded each day the observations occurred. Although there is a lack of a scientific standard for these observations, they provide an overview of what jackals do inside OPC during hours when they are less active by the corridors.

4.5 Social, sustainability and ethical aspects

It is imperative to note that these mesopredators are crucial to the ecosystem in which they live. Due to their ability to suppress hare (*Lepus capensis* & *L. saxatilis*) and ungulate populations (Kamler *et al*. 2012; Bagniewska & Kamler, 2014), which leaves less grazing competition for livestock in the area (Nattrass *et al.* 2020b, 2020a) they are beneficial to farmers. Research also show that killing mesopredators increase livestock loss the following year because of changes in jackals' social systems; where younger females do not stay within their family group and instead breed and immigrate to new areas (Doherty & Ritchie 2017; Nattrass *et al.* 2020a). Killing territorial predators may also increase wild herbivore populations in the area, out competing livestock and enhance depredation by other predator species (Humphries *et al.* 2015; Treves *et al.* 2016; Doherty & Ritchie 2017; Nattrass *et al*. 2020a). Farmers of large livestock, like cattle, are likely to suffer a loss due to larger predators, like lions and spotted hyenas being attracted to larger herbivores. It is therefore in the best interest of farmers to keep jackals in the area, even though to some farmers in south Africa they have the reputation of being a livestock pest in regions where they live due to their livestock depredation (Hoffmann 2014; Nattrass *et al.* 2020b). Still, previous attempts to eradicate jackals in south African areas have been unsuccessful and jackal populations have bounced back to stable populations in those areas again (Nattrass *et al.* 2020a).

Research in Kuku Group Ranch, Kenya, found that during 2012-2013 a total of 517 incidents of predation was found to be caused by black-backed jackals, second highest after spotted hyaena (Bauer *et al.* 2017). 515 of these incidents happened while herding and only 2 was recorded inside bomas. Compensation was paid out for depredation on sheep & goats, yet none was compensated to cattle and donkey farmers (Bauer *et al*. 2017). This difference was not explained in the article but coincide with Kamler *et al.* (2012) study which found that jackals in South Africa did not consume cattle or goat and that this was most likely due to the specific animals living within a closer proximity to humans. How farmers keep animals, as well as how they care for them during herding is therefore an important aspect to consider.

Since black-backed jackals are not included in the CITE Appendix they are therefore not protected from being killed or hunted outside of protected areas (Hoffmann 2014). Since the trophy hunt ban in 1977, killing wildlife has been strictly illegal in Kenya except when it comes to self-defence, farmers may therefore still legally kill jackals and other predators in defence of their livestock (Ogada *et al.* 2003; Bauer *et al.* 2017). Often, lethal predator management in South Africa is retaliatory (Nattrass & Conradie 2018). Lethal shooting, trapping or poisoning are among the methods of management, as well as bio-control methods such as fences, donkeys, or guard dogs (Humphries *et al.* 2015). A report from South Africa found that more than half of farmers used poison, which is illegal, but also detrimental to the environment and ecosystem since it is not a targeted control method (Nattrass & Conradie 2018). The poison does not only affect the animal it is intended for, but also other animals that might feed or drink from the same source, or scavenging animals that feed on their bodies (Nattrass & Conradie 2018).

With increased agricultural land and settlement demand the conservation and continuous study of this mesopredator is important for the ecosystem it provides to farmers as well as wildlife. This study is an initial step to understanding black-backed jackals better and could be used to promote better housing practices and to prevent cruelty by making farmers aware that retaliatory killing of this mesopredator comes with high risk and low reward.

5. Conclusion

This study shows that jackals' migratory behaviour at the corridors in OPC are affected by temperature, cloud cover and rainfall during the day, and that moon phases affect their behaviour during the night while cloud cover does not. During my direct daytime observations inside OPC, jackal activity continues at hours when activity in the corridors slows down. This indicates that activity in the corridor may not be a reliable measure of jackal activity as a whole inside OPC, but rather just for the corridors. Future studies should combine other tools and methods to reliably measure their activity in the area.

These results provide a much needed and updated insight into jackal ecology, especially as an eastern subspecies. Further research should also be conducted on how temperature and weather affect their behaviour, as well as their prey's behaviour, considering there has not been any recent progress in this area.

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Popular science summary

Did you know that jackals dislike heavy rain, or that they prefer a full moon over a new moon?

Jackals are playing an important role in the ecology as they keep wild herbivore populations down, such as gazelles and hares, which leaves enough food for livestock animals like cow, sheep and goat. There are two types of black-backed jackals in Africa, one in the east and one in the south, with their name based on the black and white speckle saddle on their backs. This study looked at jackals living in a fenced wildlife conservancy in Kenya and was made by studying camera trap pictures collected for 5 years and comparing jackals' activity with weather, time of day and moon phase data. Although previous studies provide an idea of when jackals are active; inactive during the day and active at night, it has not been studied in East Africa before. There are a few studies on their diet and territory, however, not from the eastern jackals but rather the southern jackals. The eastern jackals live in a completely different landscape with other animals and different seasons and often sharing their living space with farm animals. Using factors like weather (temperature, cloud cover in the sky and rainfall) and light at night (moon phases and cloud cover) the goal of this study was to understand more as to why and when jackals are active. By watching them directly inside the wildlife reserve, I could study their activity in detail.

Jackals migrated out from the reserve between 19:00 and 06:00 while staying inside the reserve during the day. If this is because they are afraid of human activity outside, or because their favourite prey is active or inactive during these hours is not yet known.

Results from the pictures showed that temperature alone did not affect jackals' migration, although the warmer it got there was a small increase in the number of jackals. Meanwhile, both cloud cover and rainfall had a huge effect on jackals' activity. If it rained and there were clouds in the sky, there was much less activity, meaning jackals do not like rain or clouds in the sky. The results also showed that jackals are affected by how much light there is in the sky at night. If there is a full moon out you are a lot more likely to find a jackal than if there is no moon in the sky, however, this is only true when the moon is at or above the horizon.

Research like this is needed to further close the knowledge gap on jackals, especially during times where temperatures around the world are rising and human population are increasing.

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