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Wildlife corridor use amongst reticulated giraffes *(Giraffa camelopardalis reticulata)* at Ol Pejeta Conservancy, Kenya

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Summary

The African continent is home to many large and unique wildlife species and is, as is commonly known, considered to be the birthplace of the human race. The numbers and strength of this wide array of species is however diminishing rapidly before our eyes (Campbell *et al.*, 2003; Ogutu *et al.*, 2016). In merely the last three decades, the population of reticulated giraffe (*Giraffa camelopardalis reticulata*) in Africa has seen a rapid decline of 56% with a steady downward trend (Muneza *et al.*, 2018). The reticulated giraffe is since March 2018 listed as endangered on the International Union for Conservation of Nature's (IUCN) red list of threatened species and there are currently an estimated 11,000 reticulated giraffe roaming the East African plains.

This study aims to gain further knowledge about migration behaviour, specifically the use of wildlife corridors, in reticulated giraffes in order to better understand the needs of this magnificent species and thereby facilitate work in constituting strategies of conservation. The study took place at Ol Pejeta Conservancy, a 360 km^2, fenced, private reserve in Laikipia County, Kenya. Camera traps set up at three specific entrance/exit points in the fence, recorded passages in and out of the conservancy for a total period of three years (October 2015–September 2018). The data collected for reticulated giraffes consisted of approximately 30,000 images, from which 563 passages were excerpted. For each passage time, date, choice of corridor (1–3), direction of travel, sex, group size and lunar phase were noted. If possible, individual giraffes were identified by their unique coat pattern. A passage was defined as a single animal passing through the wildlife corridor either in or out of the conservancy. Weather data consisting of temperature, precipitation and cloud coverage was obtained online. The different variables were analysed in order to find spatial and temporal factors correlating to giraffe migration.

A total of 563 passages were recorded and in 461 of them the sex could be verified. Male giraffes accounted for 447 of these passages (97% of all passages with recorded sex) and females 14 (i.e., only 3% of all passages with known sex) during the three-year period. Passages were made significantly more often during early morning and late evening ($p<0.005$) with peak in-passages recorded in the morning and out-passages in the afternoon. Mean group size was 1.6 giraffes, where lone bulls accounted for 85% of all single animal passages ($n=396$). Corridor 2 was favourited by the giraffes, while the other two corridors were rarely used. During the night, giraffes were more inclined to use the corridors during high lunar luminosity and less so during low lunar luminosity. No impact of temperature or cloud coverage on giraffe migration was seen in this study; the impact of current previous precipitation remained unclear. The reasons for male giraffe migration in and out of the conservancy could not be determined within this study but is hypothesised to be a result of search for receptive females in oestrus and/or as a part of predator avoidance.

Content

Introduction

Wildlife conservation

The African continent is home to many large and unique wildlife species and is considered to be the birthplace of the human race. The numbers and strength of this wide array of species is, however, diminishing rapidly before our eyes, much due to the constant confrontations that arise when humans and animals have to share the ecosystems and resources around them (Campbell *et al.*, 2003; Ogutu *et al.*, 2016).

Wildlife conservation throughout Africa and the rest of the world constantly faces challenges with designing and maintaining strategies that manage to combine ensuring long-term survival of particular species and ecosystems while remaining agreeable to, and manageable by, the local human population and ruling governments (Newmark & Hough, 2000). Much of this struggle stems down to the simple fact that the coexistence of man and animal is not a relationship based on mutual respect and understanding as much as it is a tug of war where the interests of one side often collides with, or even directly counteracts, those of the other. Human-wildlife conflicts occur both in rural and in urban areas and although they may differ in expression and/or severity, the fact remains that in order to successfully preserve threatened flora and fauna, the interests and concerns of adjacent human groups have to be addressed and prioritized within the conservation strategies themselves (Ekdahl, 2012). In Kenya, an increasing amount of conflicts between humans and wildlife has arisen over the past few decades. Meanwhile, many of the country´s wildlife populations, the reticulated giraffe included, have during this same time dramatically decreased (Ogutu *et al.*, 2016; Ojwang' *et al.*, 2017).

Giraffe Conservation

The giraffe is currently recognized as a single species, *Giraffa camelopardalis*, with nine subspecies (Dagg, 2014). Although this taxonomic classification is somewhat disputed it will not be further discussed in this paper. The reticulated giraffe, *Giraffa camelopardalis reticulata*, is as of 2018 listed as endangered on the International Union for Conservation of Natures (IUCN) red list of threatened species (Muneza *et al.*, 2018). The major threats to the giraffe population in Central and Eastern Africa are habitat loss through conversion of land for farming and increased human populations, drought, illegal hunting for meat and hide, and armed conflict throughout unstable regions (Muller *et al.*, 2016). Over the last 30 years (3 giraffe generations), a decline in reticulated giraffe population by ~56% has been observed and the population is currently estimated to about 11,000 mature individuals, with the population trend continuously decreasing (Muller *et al.*, 2016). This rapid decline and threat to the giraffe population has only recently gained awareness and led to an increased interest in giraffe conservation. The first ever national giraffe conservation strategy was implemented in Niger in 2017 and a similar action plan was launched in Kenya in November 2018 (Giraffe Conservation Foundation, 2018).

Migration behaviour

Giraffes are the tallest mammals on earth with a striking height of up to 5.5m, and the world´s largest ruminants with adults weighing >1,000 kg (Dagg, 1971; Kingdon, 1979). Giraffes are browsing herbivores and are, although their numbers are dwindling, frequently seen on the African savannah. Despite the effectiveness of their rumination, due to their size, giraffes need to consume large amounts of feed daily. Hence, much like other large herbivores, they spend most of their time foraging (Le Pendu & Ciofolo, 1999; van der Jeugd & Prins, 2000). Generally, the availability of food and water significantly influences the movement and home range size of mammals, with animals living in arid landscapes having a more expansive home range than those adapted to areas with higher rainfall (Du Toit, 1990; Le Pendu & Ciofolo, 1999; Fennessy, 2009). For most giraffe populations the distance travelled as well as time spent foraging, greatly differ during the seasons, with home ranges during the dry season being approximately twice of those during the rainy season (Ciofolo & Le Pendu, 2002). However, this variance in home range may not be as apparent in populations whose habitat contain year-round available water sources (Leuthold & Leuthold, 1978). In Kenya, bulls and cows live in overlapping home ranges that vary from 16.5 to 164 km^2 and from 13 to 162 km^2, respectively, with the average home range within Ol Pejeta Conservancy (OPC) being 101 km^2 and 73.5 km^2 for bulls and cows respectively (Foster & Dagg 1972; Leuthold & Leuthold 1978; VanderWaal *et al.*, 2014). Aside from being driven by the search for food, water and mates, giraffe migration behaviour is also in part driven by predator avoidance, with the main predators to the giraffes within OPC being lions (*Panthera leo*), leopards (*Panthera pardus*) and hyenas (*Crocuta crocuta*) (Le Pendu & Ciofolo, 1999; Burkepile *et al*., 2013).

Aims of the study

The usage of wildlife corridors by reticulated giraffe has not previously been studied, and recent research in the area (VanderWaal *et al.*, 2014) imply that the wildlife corridors in OPC are not used by the giraffes to any great extent. With this study, we aim to investigate if, when, and to what extent, the wildlife corridors are in fact used by the giraffes. Furthermore, the study will investigate if/how the closing of one of the original three corridors had an impact on the movements of the giraffes within the conservancy.

Questions:

1. Do the giraffes at Ol Pejeta Conservancy use the wildlife corridors?

   If yes,

2. when, in terms of season and time of day, do the giraffes at Ol Pejeta Conservancy use the wildlife corridors?
3. is there a difference in corridor usage amongst the sexes?
4. did the closing of corridor 3 in April 2017 influence giraffe migration through the corridors that remained open?
5. does rainfall affect giraffe migration through the wildlife corridors?

Methods

Study area

The study was conducted in Ol Pejeta Conservancy (0ºN, 36º56′E), a 364 km^2 privately-owned wildlife reserve located on the Laikipia plateau in Laikipia County (Fig.1). The plateau (altitude 1800m) is part of the greater Ewaso ecosystem which covers much of the central part of northern Kenya. The parks and reserves spread across this vast area of land, OPC included, contain the greatest diversity and density of wild ungulates in East Africa outside the Serengeti-Mara ecosystem at the Kenyan-Tanzanian border. More than 20 species of indigenous large mammals, the reticulated giraffe included, roam these northern range-lands (Ojwang' *et al.*, 2017). The Laikipia plateau is home to an estimated 1,500 reticulated giraffes and the giraffe population within OPC itself is estimated to approximately 200 giraffes (Giraffe Conservation Foundation, 2017; Ol Pejeta Conservancy, unpublished data; VanderWaal *et al.*, 2014).

Fig. 1 *Laikipia County with OPC marked in dark green.*

Credit: OPC GIS/RS Office.

The reserve receives an annual 800–900 mm of rainfall and is a semi-arid grassland-woodland mosaic consisting of five different types of habitats (Fig. 2). Peak precipitation occurs during March–May and October–December, with January being the driest month with little to no rainfall (Schmocker *et al.*, 2016).

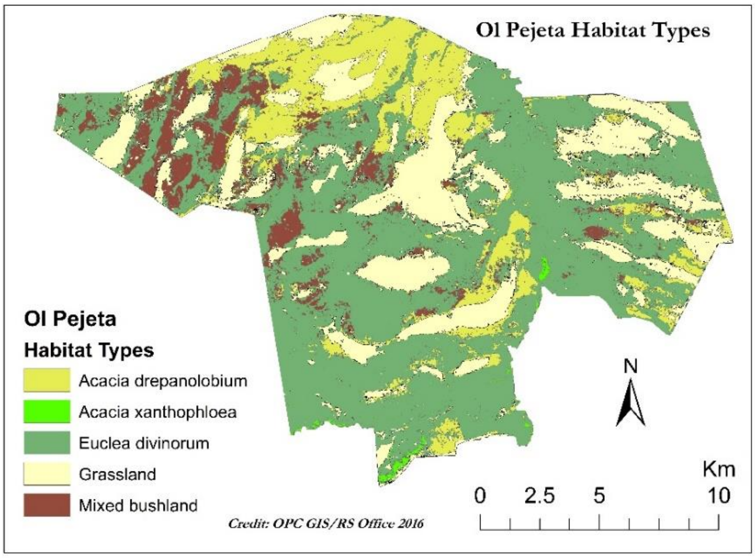

Fig. 2. *Ol Pejeta Habitats.*

Credit: OPC GIS/RS Office.

Wildlife corridors

OPC is an enclosed reserve lined with a 120 km long, solar powered electric fence. Along the north western side of the fence, there are currently two intentional gaps allowing all but one animal species to migrate freely into and out of the conservancy (Fig 3). Only rhinos, needing to be kept safe and guarded within the confines of the conservancy, are unable to leave. Other large animals can easily pass and are thus free to move and migrate as they wish, albeit only through these designated points along the fence (Ol Pejeta Conservancy, 2019). Up until April 2017, however, there were three monitored wildlife corridors in OPC. The westernmost gap (corridor 3) had to be closed due to political conflicts in the area. The corridors vary in length and surrounding vegetation. Corridor 1 measures 184m across and is situated in an open grassland while the corridors 2 and 3 both measure 34m and are surrounded by mixed bushland (Sernert, 2016).

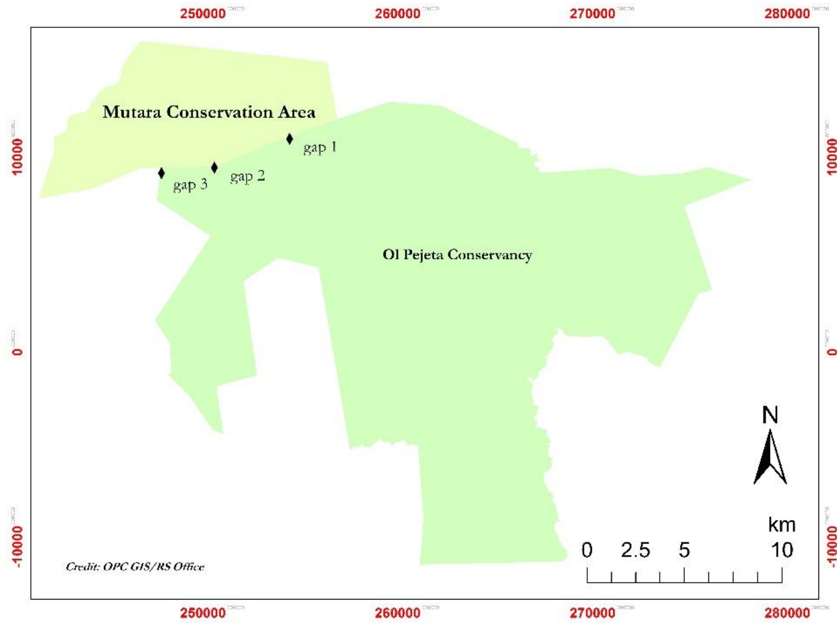

Fig. 3. *Fence gaps at OPC. The gaps open the conservancy to an adjacent conservancy, namely Mutara Conservancy, to the north.*

Credit: OPC GIS/RS Office.

Data collection and analysis

Each of the corridors lining the fence have, since June 2015, been monitored by infra-red movement activated trap cameras (model: Reconyx HC600 Hyperdrive) that photograph animals passing by. The cameras are set up approximately 1 meter above ground and overlook different areas of the corridor in order to minimize the risk of blind spots (Sernert, 2016). Depending on the length of the corridor, they have each been equipped with either three or four cameras. The detection range of the cameras is approximately 24 meters in optimal daylight conditions and 18 meters during night-time due to flash limitation. The camera is triggered when an object with a temperature different to that of the surround-dings moves across zones through the detection bands of the cameras' field of vision (Fig. 4). By default; date, time, temperature, lunar phase, corridor and number in the set sequence (1-3/3 or 1-5/5) are registered to each photograph as top and bottom data bands (Fig. 4).

From June 2015 until October 2018, a total of 3 million images were captured and sorted into files depending on animal species, with giraffe data amounting to approximately 30,000 images. The images were further viewed in Adobe Lightroom and for each passage in or out of the conservancy, time, date, lunar phase, choice of corridor, direction of travel, sex and group size was noted in a spreadsheet. If possible, individual giraffes were identified by their unique coat patterns and a databank of "frequent crossers" was set up. A passage was defined as a single animal passing through the wildlife corridor either in or out of the conservancy and images captured by the camera of animals passing by the corridor, without entering or exiting the conservancy, were excluded. Additionally, weather data consisting of daily mean temperature, precipitation and cloud coverage from Nanyuki Town was collected online from OpenWeatherMap. Due to technical difficulties regarding the first months of collected giraffe data, the analyses were made on data from October 2015 through September 2018. For the analyses, single factor ANOVA's, followed by T-tests for multiple comparisons were used when appropriate. Significance was determined at $p<0.05$.

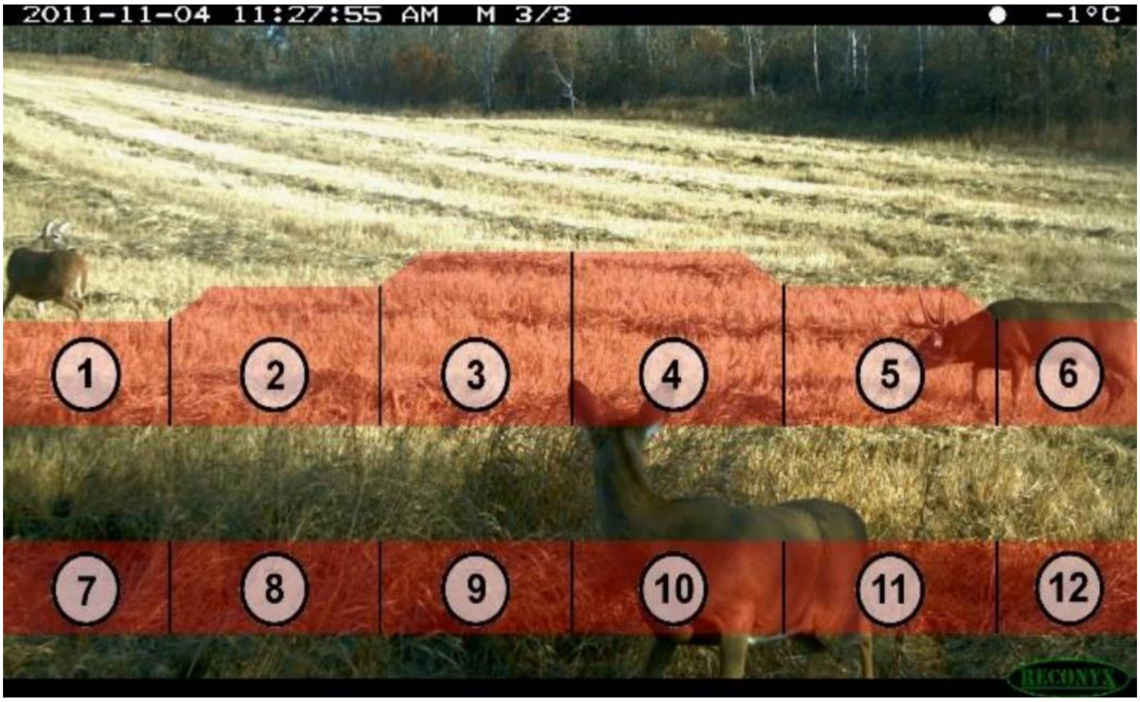

Fig. 4. *Camera trap sample image. The shutter is triggered when an object with a temperature different from the background temperature moves across the black lines dividing the zones. In the upper data band, date, time, image in sequence, lunar phase and temperature is registered whereas corridor and camera is registered in the lower data band.*

Results

Migration patterns

A total of 563 passages through the corridors were recorded during the three-year period of data collection. 519 (92%) of these passages were done by single animals (group size 1) or small groups (group size ≤3). The largest group size recorded was six individuals (Fig 5.). In 102 passages, the sex of the animals could not be determined (Fig. 6.) Male giraffes accounted for 447 passages and females for only 14 passages, i.e., 97 vs 3% of all passages with known sex.

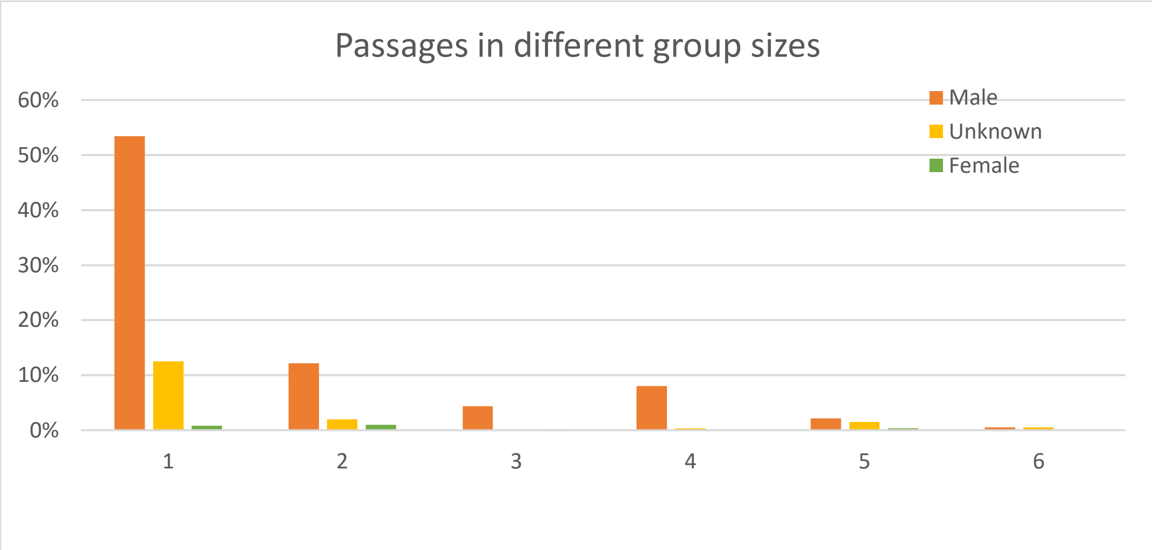

Fig. 5. *Percentage of passages by giraffes by group size (1-6 on the x-axis) and sex. Single animals and small groups ≤3 accounted for 92% of all passages. Female giraffes were rarely seen using the corridors during the three-year period.* σ_{male}*=129,* $\sigma_{unknown}$*=32.6,* σ_{female}*=2.16*

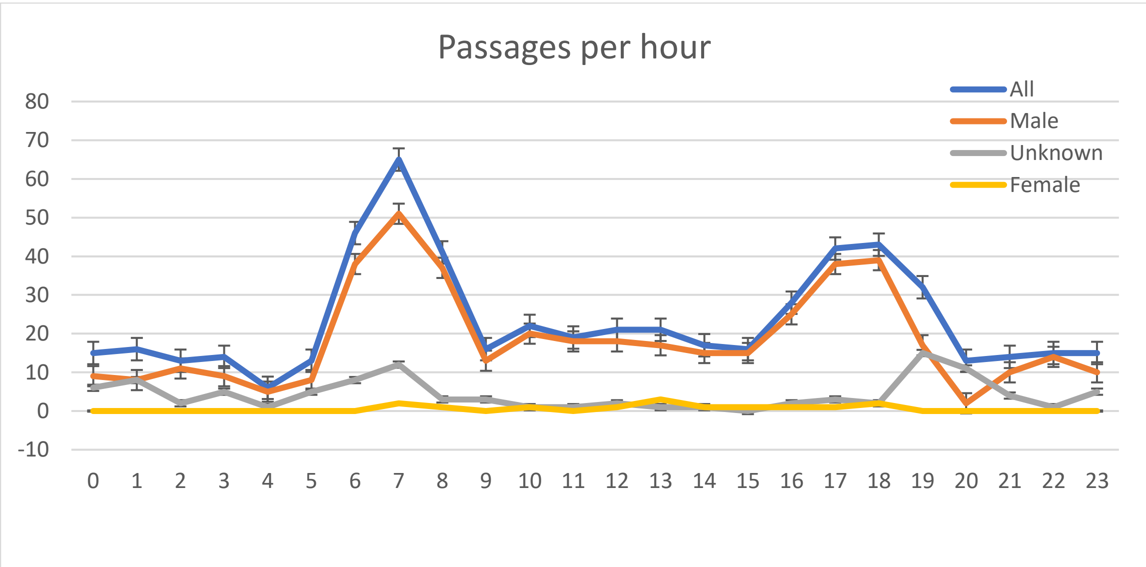

Fig 6. *Corridor usage by time of day for male and female giraffes as well as the total number of passages and giraffes of unidentified sex. Standard error shown in error bars.* σ_{all}*=13.9,* σ_{male}*=12.5,* $\sigma_{unknown}$*=3.88,* σ_{female}*=0.799*

Passages were most frequently made during early morning (6.00–8.59) and late afternoon (17.00–18.59), p=0.0004. For bulls, peak in-passages occurred during the morning hours while out-passages were most common during the afternoon (p=0.053, p=0.003). Cows, however, seemed more likely to use the corridor during late morning and mid-day, although this difference was not significant (p=0.42) (Fig. 6).

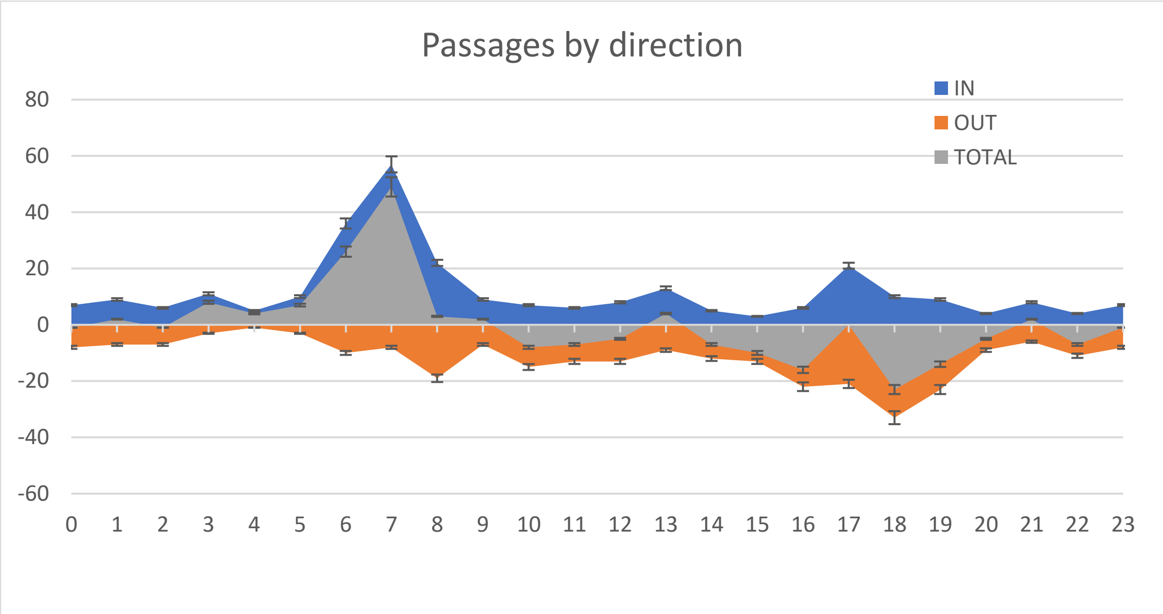

Fig 7. Passages by giraffes in and out of OPC depending on time of day, as well as the net amount with standard error. In-passages the more frequent during early mornings and out-passages more frequent in the late afternoon (p=0.053, p=0.003). $\sigma_{in}=11.8$, $\sigma_{out}=7.28$, $\sigma_{total}=13.9$

The most frequently used corridor by the giraffes was by far Corridor 2 (528 out of 563 passages, 94%) (p<0.001). Prior to being closed in April 2017, corridor 3 was the least used corridor in the conservancy with only six recorded giraffe passages (1%). 29 passages (5%) were noted through corridor 2. The closing of corridor 3 did not result in a significantly increased use of corridor 1 and/or 2 (p=0.940).

Migration and weather

During the dark hours of the day (from 20.00–5.59) there was a significant increase in corridor usage during lunar phase 3–7 when the moon disc is 50–100% illuminated (p=0.005) compared to during the lunar phases with little to no disc illumination, when the giraffes avoided using the corridors (Fig. 8). No difference was seen between in- or out-passages depending on lunar phase (p=0.907).

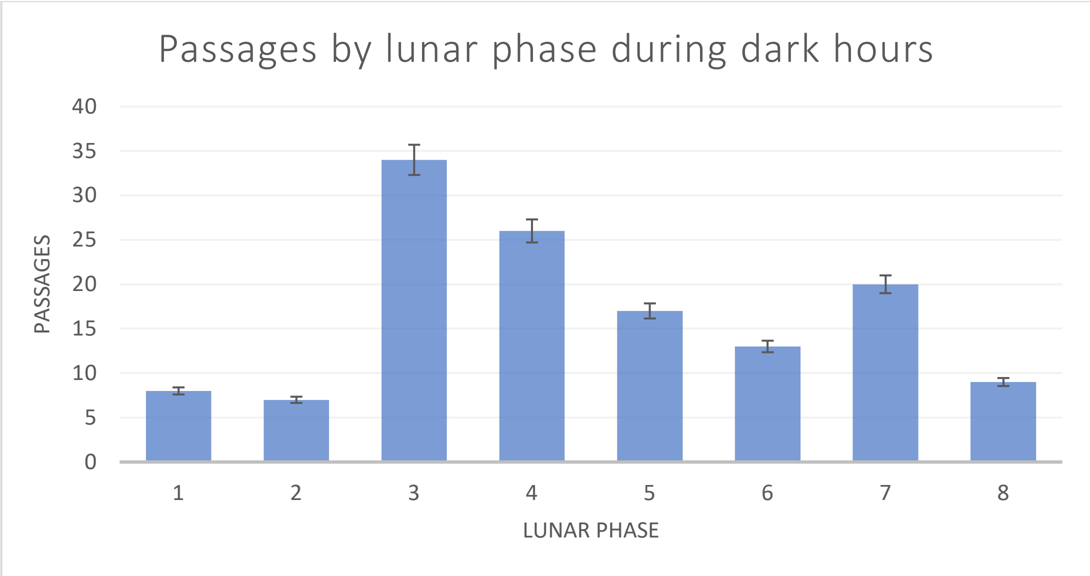

Fig 8. Passages by giraffes made between 20.000–5.59 (the dark hours of the day) by lunar phase (description of different lunar phases below) with standard error. Passages were less frequent during lunar phase 1, 2 and 8, when the lunar illumination was low. Significantly more passages (p=0.005) were made during high lunar illumination (phase 3–7).

1: new moon, 2: waxing crescent moon, 3: first quarter moon, 4: waxing gibbous moon, 5: full moon, 6: waning gibbous, 7: last quarter moon, 8: waning crescent moon. $\sigma_{phase}=8{,}94$, $\sigma_{luminosity\ 0\text{-}49.9}=0.8$, $\sigma_{luminosity\ 49.9\text{-}100}=7.34$

There was no statistically significant correlation between rainfall and corridor use amongst the giraffes, neither for rain fallen at the time of passage, nor the rain fallen in the previous 7, 30 or 90 days respectively (p=0.074, 0.083, 0.078 and 0.167 respectively) (Fig. 9). However, some statistical tendencies could be implicated by these p-values. Furthermore, no effects of daily mean temperature or cloud coverage on corridor use and was found (p=0.907, p=0.336).

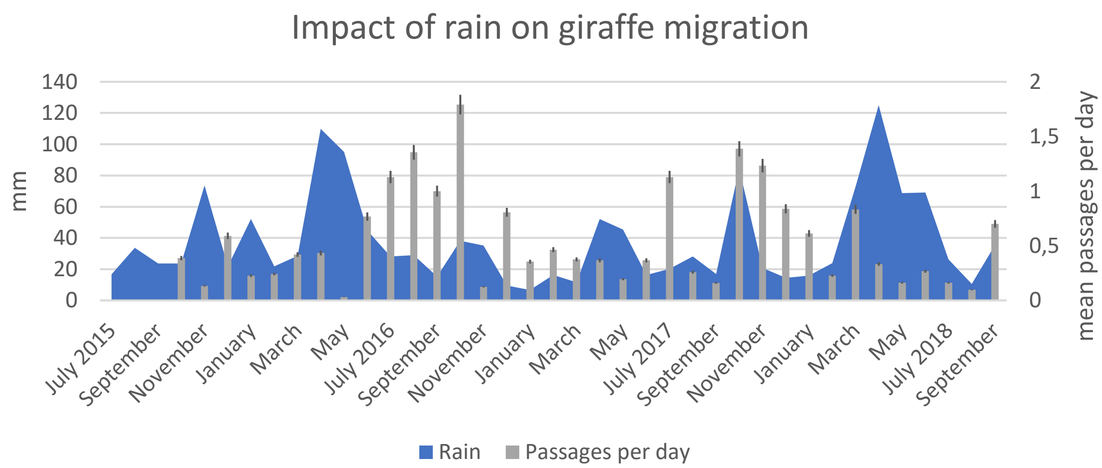

Fig 9. Mean passages per day during the three-year period of data collection as well as the total amount of rainfall per month during the same time and three months prior. The corridor use was not evenly spread out throughout the months of the year. However, it did not correlate with current or previous rainfall. $\sigma_{passages}=22.0$

Discussion

Data collection and analysis

The collection of raw data by use of mounted motion capture cameras has numerous advantages and disadvantages.

As the cameras are triggered automatically without need for human on-site intervention the risk of affecting the animals' behaviour with human presence is eliminated. However, it was obvious that the cameras still managed to evoke curiosity and/or fear in some cases, especially when the flash was used during the darker hours of the day. Animals were on several occasions seen examining and/or lunging away from cameras. The giraffes must therefore be believed to have taken notice of the cameras on several occasions if not all, and the extent to which this may have had an influence on their behaviour when passing through the corridors is uncertain.

The cameras are, as previously mentioned, placed at a height and at angles deemed most appropriate for the successful capture of as many different animal species as possible. This meant that the giraffes were often too large to be photographed in an optimal manner and only the legs of the giraffes were visible when they passed close to the camera. This made it impossible to determine the gender of the individual as well as to identify the individual giraffe based on the coat pattern of the neck or side body. For future research focused on giraffe (and/or other larger mammals like elephants) it would greatly enhance the quality of the data if the cameras were mounted in ways that correspond best to capturing animals of greater size.

Due to time limitations, the identification of individual giraffes was only done in part throughout this study and no analyses were run based on the individual data. When identifying individual giraffes based on their unique coat patterns a good quality image of both body sides of the giraffe is essential. If a giraffe is identified based solely on one body side there is a high risk of falsely identifying one and the same giraffe as two separate individuals (J. Doherty, pers. com. 2018). For studies aimed at identifying specific individuals, the use of motion capture cameras must therefore be considered of limited value as there presently is no way for the camera itself to determine the optimal angle in which to photograph a giraffe for ideal identification or to capture both sides of the animal at every given recording. However, like the issue mentioned above regarding the ways the cameras were mounted, both problems could, at least in part, surely be addressed by optimizing camera placement.

Data sorting

The use of several cameras at each corridor is key in order to be able to cover as much area as possible so as not to miss any individuals that may be passing. However, in the years in which the data used for this study were collected, several complicating factors as a result of this were discovered. Firstly, the set time was not always the same for all cameras, sometimes differing by as much as several minutes between two cameras at the same corridor. This was for the most part easily compensated for during second level sorting by using distinguishing characteristics, direction and group size to determine if photographs taken a few minutes apart were of the same individuals or not. Also, as these deviances in time remained the same for weeks or even months on end, it soon became routine knowing that, for example, a certain camera was set a certain number of minutes behind the rest.

During the dark hours of the day, when camera range and visibility was limited, the sex of the passing giraffes could only be determined with great difficulty and was, more often than not, noted as unknown. This results in a greater uncertainty in the data collected during the night than that of the day. For this study, male giraffes accounted for the majority of observations, with only 14 females recorded. In theory, although highly unlikely, all the unknowns could represent females which would greatly alter the statistics. However, males would still account for 80% of recorded passages making this theoretical error of slightly less importance.

Results

Migration patterns

During the three-years of data collection, Ol Pejeta Conservancy experienced two periods of heavy rainfall (March-April 2016) and (March-April 2018) with the rain season of 2017 being unusually dry (Fig 9.) which eventually resulted in conflicts leading up to the permanent closure of corridor 3. It was hypothesized that the closing of this corridor would lead to an increased use of the remaining two. This was, however, not the case much due to the low number of passages through corridor 3 to begin with, and therefore lack of a large enough sample size. The area close to corridor 3, located at the far north-eastern corner of OPC is in many aspects much like corridor 2. Corridor 2, which was the most frequently used corridor out of the three, but for a few major differences. By crossing corridor 2, the exiting giraffes venture into another protected area, namely the Mutara conservancy, stretching further north and eventually, joint by several wildlife corridors, reaching as far as Samburu national park and beyond. By using corridor 3 or 1, the animals enter to or from unprotected areas inhabited by pastoralist and their livestock (mainly cattle, sheep and goats). Although the giraffes at OPC are well used to the presence of cattle due to the conservancy also serving as a cattle ranch, this might be a determining factor in corridor selection. The giraffes may well understand that people with or without cattle might be potential poachers.

The corridors were, by far, more frequently used by male giraffes than by females and several contributing factors to this are possible, although some more plausible. Male giraffes adopt a roaming reproductive strategy in search for females in oestrus (Dagg, 2014; Leuthold & Leuthold 1978; Bercovitch *et al.*, 2006) and venturing outside OPC might be part of this tactic. This type of reproductive strategy is more likely to develop for animals whose breeding is nonseasonal, females are broadly distributed and living either alone or in small groups, and the time for sexual receptiveness is limited (Parker, 1974; Forchhammer & Boomsma, 1998), as it is in giraffe. The female giraffe is polyoestral with an oestrous cycle of 14.7 days and a peak reproductive window lasting for merely 4 days (del Castillo *et al*., 2005; Berkovich *et al.,* 2006). By adopting this strategy male giraffes can confront the time budget dilemma otherwise encountered when time invested in mate guarding a single female reduces the search time available for finding, and mating with, other females (Alberts *et. al.*, 1996; Harts & Kokko, 2013). Venturing outside OPC might therefore be a way for bulls to search for receptive cows in oestrus.

In the animal kingdom, migration as a result of search for food and water is ever present (Talbot & Talbot, 1963; Boone *et al.,* 2006; Naidoo *et al.,* 2012). This pattern is even more evident in areas, like OPC, with distinct dry and wet seasons (Boone *et. al.,* 2006). For this reason, one could easily assume the same pattern would be visible in giraffe migration. However, when it comes to OPC, this could be argued not to be the case. Firstly; water is readily available inside OPC, with several man-made waterholes for both wildlife and cattle. North of the conservancy the water availability is scarce at best, with few natural water resources and only one artificial waterhole (N. Ndiema, pers. comm. 2018). It can be hypothesised that water availability is a potential drive for giraffes to stay within the confines of the conservancy. Giraffes are however well adapted to hot and arid environments, with several thermoregulatory mechanisms and a low daily requirement of free water (Mitchell & Skinner, 2004). Not unlike camelids, giraffes are very good at conserving water and consume a large quantity of their water intake from succulent plants (Foster & Dagg, 1972; Mitchell & Skinner, 2004). Access to free water may therefore not necessarily be a determining factor for giraffe migration. If free water availability is assumed not to affect giraffe migration to any great extent, the access to succulent plants and browse must be of greater importance. Inside OPC, the giraffes share browse with several other browsing herbivores including impala (*Aepyceros melampus*), Grants' gazelle (*Nanger granti),* black rhinoceros (*Diceros bicornis*) and African elephant (*Loxodonta africana*). The browsing within OPC is however less extensive than outside due to pastoralists not being allowed to browse their goats inside the conservancy boundaries (R. van Aardt, pers. comm. 2018). This fact is believed to give the OPC-giraffes a higher incentive to stay within the confines of the conservancy, rather than to venture outside, where food (and therefore water) is less plentiful. Based on available food and water, it would seem the OPC-giraffe have little incentive to leave the confines of the conservancy. This could, at least in part, explain why so few female giraffes were seen using the conservancy corridors during the study period. The male giraffes roaming reproductive strategy could make them more inclined to venture outside the conservancy boundaries, whereas the female giraffes have little to no reason to do so.

Giraffe home ranges vary very little between the two sexes, and the conservancy itself, being 340km^2, is much larger than the average giraffe home range of 13–164 km^2 (Leuthold & Leuthold 1978; Dagg, 2014; VanderWaal *et al.*, 2014). However, home range sizes do differ somewhat among studies depending on animal density (i. e. distance between females), environmental features (vegetation, fenced/non-fenced area) and study methods (Le Pendu & Ciofolo 1999; Gieling, 2011; Caroline & Adhiambo, 2013). Average home range size of the OPC-giraffe was investigated by VanderWaal *et al.* as late as 2014 and was found to be significantly smaller than the conservancy area, making the authors question/disregarding the OPC-giraffes usage of the conservancy's wildlife corridors. The relatively small home ranges were believed to be a result of a readily available food and water supply and relatively low animal density within the conservancy. When making observational studies of giraffe in the field, focus seem to diverge toward the female population with observations of males being done mainly when they are in close proximity to females (Foster & Dagg, 1972; Dagg, 2014). This most likely stems down to the simple reason that the larger the group size is, the easier it is to spot at a distance, whereas a lone animal might be harder to find and therefore to study. For this reason, some animals (lone males) might have gone partly unnoticed in the study by VanderWaal *et al.* (2014), and the males that ventured outside the conservancy overlooked, making the authors assume the corridors were not used by the OPC-giraffe.

When regarding the results of this study, one of the main questions to be answered is why the lone males choose to leave the confines of the conservancy when there is plenty of food, water and general space to cover their apparent needs. Apart from the hypothesis of search for reciprocal females in oestrus, one other major advantage for leaving OPC must be taken into account. OPC holds one of the highest densities of wild predators within Kenya with six resident lion prides adding up to a total lion population of 72 individuals (Ol Pejeta Conservancy, 2019). For this reason, the giraffe, being one of the preferred species of prey by hunting lions along with oryx (*Oryx beisa*), buffalo (*Syncerus caffer*), wildebeest (*Connochaetes taurinus*) and zebra (*Equus quagga*) (Hayward & Kerley, 2005) must be susceptible to lesser predation risk outside the conservancy than within. To reduce the risk of predation, animals of prey can make several behavioural adaptations in order to decrease the likelihood of predator encounter (Lima & Dill 1990). Common behavioural adjustments are group formation and vigilance (Fitzgibbon, 1990; Lima, 1995; Roberts, 1996). Compared to solitary animals, individuals within a group benefit not only from the greater number of individuals standing vigilant and scanning the surroundings for potential predators (Pulliam 1973; Hunter & Skinner 1998), thereby allowing for earlier detection of an approaching predator, but are also at a lower risk of being preyed upon because of a risk dilution effect. An individual belonging to a larger group is less likely to be the target prey simply because there is more potential prey for the predator to choose from (Hamilton 1971; Dehn 1990; Scheel, 1993). There are however many different behavioural adaptations to predation. These can for instance consist of avoidance of unsafe areas and environments as well as spatial reorganisation of animals (Ripple & Beschta, 2004; Valeix *et al.*, 2009), and selection of certain habitat types and features (Creel *et al.*, 2005). Additionally, animals of prey can make temporal adjustments to avoid dangerous time periods coinciding with predator hunting (Fenn & Macdonald 1995; Roth & Lima 2007). Lone giraffes, not being subject to the benefits of the collective, might therefore adopt a predator avoidance strategy in which they leave areas of high risk during certain times. During night-time, lion activity within OPC reaches its peak (Augustsson, 2016; Haglund, 2017) and it is therefore plausible that the predation risk for lone giraffes is lessened by spending the night elsewhere. This hypothesis could to some extent explain the corridor usage depending on time of day. From the point of view of the giraffes, poaching by humans might be a similar threat to that of wild predators. Poaching is not a problem within OPC, but further north there has been severe poaching on giraffes during the past years (J. Doherty, pers. com. 2018).

The corridors were more frequently used during early morning and late afternoon, with peak in-passages occurring at dawn and peak out-passages at dusk (Fig. 7). The results indicate that some animals chose to spend the dark hours of the day outside the conservancy only to re-enter in the morning. Since individual giraffes were not noted in this study to any great extent, it is of course possible that the exiting and entering giraffes were not in fact the same individuals. It is possible that some individuals left the conservancy only to never return or re-entered at some other point in time, not necessarily the next morning. However; for the individuals that were recorded and identified on several occasions, the pattern of exiting the conservancy at night and re-entering in the morning was evident even though these results are not included within this study.

As mentioned, lion activity within OPC reaches its peak during night-time, and previous studies have shown increased hunting success for lions during nights when the moon is absent or obscured by clouds (Funston *et al*. 2001, Packer *et al.* 2011). When observing the giraffes' corridor usage in relation to lunar phase, a pattern of "dark night avoidance" is evident. In the present study, a giraffe was four times more likely to use the wildlife corridors during high lunar luminosity (i.e. during half to full moon) than during night with less lunar luminosity. The moons illumination dramatically decreases night-time visibility and a reason for increased corridor usage during night with greater lunar luminosity could be increased visibility. Giraffes orient primarily by sight (Kingdon 1984; Lee 1991; Jolly 2003) and have, by direct observational studies, previously been suggested to have excellent eyesight with the ability to see objects over 2 km away (Backhaus 1959; Dagg & Foster 1976). Recent studies of giraffe eye morphometrics by Mitchell *et. al.* (2013) show that giraffes have a larger eye and retina surface area than many other land mammals, which confirms the previous suggestions of good eyesight. Being an animal that largely relies on sight for orientation, it is natural to assume that giraffes might be less inclined to move about during periods of low visibility, i.e. during dark nights when the light from the moon is absent. There was no difference in direction of travel depending on lunar phase, suggesting that giraffe migration as a whole decrease during low lunar luminosity. The results of this study indicate that moonlight strongly affects the migration behaviour of giraffe and further research examining its role will be illuminating.

Previous studies at OPC have shown no difference in lion activity through the corridors depending on lunar luminosity (Augustsson, 2016; Haglund, 2017). These findings do not necessarily correlate with decreased lion activity *per se*, but merely give information about the activity at certain fixed areas of the conservancy (i.e. at the different corridors). The images from the corridor camera traps give a valuable snapshot of current events at the corridors, but no conclusions can be drawn about animal activity elsewhere in the park.

Seeing as corridor usage amongst giraffe decreased during dark nights it was hypothesised that decreased corridor usage would also correlate to increased night-time cloud coverage. When analysing the gathered image data in relation to cloud coverage, no correlation between increased night-time cloud coverage and corridor usage was found. However, since the cloud coverage data was obtained from weather stations at Nanyuki Town, situated approximately 45 km away from the corridor, it is possible that the data obtained did not correspond perfectly to the weather conditions at the corridors. The same is true for obtained precipitation data, and the results regarding rainfall and giraffe migration might for this reason also be faulty.

The results obtained during this study cannot give a clear answer to why the giraffes choose to enter or leave Ol Pejeta Conservancy. Neither can they tell us where the giraffes go after having exited. To find out what drives the giraffes to behave as they do, more research is needed, and this research needs to be of another layout. The use of static camera traps is in many ways very efficient when wishing to gather large amounts of data from one place but is also extremely limited as it does not tell us anything about what happens out of frame or before and after an image is taken. Future studies wishing to investigate the drivers behind giraffe behaviour need therefore be structured in ways whereby the giraffes can be observed during longer periods of time (and space), for example, with the aid of GPS-tracking or drones. The use of a drone was initially discussed for the gathering of data for this study, but had to be abandoned due to difficulties meeting the demands set by the Kenyan government and the Kenya Civil Aviation Authority in order to obtain the licenses needed to fly a non-military drone in Kenyan airspace. If said demands were to be made less restrictive in the future, using drones to follow the giraffes in order to see where they go after exiting the conservancy may be a very telling source of data to use in upcoming studies. Following the giraffes when leaving OPC and identifying more animals individually when crossing would improve the knowledge of the giraffe migration at OPC dramatically.

Conclusions

The following bullets are answers to the study questions asked in the introduction (p. 2).

- The giraffes at Ol Pejeta Conservancy use the wildlife corridors; a total of 563 passages were recorded during the three-year period of data collection.
- No seasonal migration pattern could be determined throughout the study period.
- However, a significant increase in corridor use occurred during dawn and dusk, with an apparent influx of giraffe in the morning and an outflux during the evening/late afternoon.
- The wildlife corridors were most frequently used by bulls, especially lone adults, possibly to avoid predation by lions or to search for receptive females in oestrus.
- The closing of corridor 3 did not have an impact on giraffe movement through the remaining two corridors. Throughout the study, the preferred corridor was corridor 2 with a total of 528 (94%) of in total 563 passages recorded.
- The seasonal migration patterns and effect of current and previous rainfall remained unclear. There were obvious differences between months, but if that was because of previous rainfall and changes in vegetation could not be determined throughout the study period. Since we found statistical tendencies regarding rainfall at current day and for 7 and 30 days of previous rainfall, more data are needed to confirm or reject these results.

Populärvetenskaplig sammanfattning

Den afrikanska kontinenten är hemvist för en uppsjö av unika djurarter och är, så som är allmänt känt, ansedd vara människan födelseplats. Detta otroligt breda utbud av arter och antal djur minskar dock för var dag som går (Campbell *et al.*, 2003; Ogutu *et al.*, 2016) och under endast de senaste tre decennierna har populationen av nätgiraffer (*Giraffa camelopardalis reticulata*) i Afrika minskat med hela 56 % (Muneza *et al.,* 2018). Den totala populationen nätgiraffer uppskattas för närvarande bestå av endast ca 11 000 individer begränsade till tre östafrikanska länder. Nätgiraffen, en av giraffens nio underarter, är sedan mars 2018 listad som hotad på den Internationella Unionen för Naturskydds (IUCN) röda lista över hotade arter. IUCN:s röda lista är idag världens mest omfattande förteckning över bevarandet av jordens arter där varje art kategoriseras under antingen låg risk för utrotning, utrotningshotad eller utrotad.

Denna studie syftar till att öka kunskapen om nätgiraffens migrationsbeteenden, med särskild fokus på användandet av viltkorridorer. Detta för att kunna bidra med information som kan underlätta vid framtagandet av bevarandestrategier för detta magnifika djurslag. Studien utfördes vid Ol Pejeta Conservancy, ett 360 km^2 stort, inhägnat, privatägt reservat i Laikipia län, Kenya. Reservatet är hemvist för ca 200 nätgiraffer, vars användande av viltkorridorer tidigare har varit oklart.

Tre viltkorridorer (korridor 1, 2 och 3) längs reservatets norra begränsning bemannades under en treårsperiod med rörelseutlösta kameror vilka registrerade alla passager in eller ut ur reservatet under studiens gång. Den sammanlagda datan bestod av ca 3 miljoner bilder, varav 30 000 bilder av nätgiraffer, ur vilken 563 passager kunde utläsas. För varje passage registrerades tid, datum, val av korridor (1–3), färdriktning (in resp. ut), kön och gruppstorlek. Giraffers pälsmönster är unikt för varje individ och om möjligt utifrån bildens kvalitet identifierades även individuella giraffer utifrån detta unika mönster. En passage definierades som ett djur som passerade genom viltkorridoren antingen in eller ut ur reservatet. Utöver ovan nämnda data erhölls även väderdata bestående av temperatur, nederbörd, molntäcke och månfas online. De olika variablerna analyserades därefter för att se möjliga bidragande faktorer till nätgiraffens migrationsmönster.

Av de sammanlagt 563 passagerna utgjordes 447 av hanar medan endast 14 honor (dvs. 97% respektive 3% av alla passager med känt kön) sågs använda viltpassagerna under hela treårsperioden. Aktiviteten vid vilt korridorerna var som högst under tidig morgon och sen eftermiddag, med flest antal in-passager under morgnarna och flest ut-passager under eftermiddagen. Den genomsnittliga gruppstorleken var 1,6 giraffer, där ensamma tjurar stod för 85% av alla endjurspassager (n=396). Viltkorridor 2 var den mest använda korridoren, medan de övriga två sällan användes. Denna viltkorridor leder ut till ett delvis inhägnat djurskyddsområde vilket kan vara anledningen till att girafferna föredrog denna korridor framför de andra.

Användandet av viltkorridorerna påverkades inte av vare sig temperatur, nederbörd 90 dagar tidigare eller molntäcke, men däremot av månfas. Om nederbörd samma dag, den senaste veckan eller senaste månaden påverkar är oklart. Under dygnets mörka timmar var girafferna mer benägna att använda korridorerna under halv -och fullmåne, då nätterna var ljusare, än under nymåne, då sikten är sämre. Giraffen är, trots sin ansenliga storlek, ett bytesdjur och dess främsta rovdjurshot utgörs av lejon. Tidigare studier har visat att lejon har en mer framgångsrik jakt under nymåne, då sikten för många bytesdjur är dålig.

Sammantaget kan giraffernas nyttjande av viltkorridorerna i Ol Pejeta Conservancy antas visa hanligt sökande efter mottagliga honor i brunst, men även potentiellt vara ett sätt för ensamma hanar att undvika predation från lejon.

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