Migration patterns of African elephants (*Loxodonta africana*) in Ol Pejeta Conservancy

Rörelsemönster hos Afrikanska elefanter (Loxodonta africana) i Ol Pejeta´s reservat

Emelie Grabbe

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Studentarbete **Nr. 726**
Sveriges lantbruksuniversitet
Institutionen för husdjurens miljö och hälsa

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Handledare: Jens Jung, Department of Animal Environment and Health, P.O.B 234,
532 23 SKARA
Examinator: Jenny Yngvesson, Department of Animal Environment and Health, P.O.B 234,
532 23 SKARA

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Sveriges lantbruksuniversitet
Fakulteten för veterinärmedicin och husdjursvetenskap
Institutionen för husdjurens miljö och hälsa
Box 234, 532 23 SKARA
E-post: hmh@slu.se, **Hemsida:** www.slu.se/husdjurmiljohalsa

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Table of content

Abstract

Migration is important for many animals survival; however, due to human impact the animals get more restricted. The African elephant (*Loxodonta africana*) is a keystone species and dependant on long-distance movement. When the migration is restricted this can cause conflicts, for example more habitat destruction or crop raiding. In this study I document elephant migration patterns in and out of Ol Pejeta Conservancy, Kenya. Camera-traps were used in order to register the passages that later were compared with data of moon phase, rainfall, month and time of the day. There was a variation in activity depending on time of day and month of the year. Moon phase effected the migration when using only the passages occurring during night (between 19pm - 7am). The amount of rainfall during the previous seven days effected migration as well but not amount of rainfall during the previous 30 or 90 days. Possible explanations of why the elephants migrate are water, food, human impact such as settlements and predation by especially lions. Because the study only used camera-traps at the boarder of the conservancy it is difficult to get a full picture of why the elephants migrate and where they go and come from. By only having one year of data there can also be hard to find a seasonal variation, which also makes the task a bit harder. In order to confirm why the elephants migrate in and out of Ol Pejeta Conservancy, more information with partly different methods is needed.

Sammanfattning

Migration är viktigt för många djur, men på grund av människors påverkan blir djuren mer begränsade. Afrikanska elefanten (*Loxodonta africana*) är en nyckel art och väldigt beroende av att kunna migrera långt. När deras migration blir begränsad kan detta skapa konflikter och till exempel mer förstörelse av naturliga habitat eller åkrar. I denna studie dokumenterar jag elefanternas migrationsmönster in och ut ur Ol Pejetas reservat, Kenya. Kamerafällor användes för att kunna registrera antal passager som sedan jämfördes med data på månfas, mängd regn, månad och tid på dagen. Det fanns skillnader i aktiviteten för olika timmar på dygnet och för olika månader på året. Månfas påverkades endast när passager under natten (mellan 19-7) jämfördes. Även nederbörd under de senaste sju dagarna påverkade migrationen, dock inte nederbörd under de föregående 30 eller 90 dagarna. Möjliga förklaringar av elefanternas migration är vatten, mat, mänsklig påverkan som t.ex. bosättningar och predation av speciellt lejon. Eftersom att denna studie bara använt kamerafällor längs gränsen av reservatet är det svårt att få en fullständig bild av varför elefanterna migrerar och vart de går och kommer ifrån. Genom att bara ha ett års data kan det dessutom vara svårt att upptäcka en variation för regnperioder, vilket också försvårar uppgiften. För att kunna fastställa varför elefanterna migrerar in och ut från Ol Pejetas reservat behövs mer information med delvis andra metoder.

Introduction

Migration occurs over a wide range of animal taxa and is important for survival and reproductive success (Lennox *et al.*, 2016). Many factors affect migration in animals, such as seasonal changes (Madsen and Shine, 1996), environmental factors such as availability of food, shelter, breeding (Dingle and Drake, 2007), predation risk, competition and climate (Jachowski and Singh, 2015). Other factors that influence migration are temperature, wind and humidity (Cahn, 1925). Ecosystems benefit from many animals moving between habitats which make the systems more resilient to disturbance over time (Lennox *et al.*, 2016). This in turn can affect population size, nutrient transport and growth of vegetation and can affect ecological characteristics such as community structure, population size or carrying capacity, community interactions between nutrient transport and vegetation growth and predator-prey dynamics (Wall *et al.*, 2013). However, long-distance movement have been lost or is threatened by human activity, such as habitat destruction and barriers (Bauer and Hoye, 2014). The whole ecosystem can be affected if a species can no longer maintain a long-distance movement (Wall *et al.*, 2013) One animal that is adapted to long-distance movement (Graham *et al.*, 2009) and is affected by habitat loss is the African elephant (*Loxodonta africana*).

Ecology and foraging

The elephant is a keystone species and has an important role in the food web (Graham *et al.*, 2009; Kohi *et al.*, 2011). Elephants are also considered to be ecosystem engineers (Jones *et al.*, 1994), by destroying and disturbing trees and shrubs they affect the ecosystem. This causes changes of the vegetation by redistributing and improving available biomass for herbivores that feed at lower heights, which have an affect population dynamics (Kohi *et al.*, 2011). Elephants are considered to be "*vulnerable*" according to the IUCN Red List (2008). The hunting of elephants for ivory used to be the main reason of the species decline and also why there are so few elephants now compared to before (WWF, 2017). However, fragmentation and loss of habitat is a major problem since long distance movement is affected (WWF, 2017). A reduction of areas to migrate and availability for seasonal migration is likely to cause more habitat destruction and biodiversity loss from the protected areas the elephants live in (Poole *et al.* 1996).

Elephants are mixed feeders (Shannon *et al.*, 2013) and consume the highest amount per day of all terrestrial herbivores (Pretorius *et al.*, 2012). Their diet is seasonally variable where during the wet season they prefer green grass and herbs (O'Connor *et al.*, 2007) and switch to browsing during the dry season (Codron *et al.*, 2011). Elephants can change the landscape while foraging by reducing plant biomass, changing species composition and increasing nature patches (Vogel *et al.*, 2014). These transformations made by elephants have consequences for animals that are dependant on certain vegetation and are a concern in areas dominated by elephants. By browsing, debarking, breaking of branches and pulling up trees from the ground the elephants cause a decline of the abundance of large trees; this is most common in areas with a high density of elephants (Vogel *et al.*, 2014).

Migration and behavior

Elephants can migrate over long distances (Galanti *et al.*, 2006); the migration is seasonally variable, temporally complicated and closely linked with rainfall events (Cushman *et al.*, 2005). They generally move between different habitats (Blanc, 2008), for example savanna, grasslands, dense forest and sometimes desert. Migration is affected by environmental factors (Poole *et al.* 1996), for example elephants are more concentrated around waterholes during dry seasons and more dispersed during the wet season due to the higher amount of available waterholes (Loarie *et al.*, 2009b; Verlinden & Gavor 1998). There is also a difference between individuals: elephants that come from a dry place generally migrate more and over larger areas than elephants from a more wet area (Loarie *et al.*, 2009b). In order to avoid the warmest time of the day elephants are more active during the night (Loarie *et al.*, 2009b). This behavior is also a way to avoid people, which is most likely due to human activity and poaching (Shannon *et al.*, 2009). Social behavior such as musth can also affect migration (Schulte, 2000). Food and water resources are temporally and spatially patchy, therefore elephants need to migrate long distances to specific areas at specific times in order to survive (Cushman *et al.*, 2005). Elephants can also migrate in order to raid crop fields (Gadd, 2005; Harich *et al.*, 2013; Thouless and Sakwa, 1995), for example maize (Kikoti *et al.*, 2010; Hahn *et al.*, 2017) and banana (Naughton-Treves, 1998). While raiding the fields the elephants may destroy fences (Ol Pejeta Conservancy, 2016). This combination can severely affect famers and threaten their source of income (Harich *et al.*, 2013) and may therefore cause conflicts with humans.

Human-elephant conflict

The conflict between humans and wildlife is one of the greatest challenges for the survival of many large mammals, especially for elephants. One of the biggest challenges in this conflict for farmers in Africa is elephant crop raiding (Sitati *et al.*, 2005), which is often local but the damage could be devastating for the affected farms (Naughton-Treves, 1998). Besides that elephants usually cause more damage than other species they are also more dangerous to humans than other herbivore species as they can cause deaths and injuries (Sitati *et al.*, 2005). A better understanding of the how and when the elephants migrate within human-dominated landscapes is important for conservation (Graham *et al.*, 2009). These findings would also, provide information in how to mitigate the human-elephant conflict.

Aim and objectives

This study's main objective is to analyse the elephant's movement pattern to and from Ol Pejeta conservancy, Lakipia, Kenya. The aim of this study is to record when and to discuss why the elephants move in and out of the conservancy since they might have enough resources inside Ol Pejeta. I analyse if the movements correlates with environmental factors.

The questions that have been included in this study are:
1. When during day and night are the elephants more active?
2. Does rainfall affect their migration patterns; is there a difference between wet and dry seasons?
3. Does moon phase affect the elephant's migration patterns?

Methods

Study area

Ol Pejeta Conservancy is a private wildlife reserve situated in Laikipa, Kenya. The conservancy is 90 000 acres (Ol Pejeta Conservancy, 2017) and is surrounded by a 120 km electric fence except for three corridor openings (fig 1), which all animals except rhinoceros can pass. All openings are facing north and are lined with wooden pillars that are one meter high and separated by 55 cm between each pillar. Corridor 1 is 183 m long and there are four cameras situated along the corridor. Corridors 2 and 3 are each 34 m long and have three cameras each. The cameras at each corridor are labelled A, B and C in order to differentiate between them. In corridor 1 the fourth camera is labelled D. Due to less activity in corridor one, only corridor two and three were included in this study. Close to corridor 3 there is also a small local village and there is also an unpaved road with limited car traffic outside both corridors. In the conservancy there can be up to 300 elephants at the same time (Ol Pejeta Conservancy, 2017).

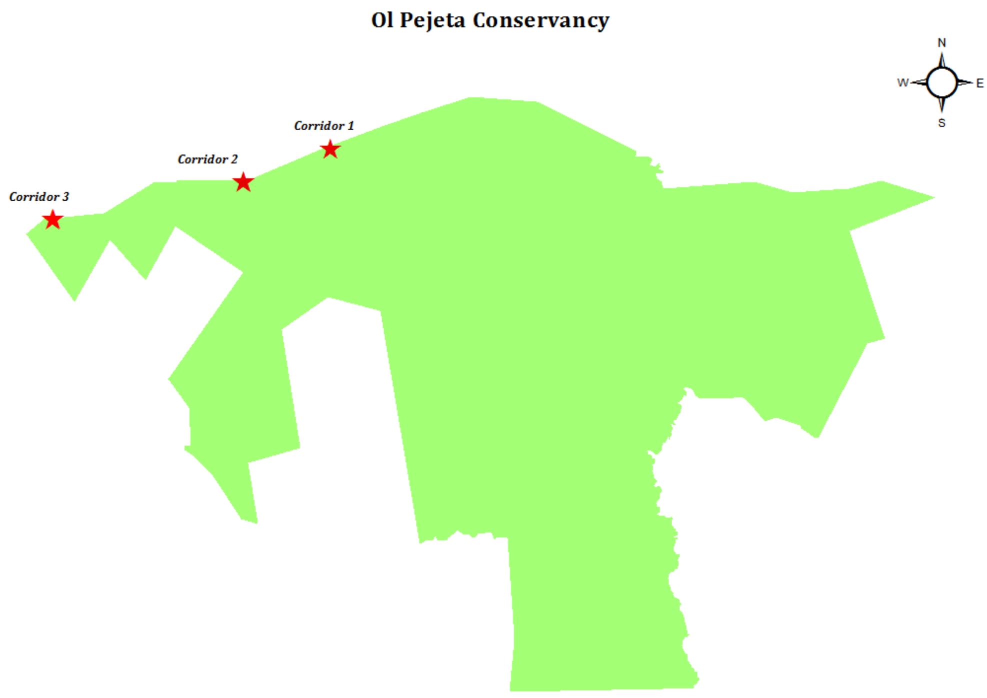

Figure 1. Map of Ol Pejeta Conservancy pointing out the corridors.

Data collection
In order to collect data, motion-activated Reconyx HC600 Hyperfire camera traps were used. The detection range of the cameras is 24 meters during day and 18 meters during night due to flash limitation (Reconyx, 2013). When an animal or human approached the camera 3-5 pictures were taken with 1-5 seconds intervals, the silent period between the sessions varied between 0-5 seconds. On each picture the cameras also register date, time, temperature and moon phase. Ol Pejeta´s field assistants collected these data on Fridays every week when they also changed the batteries and checked that the cameras where working. One year of data was used in this study, from first of June 2015 until last of May 2016.

Sorting of data
The field assistants at Ol Pejeta sorted the pictures in folders by date when the data were collected. In these folders the data later was sorted into which corridor and camera they came from. Later pictures were divided into species folders for aardvarks, baboons, birds, buffalos, cheetahs, elands, elephants, giraffes, Grant´s gazelles, human activity (humans, cattle, vehicles etc.), impalas, interesting pictures (interactions between species), jackals, lions, leopards, rare species, spotted hyenas, striped hyenas, Thomson´s gazelles, unknown animals (for example if there are eyes only in the picture), warthogs, wild dogs and zebras. After the sorting the folders were uploaded to Dropbox, in order to make the upload easier only the species relevant for the study were uploaded.

I downloaded the elephant pictures from Dropbox and sorted them in more detail; every passage was recorded using Microsoft Excel 2011 (for macs). Each passage was also given the image number, corridor name, camera number, date, if the individual was full grown or a calf, whether the individual was going in, out or along the corridor, group size, group number and if the individual migrated with a group (called family) or alone (called solitary). If it was not possible to see if the elephant was going in, out or along the fence, or if it was a calf or full grown these factors were recorded as unknown. A group was defined as more than one individual passing the cameras within five minutes after the last individual had passed by. Each camera was installed with a 45 degree angle to the corridor, this knowledge was used in order to estimate if the animals where going in, out or along the fence. Later moon phase and rainfall were added to the excel sheet. Moon phase information was found on the website Weather Underground (https://www.wunderground.com/) and rainfall were taken from two different weather stations located a few kilometres from the corridors. The days no passages were recorded were also put in Excel as a zero in order to calculate average number of passages per day for each month. However problem occurred when pictures disappeared or the camera stopped working. These days was recorded as a missing value, since I did not know if an elephant was there or not and inserting a zero would mess with the results.

Statistics
Moon phase was first recorded from 0-100% of moon visibility at clear sky, depending on where in the phase the moon was in, here 0% represented new moon and 100% represented full moon. Later this column was divided into 3

phases where 0-33% was phase 1, 34-66% was phase 2 and 67-100% was phase 3. For further analysis the passages during the day were removed and only passages at night (between 19pm and 7am) were included in the comparison of each moon phase. Rainfall was calculated as the mean of the two weather stations. From these data three different columns were made which represented how much it had rained during the previous 7, 30 and 90 days. Later each column was sorted separately after amount of rain from lowest to highest and every day of the year was sorted into three groups with 122 days each in order to test the rainfall.

Statistical analyses were conducted by using Microsoft Office Excel 2010 and Minitab Express statistical software. All analyses were made regardless of corridor and year. Activity was defined as number of passages and one passage represented one individual going in front of the camera. The accepted value of significance was when P was less than 0.05. An ANOVA was used in order to see if passages were affected by moon phase, previous rainfall, hour and months.

Results

A total number of 3122 passages were recorded during the twelve months; there were less than 365 days for each camera due to camera failures. Mean group size was 9.9 elephants. The frequency of passages per moon phase 1-3 did not differ significantly when all passages including on daytime were analysed. However, when comparing the amount of passages per moon phase during night only (between 19pm-7am), there was a significant difference between moon phases ($p<0.001$, Fig. 2).

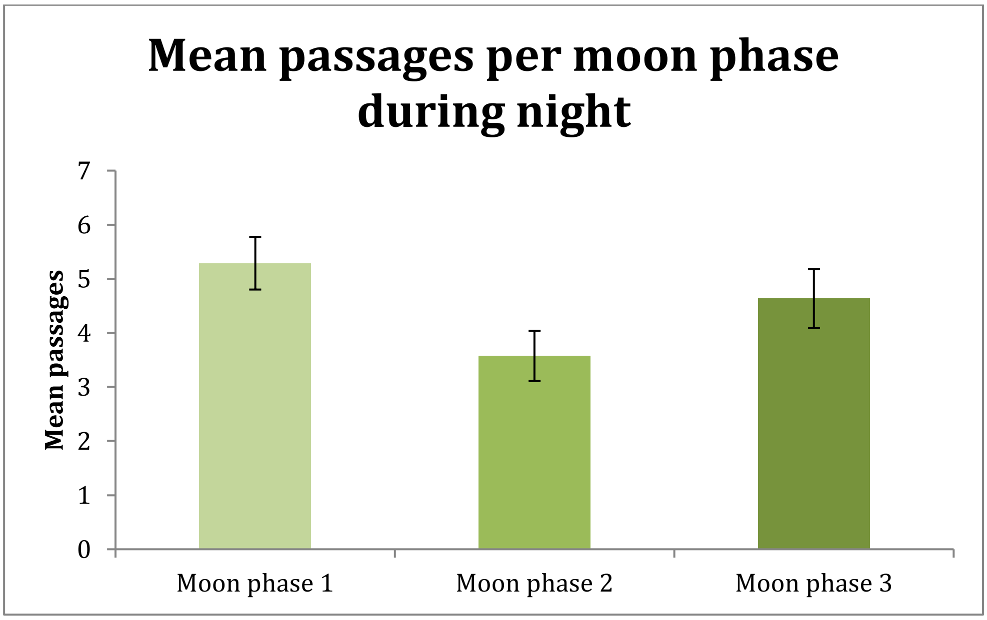

Figure 2. Mean passages ±SE per night for different moon phases where phase 1 represents new moon and phase 3 represent full moon.

Mean passages were affected by month (p = 0.004). During May and November less migration seems to occur compared to other months (Fig. 3).

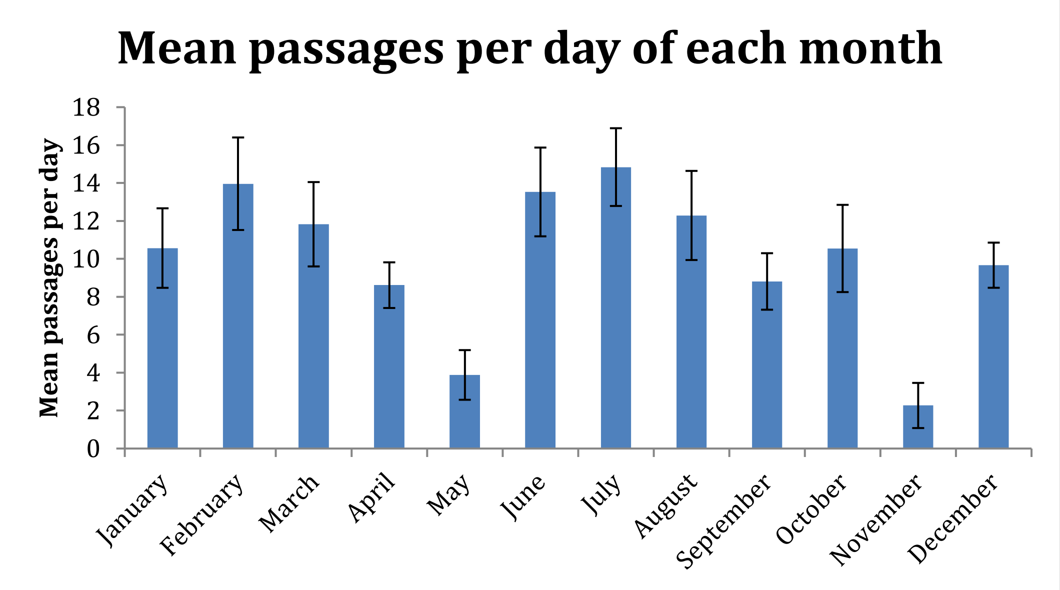

Figure 3. Mean passages per day ±SE for different months.

When recording the number of daily passages in relation to rainfall there was no significant effect for daily rainfall, i.e. passages per 24 hours on wet or dry days and nights. The same was found for passages in relation to rainfall for the previous 30 and 90 days. However, rainfall during the previous 7 days had a lower amount of passages in period 3 which reflect the wetter days, i.e. the dry phases had a higher frequency of migration ($p<0.001$, Fig 4).

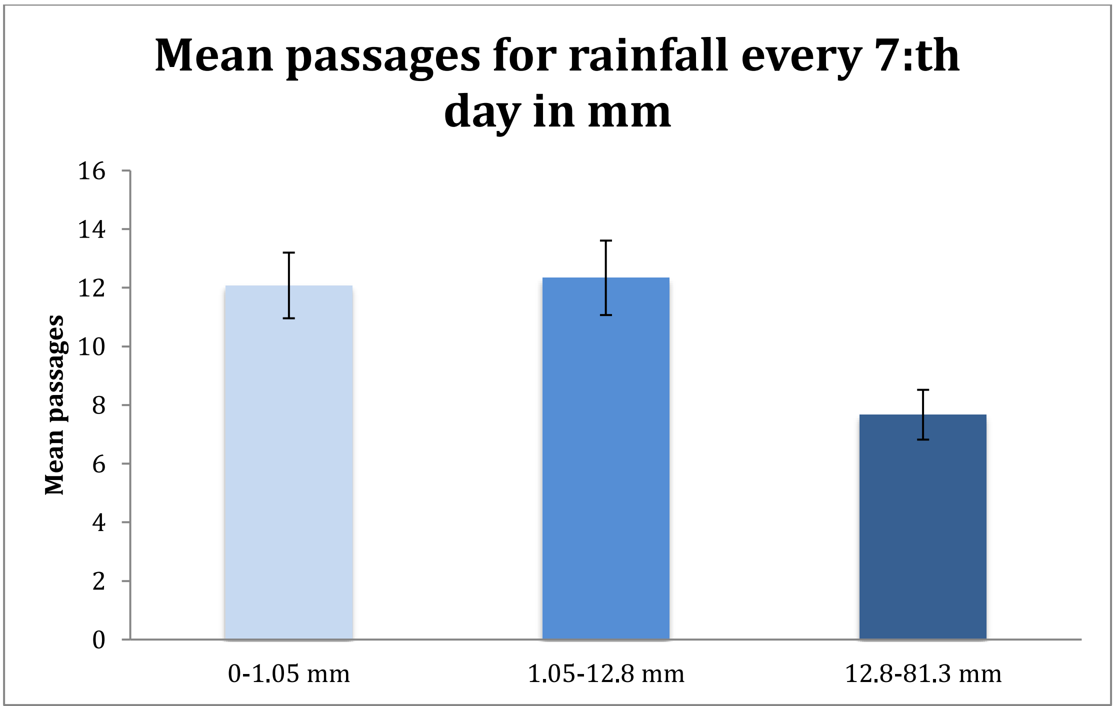

Figure 4. Mean passages per day ±SE compared to combined rainfall during the previous 7 days. Rainfall is divided into three categories from lowest to highest amount of rain, seen here in mm.

When looking at the sum of passages per hour and at the same time also comparing when the elephants are going in and out of the conservancy, there is a clear pattern (p<0.0001, Fig. 5). There were peaks of passages around 10 am and 18 pm. Most of the passages in to the conservancy occurred at 10 pm, however at 18 pm the elephants seems to migrate both in and out of the conservancy.

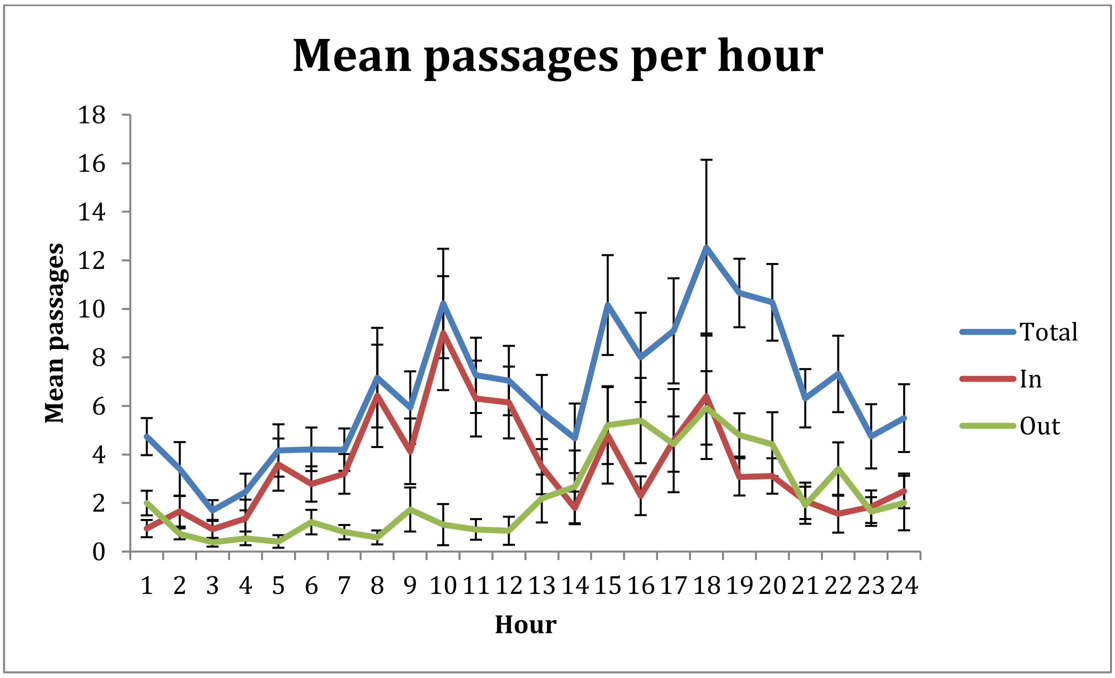

Figure 5. Mean passages ±SE during each hour, showing the mean of total passages and the mean of passages going in or out of the conservancy.

Discussion

Migration of elephants can be affected by many variables, which makes it complicated to study. These variables need to be assessed before conclusions can be made and therefore this study documents when they walk in and out and discusses possible explanations. Some relationships have been found between elephant migration and moon phase, rainfall events, monthly and hourly difference. Having only one year of data makes seasonal differences hard to detect.

Waterhole and vegetation availability

Water in Ol Pejeta is abundant because of many of the artificial waterholes for cattle. Outside the conservancy there is probably not as much water as inside Ol Pejeta. However there are most likely also water sources outside. Food availability is expected to be better outside of Ol Pejeta due to the lower numbers of cattle and wildlife. Outside the conservancy there are for example other conservancies, a ranch, farmland, human settlements, possible more preferable vegetation but less security from human threats. Therefore when walking out of the conservancy there is a possibility of better food but also a higher risk of human interactions, which can maybe explain why elephants have a peak of migration during 18 p.m. and 10 a.m. when humans are less active. Elephants migrate on average 5-10 km per day when they are provided with much space and there are no extreme conditions (Holdgate *et al.*, 2016), but they can migrate as much as 80 km in one day if necessary (Sheldrick, 2015). In order to truly find out where the elephants migrate when they are outside the conservancy GPS-collars or other methods such as drones have to be used.

Elephants are dependent on water resources (Smit *et al.*, 2007). Therefore does the presence of waterholes restrict elephant movements, especially during the dry season or in areas that are drier (Harris *et al.*, 2008). However, the distribution of vegetation is also important and affects the migration patterns as well. If suitable vegetation is further away from the water the elephants need to migrate longer from water to the vegetation, even if there is a dry season or a dry area. Elephants prefer areas with diverse and high vegetation production, keep close to a water-source and prefer to move short distances each day (Harris *et al.*, 2008). There is also a difference in how dominant the group is and how far they migrate (Wittemyer *et al.*, 2007). More dominant groups have smaller home ranges during the dry season with easier access to water, while less dominant groups have a much bigger home range during the dry season. The same effect of dominance is not seen during the wet season, when more resources are available (Wittemyer *et al.*, 2007). During the wet season elephants have more resources, which could lead to less usage of natural corridors (Adams *et al.*, 2017). This could not be shown in this study, but would be interesting to see if there is a seasonal difference between years.

Rivers may be preferred by elephants since they spend more time at rivers compared to artificial waterholes, this is presumed to be because the river provides water, vegetation and shade (Purdon and van Aarde, 2017). Elephants can spend up to 18 hours foraging, therefore time spent on searching food is very important (Clegg and O'Connor, 2017). Meanwhile the elephants prefer areas with greener vegetation during both seasons, however more constrained by water availability during the dry season (Loarie *et al.*, 2009a). Vegetation availability differs between vegetation variety and this differs between seasons as well. The change in diet and range during the seasons can be explained by grass and trees have different requirements for water and soil, which often makes these resources occur in different areas (Clegg and O'Connor, 2017).

Predation and avoidance of other animals

No killing of elephants by lions (*Panthera leo*) inside Ol Pejeta has been reported during the study period. However inside Ol Pejeta the lion population is 72 (Ol Pejeta Conservancy, 2017) and is considered to be at maximum of how many the conservancy can hold. Predation of lions occurs, however rarely found regularly in their diets (Loveridge *et al.*, 2006). There has been some findings of elephants regularly hunting elephants, for example in Botswana (Joubert, 2006; Power and Compion, 2009) and Zimbabwe (Loveridge *et al.*, 2006). The installation of artificial waterholes can cause the elephant population to stay resident instead of their usual seasonal migration during the dry season (Power and Compion, 2009). With a high resident population of elephants the lions may specialize on them as prey. These killings mostly occurs on calves between 4-15 years old (Joubert, 2006; Power and Compion, 2009), during the dry season (Loveridge *et al.*, 2006; Power and Compion, 2009) and at nights (Joubert, 2006). Mostly the lions go after calves that are alone for different reasons (Loveridge *et al.*, 2006). For example during the dry season the elephants travel more long distances and with years with more extremely water shortages there is more possible family groups can leave calves that cannot follow (Loveridge *et al.*, 2006). Calves that have been orphaned by poachers can also be preyed upon (Power and Compion, 2009). This is one possible explanation the elephants therefore could avoid lions inside or outside of Ol Pejeta, especially inside where there are a high number of lions that can cause the elephants to be more stressed and perhaps use the corridors more regularly than usual.

When being exposed to the sound of African honeybees (*Apis mellifera scutellata*), the elephants have been found to act defensive by headshaking and moving away from the bees (King *et al.*, 2010). Even elephants that not have been stung by bees have a negative reaction to bee sounds (Vollrath and Douglas-Hamilton, 2002). The elephants can also make rumbles while walking away, these kind of alarm-calls differ from alarms when humans are present (Soltis *et al.*, 2014). Therefore it would be interesting to know if there are any bees in or around Ol Pejeta, since elephants have been seen to avoid African honeybees. The bees have also been successfully used to deter elephants from raiding crops (King *et al.*, 2009), possibly limiting some food sources, and therefore could make the elephants migrate in and out of Ol Pejeta more often. However how many bees that is inside or outside Ol Pejeta conservancy is not known so this needs to be studied further.

Human impact on migration behaviour

Ol Pejeta is fenced and also has guards that patrol the area regularly in order to reduce the risk of poaching and inside the conservancy there is not much risk of human conflicts. It can therefore be considered as safe for the elephants. Outside there is less safety and most likely more conflicts with humans, especially if the elephants migrate to human settlements and farms. No recent poaching outside Ol Pejeta has been reported during this study. Poaching also seems to decrease overall in Kenya, however poaching still affects the elephant population (Ihwagi *et al.*, 2018). Even if poaching is low around Ol Pejeta previous experiences of poaching and spearing may affect the elephants even today.

Poaching might alter the behaviour in elephants since it has been found that poaching occur less in protected areas (Wittemyer *et al.*, 2005) than unprotected areas (Ihwagi *et al.*, 2015). The elephants also increase their speed, both during night and day, with higher poaching levels (Ihwagi *et al.*, 2018). If elephants are injured by poachers in a unprotected area they have been found to seek refuge inside reserves (Ihwagi *et al.*, 2015). Sometimes, however, the elephants can build up a tolerance against humans, as it has been found they do not perceive vehicles as a threat (Goldenberg *et al.*, 2017). This could be because the elephants do not associate vehicles as a mortality risk, as they do with humans on foot. Most of the poaching occur on foot and often outside the protected area and is considered as a higher threat than tourist with vehicles by the elephants. At the same time elephants can also avoid vehicles (Goldenberg *et al.*, 2017).

If there is human settlements the elephant cows prefer to stay at least 5 km from them (Harris *et al.*, 2008). Elephants have been found to move faster trough corridors that are affected by more disturbance (Adams *et al.*, 2017). In this study the small village of some dozen people at corridor 3 could have affected the elephants. Probably some elephants avoided the area completely or during certain times and move fast through the corridor. Compared to protected areas, elephants move more quickly through unprotected areas (Douglas-Hamilton *et al.*, 2005; Graham *et al.*, 2009). Unprotected roads are also avoided by elephants who do not cross these areas, only one elephant in the study by Blake et al. (2008) crossed an unprotected road, with a very high speed. This suggest the elephants spend less time at these areas, and generally the elephants changed their behaviour in response to risk of human interactions (Graham *et al.*, 2009). The elephants in this study where maybe affected by the small unpaved road close to the corridors, however most likely not. In Blake *et al*. (2008) they found that on small roads inside protected areas the elephants could cross the roads routinely while unprotected roads were only crossed once and very fast. Since the area on both sides of the road are wildlife conservancies I suggest the small road close to the corridors are protected and therefore not considered as dangerous. Elephants that spend more time inside protected areas have also found to be calmer (Goldenberg *et al.*, 2017). If there are more disturbances in one corridor this could affect the results. Around 10 a.m. many of the elephants came inside the conservancy, which may suggest that the elephants consider Ol Pejeta as safer place during the day. However this cannot be confirmed by only using my data.

Fences and artificial waterholes change the migration patterns of elephants significantly (Shrader *et al.*, 2010). For example the elephants can revisit the same place more often during the wet seasons (Loarie *et al.*, 2009b). Generally elephants are more dispersed during the wet season and with a fence they are more restricted. Both artificial fences and artificial waterholes affect the migration patterns by decreasing the difference between the wet and dry season (Loarie *et al.*, 2009b). It is therefore important to understand that this study could be affected by these factors and may not completely reflect the elephant's migration patterns. However by using fences it is easier to protect endangered species, especially by protecting them from poachers (Ol Pejeta Conservancy, 2017).

Crop raiding and the moon

Full moon can affect the elephants activity during crop raiding (Barnes *et al.*, 2007; Gunn *et al.*, 2014). Less crop raiding occur during the full moon, most likely due to human activity and that the elephants can more easily be detected during the full moon. In the present study there were fewer passages around half-moon than around full and new moon. This might be an indication that there was no correlation between passing the cameras and elephant crop raiding, but we do not know. Barnes *et al.* (2007) was the first article showing that the moon affected elephant's behaviour and only a few studies have been made on moon phase effect after this, always correlating with crop raiding. It is possible that if the cameras where situated by preferred elephant vegetation the result might have been different. More studies need to be made in order to confirm the effect on elephant´s migration during different moon phases.

Elephants are most likely colour blind and therefore only see two types of colour during the day (Yokoyama *et al.*, 2005). Overall the elephants can see quite well, they can scan the horizon for other elephants or predators as well as see small details when searching for preferable food (Pettigrew *et al.*, 2010). Elephants are active during both night and day, which indicate the eyes also are arrhythmic (Kuhrt *et al.*, 2017; Pettigrew *et al.*, 2010). Lions can probably see much better than elephants at night (Power and Compion, 2009). However, their nocturnal activity pattern have been found to be constant during the lunar cycle (Cozzi *et al.*, 2012) and therefore the elephants migrating behaviour should not be affected by lions (Gunn *et al.*, 2014). Searching for vegetation can also be a reason since it is probably harder to find vegetation when vision is less. During the full moon they can see much better and therefore find the food easier and maybe they migrate more in order to find their preferred vegetation. However humans and lions also have improved vision at the same time and the extra migration may be in order to avoid these as well. Elephants in Ol Pejeta also break the electrical fence in order to go outside, presumably to raid fields or to access areas with other good forage (Samuel Mutisava, personal communication). These breakouts only occur at night and the elephants later come back inside in the morning, suggesting the elephants avoid humans as much as possibly when breaking fences.

Diurnal and nocturnal variations

Corridor activity has been found to occur mostly at night (18-06) compared to the day (06-18, Adams *et al.*, 2017). This does not correlate with the present study that has about the same amount of movement during these hours. The elephants activity occurs during the cooler periods of the day (Leggett, 2009), which in Leggett's study (2009) occurred between 7-11 pm and 15-19 pm. However in present study there is only an obvious drop of activity around 14 pm and the peaks of activity were around 10 am and 18 pm. This difference could be due to that Leggett (2009) made direct observations, while this study does not indicate exact activity patterns of the elephants for every hour, only when they pass the cameras. It is also important to note that this data does not say what the elephant did after passing the cameras; in reality they could have walked to a place with better shade or food in order to eat later when it was cooler. Around 10 a.m. there is a peak of elephants going in to the conservancy (fig. 5), however around 18 p.m. the elephants seem to go both in and out of the conservancy. In total there were 1579 individuals going in and 1145 individuals going out. This could have been because the elephants in this study generally walked in for reasons unknown, or had not gone outside yet when the study ended. However a much more possible reason would be that the cameras are positioned in a way that they do not detect all of the individuals going out of the conservancy.

Elephants have been found to manly drink from waterholes at dusk (Chamaillé-Jammes *et al.*, 2007), however this is not consistent as they have been found to drink on day as well (Hayward and Hayward, 2012; Valeix *et al.*, 2007). This could explain elephants going in and out of the conservancy at certain times, perhaps preferring different times to drink or different sites.

Monthly and seasonal variation

Variation between months differed significantly (Fig. 3). May and November had less activity than other months. However, some of the cameras seemed to take fewer pictures, or stop working completely sometimes in November and May. How important this affected the study is hard to grasp, most likely it has an effect. It is also important to note that in December there were most missing pictures, where one week was missing completely. Therefore it is a possibility that the elephants migrated less during May and November. With no other data or articles to compare monthly variation, more data is needed to confirm this variation. The cameras most likely stopped working because of lacking battery-power.

Rainfall did not have a significant effect on the migration of the elephants, which is surprising since less usage of corridors during the wet season have been found in a previous study (Adams *et al.*, 2017). Rainfall has previously been linked to higher availability water and food resources, which have been seen to reduce the use of urban corridors. Compared to our study, however, the corridors, in Adams *et al.* (2017), provided the elephants access to a river. Since there is no difference found during the wet season (which would correlate to the previous 90 days), this could suggest water might not the most important factor in corridor use at Ol Pejeta. However, it has also been found that elephants may avoid people and cattle during the wet season since both water and vegetation is more available (Chiyo *et al.*, 2014). Since Ol Pejeta has many cattle there is a possibility there is an avoidance strategy that make the elephants use the corridors more than they would if the cattle and people was not there. Looking at rainfall during the previous 7 days, the elephants migrated more during categories 1 and 2, which represent less rain. Loarie *et al.* (2009b) found that in areas that have more water there were less seasonal differences in how much area that was covered by the elephants. Furthermore, during the dry periods elephants migrate over large distances between vegetation and waterholes. This could be the reason for no significant difference in rainfall for the previous 30 and 90 days. Since Ol Pejeta Conservancy has artificial waterholes the elephants do not need to migrate in order to get water. Therefore it is possible that more migration occur in front of the cameras because the elephants move between the stationary waterholes in Ol Pejeta and preferred food source.

Implications and improvements of study

In order to truly find out why the elephants move in and out of the conservancy more information need to be gathered. For example mapping the vegetation inside and outside of Ol Pejeta could provide insight where vegetation is more productive and diverse, which the elephants prefer (Harris *et al.*, 2008). Since vegetation availability difference between seasons (Clegg and O'Connor, 2017), this most likely influences the migrating patterns. Mapping the waterholes inside and outside could also provide information if the elephants need to move in or out of the conservancy in order to get water. An identification of the places where poachers have been found would also provide good information. Recording the place and if the poacher where inside or outside the conservancy could be compared to the dates on cameras and see if there is any difference of elephants going in our out these days. However since I have no knowledge how much poaching inside or outside Ol Pejeta occurs this hypothesis could be hard to test.

To find out what they do inside or outside the conservancy drones can be used in order to see what the elephants generally do after passing the cameras, or in what direction they are walking. However this need to be carefully used since the elephants have been observed reacting to the drones when used for photographs, and has effectively been used to scare off elephants from raiding crops (Hahn *et al.*, 2017). GPS collars can be used in order to find out exactly what the elephants do all the time. However this is a quite expensive method (Forin-Wiart *et al.*, 2015) and in order to find why they move in and out of Ol Pejeta, individuals that continues to migrate in and out during all the seasons need to be identified first. There is also a possibility that individual elephants mess up the data; one elephant can walk in and out more than others with correlation to nothing. Therefore a study on the individuals would be interesting, however there was not enough time for me to study this. Also identifying all the elephants would not be possible since sometimes you only see the legs or trunk of the elephants, it is too dark or foggy, etc. Here a drone might improve the identification of the individuals.

Conclusions

- The elephants were more active during the day, especially around 10 am and 18 pm. There were monthly variations with much fewer daily passages during May and November.
- I could not show a seasonal difference of passages except a small difference when looking at rainfall during the previous seven days. The lack of seasonal differences could be due to the limited amount of data of one year.
- Moon phase has an affect on migration when only using the passages occurring during night (19 p.m. - 7 a.m.), with fewer passages around half-moon. In previous research moon activity has only been compared with crop raiding and is therefore hard to make conclusions since we do not know where the elephants migrate.
- Reasons for migration can be many, such as vegetation, waterholes, predation and avoidance of for example humans, lions and bees. More data needs to be collected in order to find out why the elephants walk in and out of the conservancy.

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References

Adams TSF, Chase MJ, Rogers TL, Leggett KEA. 2017. Taking the elephant out of the room and into the corridor: can urban corridors work? Oryx 51:347–353.

Barnes RFW, Dubiure UF, Danquah E, Boafo Y, Nandjui A, Hema EM, Manford M. 2007. Crop-raiding elephants and the moon. African Journal of Ecology 45:112–115.

Bauer S, Hoye BJ. 2014. Migratory Animals Couple Biodiversity and Ecosystem Functioning Worldwide. Science 344:1242552–1242552.

Blake S, Deem SL, Strindberg S, Maisels F, Momont L, Isia I-B, Douglas-Hamilton I, Karesh WB, Kock MD. 2008. Roadless Wilderness Area Determines Forest Elephant Movements in the Congo Basin. Plos One 3:e3546. https://doi.org/10.1371/journal.pone.0003546

Blanc J. 2008. *Loxodonta africana*. The IUCN Red List of Threatened Species. e.T12392A3339343. http://dx.doi.org/10.2305/IUCN.UK.2008.RLTS.T12392A3339343.en.

Cahn AR. 1925. The Migration of Animals. The American Naturalist 59:539–556.

Chamaillé-Jammes S, Valeix M, Fritz H. 2007. Elephant Management: Why Can't We Throw out the Babies with the Artificial Bathwater? Diversity and Distributions 13:663–665.

Chiyo PI, Wilson JW, Archie EA, Lee PC, Moss CJ, Alberts SC. 2014. The influence of forage, protected areas, and mating prospects on grouping patterns of male elephants. Behavioral Ecology 25:1494–1504.

Clegg BW, O'Connor TG. 2017. Determinants of seasonal changes in availability of food patches for elephants (*Loxodonta africana*) in a semi-arid African savanna. PeerJ 5:e3453; DOI 10.7717/peerj.3453

Codron J, Codron D, Lee-Thorp JA, Sponheimer M, Kirkman K, Duffy KJ, Sealy J. 2011. Landscape-scale feeding patterns of African elephant inferred from carbon isotope analysis of feces. Oecologia 165:89–99.

Cozzi G, Broekhuis F, McNutt JW, Turnbull LA, Macdonald DW, Schmid B. 2012. Fear of the dark or dinner by moonlight? Reduced temporal partitioning among Africa's large carnivores. Ecology 93:2590–2599.

Cushman SA, Chase M, Griffin C. 2005. Elephants in Space and Time. Oikos 109:331–341.

Dingle H, Drake VA. 2007. What Is Migration? BioScience 57:113.

Douglas-Hamilton I, Krink T, Vollrath F. 2005. Movements and corridors of African elephants in relation to protected areas. Naturwissenschaften 92:158–163.

Forin-Wiart M-A, Hubert P, Sirguey P, Poulle M-L. 2015. Performance and Accuracy of Lightweight and Low-Cost GPS Data Loggers According to Antenna Positions, Fix Intervals, Habitats and Animal Movements. Plos One 10:e0129271. https://doi.org/10.1371/journal.pone.0129271

Gadd, ME. 2005. Conservation outside of parks: attitudes of local people in Laikipia, Kenya. Environmental Conservation 32:50–63.

Galanti V, Preatoni D, Martinoli A, Wauters LA, Tosi G. 2006. Space and habitat use of the African elephant in the Tarangire–Manyara ecosystem, Tanzania: Implications for conservation. Mammalian Biology - Zeitschrift für Säugetierkunde 71:99–114.

Gerhardt KV, Niekerk AV, Kidd M, Samways M, Hanks J. 2014. The role of elephant (*Loxodonta africana)* pathways as a spatial variable in crop-raiding location. Oryx 48:436–444.

Goldenberg SZ, Douglas-Hamilton I, Daballen D, Wittemyer G. 2017. Challenges of using behavior to monitor anthropogenic impacts on wildlife: a case study on illegal killing of African elephants. Animal Conservation 20:215–224.

Graham MD, Douglas-Hamilton I, Adams WM, Lee PC. 2009. The movement of African elephants in a human-dominated land-use mosaic. Animal Conservation 12:445–455.

Gunn J, Hawkins D, Barnes RFW, Mofulu F, Grant RA, Norton GW. 2014. The influence of lunar cycles on crop-raiding elephants; evidence for risk avoidance. African Journal of Ecology 52:129–137.

Hahn N, Mwakatobe A, Konuche J, Souza N de Keyyu J, Goss M, Chang´a, A, Palminteri S, Dinerstein E, Olson D. 2017. Unmanned aerial vehicles mitigate human–elephant conflict on the borders of Tanzanian Parks: a case study. Oryx 51:513–516.

Harich FK, Treydte AC, Sauerborn J, Owusu EH. 2013. People and wildlife: Conflicts arising around the Bia Conservation Area in Ghana. Journal for Nature Conservation 21:342–349.

Harris GM, Russell GJ, Aarde RI van, Pimm SL. 2008. Rules of habitat use by elephants (*Loxodonta africana*) in southern Africa: insights for regional management Oryx 42:66–75.

Hayward MW, Hayward MD 2012. Waterhole use by African Fauna. South African Journal of Wildlife Research 42:117–127.

Holdgate MR, Meehan CL, Hogan JN, Miller LJ, Soltis J, Andrews J, Shepherdson DJ. 2016. Walking Behavior of Zoo Elephants: Associations between GPS-

Measured Daily Walking Distances and Environmental Factors, Social Factors, and Welfare Indicators. Plos One 11: e0150331. doi:10.1371/journal.pone.0150331.

Ihwagi FW, Thouless C, Wang T, Skidmore AK., Omondi P, Douglas-Hamilton I. 2018. Night-day speed ratio of elephants as indicator of poaching levels. Ecological Indicators 84:38–44.

Ihwagi FW, Wang T, Wittemyer G, Skidmore AK, Toxopeus AG., Ngene S, King J, Worden J, Omondi P, Douglas-Hamilton I. 2015. Using Poaching Levels and Elephant Distribution to Assess the Conservation Efficacy of Private, Communal and Government Land in Northern Kenya. Plos One 10:e0139079. doi:10.1371/journal.pone.0139079.

Jachowski DS, Singh NJ. 2015. Toward a mechanistic understanding of animal migration: incorporating physiological measurements in the study of animal movement. Conservation Physiology 3:cov035: doi:10.1093/conphys/cov035.

Jones CG, Lawton JH, Shachak M. 1994. Organisms as Ecosystem Engineers. Oikos 69:373–386.

Joubert D. 2006. Hunting behaviour of lions (*Panthera leo*) on elephants (*Loxodonta africana*) in the Chobe National Park, Botswana. African Journal of Ecology 44:279–281.

Kikoti AP, Griffin CR, Pamphil L. 2010. Elephant use and conflict leads to Tanzania's first wildlife conservation corridor. Pachyderm 48:57–66.

King LE, Lawrence A, Douglas-Hamilton I, Vollrath F. 2009. Beehive fence deters crop-raiding elephants. African Journal of Ecology 47:131–137.

King LE, Soltis J, Douglas-Hamilton I, Savage A, Vollrath F. 2010. Bee Threat Elicits Alarm Call in African Elephants. Plos One 5:e10346. doi:10.1371/journal.pone.0010346

Kohi EM, de Boer WF, Peel MJS, Slotow R, van der Waal C, Heitkönig IMA, Skidmore A, Prins HHT. 2011. African Elephants (*Loxodonta africana)* amplify browse heterogeneity in African savannah. Biotropica 43:711–721.

Kuhrt H, Bringmann A, Härtig W, Wibbelt G, Peichl L, Reichenbach A. 2017. The Retina of Asian and African Elephants: Comparison of Newborn and Adult. Brain, Behavior and Evolution 89:84–103.

Leggett K. 2009. Diurnal activity of the desert-dwelling elephants in northwestern Namibia. Pachyderm 45:20-33.

Lennox RJ, Chapman JM, Souliere CM, Tudorache C, Wikelski M, Metcalfe JD, Cooke SJ. 2016. Conservation physiology of animal migration. Conservation Physiology 4:cov072; doi:10.1093/conphys/cov072.

Loarie SR, van Aarde RJ, Pimm SL. 2009 a. Elephant seasonal vegetation preferences across dry and wet savannas. Biological Conservation 142:3099–3107.

Loarie SR, van Aarde RJ, Pimm SL. 2009 b. Fences and artificial water affect African savannah elephant movement patterns. Biological Conservation 142:3086–3098.

Loveridge AJ, Hunt JE, Murindagomo F, Macdonald DW. 2006. Influence of drought on predation of elephant (*Loxodonta africana*) calves by lions (*Panthera leo*) in an African wooded savannah. Journal of Zoology 270:523–530.

Madsen T, Shine R. 1996. Seasonal Migration of Predators and Prey -A Study of Pythons and Rats in Tropical Australia. Ecology 77:149–156.

Naughton-Treves L. 1998. Predicting Patterns of Crop Damage by Wildlife around Kibale National Park, Uganda. Conservation Biology 12:156–168.

O'Connor TG, Goodman PS, Clegg B. 2007. A functional hypothesis of the threat of local extirpation of woody plant species by elephant in Africa. Biological Conservation 136:329–345.

Ol Pejeta. 2017. WWW document: https://www.olpejetaconservancy.org/wildlife/wildlife-habitats/elephants/. Accessed 2017-12-17.

Pettigrew JD, Bhagwandin A, Haagensen M, Manger PR. 2010. Visual Acuity and Heterogeneities of Retinal Ganglion Cell Densities and the Tapetum Lucidum of the African Elephant (*Loxodonta africana*). Brain, Behavior and Evolution 75:251–261.

Poole J. 1996. The African elephant. In: Kangwana K. (red.). Studying elephants, pp. 1-8. African wildlife foundation, Nairobi, Kenya.

Power RJ, Compion RXS. 2009 Lion predation on elephants in the Savuti, Chobe National Park, Botswana. African Zoology 44:36–44.

Pretorius Y, Stigter JD, de Boer WF, van Wieren SE, de Jong CB, de Knegt HJ, Grant CC, Heitkönig I, Knox N, Kohi E, Mwakiwa E, Peel MJS, Skidmore AK, Slotow R, van der Waal C, van Langevelde F, Prins HHT. 2012. Diet selection of African elephant over time shows changing optimization currency. Oikos 121:2110–2120.

Purdon A, van Aarde RJ. 2017. Water provisioning in Kruger National Park alters elephant spatial utilisation patterns. Journal of Arid Environments 141:45–51.

Reconyx. 2013. WWW document: http://images.reconyx.com/file/HyperFireManual.pdf. Accessed 2017-08-24.

Scheldrick D. 2015. WWW document: https://www.thedodo.com/ivory-poachers-are-not-the-only-humans-killing-elephants-1355722161.html. Accessed 2017-12-17.

Schulte BA. 2000. Social structure and helping behavior in captive elephants. Zoo Biology 19:447–459.

Shannon G, Mackey RL, Slotow R. 2013. Diet selection and seasonal dietary switch of a large sexually dimorphic herbivore. Acta Oecologica 46:48–55.

Shannon G, Matthews WS, Page BR, Parker GE, Smith RJ. 2009. The affects of artificial water availability on large herbivore ranging patterns in savanna habitats: a new approach based on modelling elephant path distributions. Diversity and Distributions. 15:776–783.

Shrader AM, Pimm SL, van Aarde RJ. 2010. Elephant survival, rainfall and the confounding effects of water provision and fences. Biodiversity and Conservation. 19:2235–2245.

Sitati NW, Walpole MJ, Leader-Williams N. 2005. Factors Affecting Susceptibility of Farms to Crop Raiding by African Elephants: Using a Predictive Model to Mitigate Conflict. Journal of Applied Ecology 42:1175–1182.

Smit IPJ, Grant CC, Whyte IJ. 2007. Elephants and water provision: what are the management links?. Diversity and Distributions 13:666–669.

Soltis J, King LE, Douglas-Hamilton I, Vollrath F, Savage A. 2014. African Elephant Alarm Calls Distinguish between Threats from Humans and Bees. Plos One 9:e89403. https://doi.org/10.1371/journal.pone.0089403.

Thouless CR, Sakwa J. 1995. Shocking elephants: Fences and crop raiders in Laikipia District, Kenya. Biological Conservation 72:99–107.

Valeix M, Chamaillé-Jammes S, Fritz H. 2007. Interference Competition and Temporal Niche Shifts: Elephants and Herbivore Communities at Waterholes. Oecologia 153:739–748.

Verlinden A, Gavor IKN. 1998. Satellite tracking of elephants in northern Botswana. African Journal of Ecology 36:105-116.

Vogel SM, Henley MD, Rode SC, van de Vyver D, Meares KF, Simmons G, de Boer WF. 2014. Elephant (*Loxodonta africana*) impact on trees used by nesting vultures and raptors in South Africa. African Journal of Ecology 52:458–465.

Vollrath F, Douglas-Hamilton I. 2002. African bees to control African elephants. Naturwissenschaften 89:508–511.

Wall J, Wittemyer G, Klinkenberg B, LeMay V, Douglas-Hamilton I. 2013. Characterizing properties and drivers of long distance movements by elephants (*Loxodonta africana*) in the Gourma, Mali. Biological Conservation 157:60–68.

Wittemyer G, Daballen D, Rasmussen H, Kahindi O, Douglas-Hamilton I. 2005. Demographic status of elephants in the Samburu and Buffalo Springs National Reserves, Kenya. African Journal of Ecology 43:44–47.

Wittemyer G, Getz WM, Vollrath F, Douglas-Hamilton I. 2007. Social dominance, seasonal movements, and spatial segregation in African elephants: a contribution to conservation behavior. Behavioral Ecology and Sociobiology 61:1919–1931.

WWF. 2017. WWW document: https://www.worldwildlife.org/species/african-elephant#. Accessed 2017-12-18.

Yokoyama S, Takenaka N, Agnew DW, Shoshani J. 2005. Elephants and Human Color-Blind Deuteranopes Have Identical Sets of Visual Pigments. Genetics. 170:335–344.

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