CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Home range and habitat use of Eastern Derby eland (*Taurotragus derbianus gigas*) in Chinko Project area, Central African Republic

Master's Thesis

Prague 2017

Supervisor:
Ing. Karolína Brandlová, Ph.D.

Author:
Bc. Markéta Švejcarová

Declaration

I declare that this master's thesis entitled "Home range and habitat use of Eastern Derby eland (*Taurotragus derbianus gigas*) in Chinko Project area, Central African Republic" is my original work. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

In Prague: 27.4. 2017

……………………………………..

Markéta Švejcarová

Acknowledgement

I would like to express my sincere gratitude to all those who contributed to accomplishment of this thesis. To my supervisor, Karolína for her expertise, professional help and for allowing me finish the studies due to her grand tolerance and understanding.

To everyone in Chinko who welcomed me and helped me during my stay and afterwards. Especially to the Parc Manager, David Simpson for everything I learned from him and the experiences I would never gain without his support as well as the head of the research Thierry Aebischer, for his unbeatable knowledge and never ending optimism that made him believe in me. Together with Raffael Hickisch they trusted me with the opportunity to be a part of the unique and amazing project that Chinko is.

I would also like to express my appreciation to prof. RNDr. Pavla Hejcmanová, Ph.D., who helped me with the study design.

My family and friends continue to encourage me no matter what and I would not be where I am now if it wasn't for them.

Abstract

Home range and habitat use of Eastern Derby eland (*Taurotragus derbianus gigas*) in Chinko Project area, Central African Republic

Animals usually do not wander randomly during their normal activities but their movement is restricted to certain area. This area presents the concept of home range and its size, shape and location vary among species and individuals. Knowledge of animals' home range characteristics is essential part of their behaviour ecology. It often plays an important role in management decisions of protected areas and conservation programs, however no analysis of annual home range size for Derby eland has been published so far.

Our results present the estimation based on data of four Eastern Derby elands, two males and two females collared in Chinko Project area, Central African Republic. Spatial data of each individual which were collected for twelve months have been analysed by Minimum Convex Polygon and Kernel Density Estimation methods. Size of the annual home range among the animals was minimum 306 km² and maximum 672 km². High inter individual variation was observed which is not uncommon in other species.

Results revealed significant seasonality in the animals' movement ($P \approx 0.0017 \rightarrow P < 0.05$) based on minimum distance walked per month and furthemore significant difference in intensity between males and females ($P = 0.01339 \rightarrow P < 0.05$).

Available telemery data offer the possibility to analyse also habitat use of the collared animals. We found the same composition of preffered habitat types among all individuals with some differences in the proportion. The habitat with absolute majority of occurrence was Open Woodland Savanna therefore we can confirm the public perception of preffered habitat of the Derby eland.

Key words: radio collars, home range, GPS tracking, QGIS, movement

Content

List of figures and graphs

List of tables

List of the contractions used in the thesis

ANOVA	Analysis of Variance
APN	African Parks Network
AWT	Africa Wildlife Tracking
CAR	Central African Republic
CAWA	Central African Wildlife Adventures
CCF	Closed Canopy Forest
CPA	Chinko Project Area
DF	Degrees of Freedom (for statistics)
DLG	Dry Lakéré Grassland
DOP	Dilution of Precision
GMT	Greenwich Mean Time
GPS	Global Positioning System
HDOP	Horizontal Dilution of Precision
HR	Home Range
KDE	Kernel Density Estimation
KML	Keyhole Markup Language
KMZ	Keyhole Markup Language Zipped
LANDSAT	Land Remote-Sensing Satellite (System)
MCP	Minimum Convex Polygon
MS	Microsoft
OWS	Open Woodland Savanna
QGIS	Quantum Geographic Information System
SAT	Satellite
UD	Utilisation Distribution
UNIFR	University of Fribourg
WMG	Wet Marshy Grassland
WSB	Water Surface Body
XLS	Microsoft Excel Spreadsheet
XML	Extensible Markup Language

1 Introduction

Very little is known about the movement patterns and home range (HR) size of an ungulate species Derby eland (*Taurotragus derbianus*). Assumptions about the habitat preferences and the eland being a savannah species are usually based on direct observations, repeated and not yet scientifically proven. Importance of these information is besides the research itself particularly high for management of conservation areas, emplacement of antipoaching activities etc.

Chinko river drainage basin where an area of this study lies, covers together with headwaters of Mbari, Kotto and Ouarra approximately 70,000 km² almost uninhabited eastern Central African Republic (CAR). It is one of the last true wilderness left in the world and apart of over eighty other mammalian species it is also home for the Derby eland. In early 2016, seven individuals were collared to obtain telemetry data of their movement and these data were used for analyses of their HR and habitat use in this thesis.

Derby eland is an antelope inhabiting Central (eastern subspecies *T. d. gigas*) and Western (western subspecies *T. d. derbianus*) African woodland savannahs. With its size and especially due to the horns length it is considered the largest of all antelopes overcoming even the common eland (*Taurotragus oryx*) (Burton and Burton 2002, Prothero and Schoch 2002). Movement of wild animals is driven by multiple biological factors and it depends on the species' ecology and social structure. The elands are gregarious species, meaning they are forming herds. The same structures were observed in both subspecies although the group size may vary significantly based on the conditions, especially habitat and predator pressure (Caro 2005, Bercovitch and Berry 2010, Creel et al. 2014). Nevertheless, the information about species social behaviour allow assumptions of the animals companionship or solitude and to discuss reasons for individuals' HR overlap.

HR size is a key knowledge for any species, essential for management of an area where the species is present. Many conservation projects face the problem of the whole animal population leaving the protected area for certain part of a year due to various drivers and being unable to protect them outside. Other species' characteristics are related to the HR as territorial behaviour having a direct impact on the carrying capacity of any specified area. However, it can be difficult to obtain that information depending on the species behaviour. Modern technology such as telemetry with GPS units able to provide very precise coordinates of the animals' position brings new possibilities. (Hebblewhite and Haydon 2010, Walter et al. 2011).

Although several attempts to collar the Derby eland are known, only one report was published based on the telemetry data. Phillipe Chardonnet collared five individuals during in 2003 and 2004 in northern CAR. From those data the first spatial analyses were done for the Derby eland. Results obtained from this primary survey show significant differences between the two sexes and compare time period of rut with the rest of the year. To compare those data with individuals from Chinko will bring a better idea about the HR size and more reliable results (Graziani and d'Alessio, 2004)

Habitat use analysis, based on the probability of occurrence in different types of habitat within the HR of an individual will help to establish a suitable environment for the species. The occurrence is mainly influenced by the food and water availability and by the sexual selection during the time period of rut.

The interpretation of results offers management recommendations concerning the suitable habitat for the species and size of the area which needs active protection. The actual occurrence of the animals supported by the analyses compared to the placement of antipoaching activities and the protection zone gives a strong argument for future needs of funding.

2 Literature review

2.1 Derby Eland Ecology

Derby eland is a large African ungulate, commonly known also as giant eland (Kingdon et al. 2013). Together with common eland, those species are two members of genus *Taurotragus*, family Bovidae. They are light brown or beige colour with usually around 10-17 white vertical stripes on the body and expressive black marks on the head, neck (in males, intensified during the rut as a sign of dominancy) and above hooves. Males also have typically large dewlap that stretches from the chin towards the chest. Both sexes have spiral-shaped horns, it is not unusual for the length to be over 1 meter long. More detailed description for example in (Lutovská 2012, Kingdon 2015) see Figure 1.

Elands, formerly widely spread throughout several countries were introduced to the western society in the middle of 19^{th} century (Gray 1847, Heuglin 1863). Hunters call the Derby eland an elusive and wary species given its behaviour in uneasily accessible environment. Being chased in the long term and not previously studied in detail, it is possible today's occurrence does not represent the original habitat in some locations. Elands are generally assumed to live in habitat ranging from scrubs forests, woodland savanna to the wet forest-grasslands mosaic (Bro-Jorgensen 1997, Corporation 2001, Kingdon 2015). Kingdon (2015) conditions giant eland's distribution by occurrence of *Isoberlinia doka*, one of their diet's plant species (Kingdon 2015).

The primary difference that distinguishes the species from common eland and is related to the habitat use is feeding strategy. While the common eland is mostly grazer, browsing is prevalent in the Derby eland (Wilson et al. 2011). The Derby elands were shown to feed on over thirty plant species just in Senegal and more than 60 in CAR (Hejcmanova et al. 2010). Therefore they can be considered generalists as long as enough browsing plants are present. It is usual that they use their horns to break branches out of their reach to feed on them (Bro-Jorgensen 1997, Burton and Burton 2002, Hejcmanova et al. 2010).

The natural predator for eland is lion (*Panthera leo*) and African Wild dog (*Lycaon pictus*), other predators such as leopard (*Panthera pardus*), spotted hyena

(*Crocuta crocuta*) or cheetah (*Acinonyx jubatus*) can be a threat for calves (Angwafo 2006, Kingdon et al. 2013).

Figure 1. Male and female of Western Derby eland, Senegal (photo credit: author)

In nature, elands may be encountered in distinct social structures depending mainly on the sex. Females and subadult individuals of both sexes stay almost exclusively in herds of various sizes. Bro-Jorgensen observed elands in groups between 1 and 66 individuals, the size fluctuated during the year. He listed observations by other authors ranging from 30 up to over hundred individuals in one herd (Bro-Jorgensen 1997). Dominant male stays usually with the herd, being challenged by other males during the rut period (Graziani and d'Alessio, 2004). Fighting between males is mostly ritualised, but injuries occur. Youngsters may stay with the herd as long as being tolerated by the dominant male. Adult males who do not follow the herd move either solitary or form bachelor groups (Estes 1991, Bro-Jorgensen 1997, Hejcmanova et al. 2011, Brandlová et al. 2013).

Female leaves the herd temporarily to give birth and then cares for the offspring up to a few weeks via the hiding strategy until the young is able to keep up with the herd's pace. During that time it is both possible for the female to re-join the herd during the day if within reach or to stay separately (Hejcmanova et al. 2011). Fisher et al. suggests that in more closed habitats, it is more energetically beneficial for the hider offspring if milk is brought to him (Fisher et al. 2002). That could be true for elands in woodland savanna habitat where high grass is present during the breeding period.

Description of breeding strategy is essential for understanding of the patterns in species seasonal movement. The rut period takes place in relation to the ideal time for the offspring to be born. The gestation period is 8-9 months and majority of offspring are born in late rainy season, the exact months depend on the location. We can expect higher mobility of males in dry season in order to mate with as many females as possible to produce offspring. (QUOTE)

2.2 Eastern Derby Eland Population

Elands are favourite subject of hunting by local populations because of their size, they are relatively easy to track down and they occur in numerous herds. For the professional hunters, today the trophy of giant eland belongs to the most valued and hard to get on the African continent (Wilson et al. 2011).

Those are some of the factors among other that caused minimization of formerly rather large areas of Derby eland occurrence from Nigeria through Cameroon, CAR and South Sudan to northern Uganda, occasionally crossing boundary into Chad, Sudan or Democratic Republic of Congo (East 1999), see Figure 2.

Today's viable populations of Eastern Derby eland are restricted to three national parks Faro, Bénoué and Bouba Ndjida with managed hunting concessions in Cameroon, a population of unknown size in South Sudan and the majority of Derby elands left in the wild are in CAR (IUCN, 2008).

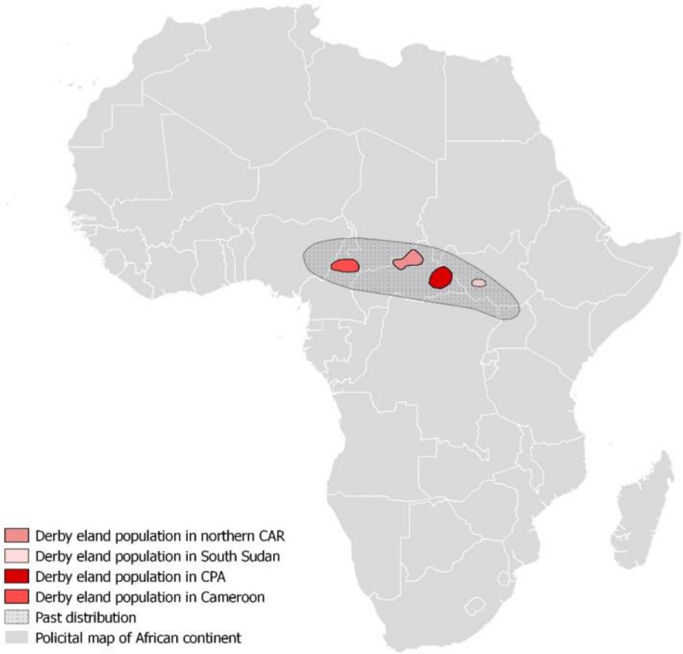

Figure 2. Past and present distribution of Eastern Derby eland

East estimated in 1999 that at least 15,000 Eastern Derby elands were in CAR which could have been three quarters of overall population at that time based on estimated total numbers. Although the numbers of astern Derby elands were considered decreasing as many others, populations were thought to be stable or increasing due to many functioning hunting companies operating in eastern CAR (East 1999). Elands remain mainly in the East, from time to time observed in the North of the country.

Hunting is still an important livelihood and source of food or income for local population in CAR. Protected areas are usually large, not fenced with fluctuating number of law enforcement employees. Therefore, the poaching pressure is high and there are almost no real consequences for the poachers as the law enforcement in the whole country is not functioning.

The most important change in the past 20 years was the arrival of nomadic cattle herders coming from Chad, Sudan and mainly South Sudan to CAR due to the extension of the desert in Sahel, drying out of the lake Chad and general lack of water for unsustainable numbers of cattle kept by the herders. The herders poach while passing through the country in massive amounts. This trend caused decimation of practically all mammal species of the Eastern CAR, not forgetting the Derby eland. As one of the main threats for the study area, more information described further.

2.3 Wildlife in CAR

Huge decline of large mammal species started to be an issue in Africa mostly during the 20th century. Many factors contribute to that and may vary throughout the continent. Unlike other parts of the continent, central Africa did not yet face big population growth that usually comes with western medicine and humanitarian organisations. The life expectancy less than 50 years and extremely high mortality rate places CAR in a long term humanitarian crisis (report of MSF, . With eight inhabitants per square kilometre, CAR is one of the countries with the lowest population densities in the world. The total population is only around five million people which may be one of the reasons why there is still surviving wildlife.

In Northern CAR, the wildlife populations have gone through a major decline in 1970s and 1980s due to the increase of hunting, poaching and a rinderpest outbreak to which are elands highly susceptible (Ruggiero 1984, Estes 1991, Hendrikx et al. 2001). Philippe Bouché and others monitored the situation by conducting aerial surveys in 2005 and 2010, comparing the results to the previous survey from 1985. They covered 95,000 km² and stated up to 94 % decline in numbers of large mammals between 1978 and 2010.

The most suffered the elephant (*Loxodonta africana*), topi (*Damaliscus lunatus*) and Buffon's Kob (*Kobus kob*) populations. In the survey from 2005, the populations of Derby eland together with buffalo (*Syncerus caffer*) and roan antelope (*Hippotragus equinus*) were assessed being stable or even increasing. Already in 2005, the cattle transhumance was mentioned as one of the threats and reasons for the wildlife collapse with the risk of diseases transmission (Bouché et al. 2010, Bouché et al. 2012). Today the nomadic pastoralism is probably the main threat for the wildlife concurring for the resources in nature and due to unsustainable practices of the herders. After 2005, all species declined while the domestic cattle numbers were higher.

Bouché (ROK) stated that one of the reasons to repeat the survey in 2010 was to inspect the impact of rebellion which escalated in 2006 on wildlife. Socio-political situation has a big impact on the animal numbers in CAR especially in past fifteen years. Although wildlife may generally benefit from the low human population, the underdevelopment brings its negatives. The non-existence of roads and other infrastructure in the country makes any law enforcement including antipoaching activities extremely difficult, the illiteracy or low level of education and lack of employment opportunities results in a large proportion of the population being dependant on the illegal bush meat (Fargeot 2004, Bouché et al. 2012). Even though the aerial surveys covered only northern part of CAR, the results reflect the situation which had the same course of action throughout the country. On the other hand, it needs to be mentioned while looking at the numbers that were observed, the efficiency of aerial survey is debatable given the habitat and animal behaviour. It has been observed in the study area that many large ungulate species under the human pressure adapt by moving mostly at night, staying in smaller group and hiding during the day which obviously lowers the chance to spot them? from the air.

Chinko Project was established in 2013 by David Simpson, Eric Mararv, Thierry Aebischer, Raffael Hickisch and Charlotte Mararv in eastern CAR. They achieved to obtain a 50-year mandate for conservation of a large area designated as hunting blocks since 1970s. The area totals more than 17,000 km² (see Figure 2) and its remoteness is one of the main advantages for the project There are no public roads crossing the area and no permanent settlements inside or nearby. The size, comparable to Kruger National Park, guarantees no issues in the future with carrying capacity and hopefully self-sufficiency in predator-prey dynamics.

Until early 2015, there was a hunting company Central African Wildlife Adventures (CAWA) operating on part of the area and the basic infrastructure of roads, airstrip and camps built by the company made it possible to create the Chinko Project. In 2014, Chinko Project became a member of the African Parks Network (APN) which is a non-profit organisation that takes on direct responsibility for the rehabilitation and long-term management of national parks and protected areas across Africa, in partnership with governments and local communities. Partnership with APN enabled another scale of operations in all departments of the Chinko Project. (QUOTE booklet nakonec)

Figure 3. Location of CAR and the study area (map credit: J. Piff, weissgrad.at)

There are three major threats for Chinko's wildlife: poaching, mining and pastoralism (Chinko Booklet, 2015). None of those activities is legal in protected area according to the CAR law. Both diamond and gold resources are occurring luring both local and neighbouring population to come in set up illegal mines while destroying the nature resources in much larger area. Due to desertification and lack of accessible water and feed in Sahel and further south, the transhumance has undergone rapid growth mainly in past twenty years. There are hundreds of pastoralist groups coming seasonally from Chad, Sudan and South Sudan through the Chinko Project area (CPA) or settling inside. The number of cattle in each group may vary from a few dozen up to several thousands of animals often accompanied by other domestic livestock. Apart from the competition with the wild herbivores, cattle brings transmissible zoonosis and the herders are regularly killing predators. Both mining and pastoralism results in massive poaching. Given the area's remoteness, poaching by the local communities is not a number one issue. However the scale of poaching by the cattle herders using automatic weapons is unsustainable and damages the whole ecosystem.

2.4 Home Range (HR)

First widely adopted definition of HR was formulated by W. H. Burt (1943) as follows: "area traversed by the individual in its normal activities of food gathering, mating, and caring for young" (Burt 1943). By restricting its utilisation by "normal activities" he already indicated that HR does not cover every place where the individual actually occurs (White and Garrott 2012). Therefore in addition to that he stated "occasional sallies outside the area, perhaps exploratory in nature, should not be considered as in part of the home range" (Burt 1943). Those positions outlying from the HR are usually referred to as outliers (Kenward 2001, Walter et al. 2011).

The definition has been criticised by many authors mainly for the uncertainty of term "normal activities" and no detailed description of "occasional sallies" making it difficult to quantify (Mohr 1947, Hansteen et al. 1997, Millspaugh and Marzluff 2001, Kie et al. 2010). Other authors welcome vague wording for making the definition generally applicable on wide spectrum of behaviour (Boitani and Fuller 2000). There is also no consideration for temporal change of individual's HR (Hansteen et al. 1997).

Many species have sort of cognitive map of the area where they live (Peters 1978). HR is beneficial for the animal due to higher familiarity with the area enabling the animal to use efficiently its resources (Mills and Marchant-Forde 2010)

Many estimators have been developed for HR estimation and their reliability is often a matter of discussions and comparisons (Seaman and Powell 1996, Nilsen et al. 2008). Two basic methods were review in this study.

Minimum Convex Polygon (MCP) is considered the most simple and widely method to estimate the size of HR. It is based on creating a polygon between determined percentage of GPS positions. The only requirement is for the angle between each two points to be convex = less than 180 ° (Boulanger and White 1990, Nilsen et al. 2008). Validity of HR estimations based on MCP method are often source of discussion (Nilsen et al. 2008) whereas some authors resent its application completely (Börger et al. 2006a, Laver and Kelly 2008). 95 % of available GPS positions is most commonly used for the analyses eliminating the most outlying values.

Another method is the Kernel Density estimation (KDE). The main advantages of KDE are that it does not assume a certain spatial distribution of the data points and provides a continuous utilization distribution (UD) instead of only a binary home range border (Hansteen et al. 1997; Seaman et al. 1999). 95% of the fixes is usually used for the KDE as well as in MCP. The UD of 50% is referred to as core area (Samuel et al., 1985). The resulting UD can be visualised both two or three dimensional whereas we used two dimensional in this study. The requirement for this method is choosing the appropriate method for calculation two parameters for its algorithm, the smoothing parameter (bandwidth) and the Kernel.

Girard states that generally, HR size calculated by MCP underestimates the real area and in contrary, KDE often overestimates the true size (Girard et al. 2002).

3 Aims of the Thesis

First aim was to calculate the area and utilisation distribution of annual HR, and to compare seasonal dynamics and differences between the two sexes.

The second aim was to analyse the positions in terms of different habitat the individuals occurred in and to compare differences between males and females. The habitat use of the animals was related to the individuals' HR where the habitat structure was quantified.

4 Methods and Material

4.1 Study Area

The study site is defined by movement of the collared animals. No individual left the CPA during the monitored period. CPA ranges approximately between latitude 5.1 and 7.1 North and between longitude 23.27 and 24.7 East.

CPA extends over three ecoregions of central Africa (based on classification by World Wildlife Foundation, 2001): the Northeastern Congolian lowland forest, the East Sudanian savanna and mainly the Northern Congolian forest-savanna mosaic which spreads between Cameroon Highlands in the west and South Sudan and Democratic Republic of the Congo in the east. CPA is the place where ecoregion Northern Congolian forest-savanna mosaic exists in its narrowest belt. The distance between is there less than 100 km north-south. Meaning 100 km apart there can be observed completely distinct habitats.

This habitat mixture forms the extraordinary species diversity which makes it an important area for conservation efforts. This unique situation results in close co-existence of typically savanna and exclusively forest species. Different habitat adaptations of certain species over the millions of years often resulted in such distinct genotypes they are today classified as separate subspecies or even species. There are not many places where those subspecies could meet in nature and Chinko is one of them. It creates the hybridisation zone where for example buffalo and elephant populations bear the characteristics of both subspecies and the adaptability to both habitats brings indisputably an advantage for survival.

Chinko is home to more than 80 large and medium sized mammal species and over 400 bird species. From the key species in the project area can be found for example both species of African elephant (*Loxodonta Africana* and *Loxodonta cyclotis*), eastern chimpanzee (*Pan troglodytes schweinfurthii*), large ungulates such as lowland bongo antelope (*Tragelaphus eurycerus eurycerus*) or Lelwel hartebeest (*Alcelaphus lelwel*). From the big predators those are especially lion, African wild dog, leopard and spotted hyena. The population of the focus species Eastern Derby eland within the project area is estimated at minimum over 400 individuals (Brandlová et al. 2017, in press).

4.2 GPS Data

4.2.1 Data Collection and Access

The initial step to obtain and analyse spatial data of Derby eland in CPA was to collar the animals. Due to logistical demandingness and current infrastructure it was decided prior the mission that the darting of animals should be done from a helicopter carrying veterinarians, pilot and support staff.

It turned out to be very efficient and cost less way to use the best trackers to find and follow the eland herds on the ground. Four teams of local trackers were sent to different localities. When trackers signalled localisation of the elands, helicopter was called and directed to the place.

After successful darting using a combination of drugs, the helicopter followed animal until the first sign of immobilisation were shown. Pilot had to find a suitable place for landing and the collaring team could approach the animal. The tasks fulfilled with each individual were as follows: placing the collar and activating it; appropriate rapid health check and care; taking horn measurements and DNA sample; taking a photograph and applying the antagonist drugs. The whole action took under twenty minutes each time.

All animals were collared between 19th and 27th of February 2016. At the end, there were 7 Eastern Derby elands collared in total, four males and three females out of which all animals were adult except one subadult male estimated 2-3 years old based on horns growth.

All used collars were manufactured by Africa Wildlife Tracking (AWT) based on neck size measurements of Western Derby eland provided by Derbianus Conservation z.s. from Senegal. AWT SAT (Iridium) collars for eland were equipped by 2 D cell batteries for the GPS unit providing the positions through satellite fixes and 1 D cell battery for the VHF transmitter allowing precise tracking of the animal in real time by using the VHF receiver.

All data were stored at the AWT website available online at https://www.awetelemetry.com/awt/tracking.php. The platform allows direct viewing of the latest positions for each individual on Google maps satellite images; data download in form of KML/KMZ file or in an Excel sheet for desired time span.

4.2.2 Pre-processing and Final Data

For purposes of this thesis data for each individual were downloaded as an XLS file and pre-processed in MS Excel (Microsoft 2016). The initial position of each individual, determining "Start date" (see Table 1) refers to the first position after collar was placed on animal and therefore varies by date and/or time. To have full one year dataset for the four individuals with functioning collars, data until the 28th February 2017 were retrieved.

Three collars stopped functioning during the monitored period. Eland female with collar 1581 was poached within two weeks after collaring (verified on ground by ranger team). Due to low number of GPS fixes and time span of data less than month, the data were not used for any of the analyses. Two collars on adult males, 1580 and 1585 stopped working several months after collaring due to technical issues (from correspondence with Sophie Haupt, AWT) and the data were used for some of the analyses. For those three individuals "End date" is date of the last available position (see Table 1).

All information that were not needed for the analysis such as temperature information and zero values data were neglected and multiple readings for the same position were deleted based on 0 m distance from the last coordinates. Date and time of the GPS fixes was kept in GMT taking in consideration that local time in CPA is GMT+1.

Positions with HDOP value equal or higher than 10 were excluded for their low reliability. The excluded positions did not consist of more than 2 % of each individual's data.

Due to the transfer from XLS to XML file after retrieving the data, some of the latitude values resulted in invalid format. Those were manually corrected by downloading the data as KML file and using Google Earth Pro 7.1.8.3036 (Google 2017) to verify true location.

There were 3375 GPS positions available in total for the analyses from all seven collars after the pre-processing. Not all data were used for all the analyses, but appropriate data were filtered for the specific use and explained in the methodology of each analysis.

Individual	**Sex**	**Age category**	**Start date**	**End date**	**Number of positions**	**Maximum gap**
1578	M	subadult	19.2.2016	28.2.2017	426	16 days
1580	M	adult	21.2.2016	21.6.2016	321	6 days
1581	F	adult	22.2.2016	4.3.2016	50	1 day
1582	F	adult	25.2.2016	28.2.2017	866	4 days
1583	F	adult	27.2.2016	28.2.2017	664	5 days
1584	M	adult	27.2.2016	28.2.2017	694	9 days
1585	M	adult	27.2.2016	10.10.2016	354	6 days
			Total number of positions:		**3375**	

Table 1. Complete dataset available for analyses after pre-processing

4.3 Habitat Map

The habitat map used for the analysis of habitat use was created by team at University of Fribourg, Switzerland. Software QGIS 2.4.0-Chugiak (QGIS Development Team 2014) and MATLAB 8.4 R2014b (MathWorks 2014) were used to classify the land cover of the eastern CAR into five major habitats: Closed Canopy Forest (CCF), Open Woodland Savanna (OWS), Dry Lakéré Grassland (DLG), Wet Marshy Grassland (WMG) and Surface Water Body (SWB).

To obtain a high visibility despite cloud cover and smoke from fires, twenty LANDSAT images taken between January and February (dry season) of 2014 and 2015 were used. The remote sensing data were calibrated by Thierry Aebischer with observed ground truth based on his surveys from 2012 to 2016.

The final map has a resolution of 30x30m pixels. In Figure 3 is shown a small area including all five habitats for better understanding of the map. Style of the layers was personalised for purposes of this thesis.

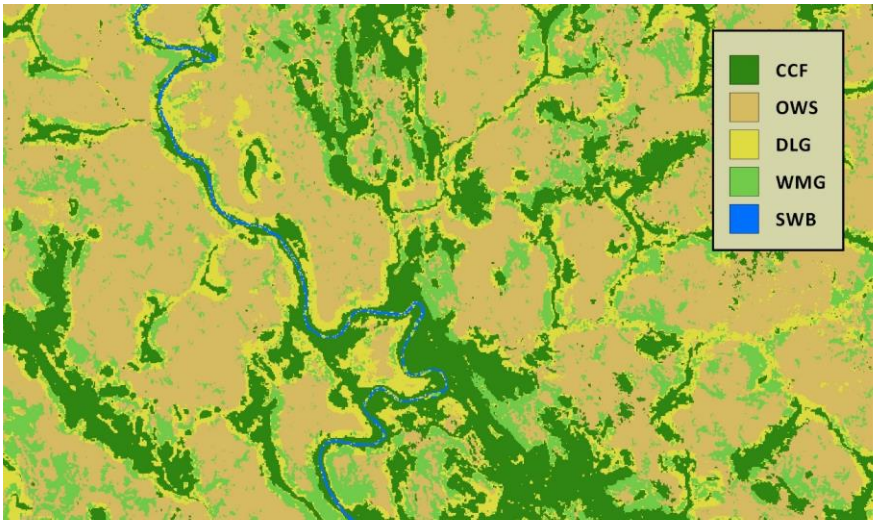

Figure 4. Part of the habitat map zoomed on scale 1:100,000 (map credit: T. Aebischer, UNIFR team)

4.4 Analyses

4.4.1 HR Estimation

The overall HR size was estimated for four individuals whose collars functioned successfully for the period of one year: two males (1578; 1584) and two females (1582; 1583) fulfilled the requirement. For these analyses, data of each animal were reduced to one position per day (see Table 2) because different settings of the fixes frequency over the time and the contrast between number of successful fixes in dry and rainy season resulted in unequal distribution of GPS points. By reducing the positions, the best possible balance was achieved throughout the year.

Individual	Sex	Age category	Start date	End date	Number of positions
1578	M	subadult	19.2.2016	28.2.2017	232
1582	F	adult	25.2.2016	25.2.2017	346
1583	F	adult	27.2.2016	27.2.2017	319
1584	M	adult	27.2.2016	27.2.2017	326

Table 2. Data set used for annual HR estimation

The analyses were conducted in QGIS 2.18.5 (QGIS Development Team 2017) with plug-in AniMove for QGIS 1.4.2. (Bruy et al. 2014). This plug-in uses Python programming language to run the algorithms. Size of the area was obtained using $area function in Field calculator of QGIS.

The first method - MCP was calculated with commonly used 95 % of the positions. The second method - KDE used the regular 95 % and 50 % of positions to calculate the probability of occurrence in the area. The plug-in uses method Rule of thumb to choose a bandwidth value which results in 2,00.

Possible factors were tested in Statistica 12 (StatSoft 2013). T-Test was used for independent samples for dependant variable “HR size [km2]” and grouping variable “Sex” to test impact of sex on HR size.

4.4.2 Seasonal Dynamics

We decided to base comparison of seasonal dynamics on the greatest distance between two points (out of all positions taken) each month for the specific individual. Or, expressed otherwise, the length of 100 % MCP diagonal calculated for each month. Therefore the dynamics refer to spatial use not in terms of an area but minimum distance walked (MDW) by the individual during the specific month. Reason for that is in definition of HR itself requiring HR to cover area used when the animal is searching mates and breeding. Because breeding in the species depends on seasonal rut (see Literature review, chapter 2.1), calculated area would contradict with HR definition for majority of the months. UD based estimators could be used the purpose, but would require larger dataset.

The analyses were performed for two datasets. Firstly, dynamics were based on the data of every month starting by March 2016 as first complete month since the collaring and ending by February 2017 to have 12 months in total. Secondly we defined seasons for purposes of the study by choosing 3 months in peak of each season based on personal perception and ground observation. We selected December, January, February as the dry season and August, September, October as the rainy season.

Data used for these analyses form the GPS positions of four individuals with collars active until end of February 2017, see Table 3.

The results were statistically evaluated and compared in Statistica 12 (StatSoft 2013). One-way ANOVA was used to test significance of month-by-month fluctuation. Furthermore we analysed the effect of two factors – "Sex" and "Season" on the dependant variable "Distance" by two-way ANOVA for multiple factors.

Individual	Sex	Age category	Start date	End date	Number of positions
1578	M	subadult	1.3.2016	28.2.2017	366
1582	F	adult	1.3.2016	28.2.2017	843
1583	F	adult	1.3.2016	28.2.2017	658
1584	M	adult	1.3.2016	28.2.2017	680

Table 3. Data set used for the analyses of seasonal dynamics

4.4.3 Habitat Use

The habitat use was analysed for all positions laying inside of each individual's HR (= area of polygon shapefile which was a result of 50/95 % KDE in previous analysis, see Table 5), overview in Table 4.

Individual	Sex	Age category	Start date	End date	Number of positions
1578	M	subadult	19.2.2016	28.2.2017	387
1582	F	adult	25.2.2016	28.2.2017	835
1583	F	adult	27.2.2016	28.2.2017	637

1584	M	adult	27.2.2016	28.2.2017	612

Table 4. Data set used for the analyses of habitat use

Originally it was planned to conduct the analysis in software PgAdmin, but in the end, there was simpler solution found in QGIS 2.18.5 (QGIS Development Team 2017) using plug-in Point Sampling Tool 0.4.1 (Jurgiel 2016). The plug-in assigns to each position appropriate value corresponding with one of the five habitats. The compositional analysis for each individual was carried out in MS Excel (Microsoft 2016).

For statistics was used software Statistica 12 (StatSoft 2013). The contingency table to summarize positions taken per habitat type. Data were transformed into histogram categorised on habitat basis for each individual.

5 Results

5.1 HR Estimation

The calculated size of annual HR was between 306 km² (MCP method) and 672 km² (KDE method). In three out of four cases, the resulting HR size was similar in both methods.

Individual	Sex	95 % MCP HR [km²]	95/50 % KDE HR [km²]	Difference
1578	M	596	592	0.7 %
1582	F	306	329	7.5 %
1583	F	645	672	4.2 %
1584	M	492	332	32.5 %

Table 5. Results of annual HR size estimation. Value in column "Difference" refers to the difference in size of the area calculated by KDE compared to the size of area calculated by MCP (= 100 %).

The factor of sex was not proved statistically significant ($P > 0.05$).

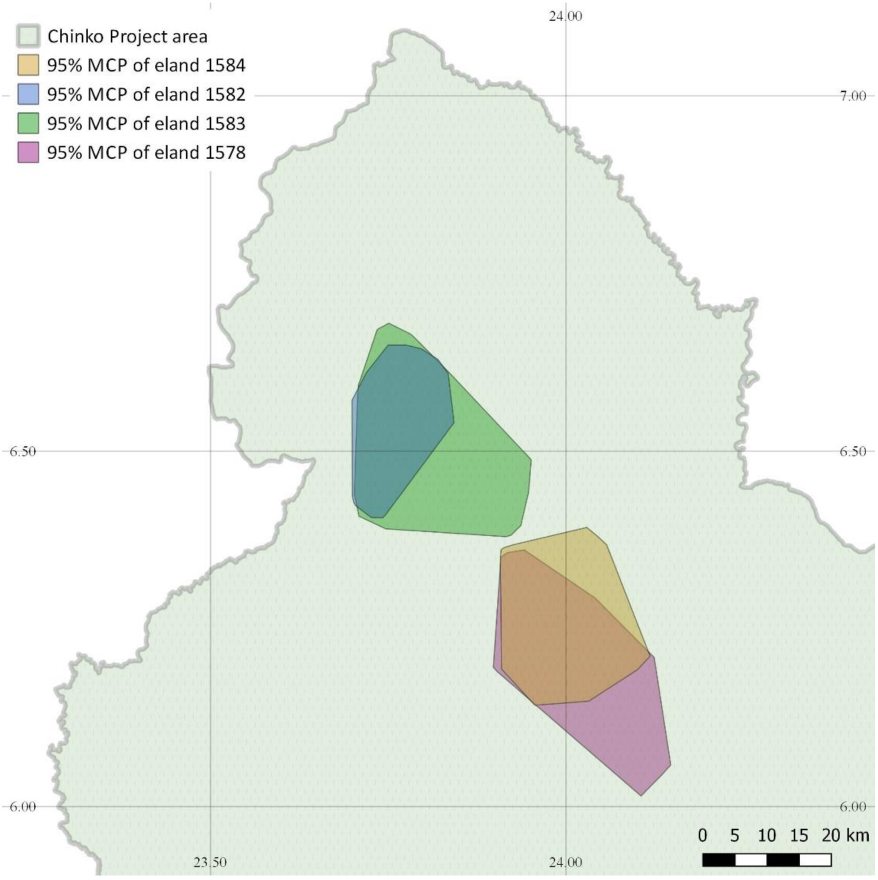

Figure 5. Annual HR of four collared elands (MCP), spatial distribution in CPA

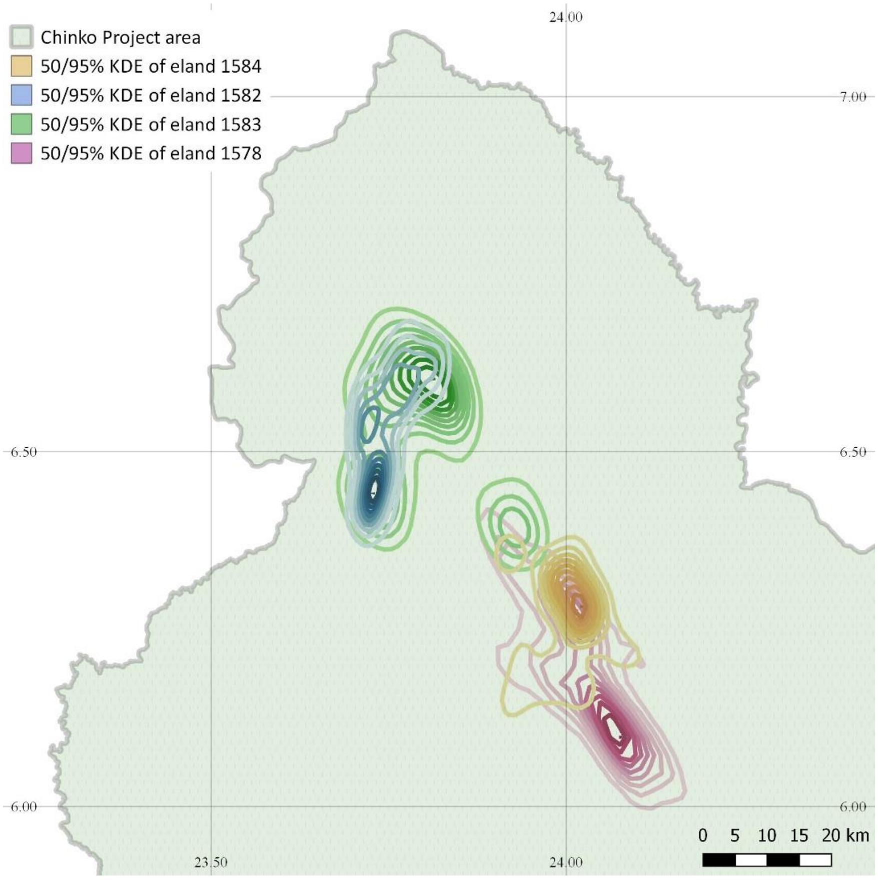

Figure 6. Annual HR of four collared elands (KDE), spatial distribution in CPA

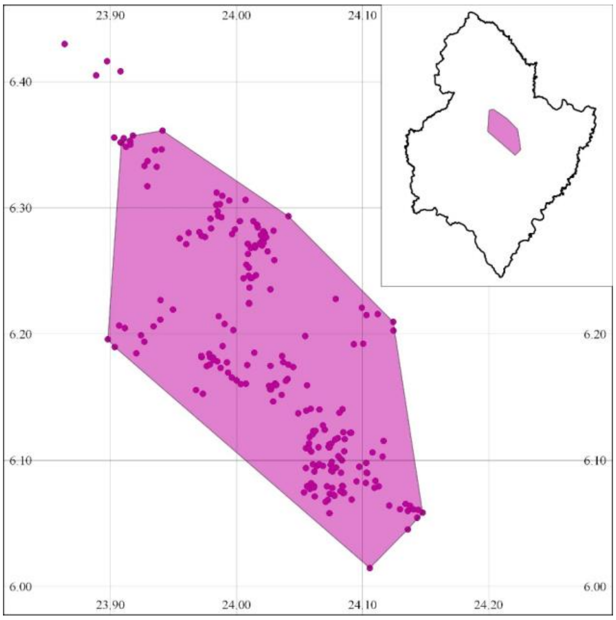

Figure 7. MCP HR of eland 1578

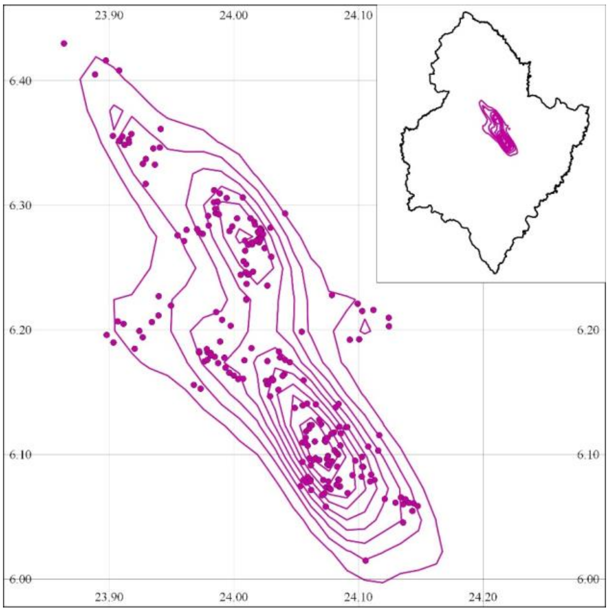

Figure 8. KDE HR of eland 1578

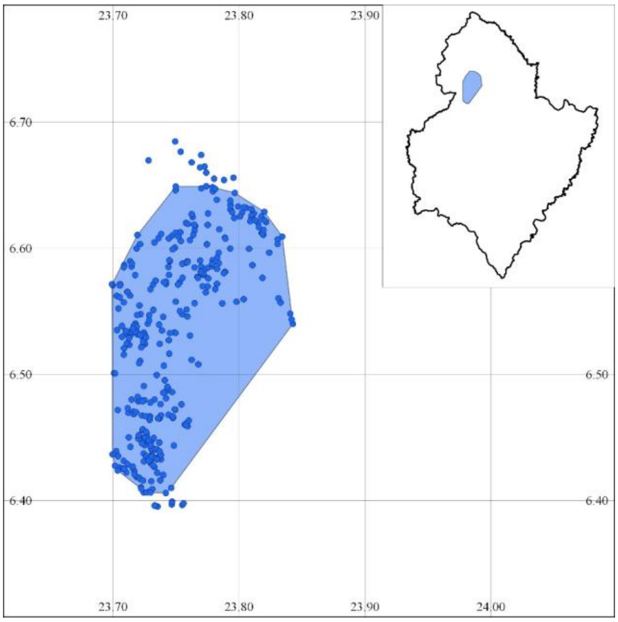

Figure 9. MCP HR of eland 1582

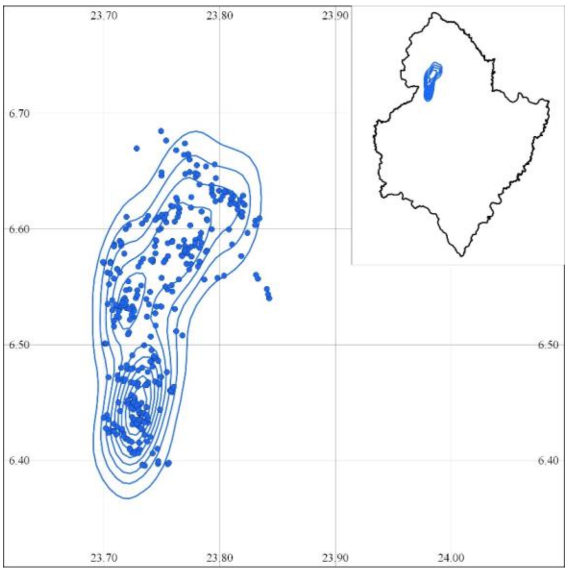

Figure 10. KDE HR of eland 1583

5.2 Seasonal Dynamics

Analysis of distances for each month did not result in significant fluctuation (F (11, 36) = 1.7860, P > 0.05). However, there were obvious tendencies in aspect of seasons (see Figure 6) thus following analyses were carried out.

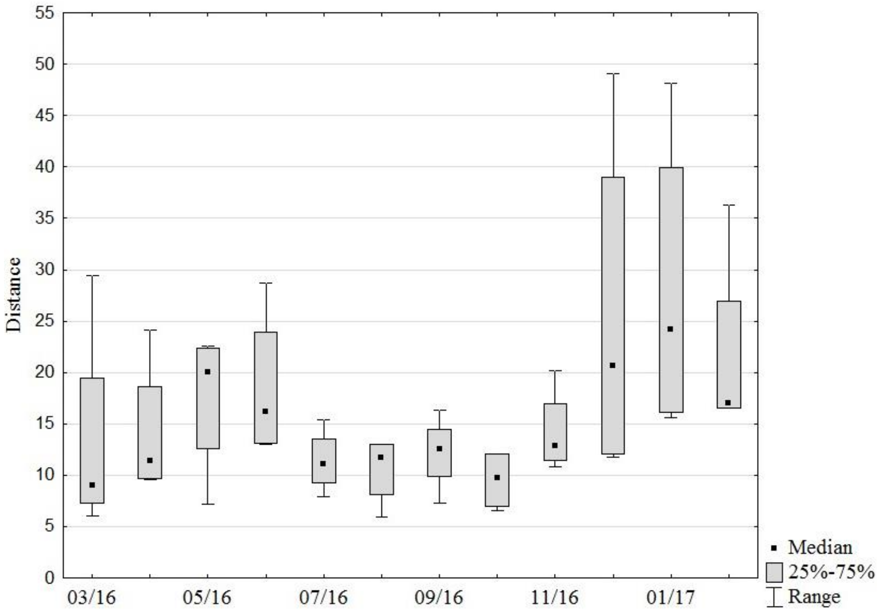

Figure 11. Seasonal dynamics based on MDW per month

The best demonstrable dynamics were shown by variance between the periods of dry and rainy season (defined in chapter Analyses 4.4). The effect was significant (P ≈ 0.0017 → P < 0.05) when calculated out of values from all individuals by T-Test for independent samples with dependant variable "Distance" and grouping variable "Season". The average distance in rainy season was ≈ 10.76 km with standard deviation ≈ 3.23 while in dry season it was ≈ 25.08 km, standard deviation ≈ 13.46.

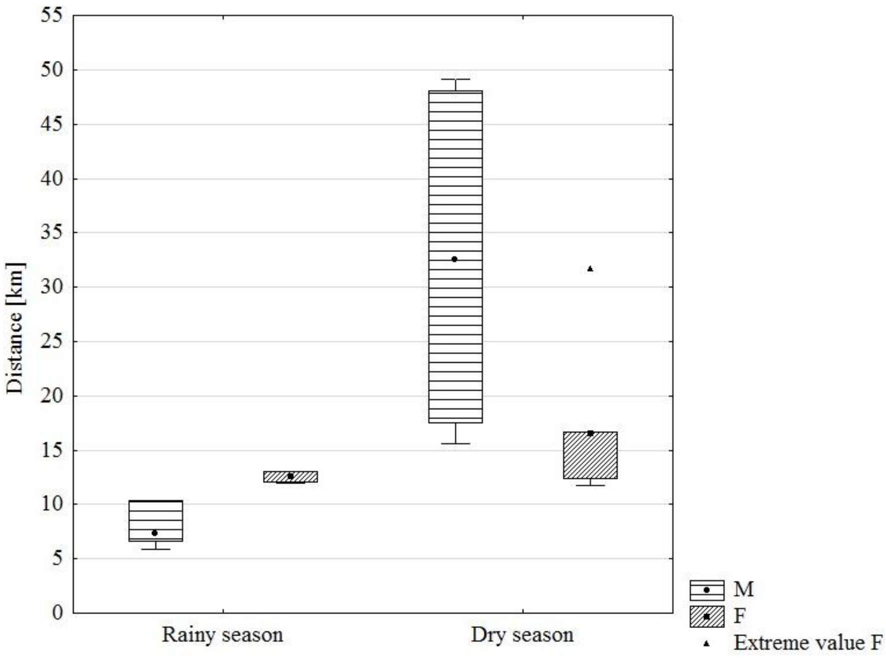

Figure 12. Seasonal dynamics based on MDW per season

The graph visualised generally higher mobility of the animals during dry season. Variability of the distance between both sexes in each season was proven, notable especially in the dry season where the average value for males is almost double compared to females, see Table 6.

Average MDW in males during rainy season	**≈ 8.98 km**
Average MDW in males during dry season	**≈ 32.57 km**
Average MDW in females during rainy season	**≈ 12.53 km**
Average MDW in females during dry season	**= 17.6 km**

Table 6. Summary of average MDW of both sexes per season, standard deviation ≈ 3.4 km

5.3 Habitat Use

Number of individual's positions taken in each habitat are summarized in Table 7. Pearson's chi-squared test for expected values based on the contingency table was 62.5112 with DF = 9 and P < 0.05 proving that it is highly probable more values would follow the same distribution.

		Number of positions taken in each habitat				
Individual	**Sex**	**CCF**	**OWS**	**DLG**	**WMG**	**Total**
1578	M	3	263	45	76	387
1582	F	5	661	74	95	835
1583	F	1	549	33	54	637
1584	M	1	516	43	52	612

Table 7. Contingency table of habitat use per individual

Contingency table analysis categorised on the basis of sex did not prove an effect of sex on the habitat use (Pearson's chi-squared test ≈ 6.95; DF = 3 and P ≈ 0.0735 → P > 0.05). In Figure 8 see histogram.

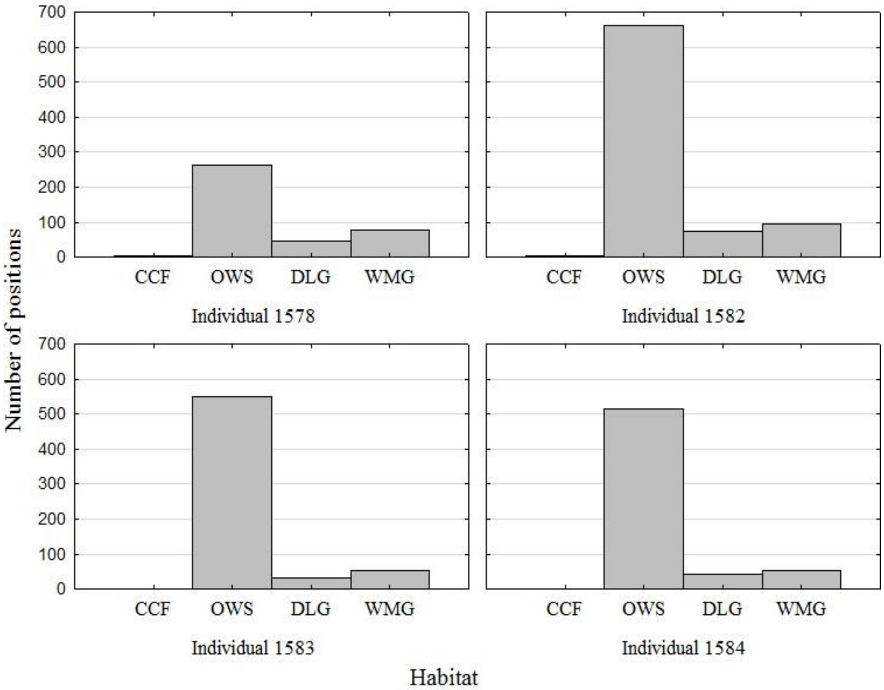

Figure 13. Histogram of habitat use proportion per individual

Calculated average values visualised in Figure 9 present the overall habitat use of collared elands during a period of one year. The vast majority formed OWS with nearly ⅘ of all positions. Minimum number of positions was taken in CCF with 0.4 % representation.

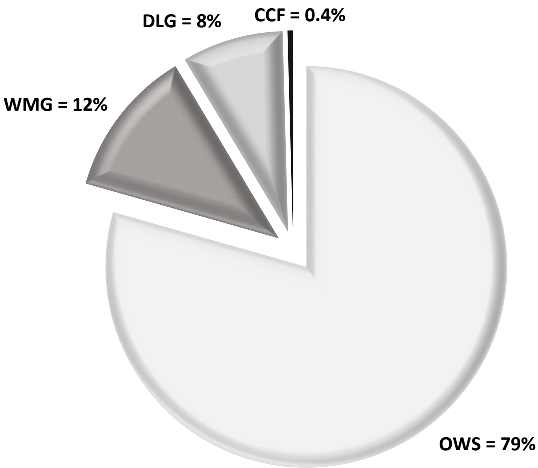

Figure 14. Average proportion of habitat use by all analysed individuals

6 Discussion

6.1 HR Estimation

First result of this study provided a quantitative HR sizes of four analyzed elands. The resulting numbers are valuable and provide a basis for future management decisions (Clemmons and Buchholz 1997, Caro 1998) as well as opportunity for comparison between populations or with other species. However, we should not forget importance of the basic map of locations providing practical information which is lost if HR is expressed by number (White and Garrott 2012).

Factors possibly affecting the HR need to be considered before making any biological conclusions. Size of HR analysed by both used methods MCP and KDE can be largely influenced by the sample size (Boulanger and White 1990, Seaman and Powell 1996, Seaman et al. 1999, Girard et al. 2002). In this study sample size should be considered in two different meanings. As first we define the sample as each individual's dataset, then its size might potentially affect the shape and area surface of the HR. In the second meaning we refer to the sample as the number of animals whose data were used in analysis when comparing males and females or trying to generalize the results in terms of species. Then there is a question of the results' validity in order to make an assumption.

Millspaugh and Marzluff (2001) speak of "biological sample size" where the researcher himself decides whether the sample size is sufficient or not with consideration of the animal's biology. Other authors tried to determine a minimum sample size to achieve reliable results of HR estimation. Seaman et al. (1999) tested the effect of sample size on KDE results by computer simulations and they recommend to use minimum of 30 observations per animal, preferably ≥ 50. Other authors suggest between 100 and 200 locations with a reference to the species' size whereas for smaller animals with smaller HR fewer locations may be sufficient (Bekoff and Mech 1984). Based on real GPS data other research team observed no significant difference in HR estimate by MCP if dataset contained > 180 locations (Kolodzinski et al. 2010).

Our dataset used for the HR calculation ranged between 232 and 346 positions per individual which seems sufficiently fulfilling above proposed sample size. Moreover even though small sample size results in some differences, Seaman et al. 1999 reported the produced surface was similar for most simulations. Therefore sample size of dataset used in this study should not have any negative effect on the annual HR estimation.

There are no guidelines on how big should be the sample size when referred to as individuals. Obviously we cannot determine the size of species' HR based on 4 individuals from the same area. On the other hand, individuals were collared in different locations of the CPA, from several groups and are considered to be a representative sample of local population. Thanks to the equal ratio of males and females we could analyse their impact of HR and even though we cannot make general assumptions based on 4 collared animals, the results are valid as long as related to the individuals in this study. The results also give us an idea about what should the future research focus on.

Considering the collared animals' movement has a span over 50 km west-east and more than 90 km north-south which is almost the distance between the distinct ecoregions Northeastern Congolian lowland forest and East Sudanian savanna, habitat and associated food availability could influence the HR estimation. However, distribution of the collared elands was in the savanna and mainly followed the forest-savanna mosaic towards south-east, never entering pure forest. For that we do not presume difference in habitat composition and its richness. Habitat occupied by Derby eland is considered to be rich

(Graziani and d'Alessio, 2004) and therefore the HR can be smaller than in might need to be in other habitat.

Our results show very high variation between the individuals in both males and females which is not unusual among other species (Börger et al. 2006b). Unknown social status and other specifics that may have an impact on these individuals make it impossible to decide towards which end to lean whilst searching for definite answer. We suggest that the resulting HR size of the Derby eland in this study should not be perceived as an average of acquired results but a range of crude minimum and maximum area.

The influence of sex in the size of HR was not proven in our study. This can be caused by the small sample size of our animals and we do not reject that sex may have an impact on HR size.

Age of the individuals is not considered to severely affect the HR (Börger et al. 2006b). Likewise, the maximum differential in altitude was 324 m in the female 1582, hilliness is not uncommon in the HR and we do not consider this elevation of any significance. From other factors that can influence the size of HR a variability in social status of the individual (hierarchy) is worth mentioning (Bekoff and Mech 1984, Börger et al. 2006b). We cannot evaluate its impact due to lack of information about the social status of collared animals. The interactions among the individuals were observed in the data and in the field, several individuals met and separated again for some time periods resulting is overlap of their HR (see Figures 4 and 5). The association of specific individuals and its impact on HR size should be further studied and combined with direct observations on the ground and/or camera trap photos in the study area. Except for percentage overlap of animals' HR, further analysis to understand temporal fluctuation in herds' size and structure can be hardly done based purely on GPS data.

The only comparable spatial analysis of Derby eland is available as a report called "Monitorage radiotélémetrique de l'Eland de Derby (*Tragelaphus derbyanus gigas*) dans le Nord de la République Centrafricaine" compiled by P. Graziani and S. G. d'Alessio in 2004. The report presents analyses based on data of 2 males and 3 females collared in other part of CAR. Area of their study is slightly further north with accordingly drier habitat without presence of rain forest. Unfortunately none of the collars functioned for the whole year to estimate the annual HR. Except for one, the collars ran approximately 3 months at most and the result cannot be compared statistically. Although it is not specified in the report, it seems authors used 100 % of locations for calculation of MCP unlike 95 % in this study. That is probably the reason why their MCP estimations are higher. In general, all annual HR in our study were larger using 50/95 % KDE. We can argument our dataset is based on longer time period which is especially the case in males.

For the longest period of 10 months lasted collar placed on one of the females and resulted in HR around 300 km² (see Table 8). The HR size of the female in their study is less than half the size of HR our female 1583, however comparable to our female 1582 and can be considered as valid value in aspect of the sample size of GPS locations. Similarity of those two results raises a question whether there is really such high individuality in HR size as concluded from our results or the HR size of female 1583 is somehow unusual. To answer that, further analyses of more individuals' data need to be carried out in the future.

The comparison of males shows similar tendencies as in females. HR size of the individual 1578 is outlying compared to the other males even though not as significantly as 1583 in females.

Individual	Sex	Start date	End date	Number of positions	MCP HR [≈ km2]	KDE HR [≈ km2]
1578	M	19.2.2016	28.2.2017	232	596	592
1582	F	25.2.2016	25.2.2017	346	306	329
1583	F	27.2.2016	27.2.2017	319	645	672
1584	M	27.2.2016	27.2.2017	326	492	332
150.142	F	4.3.2003	27.12.2003	258	344	292
150.099	M	6.3.2003	6.6.2003	321	410	335
150.118	M	4.3.2003	13.6.2003	371	540	439

Table 8. Overview of dataset used in this study and the dataset used by Graziani and d'Alessio

Our results show that MCP can be a suitable method for many datasets and why it may provide inaccurate results. The reliability of its results highly depends on the spatial distribution of our data, at least in our case. In three out of four analyses we obtained close results by both KDE and MCP. In the last case MCP calculated 160 km² larger area. Here we can point out again the importance of map from the positions mentioned by

White and Garrot (2012). Spatial distribution of the last dataset was curved which caused the variance. Because each angle between two points must be convex, the polygon connects the points on both ends by direct line, covering the area in between even if no positions are present there. Hypothetically, if the animal would avoid to traverse certain area by circumventing it from side with equal distribution of GPS positions, resulting MCP would include the avoided area inside of the individual's HR. This issue could be fixed by using lower percentage of locations depending on the sample size, although not generally (the excluded values could be those in the middle of distribution if in minority) and would then probably lead to underestimation of HR.

To sum up, our case shows that (in)applicability of MCP can be sometimes simply judged just by overlooking the spatial distribution of data prior analyzing it. Researchers should be aware of this when choosing appropriate method and they should be able to predict validity of its use.

It is very important to realizes *what* can the factors mentioned above affect. The sample size and method influences the quality of our results and cannot change the size of real HR. The other factors on the other hand explain the reasons why the size is as such.

6.2 Seasonal Dynamics

How exactly the season changes HR in the nature is not generally specified as it may differ among species and habitats.

The reliability of results for seasonal dynamics highly depends on what period is used as a season. We defined seasons used in this study based on climatological factors. Chosen time span in reality correlates with season definition strategy proposed by (Ferguson and Elkie 2004)) whose principally base the season on animal's perception and not the environment. Months we defined as rainy season were truly the months of lowest intensity of movement and months of dry season were those months with the highest mobility. By this overlay we confirm correct choice for the season.

Seasonality is often being related to breeding behaviour and environmental change in habitat quality on the seasonal timescale. The dry season usually offers much poorer food availability and reduced water sources (Börger et al. 2008, Hansson et al. 2014). The water availability is not considered to be influential in our study area given high river density all over. In the contrary, the tropical region has most commonly acknowledged two seasons based on the rainfall unlike four seasons in the mediate zones. This comes with much more crucial difference in the conditions between seasons. High richness of food resources during the rainy season does not require the animal to extend its HR in order to feed unlike during the dry season. This generally accepted perception corresponds with our results.

Because the rut takes place during the dry season, we cannot state whether the higher mobility is caused by the rut as behavioral aspect or the climate change related to the habitat. In any case, the seasonal dynamics are surely an important information of the species' ecology.

Even though the month-to-month dynamics were not proved, this can be caused by the small sample size of compared individuals and measured period of only one year. There are tendencies in the movement intensity throughout the year and with bigger dataset it could be possible to deduce a biological sense.

Predation avoidance and population density may also be part of the seasonality of herbivores (Ferguson and Elkie 2004, Kjellander et al. 2004). We cannot make any conclusions about effect of these factors but we acknowledge it may be influential. The seasonal dynamics are a function of the animal's movement and habitat use influenced by many factors which are hard to quantify.

6.3 Habitat Use

Our spatial analysis of habitat use which determines the suitable habitat of Eastern Derby eland confirm to be typically woodland savanna and savanna-wet grassland mosaic as defined by other authors (Bro-Jorgensen 1997, Corporation 2001, Kingdon 2015).

The validity of CCF proportion may be questioned given the decrease in effectiveness of GPS unit with increased canopy closure (Rempel et al. 1995, Moen et al. 1996). We have to presume lower rate of successful fixes in CCF compared to the other habitats. Our result of only 0.4 % of all locations were taken in CCF is therefore very likely to be underestimated. Elands in the study area were observed to travers big rivers and they approach them to drink (the rivers are often surrounded by CCF so closely that their location is classified as CCF in used habitat map).

Another approach to determine the habitat use exists, where the HR polygon is analyzed and interpreted as a result (Santosa et al. 2015). We performed additional analysis to critically review the methods and results are presented in Table 9. There is a variation especially in proportion of OWS and CCF. It has been observed the elands spend majority of their in OWS (Bro-Jorgensen 1997). Both methods are valid but the analysis of the HR for habitat use provides more likely the suitable habitat whereas the analysis based on GPS locations shows habitat selection by the animal.

Individual	Sex	Method	OWS %	WMG %	DLG %	CCF %	WSB %
1578	M	Locations	67.96	19.64	11.63	0.78	0.00
1578	M	HR	53.51	16.81	15.71	13.95	0.01

Table 9. Results of habitat use for individual's HR and for its GPS positions

In literature review we mentioned common association of Derby eland distribution with plant species *Isoberlinia doka*. Further research should be conducted to verify significance of its presence in elands' HR. More detailed habitat map has to be created in order to perform that study.

7 Conclusions

The resulting annual HR size of approximately 300 km² and 700 km² provides an essential information of Derby eland ecology in the wild. The estimation can be considered reliable thanks to large dataset and time period that has been analysed. It was not the goal of this study to achieve the most precise numbers but to obtain and present valid information which is not otherwise available given the difficulty and costs to obtain such data. Due to high individuality in HR size, we preferred to interpret the result as a range rather than providing an average value. Elands' movement was highly seasonal, especially in males and it needs to be further studied to understand all drivers and their impact.

The analysis of habitat use provides an idea of suitable habitat for the species as well as their habitat selection. Majority of OWS and WMG in individuals' spatial use confirms predications of other authors based usually on direct observations.

8 References

Angwafo, T. E. 2006. Status of Wildlife and its Utilisation in Faro and Benoué National Parks North Cameroon: Case study of the Derby Eland (Taurotragus derbianus gigas Gray, 1947) and the African Wild Dog (Lycaon pictus Temminck, 1840). Brandenburg Technical University, Cottbus, Germany.

Bekoff, M., and L. D. Mech. 1984. Simulation analyses of space use: Home range estimates, variability, and sample size. Behavior Research Methods, Instruments, & Computers **16**:32-37.

Bercovitch, F. B., and P. S. Berry. 2010. Ecological determinants of herd size in the Thornicroft's giraffe of Zambia. African Journal of Ecology **48**:962-971.

Boitani, L., and T. Fuller. 2000. Research Techniques in Animal Ecology: Controversies and Consequences. Columbia University Press.

Bouché, P., R. Nzapa Mbeti Mange, F. Tankalet, F. Zowoya, P. Lejeune, and C. Vermeulen. 2012. Game over! Wildlife collapse in northern Central African Republic. Environmental Monitoring and Assessment **184**:7001-7011.

Bouché, P., P. C. Renaud, P. Lejeune, C. Vermeulen, J. M. Froment, A. Bangara, O. Fiongai, A. Abdoulaye, R. Abakar, and M. Fay. 2010. Has the final countdown to wildlife extinction in Northern Central African Republic begun? African Journal of Ecology **48**:994-1003.

Boulanger, J. G., and G. C. White. 1990. A comparison of home-range estimators using Monte Carlo simulation. The Journal of wildlife management:310-315.

Brandlová, K., D. Mallon, P. Hejcmanová, S. Regnaut, P. Jůnková Vymyslická, T. Fedorova, M. Žáčková, P. Brandl, and S. Ndiaye. 2013. Western Derby eland (*Taurotragus derbianus derbianus*) Conservation Strategy. Czech University of Life Sciences Prague, Prague.

Změněn kód pole

Naformátováno: Písmo: (výchozí) Times New Roman, 12 b.

Bro-Jorgensen, J. 1997. The Ecology and Behaviour of the Giant Eland (*Tragelaphus derbianus*, Gray 1847) in the Wild. University of Copenhagen, Copenhagen.

Burt, W. H. 1943. Territoriality and home range concepts as applied to mammals. Journal of mammalogy **24**:346-352.

Burton, M., and R. Burton. 2002. International Wildlife Encyclopedia. Marshall Cavendish Corporation.

Börger, L., B. D. Dalziel, and J. M. Fryxell. 2008. Are there general mechanisms of animal home range behaviour? A review and prospects for future research. Ecology letters **11**:637-650.

Börger, L., N. Franconi, G. De Michele, A. Gantz, F. Meschi, A. Manica, S. Lovari, and T. Coulson. 2006a. Effects of sampling regime on the mean and variance of home range size estimates. Journal of Animal Ecology **75**:1393-1405.

Börger, L., N. Franconi, F. Ferretti, F. Meschi, G. D. Michele, A. Gantz, and T. Coulson. 2006b. An integrated approach to identify spatiotemporal and individual-level determinants of animal home range size. The American Naturalist **168**:471-485.

Caro, T. 1998. Behavioral Ecology and Conservation Biology. Oxford University Press.

Caro, T. 2005. Antipredator Defenses in Birds and Mammals. University of Chicago Press.

Clemmons, J. R., and R. Buchholz. 1997. Behavioral approaches to conservation in the wild. Cambridge University Press.

Corporation, M. C. 2001. Endangered Wildlife and Plants of the World. Marshall Cavendish.

Creel, S., P. Schuette, and D. Christianson. 2014. Effects of predation risk on group size, vigilance, and foraging behavior in an African ungulate community. Behavioral Ecology:aru050.

East, R. 1999. African Antelope Database 1998. IUCN Species Survival Commission.

Estes, R. 1991. The Behavior Guide to African Mammals: Including Hoofed Mammals, Carnivores, Primates. University of California Press.

Fargeot, C. 2004. La chasse commerciale et le négoce de la venaison en Afrique Centrale forestière. Game and Wwildlife Science **21**:817-833.

Ferguson, S. H., and P. C. Elkie. 2004. Seasonal movement patterns of woodland caribou (Rangifer tarandus caribou). Journal of Zoology **262**:125-134.

Fisher, D., S. Blomberg, and I. P. F. Owens. 2002. Convergent maternal care strategies in ungulates and macropods. Evolution **56**:167-176.

Girard, I., J.-P. Ouellet, R. Courtois, C. Dussault, and L. Breton. 2002. Effects of sampling effort based on GPS telemetry on home-range size estimations. The Journal of wildlife management:1290-1300.

Hansson, L. A., S. Akesson, and S. Åkesson. 2014. Animal Movement Across Scales. Oxford University Press.

Hansteen, T. L., H. P. Andreassen, and R. A. Ims. 1997. Effects of spatiotemporal scale on autocorrelation and home range estimators. The Journal of wildlife management:280-290.

Hebblewhite, M., and D. T. Haydon. 2010. Distinguishing technology from biology: a critical review of the use of GPS telemetry data in ecology. Philosophical Transactions of the Royal Society B: Biological Sciences **365**:2303-2312.

Hejcmanova, P., M. Homolka, M. Antoninova, M. Hejcman, and V. Podhajecka. 2010. Diet composition of western Derby eland (Taurotragus derbianus derbianus) in the dry season in a natural and a managed habitat in Senegal using faecal analyses. South African Journal of Wildlife Research **40**:27-34.

Hejcmanova, P., P. Vymyslicka, K. Kolackova, M. Antoninova, B. Havlikova, M. Stejskalova, R. Policht, and M. Hejcman. 2011. Suckling behavior of eland antelopes (Taurotragus spp.) under semi-captive and farm conditions. Journal of Ethology **29**:161-168.

Hendrikx, P., B. Dufour, J. Tulasne, and G. Kondolas. 2001. Analyse qualitative du risque d'épizootie de peste bovine en République Centrafricaine à partir du Tchad et du Soudan. Epidémiol. et santé anim **40**:83-94.

Kenward, R. 2001. A Manual for Wildlife Radio Tagging. Academic Press.

Kie, J. G., J. Matthiopoulos, J. Fieberg, R. A. Powell, F. Cagnacci, M. S. Mitchell, J.-M. Gaillard, and P. R. Moorcroft. 2010. The home-range concept: are traditional estimators still relevant with modern telemetry technology? Philosophical Transactions of the Royal Society B: Biological Sciences **365**:2221-2231.

Kingdon, J. 2015. The Kingdon Field Guide to African Mammals: Second Edition. Bloomsbury Publishing.

Kingdon, J., D. Happold, T. Butynski, M. Hoffmann, M. Happold, and J. Kalina. 2013. Mammals of Africa. Bloomsbury Publishing.

Kjellander, P., A. Hewison, O. Liberg, J.-M. Angibault, E. Bideau, and B. Cargnelutti. 2004. Experimental evidence for density-dependence of home-range size in roe deer (Capreolus capreolus L.): a comparison of two long-term studies. Oecologia **139**:478-485.

Kolodzinski, J. J., L. V. Tannenbaum, D. A. Osborn, M. C. Conner, W. M. Ford, and K. V. Miller. 2010. Effects of GPS sampling intensity on home range analyses.

Laver, P. N., and M. J. Kelly. 2008. A critical review of home range studies. Journal of Wildlife Management **72**:290-298.

Lutovská, B. 2012. Taxonomic comparison of Derby Eland and Common Eland (Taurotragus sp.) [MSc]. Czech University of Life Sciences Prague, Prague.

Mills, D. S., and J. N. Marchant-Forde. 2010. The Encyclopedia of Applied Animal Behaviour and Welfare. CABI.

Millspaugh, J., and J. M. Marzluff. 2001. Radio Tracking and Animal Populations. Elsevier Science.

Moen, R., J. Pastor, Y. Cohen, and C. C. Schwartz. 1996. Effects of moose movement and habitat use on GPS collar performance. The Journal of wildlife management:659-668.

Mohr, C. O. 1947. Table of equivalent populations of North American small mammals. The American Midland Naturalist **37**:223-249.

Nilsen, E. B., S. Pedersen, and J. D. Linnell. 2008. Can minimum convex polygon home ranges be used to draw biologically meaningful conclusions? Ecological Research **23**:635-639.

Prothero, D. R., and R. M. Schoch. 2002. Horns, Tusks, and Flippers: The Evolution of Hoofed Mammals. Johns Hopkins University Press.

Rempel, R. S., A. R. Rodgers, and K. F. Abraham. 1995. Performance of a GPS animal location system under boreal forest canopy. The Journal of wildlife management:543-551.

Ruggiero, R. 1984. Central African Republic hit by poachers. Pachyderm **4**:12-13.

Santosa, Y., L. B. Prasetyo, and A. H. Mustari. 2015. Home range and habitat use of reintroduced Javan Deer in Panaitan Island, Ujung Kulon National Park. Journal of Asia-Pacific Biodiversity **8**:203-209.

Seaman, D. E., J. J. Millspaugh, B. J. Kernohan, G. C. Brundige, K. J. Raedeke, and R. A. Gitzen. 1999. Effects of sample size on kernel home range estimates. The journal of wildlife management:739-747.

Seaman, D. E., and R. A. Powell. 1996. An evaluation of the accuracy of kernel density estimators for home range analysis. Ecology **77**:2075-2085.

Walter, W. D., J. W. Fischer, K. C. VerCauteren, and S. Baruch-Mordo. 2011. What Is the Proper Method to Delineate Home Range of an Animal Using Today's Advanced GPS Telemetry Systems: The Initial Step. INTECH Open Access Publisher.

White, G. C., and R. A. Garrott. 2012. Analysis of Wildlife Radio-Tracking Data. Elsevier Science.

Wilson, D. E., R. A. Mittermeier, P. Cavallini, C. International, and I. U. f. C. o. N. a. N. Resources. 2011. Handbook of the Mammals of the World: Hoofed mammals. Lynx.