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Population dynamics and spatial behaviour of Kordofan giraffe (*Giraffa camelopardalis antiquorum*) in Garamba National Park, DRC

Master's thesis

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Declaration

I hereby declare that this thesis entitled "Population dynamics and spatial behaviour of Kordofan giraffe (*Giraffa camelopardalis antiquorum*) in Garamba National Park, DRC" is my own work and all the sources have been quoted and acknowledged by means of complete references.

Nagero, DR Congo on the 29th of March 2018

Mathias D'haen

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Abstract

Population dynamics and spatial behaviour of Kordofan giraffe (*Giraffa camelopardalis antiquorum*) in Garamba National Park, DRC

Population numbers of Kordofan giraffe in Garamba National Park in the Democratic Republic of Congo (DRC) are decreasing. From an academic perspective but with attention for its status and conservation measurements this thesis tried to answer some critical questions. Most importantly: what are the population dynamics? what are the movement and distribution patterns? And, what is the home range size of giraffe in Garamba National Park?

With 45 giraffe assumed to be alive at the end of the research, a sex ratio of 35% male and 65% female giraffe in the population and an age class ratio of 11.2% juveniles to 17.7% subadults and 71.1% adults, a framework for future research and conservation activities is established. Furthermore, it is found that giraffe's distribution is limited to the south-central sector of the Park and that giraffe are divided in different subpopulations of which some are connected through movement patterns whereas others are assumed to be isolated.

Finally, research on home range size of six giraffe that were fitted with a GPS satellite collar in early 2016 using the Minimal Convex Polygon (95% MCP) and Kernel Density Estimation (95% KDE) methods estimated an average home range of 445.0 km^2 and 268.8 km^2 respectively. Home range sizes are, when compared to other research, relatively large, even more so if we take in account the fact that the Garamba National Park complex is much more humid (found to be negatively related with home range size) than other research sites.

Based on the outcomes of this research further questions are raised and important conservation management decisions will hopefully be made to protect Garamba's giraffe.

Keywords: Population dynamics, GIS, Social Network, Minimum Convex Polygon, Kernel Density Estimation, Democratic Republic of Congo, Giraffe

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Abbreviations

APN	African Parks Network
DRC	Democratic Republic of Congo
FAO	Food and Agriculture Organization of the United Nations
UNDP	United Nations Development Programme
GCF	Giraffe Conservation Foundation
GNP	Garamba National Park
GPS	Global Positioning System
HR	Home Range
ICCN	Institut Congolais pour la Conservation de la Nature
ITCZ	Intertropical Convergence Zone
IUCN SSC GOSG	International Union for Conservation of Nature Species Survival Committee Giraffe and Okapi Specialist Group
LNNP	Lake Nakuru National Park
SC	Soysambu Conservancy
KDE	Kernel Density Estimation
LRA	Lords Resistance Army
MCP	Minimum Convex Polygon
QGIS	Quantum Geographical Information System
SPLA	Sudan People Liberation Army
VHF	Very High Frequency

1. Introduction

1.1. General

The findings in this thesis result from the authors time in Garamba National Park, DRC (hereafter "GNP" or "the Park") from 26 September 2016 to 17 August 2017. The work is based on sound scientific research and includes a management perspective, so as to help improve knowledge on basic population dynamics and ecology in order to provide pro-active conservation management including anti-poaching support.

Before going into detail about specific aspects of GNP's giraffe population, it is important to highlight previous research and efforts undertaken previously in GNP, as well as elsewhere on the continent. As such, the thesis characterizes historic, recent and current distribution of the focal species for its long-term conservation (Caughley & Gunn 1996).

Figure 1. Two adult females and a young subadult female Kordofan giraffe (photo credit: Mathias D'haen)

1.2. Background

1.2.1. Garamba National Park and its giraffe

Garamba National Park, nestled in the north-eastern corner of the Democratic Republic of Congo (DRC) and bordering South Sudan on the Congo-Nile watershed was first created in 1938 and is one of the oldest national Parks in Africa (De Merode et al. 2000). Besides the northern white rhino (*Ceratotherium simum cottoni*), the Kordofan giraffe (*Giraffa camelopardalis antiquorum*) were important for the motivation of GNP's declaration as a World Heritage Site in 1980 (Marais et al. 2013).

Currently giraffe in the DRC uniquely occur in GNP and its adjacent Hunting Reserves in the north east of the country (East 1999; De Merode et al. 2000; Amube et al. 2009). The Garamba complex consists of GNP (5,133 km^2) and three adjacent Hunting Reserves: Azande to the west, Gangala na Bodio to the south and Mondo Missa to the east, totalling a further surface of 14,793 km^2 (Hillman Smith 1983; East 1999; De Merode et al. 2000; Amube et al. 2009).

The Park falls within the Sudano-Guinean savannah belt and its vegetation varies from well-watered open long grass savannah in the south central part of GNP to bush and woodland towards the higher ground of the north (Marais et al. 2013). The surrounding Reserves are more wooded and form an important part of the larger habitat for the giraffe seasonally.

The Park is managed by the Congolese Wildlife Authority, the Institut Congolais pour la Conservation de la Nature (ICCN). For most of the last forty years, the Park has relied on international partnerships to support its conservation activities. Following the end of a supportive programme by Food and Agriculture Organization (FAO) and United Nations Development Programme (UNDP) in the 1970s, serious illegal hunting of large mammals occurred in the Park. This resulted in a population decline of 66% for elephant, (*Loxodonta* spp.), 97% for the northern white rhino and 50% for giraffe occurring in the Park (Marais et al. 2013). It has been noted that these population declines may have been partially due to their transitory movement out of the Park (Marais et al. 2013). From 1984 to 2005 the ICCN was partnered by international donors in the management of the Garamba complex and numbers of wildlife increased until civil unrest broke out again. African Parks Network (APN), a non-profit organisation taking up management of several parks in Africa, has been managing the Garamba complex in partnership with the ICCN since 2005 (Marais et al. 2013).

Over its history GNP has faced many challenges, mostly directly or indirectly related to the region's political instability resulting in decimated wildlife numbers, including giraffe (Hillman Smith et al. 2003a; Hillman Smith & Ndey 2005; Amube et al. 2009; Cunliffe 2010).

From a giraffe perspective, the local tribes living in the Hunting Reserves bordering the Park have never hunted giraffe as they believed its meat causes leprosy (Amube et al. 2009). However, giraffe were poached by other tribes from neighbouring areas who valued the possession of giraffe tails as a status symbol (Amube et al. 2009). Even though the local traditional beliefs might have played a historical role in the survival of giraffe in the GNP complex, they seem to be of less importance nowadays as traditional taboos have mostly died out with the influence of modern society (Amube et al. 2009). Subsequently, illegal hunting of giraffe has increased in the Park (Amube et al. 2009) and declines in wildlife populations generally are linked to post-war instability, power struggles and exploitation of resources, particularly from neighbouring countries also facing civil unrest (Hillman Smith & Ndey 2005).

With the support of APN, the security measurements in the GNP complex were improved and poaching has decreased most recently e.g. poached elephant numbers in 2017 halved from 2016 (African Parks & ICCN, unpublished data).

It is in this context that this Masters thesis research on the current giraffe's population dynamics and ecology, threats and its future perspectives was undertaken to help identify and guide their ongoing conservation and management.

1.2.2. Taxonomy of study species

Species: Northern giraffe (*Giraffa camelopardalis*)

Subspecies: Kordofan giraffe (*Giraffa camelopardalis antiquorum*)

GNP's giraffe were historically named "Congo giraffe" (East 1999; De Merode et al. 2000; Amube et al. 2009) but since proved genetically identical to other Kordofan giraffe across Central Africa (Fennessy et al. 2016). As such, and based on IUCN and recently proposed giraffe taxonomy, the DRC giraffe are subsumed into *G. c. antiquorum* – a subspecies of the northern giraffe. GNP's giraffe are spatially isolated from other Kordofan giraffe populations in South Sudan, Central African Republic, Cameroon and Chad.

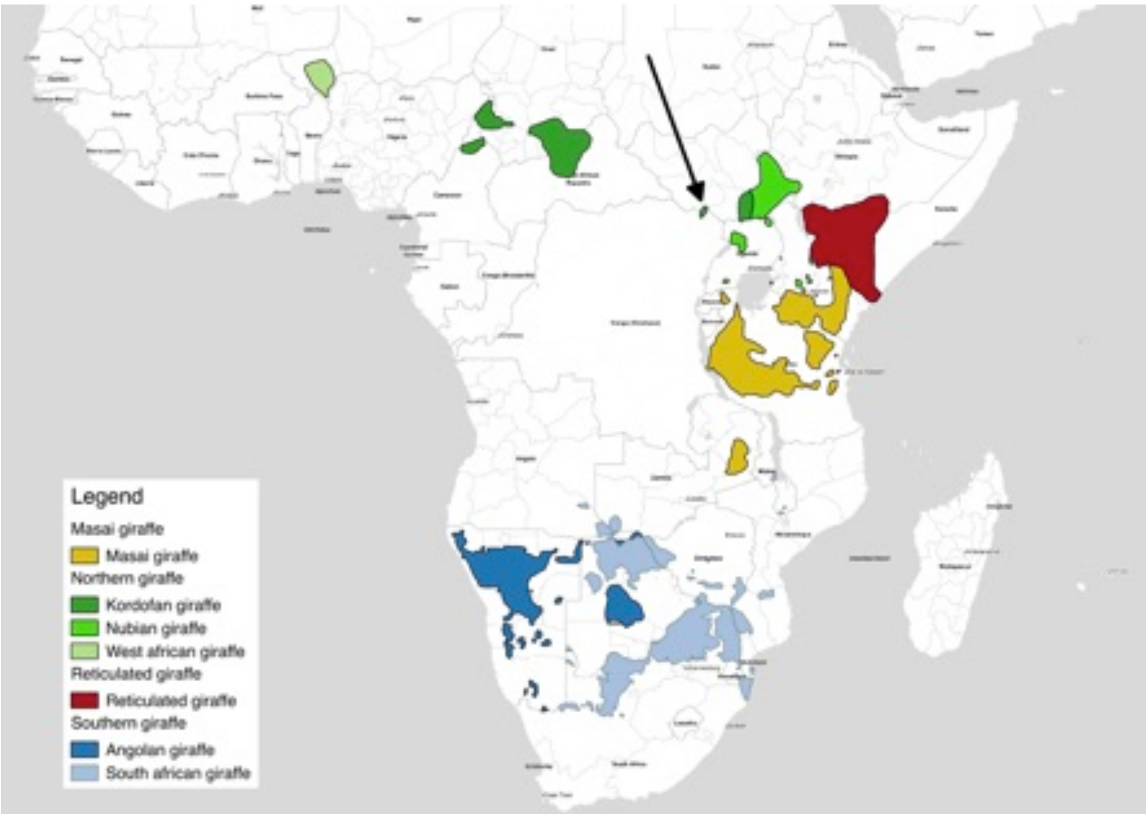

Figure 2. Distribution of GNP's Kordofan giraffe in relation with other giraffe populations based on the latest proposed giraffe taxonomy (Fennessy et al. 2016)

1.2.3. Conservation Status of study species

IUCN Red List (IUCN 2017-1; Muller et al. 2016):
Giraffa camelopardalis (as a species) – Vulnerable

Giraffa camelopardalis antiquorum – Not assessed

As a single species, giraffe was uplisted from "Least Concern" to "Vulnerable" on the IUCN Red List in December 2016 (Muller et al. 2016). A similar assessment and review for the Kordofan giraffe, as to for the other IUCN eight currently recognised subspecies, is proposed to be submitted to IUCN in 2018. Based on preliminary work and assessing the rate of decline of the Kordofan giraffe over the last 30 years (three generations of giraffe), it is likely they will be uplisted to "Critically Endangered" and of highest conservation importance (J. Fennessy, pers. comm.).

In the DRC, giraffe are classified by ICCN as a 'rare or endangered species' that is fully protected and may not be killed (Law 14/003 of 11 February 2014, article 13 and 14).

1.3. Status Review and Population Dynamics

1.3.1. Historic

Currently giraffe in the DRC are restricted to the GNP complex. Historically, and based on the observations of the Belgian explorers in the 1950s, giraffe occurred in the savannah regions of the Haut Uele province (De Saegher 1954) (See figure 3). During his large mammal explorations in the GNP complex Verschuren (1958) made note that giraffe occurred throughout the GNP complex but like most large mammals, at a lower density in the northwestern parts of the Park. During the same exploration Verschuren (1958) estimated at least 300 giraffe within the Park's boundaries and noted that Cornet d'Elzius had observed at least sixty giraffe in the neighbouring Hunting Reserve Gangala na Bodio south of the Park.

As a result of a large elephant population, as well as high numbers of buffalo (*Syncerus caffer*) and other megafauna roam in the Park, its more open habitat is favourable for giraffe (Amube et al. 2009; De Merode et al. 2000; East 1999).

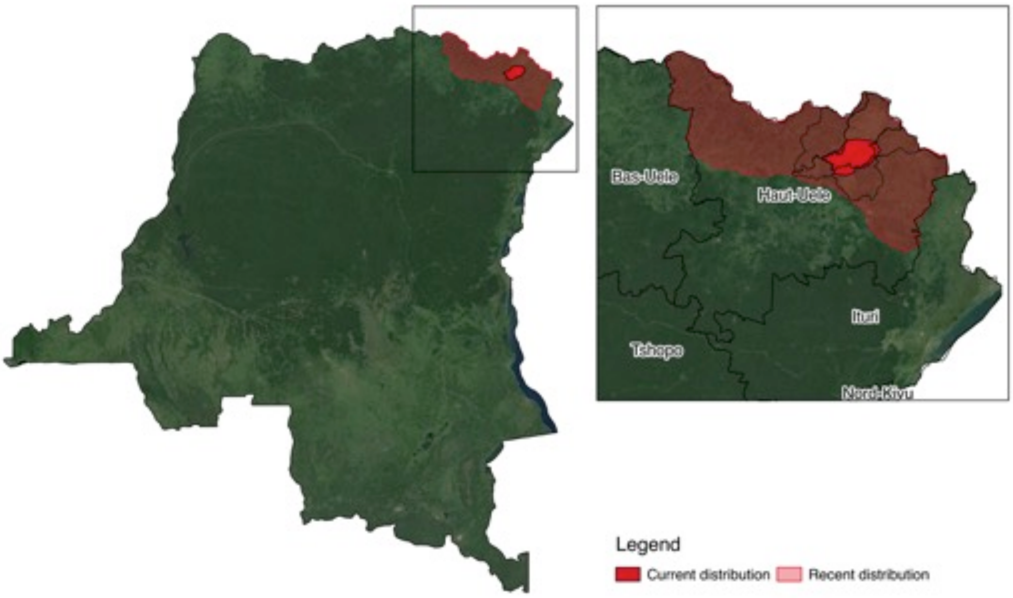

Figure 3. Recent and current distribution of Kordofan giraffe in the DRC

1.3.2. Recent

With aerial surveys undertaken from as early as 1976, the giraffe's population numbers have been relatively well documented for many decades (e.g. Savidge et al. 1976; Hillman Smith et al. 1983; Hillman Smith 1989; Smith et al. 1993). However, it is important to note that data is not always comparable as the survey areas and methodologies differed. Table 1 gives an overview of results from the aerial surveys representing the best available data on giraffe population numbers. The first aerial census in 1976 estimated the giraffe population at 350 individuals (Savidge et al. 1976). As a result of severe poaching from 1976 until 1983, giraffe numbers declined by 50%, possibly also a result of animals moving out of the Park (Marais et al. 2013).

Between 1983 and 2004, the same survey methods as first undertaken in 1976 were used (Hillman Smith 2003b). During this period, specifically from the 1980's until the 1990's, the surveys also fully covered the adjacent Hunting Reserves, although giraffe sightings in these more densely wooded areas were scarce. Additionally, even though aerial surveys in the Park have had a relatively good coverage in the south central part of GNP with dense transects, giraffe numbers still yielded high standard errors. This is due to their clumped and spread-out distribution. This resulted in fluctuations in numbers from aerial survey data but it was only after the increased poaching activities of the civil unrest that a real drop in population numbers was observed.

The period from 1984 until 1993 saw an increase in numbers of most species, including giraffe with numbers rising from 237 giraffe in 1984 to 347 in 1993. The civil war, which affected GNP in late 1996 and early 1997, resulted in the disarming of guards and anti-poaching efforts were almost completely stopped. As a result the Park was highly encroached by poachers, mostly from Sudanese origin. Counts after the war in 1998 indicated a subsequent fall in giraffe numbers to a low 144 giraffe counted. Later that year a second civil war started and even though conservation efforts were maintained and wildlife numbers kept relatively stable aerial surveys could not be conducted as transport of aircraft fuel was constrained (Marais et al. 2013).

Poaching again took a turn for the worse in 2003 and 2004 with invasions by the Sudan People Liberation Army (SPLA) and Sudanese *janjaweed* horsemen, and giraffe numbers fell again to a historic low of 22 individuals with the aerial counts of 2012 (African Parks & ICCN 2012). From 2005 onwards the aerial survey methodology changed to total counts. Therefore, the results represent a minimum number of giraffe present.

1.3.3. Current

Since 2012, giraffe numbers have fluctuated albeit slowly decreasing from an estimated 42 giraffe recorded on the 2014 aerial survey to 34 giraffe on the 2017 aerial survey (see Table 1) (African Parks & ICCN, unpublished data). The most recent figures using individual identification field methods of all known giraffe in the Park estimate a minimum of 45 individuals (M. D'haen, pers. obs.). High standard errors, different methodologies and inconsequence in covered area during aerial surveys makes it difficult to accurately compare data from year to year, however it is clear that the population dramatically decreased since the first aerial survey in 1976.

Table 1. Aerial survey and individual identification data for Kordofan giraffe in Garamba National Park and surrounding Hunting Reserves, DRC from 1976 to 2017

Year	Garamba NP	SE	Reserves	Source
1976	350	±250	Not surveyed	Savidge et al. 1976
1983	175	±163	20	Hillman Smith et al. 1983
1984	237	±144	0	Hillman Smith 1989
1986	153	±140	13	Hillman Smith 1989
1991	346	±203	46	Smith et al. 1993
1993	347	±419	0	Smith et al. 1993
1995	178	±210	52	Hillman Smith et al. 1995
1998	144	±73	Not surveyed	Hillman Smith et al. 2003b
2000	118	±64	Not surveyed	Smith and Hillman Smith 2000
2002	62	±13	Not surveyed	Hillman Smith et al. 2003b
2003	62	±75	Not surveyed	Hillman Smith et al. 2003b
2004	185	±152	Not surveyed	Hillman Smith et al. 2004
Year	**Garamba NP (South)**	**SE**	**Reserves**	**Source**
2005	48		Not surveyed	De Merode et al. 2005
2006	52		18	Emslie et al. 2006
2007	82		0	Amube et al. 2009
2012	11		11	African Parks & ICCN 2012
2014	27		15	African Parks & ICCN 2014
2017[1]	22		12	African Parks & ICCN unpublished
2017	31		14	M. D'haen, pers. obs.

[1]Numbers shown are aerial survey figures to be consistent in methodology but it has to be noted that more accurate numbers through individual identifications using unique blotch patterns are available with 31 giraffe for GNP and 14 for the Hunting Reserves observed in 2017.

1.3.4. Population dynamics other than population numbers

Research on giraffe in GNP has predominantly been limited to the monitoring of population numbers through aerial surveys, although some anecdotal observations have been collected on different aspects of their population dynamics (Amube 1989; Amube et al. 2009; Cabrera 2010). Amube (1989) makes note of a sex ratio of 1 : 1.2 (male: female), an age class ratio of 15 : 1 : 4 (adult: subadult: juvenile) and group sizes of up to 22 individuals. It is however not clear on how many giraffe observations these numbers are based.

Although information on distribution ranges of giraffe in the GNP complex are mostly restricted to fragmental georeferenced observations from aerial survey reports, a detailed description was made by Verschuren (1958) who observed giraffe to not only be common inside the Park's boundaries but also to occur south and as far east of the Park as the South Sudanese border. Giraffe were not observed west of the Park as they were reportedly poached by local tribes in this area (Verschuren 1958). Since 1958, it can be assumed that distribution ranges have been declining accordingly to population numbers restricted to the south central part of GNP and parts of adjacent Hunting Reserves (African Parks & ICCN 2014) (See figure 4).

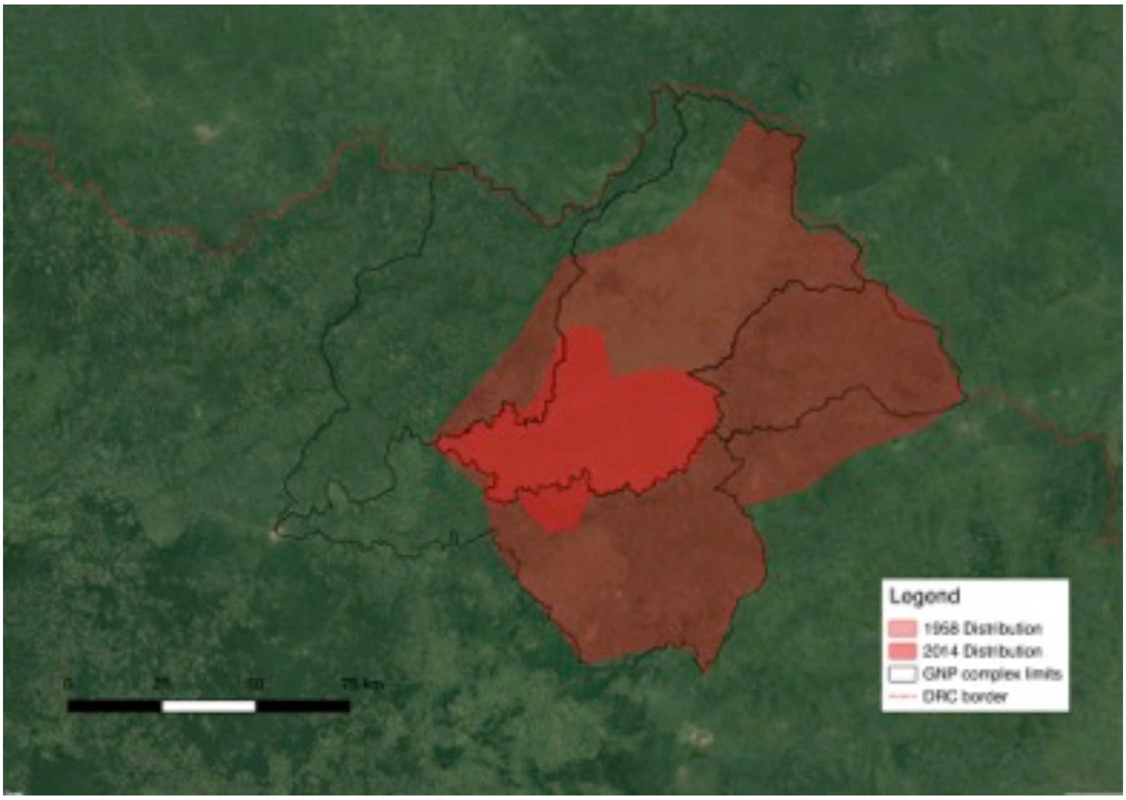

Figure 4. Distribution of giraffe in GNP in 1958 and in 2014

The first-ever giraffe GPS satellite collaring operation in DRC was undertaken in 2012 with five head harness 'collars' fitted to giraffe inside the Park (African Parks & ICCN 2012). A second 'collaring' operation was carried out in early 2016 with eight head harnesses fitted to giraffe in the Park and in the adjacent Hunting Reserve (African Parks & ICCN 2016). GPS satellite data from those giraffe that were fitted with a GPS satellite collar in 2016 was used in this research.

Genetic data of GNP's giraffe was collected with the second collaring operation (Dr. Pete Morkel, pers. comm.) and subsequently analysed highlighting that they are Kordofan giraffe and new taxonomy proposed (Fennessy et al. 2016).

Whilst not in the scope of this research, it is important to note that giraffe are known to live in a complex social system sharing many characteristics of a fission-fusion system, where individuals periodically coalesce and split up again (Bercovitch & Berry 2013a; Bercovitch & Berry 2013b; Carter et al. 2013a; Carter et al. 2013b).

1.3.4.1. Individual identification

Individual identification using an animal's unique features (e.g. coat patterns, colour, tail length, scars, gait, horn variations, ear notching, mane clipping, painting, branding, collaring and spoor identification) has been adopted by many single-species studies enabling a better understanding of the animal's behaviour and ecology. Individual identification is key to understanding of individual movement patterns, distribution, home range and behaviour. Moreover, it provides a framework to research the species' general population dynamics and ecology.

To assist the Park to better monitor and manage its giraffe, a project was set up by the Park's Research and Monitoring Department in early 2015 using individual identification of the giraffe (Liama 2015). The identification of giraffe was however based on only one side of a giraffe, which was inconsistently chosen for each giraffe resulting in varying results including sometimes triple identities for a single giraffe.

As giraffe have a unique coat pattern that remains largely unchanged throughout their life this feature is often used for individual identification allowing giraffe research to compare individual patterns within a population (e.g. Bercovitch and Berry 2013a; Carter et al. 2013; Berry & Bercovitch 2017; Muller 2018). Allocating each individual a unique code generally facilitates this method of individual identification. Moreover, Fennessy (2004), Carter et al. (2013) and Muller (2017) amongst others created a database of photos from both sides of each individual with the aim to create an overview of all individuals in the population.

1.4. Feeding Ecology

Whilst it was not in the primary objective of this thesis to describe the feeding ecology of GNP's giraffe it is importantly connected to their spatial patterns and therefore briefly reviewed.

While several authors reported giraffe diets consisting mainly of *Acacia* (*Vachellia*/*Senegalia*) species (Pellew 1984b; Brand 2007; Deacon 2015), it is not always their preferred forage species. Pellew (1984b), Innis (1958) and Field and Ross (1976) observed that *Acacia* was not dominant in the giraffe's diet of their study populations in Tanzania and South Africa, respectively. *Acacia* densities in GNP are low and as such likely accounts for GNP's giraffe dietary composition of *Acacia* being low. This hypothesis is in line with the recent findings by Bercovitch and Berry (2016) who noted that giraffe in the Luangwa Valley, Zambia, foraged on 93 different plant species of which *Acacia* was not amongst the six most eaten plants. Therefore, one can assume giraffe are general browsers in some of their populations, and not always browsers specialized on *Acacia* (Bercovitch & Berry 2016).

It has been found by authors such as Hall-Martin (1974a,b), Field & Ross (1976) and Pellew (1984b) that there is a seasonal variation in diet for giraffe. Furthermore Bercovitch and Berry (2017) noted that male and female giraffe in the Luangwa valley, Zambia, have a comparable dietary diversity with sex differences in plant species eaten during the dry season. Finally, they noted differences in feeding ecology between juveniles and adults, all concurring that giraffe have evolved a flexible foraging strategy aimed at maintaining good body condition throughout the year (Bercovitch & Berry 2017; Berry & Bercovitch 2017).

Research on feeding ecology of giraffe in GNP has been restricted to the work of Amube et al. (2009) and Cabrera (2010) who both undertook feeding preferences of GNP's giraffe and listed plant species known to be a part of their diet (Annex 1).

1.5. Home Range and Spatial Patterns

An initial definition of home range (HR) was proposed by Burt (1943) and stated: "A home range is the area traversed by the individual in its normal activities of food gathering, mating, and caring for young". By stating "normal activities" Burt indicated that a HR should not include every place an animal uses although no clear outlining of "normal" and "abnormal activities" was proposed causing criticism from other authors since (Mohr 1947; Hansteen et al. 1997; Millspaugh & Marzluff 2001; Kie et al. 2010).

Based on prior research, it is known that giraffe movements are influenced by a number of factors including abundance and distribution of food, water, climate, predators, poaching, urbanization and anthropogenic disturbance (van der Jeugd & Prins 2000; Fennessy 2009; Flanagan 2016). Availability of food and water are found to be important in the HR size and movement of giraffe (Fennessy 2004, 2009). Because of a larger body mass and high bio energetic requirements giraffe are found to have a larger HR than smaller ungulates sharing the same environment (Du Toit 1990; Fennessy 2004, 2009; Cloete & Kok 1986).

Home range size is found to be positively related with aridity of the environment (Du Toit 1990; Le Pendu & Ciofolo 1999; Fennessy 2009) with HR sizes of giraffe in Namib Desert being up to a 1,000 times greater than in humid environments. Humid environments are more productive because of higher browse abundance and as such the HR required for giraffe is reduced (van der Jeugd & Prins 2000; Fennessy 2009; Flanagan et al. 2016).

As highlighted, giraffe HR sizes vary greatly across the continent (Foster 1966; Berry 1978; Leuthold 1979; Dagg & Foster 1982; Le Pendu 1999; van der Jeugd & Prins 2000; Fennessy 2009; Deacon 2017) and individual HR often overlaps in the same environment (Leuthold 1979; Le Pendu & Ciofolo 1999; van der Jeugd & Prins 2000; Deacon 2017). Deacon (2017) observed that giraffe movements, including the amount of overlap between HR, was influenced by a combination of environmental factors such as season, rainfall and vegetation density. In the fenced Khomab Kalahari Nature Reserve in South Africa, giraffe have a smaller HR in the wet, hot season when food was abundant, while in the dry, cool season the mean HR size increased.

Until recently sampling techniques were preliminary based on field observation data, although these generally resulted in fewer data compared to telemetry or GPS satellite data (Dagg & Foster 1982; Fennessy 2009). Varying sampling techniques and limited research on HR has likely led to an underestimation of giraffe HR size in previous research (Langman 1973; Dagg & Foster 1982; van der Jeugd & Prins 2000; Fennessy 2009).

To date, two methods have primarily been used for the calculation of HR. Minimum Convex Polygon (MCP), despite often being a source of discussion because of the validity (De Boer et al. 2000; Leggett 2006; Nilsen et al. 2008), is one of the most simple and therefore widely used methods. In short, MCP HR estimations are based on the creation of a polygon with the minimal perimeter between determined percentages of the found locations, requiring the angle between each two points to be convex (Boulanger & White 1990; Nilsen et al. 2008).

The percentage of locations used for the calculation of MCP's varies according to the scope of the research. Where a factor of 100 means that all locations are used in the calculation of the isopleth. However, generally a factor of 95 is used for research on HR sizes, omitting 5% of the most outlying values from the calculation as GPS collars can occasionally provide imprecise or erroneous fixes (Hebblewhite & Haydon 2010; Frair et al. 2010). Although ecologically hardly justifiable (Börger et al. 2006) a factor of 50 is generally used for the calculation of the isopleth representing the core area (Downs & Horner 2008; Fieberg & Börger 2012; Lichti & Swihart 2011). As earlier mentioned, this arbitrarily chosen value is most important as it offers the user a relatively easy way to calculate HR and is regularly used in other research, allowing comparison between data.

Secondly, HR estimates are often calculated using the Kernel Density Estimation (KDE) method. Whilst the MCP method calculates a HR based on a binary home range border (Hansteen et al. 1997; Seaman et al. 1999), the KDE calculates HR using a continuous utilization distribution, calculating the probability densities for the locations and thus giving an insight in the intensity an animal uses its space. As with MCP, a factor of 95 is used for the HR size calculation whereas a factor of 50 is used for the core area estimation (Samuel et al. 1985). Respectively resulting in the omitting of 5%

of the most outlying values for factor 95 and the omitting of 50% of the most outlying values for factor 50.

Importantly, Girard et al. (2002) noted that HR sizes calculated by MCP generally underestimated the real area whereas KDE is apt to overestimate the true size.

2. Aims

To protect the Park and its wildlife, GNP's management has focused predominantly on law enforcement over recent years and consequently limited efforts invested in research and monitoring of key species, including giraffe. From aerial survey data dating back to 1976, it is known that GNP's giraffe population has dramatically decreased in the last forty years. A lot of questions however still surround the Park's giraffe population and their long-term future, and current data is relatively limited. Without sound research and customized actions from the Park's management, GNP's giraffe population might face a silent extinction in the coming years, similar to that observed for the northern white rhino in the Park and what appears to be occurring for some other giraffe populations throughout Africa.

In the light of the above, the primary objective of this work was to create a solid baseline on giraffe population dynamics and to characterize their spatial ecology in the Park to assist with future conservation management. Specifically the research aimed to answer the following questions:

- How many giraffe are in the GNP complex and what is their population dynamics?
- What is the giraffe distribution and movement patterns in the Park and surrounding areas?
- What is the home range size of the GPS satellite collared giraffe?

Importantly, and based on the research findings, the project sought to develop a framework for future conservation research and management on the Park's giraffe. By gaining a better understanding of the current threats, proposed research and conservation actions have been highlighted.

3. Material and Methods

3.1. Study Area

Garamba National Park, a UNESCO world heritage, is situated in the North East of the DRC and borders South-Sudan on the Congo-Nile watershed (04°13'N 29°24'E) (see Figure 5).

GNP's climate is classified as tropical semi-humid and lies in the Sudan-Guinean savannah zone. The Park and its surroundings are characterized by a long wet season, lasting from April until November and a short dry season from December until March, governed by the movements of the Intertropical Convergence Zone (ITCZ) (Jones 1998). During dry season, when the ITCZ is South of the Park, the average wind direction is from the North brings dry and hot air from the deserts to GNP. It is in this period of the year that the air is often filled with a haze of dust and smoke from bush fires.

GNP's mean temperature is 24.3°C, with March generally the hottest month, averaging 26°C. The diurnal range is greatest in the dry season, with absolute maxima of 39 °C and minima of 6.6°C recorded. A mean annual rainfall of 1,300mm is recorded in the Park (Posse & Dieudonné 2013).

Figure 5. Location of the Garamba National Park, DRC complex in Central Africa.

In 2017, Garamba's most abundant large mammal is the African buffalo with an estimated 6,728 animals (African Parks & ICCN, unpublished data). Other species occurring within the Park's boundaries are Uganda Kob (*Kobus kob thomasi)*, Lelwel Hartebeest (*Alcelaphus buselaphus lelwel)*, Bushbuck (*Tragelaphus scriptus)*, Lion (*Panthera leo)*, Spotted Hyena (*Crocuta crocuta)*, Forest elephant (*Loxodonta cyclotis)* and Savannah-Forest elephant hybrids (*L. cyclotis x L. africana).*

3.2. Individual Identification

Giraffe were identified based on their unique pelage (coat) patterns that, aside from colour changes do not change with age (e.g. Berry & Bercovitch 2012; Bercovitch & Berry 2013a; Carter et al. 2013; Berry & Bercovitch 2017). Giraffe photos taken during the research, coupled with additional photos on the Park's database, were used to build an up-to-date individual database of giraffe in the Park. Images of the left and right side of each giraffe where collected, and updated as appropriate throughout the research. Experience gained throughout the study showed that having several photos of different angles of the same giraffe helped with facilitating the identification as photos were often of poor quality as some were taken from a small aircraft (see Data collection).

All giraffe of the database were identified based on photo observations made during the research and sometimes matched with giraffe photos in the database collected during 2012–2016. This enabled better age estimations.

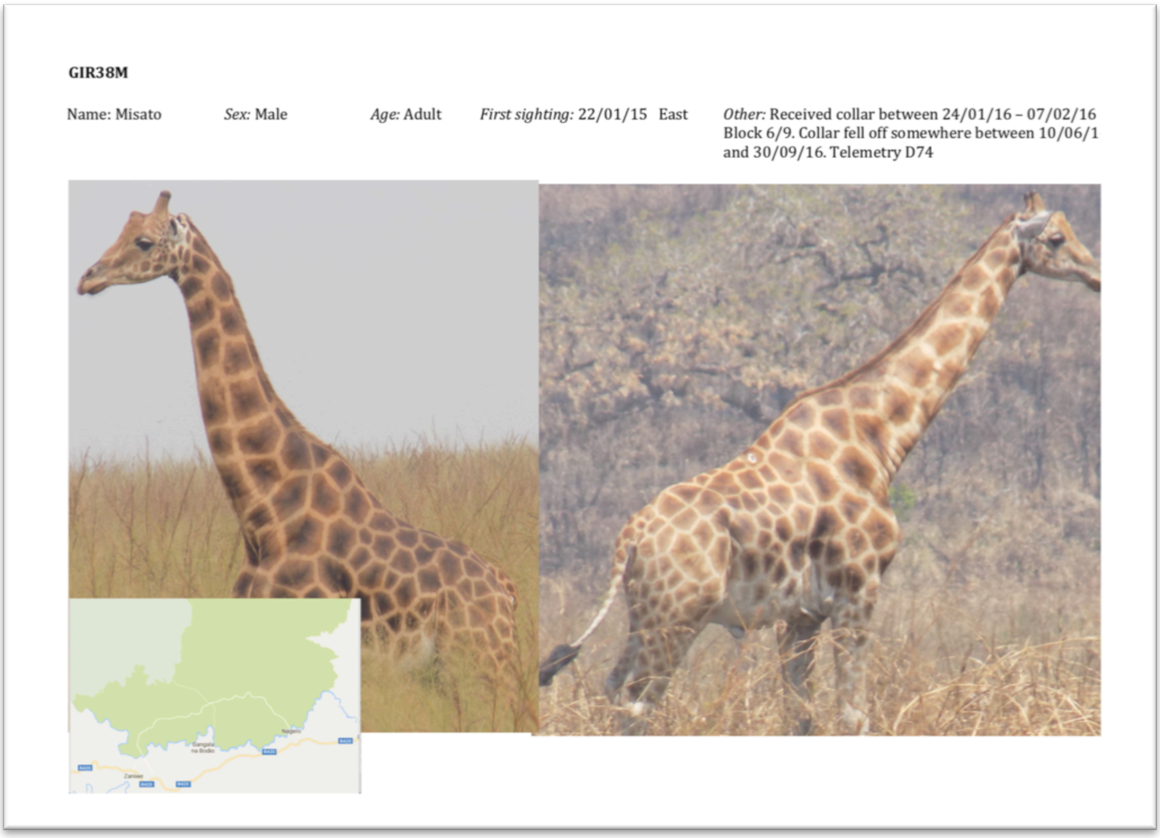

Figure 6. Example identification sheet of GIR38M in Garamba National Park, DRC

For each giraffe individual identification sheets were developed for monitoring. Identification sheets were developed in Word and consisted of the giraffe's unique code (see Naming), as well as its age, sex, date and region of first sighting, a map with its latest distribution and a clear photo of its left and right sides. Remarks were added under "Other", including information on the estimated month of birth for juveniles, mother-offspring information, GPS satellite collar data (if collared). All identification sheets were kept on a computer as well as printed out to facilitate identifications.

3.3. Naming

Each identified giraffe was given a unique code (nomenclature) using the format GIR01M, whereby GIR (referring to giraffe as there are other GPS collared species in GNP) is followed by two unique numbers (01 – giraffe number 1) and M, F or U indicating Male, Female or Unknown. Besides a unique code giraffe of which mother – offspring relations were known, as well as giraffe that had a GPS satellite collar, were given a name.

3.4. Age classification

Because precise ages of giraffe in the study were unknown they were classified in one of three age-classes as per previous giraffe research (Le Pendu & Ciofolo 1999; Cameron & du Toit 2005; Brand 2007). Giraffe were considered juvenile up to the age of 18 months by which they are reliant on their mother (Leuthold & Leuthold 1978). From 18 months until approximately four years, giraffe were classed as subadults (e.g. males that still had a fringe of hair around the horn tips were considered subadults) (Leuthold & Leuthold 1978). Giraffe older than four showed an approximate adult size and shape, and were considered potentially sexually active and classed as adults (Dagg & Foster 1982).

3.5. Data collection

Because of a variety of reasons including safety measures, GNP's priority to reduce poaching, limited road network and low giraffe densities, data were often collected through aerial reconnaissance using the Park's Aviat Husky aircraft. Data were collected on dedicated giraffe flights as well as opportunistically from other flights. On dedicated giraffe surveys the plane would normally head to one of the areas giraffe were known to inhabit and would fly transects 500m apart at an average altitude of 160–650ft., dependant of weather conditions.

Giraffe survey areas were based on previous observations in that area to maximize the total amount of giraffe per month observed. The flight's track as well as GPS locations were collected using a Garmin eTrex Venture CX GPS and data uploaded to a computer. Photos of each giraffe observed were taken with a Canon EOS D30 and 300mm zoom lens or a Canon Powershot SX50 HS. When it was suspected that a giraffe was new for the database, photos of both sides were taken, otherwise only of one side was photographed.

Additional to the data collected through flights, observations were also made in the field on dedicated giraffe surveys, law enforcement activities or around ranger outposts. The majority of these observations were not accompanied by photos so were limited for individual identifications, yet they were still included in the database as they provided valuable information regarding general distribution of giraffe in the Park.

To obtain a greater understanding of habitat giraffe use, monthly/bi-monthly field missions were undertaken over a nine day period. Together with a research-assistant and a team of eight rangers, we surveyed between 5–20km daily dependant of the height and thickness of vegetation. Considering the low densities of giraffe in the GNP complex, giraffe sightings were rare. However, when observed photos and coordinates were taken as well as faecal samples collected for potential future research.

Lastly, data was collected and subsequently analysed from the GPS satellite head harness 'collars' fitted to eight giraffe in early 2016. The African Wildlife Tracking developed 'collars' (Photo Annex 2) were scheduled to transmit three positions per day but performance was variable, especially towards the end of their battery life. The variability in number of transmitted positions per day resulted in sometimes as much as 586 data points transmitted per 24 hours. It is unclear what caused the fluctuations in frequency of transmitted locations but it was noted that these infrequencies occurred more often the older a collar got and periods with an increased amount of transmitted locations were sometimes followed by a period with a normal amount of transmitted locations. Locations were transmitted by satellite from the GPS collars to AWT's servers, of which GNP's management downloaded the data. For analyses, all data was manually processed, standardizing the interval between each two data points, as much as technically possible, resulting in three data points per day. All data were entered in an excel sheet for analysis (example format Annex 3).

3.6. Home Range Calculation

3.6.1. Minimum Convex Polygon

Home ranges were determined using the MCP algorithm, which defines polygons in which the animal spends a defined amount of time, enabling the user to calculate HR. As typically used, a factor of 95 was used to calculate an isopleth where the locations, the furthest from the centroid were excluded in a way to omit outlaying (erroneous or imprecise) values. This isopleth represents the HR (95% MCP). For the calculation of the core area a factor of 50% was used (50% MCP), again to compare with previous research and allow comparison of data.

MCP's were calculated in QGIS 2.18.11 software (QGIS Development Team 2017) through the Animove plugin. After running the MCP, the area surface was calculated through the $area function.

3.6.2. Kernel Density

Additional to the MCP method, giraffe's HR were analyzed using a Kernel density estimator with 95% probability isopleths for the HR and 50% for the core area. As for the MCP calculation, the Animove plugin was used in QGIS 2.18.11 software (QGIS Development Team 2017). The area was calculated through the $area function in QGIS.

The area of these HRs where then compared against each other, and with previously reported studies.

3.6.3. Statistics

The statistical tests were run in TIBCO Statistica (TIBCO Software Inc., 2017) version 13. For the comparison of HR sizes between sexes the t-test was used. The group size did not show normal distribution, we therefore used the non-parametrical Kruskal-Wallis test to analyse the differences between group sizes in different subpopulations. Means are presented with standard errors (SE).

4. Results

4.1. Population Dynamics

4.1.1. Distribution and Movement Patterns

All observations were georeferenced and plotted on a map to insight into the current distribution of giraffe in the GNP complex (See Figure 7).

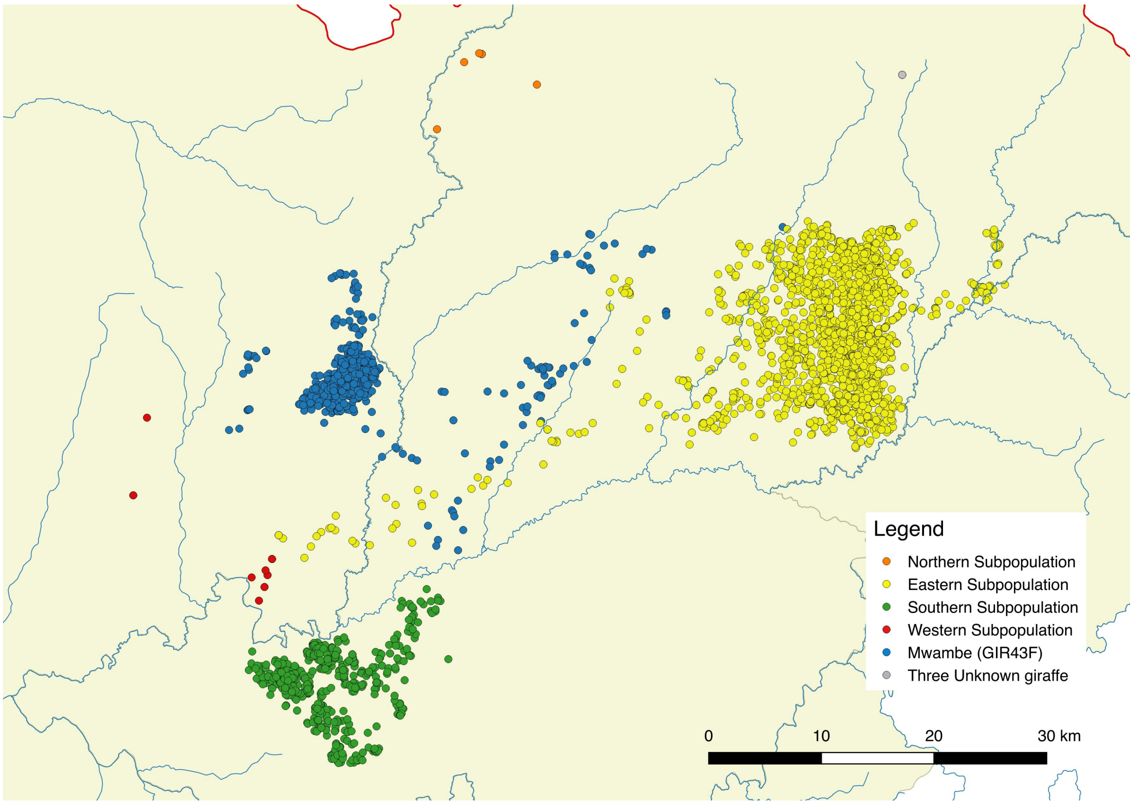

Figure 7. Distribution and migration overview of different giraffe subpopulations in Garamba National Park and complex, DRC

During the research giraffe were observed more often in certain areas of the Park – named for the sake of clarity according to the cardinal direction they resided (Eastern, Southern, Western and Northern subpopulations). Giraffe were predominantly observed in the Eastern and Southern areas of the GNP complex. Figure 7 maps the different subpopulations, each represented by a unique colour.

One animal, GIR43F, a GPS satellite collared female, was mostly on her own and her movements were not restricted to a specific area. It is important to note that the high number of locations available of this individual is a result of her being fitted with a GPS satellite collar (n=1,277).

In the following section movement patterns will refer to the movements giraffe in GNP are observed to make outside their normal region of distribution, falling largely outside the 95% MCP and 95% KDE. Besides the fact that they are outside the normal distribution area of the animal, the movement patterns are generally characterized by the giraffe covering large distances over a short period of one to two weeks through an area known to host low forage possibilities.

Inter-group movements were recorded amongst certain groups, while other groups where apparently isolated from others. Movement patterns were observed between the Western and Eastern subpopulation with animals of the latter subpopulation moving between the two regions. There have been no movements recorded from the Eastern subpopulation towards the Western subpopulation. Furthermore, giraffe of the Northern and of the Southern subpopulation were not recorded to show any movement patterns to any other subpopulation in the Park. A single observation of three giraffe was made in the northeastern region but the giraffe could not be identified as no photos were taken.

4.1.1.1. Movement patterns

Using individual identification it was noted that giraffe from the Eastern subpopulation were sometimes observed in the Western regions of the Park. Why or how long giraffe stayed in the region was however unclear. Interestingly, three out of five giraffe with a GPS satellite collar in the Eastern subpopulation independently moved to and from the Western subpopulation, giving an insight in this behaviour. The route taken by each was similar, with all three giraffe (2 males and 1 female) walking ~25 km/day along a road for 2–3 days, until they reached the west of the Park. They stayed in this area for another 2–3 days before returning along a similar route back to the Eastern subpopulation.

Besides the movements highlighted, a GPS satellite collared female, GIR43F, moved regularly between the Eastern subpopulation and an area in the northwest of the Park.

No movements were recorded to or from the North or South subpopulations. Even though one of the Park's biggest rivers divides the giraffe regions, it should easily be able to be crossed yet no giraffe were observed crossing it nor have giraffe of either side been seen at the other side of the river.

4.1.2. Population Structure

In total, 715 giraffe observations were made divided over a total of 185 groups.
Individual identification of giraffe from photo observations resulted in 49 different giraffe individuals observed. No adult giraffe was reported to have died, however, three juveniles and one subadult giraffe went missing, resulting in a total current estimated population of 45 giraffe.

The age class ratios observed are 1: 0.25: 0.16 (adult 71.1% : subadult 17.7% : juvenile 11.2%), while the sex ratio was 1 : 0.54 (male 35%, female 65%).

Eight giraffe were born during the research of which three are assumed death as their mothers were seen multiple times without the, still dependent, juvenile.

A discovery curve, showing the amount of new giraffe identified over time is added under Annex 4.

Table 2. Population structure of giraffe in the GNP complex

Region	Juvenile (5)	Subadult (8)		Adult (32)	
	Male/Female (5)	Male (3)	Female (5)	Male (11)	Female (21)
East	GIR44U	GIR02M	GIR01F	GIR04M	GIR03F
	GIR45U	GIR15M		GIR09M	GIR05F
	GIR54U	GIR17M		GIR10M	GIR06F
				GIR14M	GIR08F
				GIR21M	GIR12F
				GIR38M	GIR13F
				GIR39M	GIR16F
				GIR41M	GIR20F
					GIR37F
					GIR43F
South	GIR52U		GIR29F	GIR46M	GIR11F
	GIR56U		GIR30F	GIR19M	GIR42F
				GIR47M	GIR50F
					GIR53F
					GIR51F
					GIR28F
					GIR55F
North			GIR35F		GIR32F
					GIR33F
West			GIR26F		GIR22F
					GIR24F

4.1.3. Habitat usage

All giraffe in Garamba NP predominantly inhabited tree savannah habitats (sparsely and intermediately bushed), dominated by *Loudetia arundinaceae* and *Hyparrhenia* species. These areas also have significant numbers of *Kigelia africana*, *Piliostigma thoningii* and *Vitex doniana*. *Acacia* species are relatively sparse in the East of the Park and rare in the west and the south of the Park. Even though similar habitat is present in the south region, giraffe in this region seemed to prefer the more densely wooded parts. Giraffe of the Southern subpopulation were most often seen in intermediate woodland types, in which *Anogeissus leiocarpus* and *Lophira lanceolata* are abundant.

4.1.4. Group Size

Between June 2014 and September 2017 a total of 1,477 giraffe sightings were made, divided over 423 giraffe groups with an average of 3.5 individuals per group. Of all observed groups, 121 giraffe (29%) consisted of single individuals (singletons).

There was a significant difference amongst the giraffe group size in different subpopulations ($H_{(df=3,N=406)} = 16.15$, $p = 0.0011$). The multiple comparison showed a significant difference between Eastern and Western subpopulations only, the groups contained a mean of 3.82±2.85 (n=290, range 1-14) and 2.20±1.42 (n=40, range 1-6), respectively ($p = 0.002$).

4.2. Home Range

During early 2016, eight giraffe were fitted with a GPS satellite head harness 'collars'. Data was transmitted on an average of 3–4 times a day, but fluctuated between weeks without any transmitted signal to a maximum of 586 data points on a day. All collars had a different lifespan with a maximum of 422 days for collar GIR43F. As two collars (GIR41M and GIR42F) collected data of 51 days only they will be mentioned in the tables below but not used in any calculations.

Table 3. Basic data of information from GPS satellite collars pre-processing

N°	Name	Sex	Age	Subpopulation	Lifespan Collar (days)	Total transmitted data points
1	GIR36M	M	Adult	East	158	3,272
2	GIR37F	F	Adult	East	261	632
3	GIR38M	M	Adult	East	114	335
4	GIR39M	M	Adult	East	281	842
5	GIR40M	M	Adult	South	135	393
~~6~~	~~GIR41M~~	~~M~~	~~Adult~~	~~East~~	~~51~~	~~173~~
~~7~~	~~GIR42F~~	~~F~~	~~Adult~~	~~South~~	~~51~~	~~153~~
8	GIR43F	F	Adult	East + Northwest	423	1,277

4.2.1. Minimum Convex Polygon

Giraffe 95% MCP calculations resulted in an average HR of 445.0 km^2 (n=6), with males seemingly having a smaller HR with 340.3 km^2 on average (n=4) compared to an average of 654.6 km^2 (n=2) for females, however the difference was not statistically significant ($t = -1.30$, $p > 0.05$). 50% MCP calculations (core area) resulted in an average of 60.1 km^2 (n=6) for all giraffe with a statistically significant ($t = 1.6601$, $p=0.031$) difference between genders with 64.2 km^2 (n=4) for males compared to a lower 51.8 km^2 (n=2) for females. Table 4 summarizes all HR results with the third column showing the HR calculated with a 95% MCP algorithm and the fourth column showing the HR of the core area (50% MCP). Annex 5 shows a compilation of results of MCP calculations plotted on a map of GNP.

Table 4. Outcomes for 95% and 50% Minimum Convex Polygon calculations from eight giraffe in the Garamba complex, DRC

N°	Name	95% MCP (km^2)	50% MCP (km^2)
1	GIR36M	598.5	59.0
2	GIR37F	339.2	51.7
3	GIR38M	325.4	73.8
4	GIR39M	302.8	52.9
5	GIR40M	134.4	71.4
~~6~~	~~GIR41M~~	~~210.1~~	~~56.6~~
~~7~~	~~GIR42F~~	~~41.2~~	~~9.2~~
8	GIR43F	970.0	52.0
	Average	**445.0**	**60.1**

4.2.2. Kernel Density Estimation

Giraffe 95% KDE calculations resulted in an average HR of 268.8 km^2 (n=6), ranging from as low as 93.6 km^2 to as high as 445.0 km^2. Males had an average 95% KDE HR of 268.5 km^2 (n=4) compared to females who had an average of 269.3 km^2 (n=2) with no statistically significant difference ($t = -0.01$, $p=0.243$). For the 50% KDE HR males had an average HR of 76.6 km^2 (n=4) compared to females who had a HR of 72.8 km^2 (n=2), also not significantly different ($t = 0.07$, $p=0.753$). Table 5 summarizes all HR results with the third column showing the HR calculated with a 95% KDE algorithm and the fourth column showing the HR of the core area (50% KDE). Annex 6 shows a compilation of results of KDE plotted out on a map of GNP.

Table 5. Outcomes for 95% and 50% Kernel Density Estimation calculations

N°	Name	95% KDE (km^2)	50% KDE (km^2)
1	GIR36M	357.4	117.5
2	GIR37F	445.0	119.9
3	GIR38M	379.8	144.6
4	GIR39M	168.7	31.2
5	GIR40M	168.2	13.0
~~6~~	~~GIR41M~~	~~215.9~~	~~40.3~~
~~7~~	~~GIR42F~~	~~41.5~~	~~7.1~~
8	GIR43F	93.6	25.8
Average		**268.8**	**75.3**

5. Discussion

5.1. Population Dynamics

5.1.1. Population Structure

Of the 49 different giraffe recorded, 45 individuals were believed to be alive at the end of the study in August 2017. Three juveniles, out of a total of eight born, were excluded from the database after their mother was seen multiple times without the still dependant juvenile. Even though no carcasses were found the juveniles likely died naturally, potentially killed by lion or hyena. As no carnivore surveys are carried out in this part of the park it is difficult to assess their density, however it is believed that there is a viable population of predators in this area (D'haen, pers. obs.). All juveniles that assumed to be predated were from the Southern subpopulation. These assumed dead giraffe were excluded from the population dataset and thus not incorporated in any of the following population structure models. The dataset used was the temporal state of the population as on the end of the research, by mid August 2017. With 25 giraffe in the Eastern subpopulation and 14 giraffe in the Southern subpopulation these are currently the most viable groups. There are only three giraffe in both the Northern and the Western subpopulation.

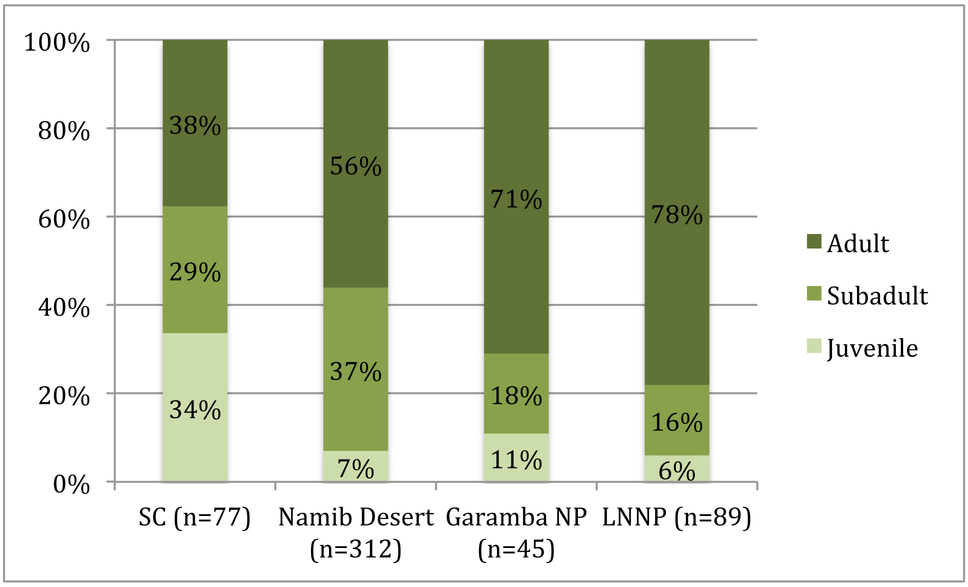

Figure 8. Age class ratios of Garamba National Park giraffe compared with age class ratios in the Namib Desert (Fennessy 2014), Soysambu Conservancy (SC) and Lake Nakuru National Park (LNNP), Kenya (Muller 2018)

Figure 8 compares the age class ratios of GNP's giraffe with research on population structure of two Nubian (Rothschild's) giraffe populations in Kenya – Lake Nakuru National Park (LNNP) and Soysambu Conservancy (SC) (Muller 2018). Muller (2018) compared the age class ratios of two giraffe populations with the LNNP population sharing its territory with a relatively dense lion population whereas SC was lion-free. Interestingly, the GNP giraffe age class structure is similar to that of the LNNP population, and possibly indicates that the impact of predation on LNNP could be similar to GNP, and as such affecting giraffe population growth.

The population structure of giraffe in the GNP is strongly skewed and female dominant (65% female : 35% male) compared to an expected 50 : 50 population structure (e.g. Fennessy 2004). However, it may be likely that some immature males were wrongly categorized as females resulting in this skewed population structure. Ongoing research is required to confirm. However, whilst skewed population structures are generally not desirable, if female dominated they are advantageous for the natural re-population of a population.

With an estimated 21 adult female giraffe in the population and a post-partum period of 3-9 months after giving birth (Foster & Dagg 1972; Pellew 1983; Bercovitch et al. 2006), one would expect a theoretical maximum 10.5-14 offspring per year (15 months of pregnancy and 3-9 months post-partum period). However, only eight juveniles were observed, which can possibly be explained by two reasons. Firstly, giraffe calves may sometimes die before being observed, or secondly, adult female giraffe may not fall pregnant because of low population densities and highly dispersed groups.

5.1.2. Distribution and Movement Patterns

Giraffe were distributed throughout the south central part of the Park but with core areas in the east, south, west and north – noted as different giraffe subpopulations. Giraffe observations were not limited to only these areas with observations also recorded in the core area of the south central part of the Park. These observations however are of giraffe that moved large distances and never stayed long in this open savannah core area, likely a result of its limited forage availability. Apart from GIR43F, which showed unique movement patterns, the giraffe of the Eastern subpopulation moved to the Western subpopulation, interconnecting both groups. No giraffe of the Western subpopulation moved to the Eastern subpopulation during this study period. Knowledge of this movement behaviour is important in the conservation of giraffe in the Park as the Western subpopulation consists of females only. Without the movement of males from the Eastern subpopulation to the Western subpopulation, no chances for reproduction would occur and if the status quo remained then the subpopulation would eventually disappear. It remains unknown why the giraffe from the Western subpopulation did not move East but is has been suggested that this is a behaviour of the remnant population that was once much more extensive. It can be assumed that giraffe of the Western subpopulation are a relict population and the last individuals of what once was a viable population with 12 giraffe observed in this area with the aerial survey of 2014.

Giraffe of the Southern subpopulation are cut off from the remainder of the Park by one of the Park's biggest rivers and were not observed to cross – as such remain isolated. The giraffe in this area inhabit a much more densely vegetated environment, being likely connected with the fact that giraffe GIR40M had a smaller HR (95% MCP and 95% KDE) as discussed below. Interestingly, the area is in close proximity (< 5km) of human settlements, yet the local people do not hunt them.

The movement patterns of the adult female GIR43F in the Eastern subpopulation highlight regular movements from the Eastern subpopulation to an area just outside of the Park's boundaries in the Azande Hunting Reserve. No other giraffe are assumed to use this area other than herself. Targeted monitoring is required to better understand why she utilises this area. Although it is very likely that she too is a last remainder of a population that was once viable with four giraffe observed in her known distribution range with the aerial survey of 2014.

Another giraffe subpopulation, north of the south central core area, consists of three females only – approximately 40km from the closest subpopulation. With only a handful of observations, knowledge of their distribution and movement patterns is limited. From a conservation management perspective, it may be critical to intervene in this isolated giraffe subpopulation, as they are outside of the well-protected south central part and, being without a male, moving towards extinction. Recommendations have been made to the Park's management to translocate these giraffe to the Southern subpopulation so as to not lose valuable potential breeding stock.

In trying to answer the question why these giraffe occur isolated from others in this area, two logical possibilities exist can be found; either through migration or the last remaining individuals in what previously was a viable population. No giraffe were found in this area on the aerial survey of 2014 and two giraffe were observed on the aerial survey of 2012.

Still much is to be learned of the distribution and movement patterns of giraffe in GNP. Ongoing and regular dedicated monitoring may enable new giraffe to be found, and similar to GIR43F, finding larger and more diverse home ranges between the reported subpopulations, and/or inside and outside the Park. Interestingly, and as observed elsewhere in Africa (Estes 1991; Kingdon 1997), pregnant giraffe would sometimes disappear for several months and would then reappear with a juvenile, suggesting that pregnant females move to other parts of the Park to give birth.

Even though giraffe historically occurred across most of the GNP complex, their distribution today is limited to a few areas only, centred around the south central part of the Park extending marginally into the adjacent Hunting Reserves. With a core area of open savannah and densely forested parts in the Hunting Reserves, giraffe distribution seems to be limited to the transitory zones between these two ecotypes.

This suitable transitory zone however extended far wider than just to the regions where giraffe occur today with vast areas in the north central part of the Park that were once home to the estimated 600 giraffe reported by Savidge in 1976. Taking this into consideration why are giraffe limited to the areas they inhabit today and ceased to occur in the areas they inhabited before?

With population numbers decreasing due to poaching to an estimated 45 individuals in 2017 giraffe herds that historically interconnected others became locally extinct and remnant groups became isolated to areas where they were better protected, less hunted and/or more difficult to find. Whilst anti-poaching efforts have helped to secure some areas in the Park, their low numbers, separation, predation threats, possibly also inbreeding, has made it difficult to rebound like that observed in Niger (Suraud 2011).

With poaching being an existing threat for giraffe in GNP some location names and figures in this text might have been altered in order not to share any vulnerable information.

In time, it is hoped that population numbers will grow and expand into former areas. With a change of the Park's management, poaching and predation of wildlife appears to have been reduced, and it is assumed that predators have shifted their diets from mainly elephant carcasses to alternatives such as giraffe (calves). To assess this further, targeted research on GNP's giraffe is required to assess identifying the importance of each threat, specifically predation.

The herd sizes in GNP do not differ from previously reported studies in which herds average 3-6 animals (e.g. Innis 1958; Foster 1966; Leuthold 1979; Pratt & Anderson 1985; Le Pendu et al. 2000; Bercovitch & Berry 2009). Some of these studies also reported that giraffe herds are smaller in woodland and thicket areas than in open habitats, regardless of season. This is in line with the findings in this research where giraffe inhabiting more densely vegetated areas have an average herd size of 3.2 individuals per herd (n=63) compared to a herd size of 3.8 individuals per herd (n=248) for the Eastern subpopulation, inhabiting a more open habitat. However this difference is not statistically significant, likely because of the small sample size.

5.2. Home Range

As mentioned earlier, the data of two GPS collars (GIR41M and GIR42F) will not be used nor will they be discussed below as they collected data of 51 days only.

When looking at HR results (MCP and KDE) for giraffe GIR43F, an adult female, results differ from other giraffe as she did not seem to have established a HR. GIR43F had a much larger home range than any other giraffe with a 95% MCP calculated HR of 970km^2. This extremely large HR is a result of the giraffes' movements across the Park. A possible explanation for this remarkable behaviour is that GIR43F shifted her HR in the timeframe of the research from her original distribution range in the northwestern parts of the Park (where more giraffe occurred as seen from the aerial survey report from 2014) to live with other giraffe in the Eastern subpopulation.

The 95% KDE HR estimate for GIR43F is more than ten times smaller than that calculated using MCP. The giraffe's unusual movement patterns as described are undoubtedly the reason for this. More specifically since GIR43F had a vast distribution range but spent the largest portion of time in an area only ten times the size of this range.

Although not statistically significant GIR40M, the only giraffe with usable data from the Southern subpopulation, had a smaller HR compared to others with a 95% MCP of 134.4 km^2 compared to an average of 394.2 km^2 (n=4) for giraffe of the Eastern subpopulation and a 95% KDE of 168.2 km^2 compared to an average of 337.7 km^2 (n=4) for giraffe of the Eastern subpopulation. A likely artefact of the different more densely vegetated habitat where GIR40M lived.

Further research to evaluate the credibility of the above assumptions is required. Importantly, as a giraffe's HR can be influenced by a number of factors including water availability, topography, climate, presence of herbivores, predators or humans, ongoing efforts to understand the GNP population is needed to elucidate what impacts their spatial use in the Park.

Table 6. Home range sizes of different giraffe populations throughout Africa

Study Area	Country	N	Mean home range (km^2)	Range (km^2)	Source (Year)
Ruma NP	Kenya	13	7.09	3.03 – 12.08	Anyango & Were-Kogogo (2013)
Lake Manyara NP	Tanzania		8.6	0.5 – 27	van der Jeugd & Prins (2000)
El Karama Ranch	Kenya	28	13		Moore-Berger (1974)
Timbavati PNR	S. Africa		24.6		Langman (1973)
Timbavati PNR	S. Africa	1	41		Langman (1977)
Ol Pejeta Conservancy	Kenya		64.2		Vanderwaal et al. (2013)
Okavango Delta	Botswana	1	67.5 (MCP)		McQualter et al. (2015)
			47.1 (95% FKDE)		McQualter et al. (2015)
Luangwa Valley	Zambia	4	68	60 – 82	Berry (1978)
Nairobi NP	Kenya	10	85		Foster & Dagg (1972)
Etosha	Namibia	68	96.2	12.7 – 352.6	Brand (2007)
Namib desert	Namibia	16	100.0 (95% MCP)	8.33 – 702.1	Fennessy (2009)
Serengeti NP	Tanzania		120		Pellew (1984b)
Etosha	Namibia	21	148.0	2.49 – 1000.5	Brand (2007)
Tsavo NP	Kenya	50	161.8	8.8 – 438.8	Leuthold & Leuthold (1978)
Namib Desert	Namibia	16	199.5 (100%)	12.9 – 1098	Fennessy (2004)
			100 (95%)	8.33 – 702.1	Fennessy (2004)
Khamab Kalahari Nature Reserve	South Africa	8	206 (95% MCP)		Deacon & Smit (2017)
Garamba NP	**DR Congo**	**6**	**268.8 (KDE 95%)**	**93.6 – 445.0**	**This study**
			445.0 (MCP 95%)	**134.4 – 970.0**	**This study**
Kruger NP	S. Africa	1	282		du Toit (1990)
Chobe NP	Botswana	3	323 (MCP)	138.3 – 623.4	McQualter et al. (2015)
			258.6 (95% FKDE)	94.5 – 536.5	McQualter et al. (2015)
Niger	Niger	14	324	151 – 1378	Le Pendu & Ciofolo (1999)
Namib desert	Namibia	44	355.5 (95% MCP)	11.5 – 1773	Fennessy (2009)

When compared with other giraffe HR studies (See Table 6), those in the GNP complex are relatively high. The GNP complex is more humid than several other study sites listed, and as such one would have assumed their HR size to be smaller in the Park as it has been reported that giraffe HR is positively correlated with aridity of the environment (Du Toit 1990; Fennessy 2009; Le Pendu 1999).

Acacia, a species that prefers dry ground, is possibly limited to occur in higher densities in the GNP because of the humid climate. Seen the importance of Acacia in some giraffe population's diet, this might suggest that giraffe in the GNP travel farther to browse on the sparse Acacia. On the other hand, some giraffe populations have been found not to have Acacia as an important source of food. More research on diet preferences of GNP's giraffe can bring clarity on the fact whether the large distribution range of giraffe relates to their diet composition.

6. Conclusion

As of August 2017, the GNP population was estimated at 45 individuals (males 26 : females 14). With 3 juvenile giraffe assumed to be predated, an insight in the population's current threat is given. Supported by an age class ratio (juveniles 11% : subadults 18% : adults 71%) importantly different from other populations with a low (Soysambu Conservancy) or normal (Namib Desert) predation level and similar as to age class ratio's of a population with a high predation level (Lake Nakuru National Park), it is likely that a growth of GNP's giraffe population is limited by predation.

Moreover, and through a combination of methods and data, the research revealed important information regarding distribution as well as movement patterns with different subpopulations that are connected through movement patterns whereas others are assumed to be isolated.

With average home range sizes of giraffe in GNP – 445.0 km^2 (95% MCP) and 268.8 km^2 (95% KDE), numbers are relatively high compared to other previous published studies. Like the giraffe living in the desert in Namibia, who reside at the extreme dry end of the habitat-scale for giraffe, the GNP giraffe reside at the extreme wet end of this scale. The preliminary research on the home range of Garamba's giraffe shows that they have much larger home ranges compared to most reported across their range.

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Annex

Annex 1. Plant species known to be part of giraffe diet in the Garamba National Park complex, DRC

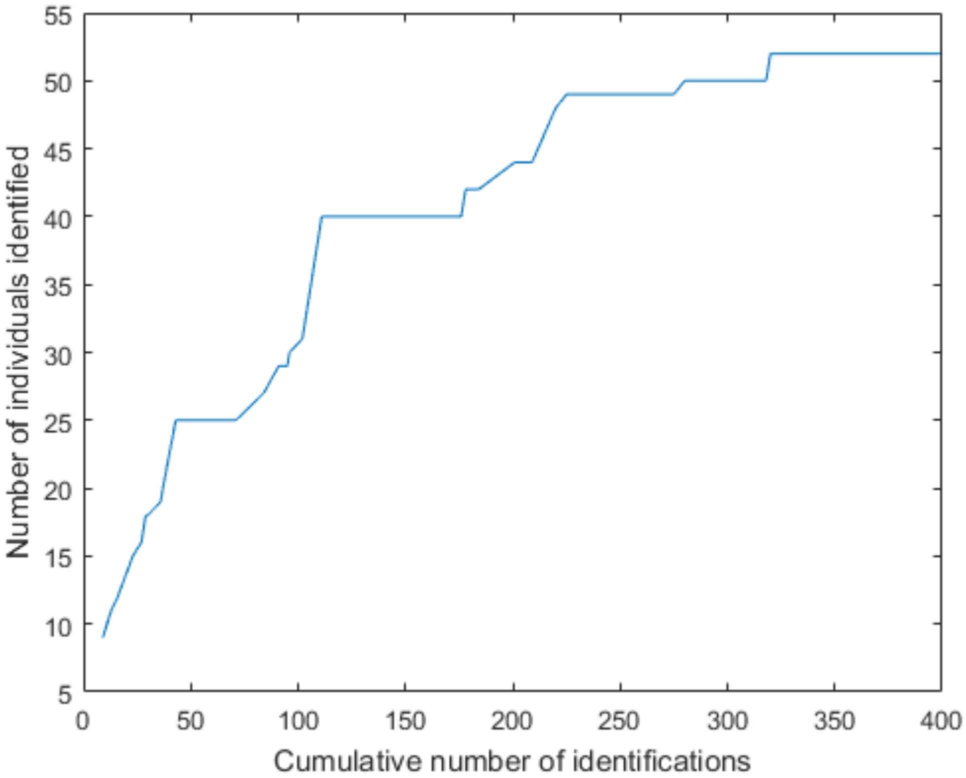
Species	Food	Status	Source
Nauclea latifolia	Yes	Common	Amube et al 2009; Cabrera 2010
Piliostigma thonningii	Yes	Common	Amube et al. 2009
Bridelia sp	Yes		Amube et al. 2009
Acacia sieberiana	Yes	Scarce	Amube 1989; Cabrera 2010
Combretum binderianum	Yes		Amube 1989
Stereospermum kunthianum	Yes	Scarce	Amube 1989
Bridelia scleuroneuroides	Yes		Amube 1989
Vitex doniana	Yes	Common	Amube 1989
Crossopteryx febrifuga	Yes		Amube 1989; Cabrera 2010
Calopongonium mucunoides	Yes		Amube 1989
Acacia seyal	Yes	Scarce	Amube 1989; Cabrera 2010
Loudetia arundinaceae	No		Hillman Smith et al. 2014
Hyparrhenia species	No		Hillman Smith et al. 2014
Kigelia africana		Common	Hillman Smith et al. 2014
Ziziphus abyssinica	Yes		Amube 1989
Lonchocarpus laxiflorus	Yes	Very common	
Acacia polyacantha	Yes		Cabrera 2010
Combretum colinum	Yes		Cabrera 2010
Annona senegalensis	Yes		Cabrera 2010
Grewia mollis	Yes		Cabrera 2010
Syzyphus senegalensis	Yes		Cabrera 2010
Calopongium mukonoides	Yes		Cabrera 2010
Lonchocarpus laxiflorus	Yes		Cabrera 2010
Bridelia soler	Yes		Cabrera 2010
Terminalia mollis	Yes		Cabrera 2010

Annex 2. Giraffe head harness collar used in the research

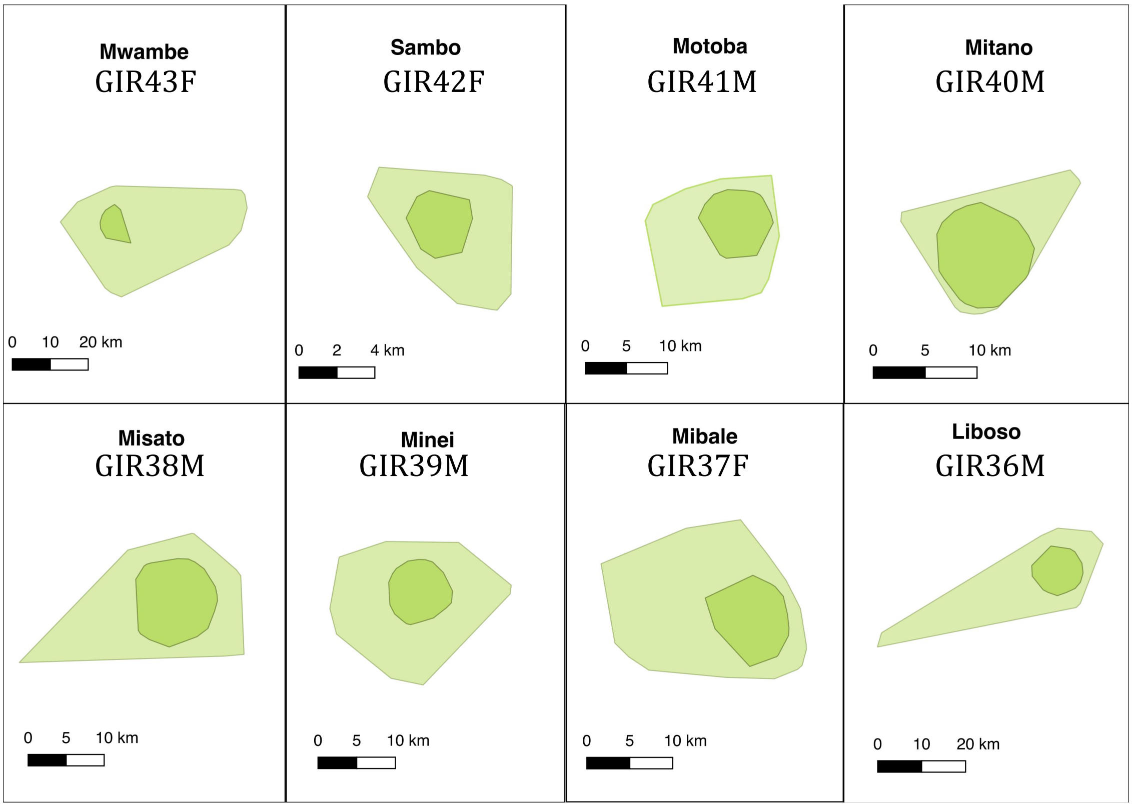
Annex 3. Example format of raw data stored in excel

	A	B	C	D	E	F	G	H	I	J	K	L	M	O	P	Q	R
1	Date	Tim	ID	Name	Sex	Age	Group size	Other i	Method	Type	Bl	Latitu	Longitu	Photo	Photo	Observer(s)	Remarks
8483	2017-03-15		Unknown		Unknown	Unknown	5		Helicopter	Seen	5			No			
8484	2017-03-15		Unknown		Unknown	Unknown	5		Helicopter	Seen	5			No		Mathias, Kate, Djuma, Didier, Arno	
8485	2017-03-15		Unknown		Unknown	Unknown	5		Helicopter	Seen	5			No		Mathias, Kate, Djuma, Didier, Arno	
8486	2017-03-15	5:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8487	2017-03-15	13:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8488	2017-03-15	21:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8489	2017-03-16	22:21	GIR05F		Female	Adult	2	GIR44U	Vehicle	Seen	8			Yes		Mathias, Kate, Djuma, Didier, Arno	
8490	2017-03-16	22:21	GIR44U		Unknown	Juvenile	2	GIR05F	Vehicle	Seen	8			Yes		Mathias, Kate, Djuma, Didier, Arno	
8491	2017-03-16	5:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8492	2017-03-16	13:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8493	2017-03-16	21:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8494	2017-03-17	5:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8495	2017-03-17	13:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8496	2017-03-17	21:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8497	2017-03-18	5:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8498	2017-03-18	13:19	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8499	2017-03-18	21:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8500	2017-03-18	21:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8501	2017-03-18	21:18	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8502	2017-03-19	4:53	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8503	2017-03-19	4:55	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8504	2017-03-19	4:55	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8505	2017-03-19	4:55	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8506	2017-03-19	6:33	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8507	2017-03-19	6:44	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8508	2017-03-19	14:43	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8509	2017-03-19	22:43	GIR43F	Mwambe	Female	Adult				Collar data	6			No			
8510	2017-03-20	16:33	GIR16F		Female	Adult	1		Airplane	Seen	9			Yes		Mathias & Alain	
8511	2017-03-20	16:41	GIR10M		Male	Adult	3	GIR21M	Airplane	Seen	6			Yes		Mathias & Alain	
8512	2017-03-20	16:41	GIR10M		Male	Adult	3	GIR43F	Airplane	Seen	6			Yes		Mathias & Alain	
8513	2017-03-20	16:41	GIR21M		Male	Adult	3	GIR10M	Airplane	Seen	6			Yes		Mathias & Alain	
8514	2017-03-20	16:41	GIR21M		Male	Adult	3	GIR43F	Airplane	Seen	6			Yes		Mathias & Alain	

Annex 4. Giraffe discovery curve showing new giraffe identified over the total amount of observations done



Annex 5. Compilation of results of MCP plotted out on a blank map of GNP



Annex 6. Compilation of results of KDE plotted out on a blank map of GNP