Ecology of the South African giraffe (*Giraffa camelopardalis giraffa*) across a land-use gradient in central KwaZulu-Natal, South Africa

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ABSTRACT

Herbivore ecology is affected by various factors such as seasonality and land use. Conservation and management strategies are highly dependent on gaining an adequate understanding of such factors and their effects. Giraffe (*Giraffa camelopardalis*) are one of Africa's iconic species but are listed on the IUCN Red List as vulnerable. The global giraffe population numbers saw a marked decline of approximately 30% between 1985 – 2015. This was because of several factors such as poaching, habitat destruction and disease.Core population numbers have shown an increase over recent years but the herbivores have become extinct in seven countries over the last century. This study investigated five key aspects of giraffe ecology in central KwaZulu-Natal: (i) the differences in home range sizes of South African giraffe (*Giraffa c. giraffa*) according to sex and seasonality across a land-use mosaic from 2019 – 2020 in the Zingela Conservation area, Kusa Kusa communal land and Emaweni Game Hunting Ranch.. This was done by fitting 12 giraffe with Ultra High Frequency (UHF) transmitters that sent out Global Positioning System (GPS) coordinates of the giraffe' positions and movements. It was found that the giraffe did not show any significant differences in home range sizes seasonally or by sex. The home range sizes were controlled by food availability and quality which should be the main focus in conservation and management of these large herbivores. The availability and quality of browse in the dry seasons is vital to the size of giraffe home ranges as the animals will change their habits to adapt to a reduction the browse quantity and quality. The study also investigated (ii) seasonal changes in habitat use by the tagged giraffe. The study used the GPS co-ordinates obtained to map out how habitat use by the giraffe changed according to changes in seasons. In addition, the study investigated (iii) the seasonal changes in giraffe feeding habits in the Zingela Conservation area that has Thukela Bushveld vegetation. Field observations were conducted between 2019 – 2020. The giraffe had a higher dietary diversity in the dry seasons (H' = 2.039) than in the wet seasons (H' = 1.628), and there was a significant difference in feeding habits between the two seasons. There was an increase in tree species fed on in the dry seasons than in the wet seasons. The changes in diet were influenced by browse availability and quality. An adequate population of evergreen and semi-deciduous tree species is important in giraffe conservation and management as these will provide dry season browse. Furthermore, the study investigated (iv) the social behaviour of the giraffe in the Zingela Conservation area. Field observations were carried out between 2019 – 2020 to investigate changes in giraffe social behaviour seasonally between herds and sexes. Herd sizes were significantly larger in the dry seasons whilst more bulls were observed with the females in the wet seasons. This was influenced by food availability and quality as the animals aggregated at food sources with the best available browse. The food quality in the wet season allowed the bulls to move between herds and searching for females. Management efforts must focus on food sources as these have the most influence on the giraffe' ecology. Vegetation investigations to quantify available browse in different seasons are important to calculate aspects such as carrying capacities.

PREFACE

The data described in this thesis were collected in KwaZulu-Natal Province, Republic of South Africa, from February 2019 to September 2020. Experimental work was carried out while registered at the School of Life Sciences, University of KwaZulu-Natal, Pietermaritzburg, under the supervision of Prof Colleen T. Downs and Dr Peter Calverley

This thesis, submitted for the degree of Master of Science in the College of Agriculture, Engineering and Science, University of KwaZulu-Natal, School of Life Sciences, Pietermaritzburg campus, represents original work by the author and has not otherwise been submitted in any form for any degree or diploma to any University. Where use was made of the work of others, it is duly acknowledged in the text.

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Mmeli J.J. Nyathi

December 2020

I certify that the above statement is correct, and as the candidate's supervisor, I have approved this thesis for submission.

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Prof Colleen T. Downs

Supervisor

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DECLARATION 1 - PLAGIARISM

I, Mmeli J.J. Nyathi, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.
2. This thesis has not been submitted for any degree or examination at any other university.
3. This thesis does not contain other persons' data, pictures, graphs or other information unless specifically acknowledged as being sourced from other persons.
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DECLARATION 2 - PUBLICATIONS

DETAILS OF CONTRIBUTION TO PUBLICATIONS that form part and/or include research presented in this thesis.

Publication 1

MJJ Nyathi, P Calverley & CT Downs

Differences in South African giraffe (*Giraffa camelopardalis giraffa*) home range in a land-use mosaic in KwaZulu-Natal, South Africa

Author contributions:

MJJN conceived the paper with CTD and PC. CTD and PC sought funding. MJJN and PC collected data. MJJN analysed data and wrote the draft paper. CTD and PC contributed valuable comments to the manuscript.

Publication 2

MJJ Nyathi, P Calverley & CT Downs

Seasonal changes in habitat use by South African giraffe across a land-use mosaic in central KwaZulu-Natal, South Africa

Author contributions:

MJJN conceived the paper with CTD and PC. CTD and PC sought funding. MJJN and PC collected data. MJJN analysed data and wrote the draft paper. CTD and PC contributed valuable comments to the manuscript.

Publication 3

MJJ Nyathi, P Calverley & CT Downs

Seasonal changes in South African giraffe feeding behaviour in central KwaZulu-Natal, South Africa

Author contributions:

MJJN conceived the paper with CTD and PC. CTD and PC sought funding. MJJN collected data. MJJN analysed data and wrote the draft paper. CTD and PC contributed valuable comments to the manuscript.

Publication 4

MJJ Nyathi, P Calverley & CT Downs

Seasonal changes in South African giraffe social behaviour in central KwaZulu-Natal, South Africa

Author contributions:

MJJN conceived the paper with CTD and PC. CTD and PC sought funding. MJJN collected data. MJJN analysed data and wrote the draft paper. CTD and PC contributed valuable comments to the manuscript.

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December 2020

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CHAPTER 1

Introduction

1.1 Land use

Rapid human growth has led to changes across the world in land use as there is a greater demand for agricultural produce to feed the population leading to mass deforestation (DeFries *et al.* 2010). Urban growth and agricultural exports were observed to be positively linked to deforestation in 41 countries across Latin America, Africa and Asia (DeFries *et al.* 2010). Additionally urbanisation has been another contributing factor to changes in land-use as the expansion of urban areas has come at the expense of wetlands, forests and agricultural lands in countries such as India (Patra *et al.* 2018). These changes have brought about an increase in carbon emissions and extinctions of some flora and fauna, with the most recent being the sixth mass extinction (Houghton 1990; Houghton 1994; Shivanna 2020). Global biodiversity is on the decline because of factors such as political corruption and weak national institutions that are not doing enough to combat wildlife habitat destruction (Gardner *et al.* 2007; Rydén *et al*. 2020).

With the increasing human population, there is an increasing demand for agricultural land and building sites (Symes *et al*. 2018). Human encroachment into different areas leaves wildlife at a disadvantage as rangelands and forests are removed (Symes *et al.* 2018). Bercovitch and Deacon (2015) noted that human encroachment also leads to an exploitation of wildlife resources in areas where wildlife and humans co-exist. For example, giraffe *Giraffa camelopardalis* numbers in East Africa have declined because of human-wildlife conflict (Bercovitch and Deacon 2015). Large scale land-use changes and poaching led to a reduction in giraffe numbers in areas where the wildlife was not protected by law (Bercovitch and Deacon 2015). Protected areas and reserves are currently widely viewed as a potential solution to this problem (Watson *et al*. 2014).

1.2 Protected areas

The IUCN (International Union for Conservation of Nature) defines a protected area as an area on land or sea that is set aside to protect and maintain biodiversity, natural and cultural resources and is managed by legal means (Dudley and Stolton 2008). Approximately 15% of the earth's terrestrial surface and 3% of the global ocean have been set aside as protected areas following the IUCN's definition (Muñoz Brenes *et al.* 2018). An example is the strategies followed in most parts of Africa such as Tanzania, Kenya and South Africa, where there are several game reserves, national parks and forest reserves (Stoner *et al.* 2007). These areas protect different levels of resources at varying levels of use with tourism, generally being the main source of funding for such areas (Biggs *et al*. 2014). National parks typically do not allow any killing of animals or cutting of trees whilst game reserves generally require permits for selective use of resources (e.g., trophy hunting permits and logging permits) (Stoner *et al.* 2007). The success of these methods of conservation can be monitored by observing changes in population densities of the protected species, with more recent studies showing a positive reaction (Thomas 1996; Barnes *et al.* 2016). Barnes *et al.* (2016) found that wildlife populations in protected areas in Europe and Africa were stable or showed a mean annual increase of 0.5%.

Protected areas form a major part of biodiversity conservation globally, with the *modus operandi* being a reduction in habitat loss (Joppa and Pfaff 2011). Protected areas were highlighted as being very important in the fight to conserve wildlife, South African giraffe *G. c. giraffa* in this case (Deacon and Tutchings 2018). Although the strategy of protected areas is being implemented globally, there is still some resistance. This is mostly from communities in and around these protected areas (Holmes 2013).

1.3 Humans and wildlife outside protected areas

Many conservation efforts for different species are being conducted at varying scales globally, and one of the threats to these conservation efforts is from rural communities (Holmes 2013). Population growth is changing the natural landscape as there is more cropland expansion to feed humans (Ehrlich and Harte 2015). Agriculture has always been the primary source of food and income in most African rural areas (Sibhatu and Qaim 2017). Agricultural practices such as crop cultivation have seen parts of rangelands being lost and has also led to human and animal conflict as the two are now sharing resources (Gemeda and Meles 2018). The main problems, in this case, become crop and livestock loss together with human safety as there is an overlap in resource demands (Hackel 1999; Seoraj-Pillai and Pillay 2016).

For example, in the past conservation efforts in northeastern Swaziland and Botswana's Okavango Delta have been met by resistance in the past from rural residents as they see them as a means of taking away their land as well as prioritising wildlife over humans (Hackel 1993; Mogomotsi *et al*. 2020). Increasing community rights have therefore led to changes in government policies which has seen the establishment of community-based conservancies (CBCs) to promote biodiversity and human development (Hackel 1999; Galvin *et al.* 2018). The CBCs have sought to help local people to benefit from wildlife resources by including them in management decision making and allowing them to own stakes in the resources (Galvin *et al*. 2018). There are several success stories from this strategy such as the Community Based Natural Resource Management (CBNRM) in Namibia and the Burunge Wildlife Management Area in Tanzania (Mupfume 2015; Lee 2018). These management strategies have been introduced in South Africa with varying results. As is the case in most areas, conservation strategies are viewed as western ideologies, and this brings about a negative stigma, in the case of Ndumo Game Reserve the distrust stems from apartheid (Teelucksingh 2007; Meer 2010). Conservancies have tried to build better relationships with communities by giving them some of the benefits, e.g., from culling (meat) done on the properties and donations from trophy hunting fees (Naidoo *et al*. 2016).

1.4 Trophy hunting

One of the most debated topics in conservation stakes is the issue of trophy hunting (Batavia *et al*. 2019). Trophy hunting has been defined as the act of hunting animals for meat and parts of their carcasses such as horns for use as trophies (Saayman *et al*. 2018; Sheikh and Bermejo 2019). Hunters purchase permits from governments to hunt these animals and the money paid is used to run conservancies where the animals were shot and to also raise of awareness on the animals (IUCN briefing paper 2016). Several areas operate as hunting areas, and some are viewed as conservation areas (Di Minin *et al*. 2016). The argument against trophy hunting is based on how the hunting may negatively impact the welfare of the wildlife and how greed may drive certain unethical practices such as artificially selecting for rare qualities in the animals (Lindsey *et al.* 2007; Di Minin *et al*. 2016). There are some strong cases of trophy hunting being beneficial to conservation and surrounding local communities (Angula *et al*. 2018). For example, an analysis of the hunting industry in South Africa showed that trophy hunting supported over 17 000 jobs and contributed over ZAR5 billion to the economy (Saayman *et al.* 2018).

1.5 Study species: Giraffe

Giraffe (*Giraffa camelopardalis*) belong to the family Giraffidae (Geraads and Bobe 2017; Muller *et al*. 2018a,b). The IUCN lists nine classified subspecies of giraffe (Supplementary information

Table S1.1), but there has been scientific evidence stating that there are four species of giraffe (Fennessy *et al.* 2016; IUCN 2016; Winter *et al*. 2018). The GCF has listed as the Masai giraffe (*G. tippelskirchi*), Northern giraffe (*G. camelopardalis*), Reticulated giraffe (*G. reticulata*) and Southern giraffe (*G. giraffa*). The subspecies are the Angolan giraffe (*G. c. angolensis*) and South African giraffe (*G. c. giraffa*) which are subspecies of the Southern giraffe. The Nubian giraffe (*G. c. camelopardalis*), Kordofan giraffe (*G. c. antiquorum*) and West African giraffe (*G. c. peralta*) are listed as the three subspecies of the Northern giraffe. The Rothschild's giraffe is genetically identical to the Nubian giraffe. The difference in the numbers of species and subspecies is due to the differing in definitions of a species. In giraffe, coat patterns, mitochondrial analyses, gene flow analyses and cranial measurements are used to classify the different species and subspecies (Bercovitch and Deacon 2015; Winter *et al.* 2018). IUCN has listed the subspecies of *G. camelopardalis* as *G. c. angolensis, G. c. antiquom*, *G. c. camelopardalis*, *G. c. giraffa, G. c. peralta*, *G. c. reticulata, G. c. rothschildi*, *G. c. tippelsckirschi* and *G. c. thornicrofti* (Muller *et al*. 2018b, Table 1.1). The different subspecies also occupy different geographical areas in their native Africa as indicated by the table (Table 1.1.) The amount of research on the various giraffe taxa varies with country and focus (Supplementary information Table S1.2 and S1.3).

1.5.1 Morphology

Giraffe are large herbivores and can weigh between 550 - 1930 kg and reach heights between 4 - 5.5 m at adulthood (Jolly 2002). This differences in height and body mass are a consequence of the sexual dimorphism shown by the giraffe, with males being larger than females (Mramba *et al*. 2017). Adulthood is reached at three years of age, and the first mating for females is at four years of age whilst for males, it is at eight years of age. The gestation period for giraffe is 15 months, with one calf being born, and the calving season is all year round (Furstenberg 2013). The calf stays with the mother for anywhere between 12 – 24 months with cows sometimes hiding their young when they leave to forage or leaving them in the care of a 'babysitter' (Bercovitch and Berry 2013).

Table 1.1: Giraffe subspecies, their geographical home range and estimated numbers in Africa.

Giraffe subspecies	Geographical zone	Estimated numbers	References
G. c. angolensis	Central Botswana, Namibia.	<17750	GCF website 2020
G. c. antiquorum	South Sudan, Cameroon, Central African Republic, Chad, Democratic Republic of Congo.	<2000	GCF website 2020
G. c. camelopardalis	Ethiopia, Kenya, Uganda, South Sudan.	<3000	GCF website 2020
G. c. giraffa,	Angola, Southern and Northern Botswana, Mozambique, Northeast Namibia, Northern South Africa, Southwest Zambia and Zimbabwe.	<37000	GCF website 2020
G. c. peralta	Niger.	<600	GCF website 2020
G. c. reticulata	North-eastern Kenya, South-eastern Ethiopia	<15700	GCF website 2020

	and South-western Somalia.		
G. c. tippelsckirchi	North-eastern Zambia, Southern Kenya, Tanzania.	<35 000	GCF website 2020

1.5.2 Home ranges

Giraffe are non-territorial mammals which means that they do not defend a territory but rather have areas of frequent use which is termed as the home range (Dagg 2014). Home range size in giraffe differ because of several reasons such as food availability, proximity to humans, mean annual rainfall, availability of mates and predation (Knuesel *et al*. 2019). Adult home range sizes were observed as low as 17.6 km^2 in the Lake Manyara National Park in Tanzania whilst a home range size of 1950 km^2 was observed in the Namib Desert (Fennessy 2009). The difference in rainfall is a direct reason for these home range sizes as the giraffe in the more arid areas move for longer distances to find feeding patches and mates (Fennessy 2009; Knuesel *et al*. 2019). Proximity to human settlements is another factor that affects giraffe home. Large herbivores have larger home ranges in areas close to human settlements as they must move for longer distances to avoid human conflict (Knuesel *et al*. 2019).

Food and water availability are important factors in mammal habitat use as they govern the animal's movements (Fennessy 2009). Giraffe are generally not water-dependent and can sustain themselves using the moisture content of their browse, especially in areas without visible surface water such as the arid Namib Desert (Fennessy 2009; Okello et al. 2015). Although they obtain moisture content from the leaves they browse on, the lack of an available surface water source influences the size of giraffe home ranges as they walk long distances to feed and drink (Knuesel *et al*. 2019). Food quality and availability are more dominant factors in habitat use as giraffe show seasonal movement according to the availability of food, favouring areas with abundant *Vachellia* species. in the wet season and areas with evergreen species in the winter (Deacon and Smit 2017).

1.5.3 Habitat use

Giraffe show different habitat uses with the varying habitats that the different subspecies are found. An animal's habitat use is influenced by the spatial arrangement of resources it needs for survival (Lawson and Rodgers 1997). Giraffe show differences in habitat use according to seasons with rainfall being the largest factor in determining how the habitat is used (Fennessy 2009). The availability of high-quality browse in the wet season generally decreases the size of giraffe home ranges compared with the dry season where high quality is not as abundant. Giraffe typically prefer *Vachellia* species. for browsing, and these lose their leaves in the dry season so this leads to a shift in preference to evergreen species which have a lower protein content which in turn leads to a change in habitat use (Hall-Martin and Basson 1975; Deacon and Parker 2016). The availability of new, higher nutrition *Vachellia* species. shoots and surface water in the rainy season shortens the distances that giraffe must travel (Hall-Martin and Basson 1975). The water content of these shoots also reduces the need for the giraffe to frequent water points (Parker and Bernard 2005).

1.5.4 Feeding behaviour

Although minimal grazing has been observed in nutrient-poor habitats, giraffe are mainly browsers, and they feed mostly on *Vachellia* species. (Seeber 2012b; Mahenya *et al*. 2016). Although these large herbivores show a preference for *Vachellia* species., their diet is not limited to these trees only (Berry and Bercovitch 2016). Berry and Bercovitch (2016) found that

Thornicroft's giraffe *G. c. thornicrofti* in the Luangwa Valley of Zambia fed on a range of 93 plant species over a 40-year observation span.

Deciduous trees like the *Vachellia* species. shed their leaves in the dry seasons with evergreen trees making up most of the available browse (Tomlinson *et al*. 2013). In the Eastern Cape, South Africa, *V. karroo* sheds its leaves in the dry season, and that is when evergreens such as *Sersia longispina* become a prominent feature in giraffe diets (Parker and Bernard 2005). These feeding patterns influence giraffe movements seasonally as the animals seek optimal browse availability (Deacon and Smit 2017). The availability of high-quality food sources in the wet season has been shown to affect juvenile mortality (Lee *et al*. 2017). Calves conceived in the wet season and born in the dry season have higher chances of survival as cows typically have higher fitness at the time of mating (Lee *et al*. 2017).

1.5.5 Social behaviour

Giraffe occur in different sized herds with herd sizes influenced by factors such as predation risk and differences in habitats (Muller *et al*. 2018a). The composition of the herds varies as females bring their juveniles to herds hence increasing the herd size whilst some herds are not breeding herds (Muller *et al*. 2018a). Bulls move away from the breeding herds to form all-male herds (Bercovitch and Berry 2014). The function of these all-male herds is to establish ranks amongst bulls, to pass on information about the habitat to younger bulls and to help in protection against predators (Bercovitch and Berry 2015). Dominant bulls obtain mating rights, and dominance is usually established by body size and age with occasional fights observed. (Pratt and Henderson 1985; Seeber *et al.* 2012a). Pratt and Henderson (1985) also established that most of the herds did not have a set leader, with the task usually falling to the older cows with calves.

1.5.6 Giraffe numbers decline: The reasons

Although the subspecies *G. c. giraffa* has been recommended to remain listed as 'Least concern' because of their increasing numbers, the IUCN Red List has listed giraffe as a vulnerable species globally because of a decline in numbers in the last 30 years (Deacon and Tutchings 2018; Muller *et al.* 2018b). The general population has seen a decrease of numbers by at least 35% in the last 30 years (Muller *et al*. 2018b). Several reasons are cited for declining giraffe numbers, including diseases such as Rinderpest in southern Africa and skin lesions affecting Ethiopian populations (Furstenberg 2013; Abate and Abate 2017). Human population growth has also influenced declining numbers of giraffe because of habitat degradation, and an increase in areas changed for human housing and agriculture (Deacon and Parker 2016).

Habitat destruction is a significant reason for giraffe population decline in all the African regions with the giraffe's favoured food source, *Vachellia* tree species, being removed and/or used to make charcoal in many countries, e.g. Ethiopia, Zambia and Tanzania (Abate and Abate 2017). Ciofolo (1995) stated that some of the West African populations of giraffe would not have gone locally extinct without human interference, but the availability of automatic firearms was a major factor in giraffe deaths and declines. The giraffe had to compete with livestock and humans for resources, further endangering them (Ciofolo 1995). Some of the lesser investigated factors affecting giraffe populations are inbreeding depression and susceptibility to lion *Panthera leo* predation in some parts of Africa such as the Lake Nakuru National Park in Kenya (Brennemann *et al*. 2009).

1.5.7 Conservation action

The conservation legislation and/or policies impacting giraffe in individual countries vary across Africa (GCF 2020; Table 1.2). The IUCN Species Survival Commission (SSC) Giraffe and Okapi Specialist Group (GOSG) is a volunteer group of experts that focuses mainly on providing technical advice on the conservation of giraffe and okapi (IUCN 2019). The herd is co-hosted by the Giraffe Conservation Foundation which focuses specifically on giraffe. GCF is an independent Non-Governmental Organisation working across 16 African counties, often with government, local and international partners to secure a long-term future for giraffe in the wild. With the noted decline in giraffe numbers across Africa, the Giraffe Conservation Foundation (GCF) is running giraffe conservation programmes for the different species of giraffe. These programmes are being run in Zimbabwe, Zambia, Malawi, Botswana, Chad, Democratic Republic of Congo, Kenya, Uganda, Ethiopia, Tanzania, Niger and Namibia (GCF 2020). The public is educated on these large herbivores and improve management efforts to stop the decline of giraffe numbers. The foundation also runs Twiga Tracker, an Africa-wide GPS staellite tagging programme that conducts genetic sampling, analysis programmes, surveys and development of national strategies. National parks and protected areas are also part of the framework to reduce poaching of the animals (GCF 2020).

A variety of methods have been tabled to assist in giraffe conservation. Bolger *et al.* (2012) generated the WildID artificial intelligence software programme to help identify Masai giraffe *G. c. tippelskirchi* individuals. The software uses pictures of giraffe coat patterns to identify individuals and was used to identify 600 individuals successfully. The images captured over three sampling points in a year helped estimate population size and survival rate (Bolger *et al.* 2012). Such examples provide more information on giraffe genetics to help deal with problems such as inbreeding which is prevalent in fenced-off protected areas (Austin *et al*. 2017). Faecal samples have also been used to investigate the genetics of giraffe populations to establish gene flow in these populations (Austin *et al.* 2017).

Translocation is a strategy that is being used across Africa to conserve threatened species such as giraffe (Muller *et al*. 2020b). This strategy either starts a new population in an area or introduces new genes into an already established gene pool (Muller *et al*. 2020b). Flanagan *et al.* (2016) highlighted this method of conservation by looking at the establishment of giraffe in three Namibian regions and was the first post-translocation study. Of the six translocated giraffe, four established home ranges in their respective areas (Flanagan *et al*. 2016).

An important part of conservation is the general public, and there has been a rise in global citizen scientists participating in conservation projects (Dickinson *et al.* 2012). Citizen scientists provide useful information on wildlife and help in making conservation projects successful. Another strategy that has been employed is the engaging of communities to teach them how to conserve specific species has been shown to bring success in conservation projects (Lee 2018). There was an increase in giraffe survival and population growth rate in the Burunge area of Tanzania because of the community-based management strategy implemented in 2014 (Lee 2018).

Table 1.2: Summary of giraffe conservation laws in different parts of Africa (GCF 2020).

Country	Giraffe conservation status	References
Angola	Fully protected	GCF website 2020
Cameroon	Fully protected	GCF website 2020
Central African Republic	Fully protected	GCF website 2020
Chad	Full protection	GCF website 2020

DRC	Full protection	GCF website 2020
Ethiopia	Hunting permit required	GCF website 2020
Kenya	Full Protection	GCF website 2020
Malawi	Not protected	GCF website 2020
Mozambique	Protected	GCF website 2020
Namibia	Hunting permit required	GCF website 2020
Niger	Fully protected	GCF website 2020
Nigeria	Fully protected	GCF website 2020
Rwanda	Fully protected	GCF website 2020
Somalia	Not protected	GCF website 2020
South Sudan	Fully protected	GCF website 2020
Swaziland	Hunting permit required	GCF website 2020
Tanzania	Fully protected	GCF website 2020
Uganda	Fully protected	GCF website 2020
Zambia	Not fully protected	GCF website 2020
Zimbabwe	Not protected; hunting permit required	GCF website 2020

1.6 Aim

The study's main aim was to investigate the movement, habitat use, social and feeding behaviour of South African giraffe (*G. c. giraffa*) in central KwaZulu-Natal in a land-use mosaic.

1.7 Thesis structure

The thesis is presented as six chapters with the first a general introduction followed by four data chapters and then a concluding chapter. The four data chapters have been prepared as draft manuscripts for submission to international peer-reviewed journals; therefore, some repetition was unavoidable. Each chapter contains its respective hypotheses and/ predictions. The chapters are structured as follows covering the following topics:

Chapter 2: Home ranges.

Chapter 3: Habitat use.

Chapter 4: Feeding behaviour.

Chapter 5: Social behaviour.

1.8 References

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1.9 Supplementary Information

Supplementary Table S1.1: Common names of the different giraffe subspecies (GCF website 2020)

Scientific name	**Species**	**Common name**
G. c. angolensis	Southern giraffe	Angolan giraffe
G. c. antiquorum	Northern giraffe	Kordofan giraffe
G. c. tippelskirchi	Masai giraffe	Masai giraffe
G. c. camelopardalis	Northern giraffe	Nubian giraffe
G. c. reticulata	Reticulated giraffe	Reticulated giraffe
G. c. giraffa	Southern giraffe	South African giraffe
G. c. peralta	Northern giraffe	West African giraffe

Supplementary Table S1.2: Summary of scientific papers on giraffe taxa accessible from the Giraffe Resource Centre (2018)

Topic	Number of papers
Giraffe	437
Angolan giraffe	12
Kordofan giraffe	2
Masai giraffe	21
Northern giraffe	5
Nubian giraffe	0
Reticulated giraffe	33
Rothschild’s giraffe	23
South African giraffe	11
Southern giraffe	13
Thornicroft’s giraffe	12
West African giraffe	15

Supplementary Table S1.3: A summary of topics in scientific papers on aspects of giraffe ecology available from the Giraffe Resource Centre (2018)

Topic	Number of papers
Speciation	293
Social Behaviour	80
Feeding Behaviour	27
Conservation	174
Habitat	177
Morphology	102

CHAPTER 2

Differences in South African giraffe (*Giraffa camelopardalis giraffa*) home range across a land-use mosaic in KwaZulu-Natal, South Africa

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Running header: Giraffe home ranges in a land-use mosaic

2.1 Abstract

Animal movements and home range assessments are an important component of animal behavioural studies. Home ranges are the area used by animals to obtain resources that they use for their survival. Giraffe (*Giraffa camelopardalis*) are large herbivores whose home ranges are variable because of many factors. We investigated changes in South African giraffe (*G. c. giraffa*) home range sizes according to sex and seasonality across a land-use mosaic. A total of 12 giraffe that use the Zingela Conservation Area, Kusa Kusa Communal Area and Emaweni Game Hunting Ranch in KwaZulu-Natal were fitted with Ecotone Ultra High Frequency (UHF) ear tags. These tags supplied Global Positioning System (GPS) co-ordinates during 2019 - 2020. Two home range methods [Minimum Convex Polygon (MCP) and Kernel Density Estimation (KDE)] were used to analyse home range and core utilisation data. The mean (± SD) home range size for the wet season was 45.76 ± 23.67 km^2 and 55.06 ± 31.82 km^2 for the dry season. We found that home range sizes were not significantly different between sexes and seasons. Giraffe home range sizes are typically controlled by food availability and quality.

Keywords: Ear tags, Kernel Density Estimate, home range, GPS tracking, South African giraffe.

2.2 Introduction

The distribution of resources has a direct effect on the movement of animals in their natural habitat, and animals use information about these spaces to survive daily (Spencer 2012). The space in which these resources are found is defined as the animal's home range (Powell and Mitchell 2012). The home range provides food, water and mating opportunities (Ruhmann et al. 2019). The availability of these resources is the main driving principle behind home range sizes (Zurell et al. 2018). Herbivores navigate through various trade-offs to establish the smallest home range possible, thereby minimising energy use (Bastille-Rousseau 2015). The dynamics of home range sizes are to minimise the negative effects on fitness and manage ecological constraints (Morellet et al. 2013).

Giraffe (*Giraffa camelopardalis*) are large mammalian browsers whose home range sizes are affected by food quality and water availability to a lesser extent (Owen-Smith 1988; Knusel et al. 2019). There are distinct wet and dry seasonal or degree of aridity variations in many parts of Africa where giraffe occur. In the Lake Manyara National Park, Tanzania, where rainfall and high-quality food were abundant, giraffe had a mean home range of 17.6 km^2 whilst a giraffe bull in the dry Namib Desert had a mean home range of 1950 km^2 (Fennessy 2009). Such differences in size are influenced by food quantity and quality as deciduous trees lose their leaves in the dry season (Fennessy 2009). Giraffe increase their diet breadth in the dry seasons to fulfil their bioenergy needs, and this increases their home ranges as there is a decrease in high-quality browse (Berry and Bercovitch 2016).

The availability of mating opportunities is another factor that affects animal home range sizes. Giraffe are non-territorial large herbivores that follow a fission-fusion social dynamic, with females showing stronger bonds between closely related individuals (Deacon and Bercovitch

2018). The herds show sexual segregation as males form all-male bachelor herds (Bercovitch and Berry 2014). Apart from these all-male herds, dominant adult bulls use a solitary roaming mating strategy (VanderWall et al. 2014). The bulls move between herds to find females that are in oestrus and are ready to mate (Van der Waal et al. 2014). Using this strategy, males move for considerably longer distances compared with the females (Fennessy 2009).

Improvement of Global Positioning System (GPS) tracking technology over the years has allowed for better investigation of animal movements (McQualter et al. 2015). Recent miniaturisation of devices and use of near real time global position has aided the acquisition of data on wildlife (Hart *et al*. 2020). The technology is helping provide more information on movements of these large herbivores, an area of study that has been relatively understudied in giraffe (Deacon and Smit 2017). We used this technology to investigate the differences in South African giraffe (*G. c. giraffa*, hereafter giraffe) home range sizes in a land-use mosaic in KwaZulu-Natal, South Africa, with distinct wet and dry seasons. We also investigated the differences in the effect that giraffe' sex had on home ranges. We predicted that the giraffe would have larger home ranges in the dry seasons compared with the wet seasons. We also predicted that giraffe bulls would have larger home ranges compared with cows.

2.3 Methods

2.3.1 Study area

Zingela Safari and River Company (28º 43.035 S 30º 03.800 E) is a conservation area located 26 km from Weenen and 35 km from Colenso in the South African Midlands of KwaZulu-Natal. The property is approximately 1200 ha and is bordered by the Tugela River. Kusa Kusa Communal Area is approximately 1500 ha large and borders the conservation area. Kusa Kusa is bordered by

Zingela and Emaweni Game Hunting Ranch which is approximately 2000 ha large. This gives a relatively small, closed environment that is approximately 4700 ha in size.

Zingela is dominated by the Thukela Valley Bushveld vegetation type. This vegetation type is dominated by *Vachellia* tree species which are *V. tortilis* and *V. robusta* together with evergreen tree species such as shepherd's tree (*Boscia albitrunca*) (Ezemvelo KZN Wildlife 2013). The area is dominated by *Blepharis natalensis* undergrowth which is a result of overgrazing in the past. The area also has high numbers of *Aloe marlothii*. Kusa Kusa comprises of Thukela Valley Bushveld and Thukela Thornveld vegetation. Emaweni Game Hunting Ranch is made up of the Thukela Thornveld vegetation type. This area is dominated by *Vachellia* tree species and turpentine grass (*Cymbopogon caesius*).

The study area receives approximately 500 mm of rain annually between October to March which is the wet season (Ezemvelo KZN Wildlife 2013). The area is a summer rainfall region. The dry season is between April to September, with winter temperature below 0 ºC having been recorded (Ezemvelo KZN Wildlife 2013).

2.3.2 Sampling techniques

The capture of the giraffe was carried out by a qualified veterinarian and a commercial game capture team over two days in July 2019. The giraffe were darted from a helicopter using a pneudart cartridge fire 389 projector gun that fired a type C, 2 cc 6.35 cm 13G needle dart. The dart administered 15 mg of Etorphine hydrochloride (M99 Reckitt) (Wildlife Pharmaceuticals, White River, South Africa). As soon as the animal was down a blindfold was put secured to protect its eyes. A team of three sat on the animal's neck to prevent it from getting up. The veterinarian then administered 150 mg of Naltrexone (Wildlife Pharmaceuticals, White River, South Africa) immediately to reverse the effects of the Etorphine. We fastened the transmitters onto the animal's ear using plastic ear tags (Supplementary information Fig. S2.1). The process took approximately 15 min. per giraffe. Morphological measurements were not taken in order to minimise the time the giraffe were down. All the animals were selected from different herds. We avoided using heavily pregnant females and young calves for the study (Bennitt et al. 2019). We fitted seven male and five female giraffe with GPS Ultra High Frequency (UHF) ear tag transmitters weighing less than 25 g each (Ecotone Telemetry, Poland). The transmitters were programmed to send the giraffe's GPS geographical location to the server every 4 h. The GPS UHF transmitters sent co-ordinates over a cellular network (GSM), and we read the *csv file through the Ecotone Telemetry online panel.

2.3.3 Data analyses

Seasonality

We split the received data into two seasons, wet and dry according to when the GPS co-ordinates were received. We imported the GPS co-ordinates into ArcGIS 10.4 (ESRI, Redlands, CA, USA), and they were projected in UTM (WGS 1984 UTM Zone 35S and 36S). We used two home range estimation methods to calculate home range, the Maximum Convex Polygon (MCP) and the Kernel Density Estimation (KDE) (Streicher et al. 2020). The R package rhr (RStudio 2015) was used to estimate the 95% area utilisation from the MCP and 95% core area utilisation from the KDE (Streicher et al. 2020).

Sex

We split the giraffe by sex using the dry season data and used the two home range estimation methods as above. The R package rhr was used to estimate the core area utilisation values

(Streicher et al. 2020). The 50% KDE was used to determine the core home range used (Streicher et al. 2020). We then analysed the differences in home range sizes between sexes. We conducted a Mann Whitney U test on the statistical programme R to calculate the difference in home range sizes and core area used by the two sexes.

2.4 Results

2.4.1 Seasonality

We found that the mean (± SD) MCP home range size for the wet season was 45.76 ± 23.67 km^2 (n = 3) and 55.06 ± 31.82 km^2 (n = 12) for the dry season (Table 2.1). The 95% KDE for the dry season was 87.00 ± 56.28 km^2 and 118.20 ± 48.08 km^2 for the wet season (Table 2.1). We found that there was no significant difference between MCP home range sizes in the different seasons (Mann Whitney, p = 2.012). We also found that there was no significant difference between KDE core utilisation in the two seasons (Mann Whitney, p = 1.217

Table 2.1: The mean (± SD) MCP home range sizes and mean (± SD) KDE core area utilisation by giraffe according to seasonal variation in the present study.

	MCP 95		**KDE 95**	
Season	**Mean (± SD) (km^2)**	**Range (km^2)**	**Mean (± SD) (km^2)**	**Range (km^2)**
Wet	45.76 ± 23.666	22.62 – 69.92	118.20 ± 48.083	74.70 – 169.83
Dry	55.06 ± 31.815	55.33 – 102.10	87.00 ± 56.277	83.25 – 195.50

2.4.2 Sex

We found that the giraffe did not show a significant difference in MCP home range sizes between sexes in the dry season (Mann Whitney test; p = 0.755). We also found that the KDE core utilisation areas did not show a significant difference between the sexes in the dry season (Mann Whitney test, p = 0.8763; Fig. 2.1). The mean home range size (± SD) MCP for males was 61.14 ± 37.749 km^2 and 46.53 ± 22.152 km^2 for females. The mean core area utilisation KDE for males was 20.91 ± 16.545 km^2 and 12.80 ± 6.071 km^2 for females.

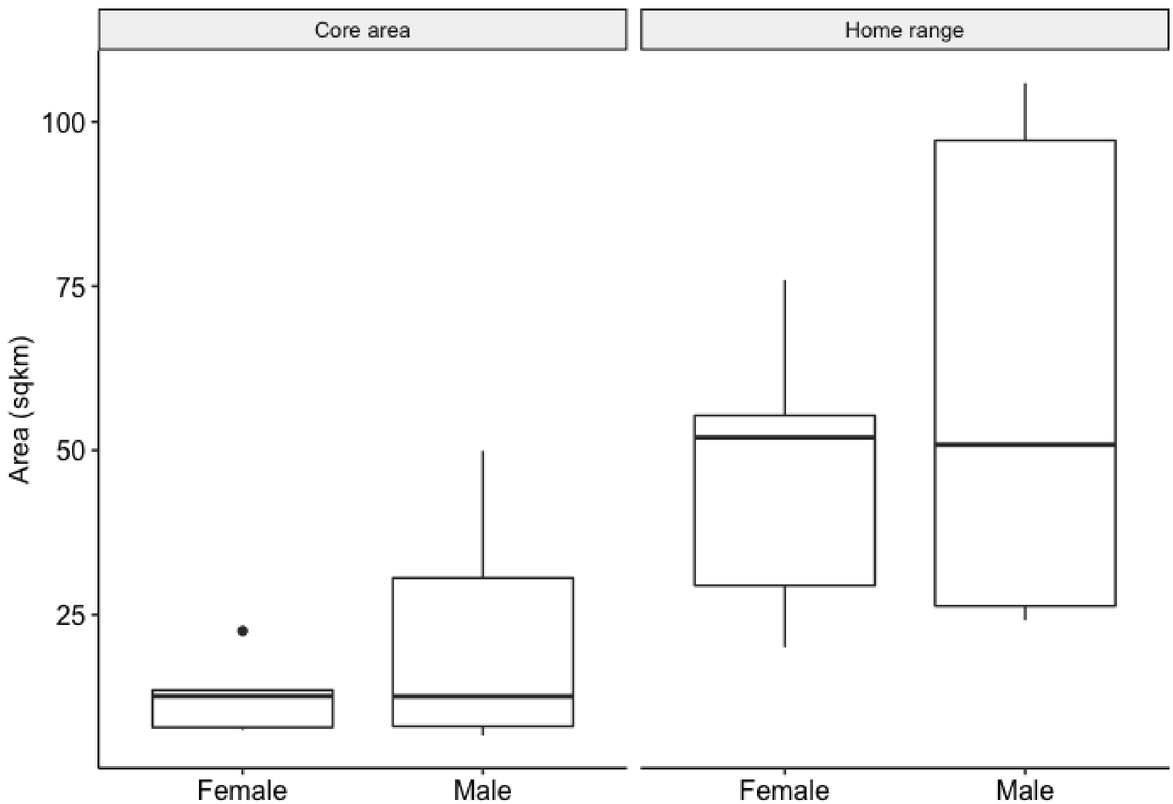

Figure 2.1: Differences in MCP home range sizes and KDE core area utilisation of male and female giraffe in the present study.

2.5 Discussion

The vegetation in the study area had considerable populations of evergreen trees, mostly *B. albitrunca* and *Olea europaea* subs. *africana* which are characteristic of Thukela vegetation (pers. obs.). The giraffe settled in certain parts of the study area with high populations of the evergreen trees in the dry seasons (pers. obs.). During the wet seasons, the giraffe did not decrease their home ranges despite the availability of deciduous trees provided food, including their preferred *Vachellia* species (pers. obs.). Giraffe in the present study appeared to favour riparian areas along the Thukela River because of the availability of browse in both seasons (pers. obs.).

Giraffe are non-territorial herbivores whose home range sizes will fluctuate according to resource availability (Dagg 2014). Food availability is an essential resource that directly influences giraffe home range sizes, and this resource is affected by seasonality (Kneusel et al. 2019). In the dry seasons when food availability and quality are low, giraffe either congregate around a permanent food source or frequently move large distances to find food (McQualter et al. 2015). In the present study, the giraffe did not show significant differences in the respective mean MCP (95), and KDE (95) home range sizes between wet and dry seasons. The vegetation in the present study area has considerable populations of evergreen trees. We found that the giraffe used the habitat in certain parts of the study area with relatively high populations of evergreen trees in the dry seasons. During the wet seasons, the giraffe did not decrease their home ranges despite the availability of deciduous trees which provided food, including their preferred *Vachellia* species.

Our study area was bordered by 8 km of Thukela River. Giraffe are not dependent on water, and they can go days without drinking water, using moisture from browse to sustain them (Okello et al. 2015). Despite this, the giraffe in the present study probably favoured riparian areas because the trees in the area obtained moisture from the river of the and could provide browse during both seasons. This influenced the giraffe home ranges as the giraffe could drink at any time without having to travel long distances to feed or drink.

Giraffe follow a fission-fusion social system where herd size and composition are constantly changing, with closely related females forming the core of the herd (Deacon and Bercovitch 2018). Adult bulls follow a roaming mating strategy where they move around looking females that are ready to mate all year round (Van der Waal et al. 2014). Giraffe bull home ranges are larger than cows' home ranges because of this strategy (Fennessy 2009). In the present study, the home ranges sizes did not show a significant difference between the sexes in the dry season. The bulls did not move large distances which may have been a consequence of the number of bulls in the area. Only the dominant bulls mate with the cows and the tagged bulls were not dominant. These males established home ranges and did not move large distances to find females. Another probable reason for the restricted movement could have been the study area being an enclosed environment.

Male giraffe create all-male herds where non-dominant bulls of different ages congregate (Bercovitch and Berry 2015). These all-male herds are used for information transfer to the younger animals and to protect them from the dominant bulls (Bercovitch and Berry 2015). The creation of all-male herds possibly also had an influence on home range sizes. In all-male herds the male giraffe did not roam as much as dominant bulls in other areas. The all-male herds followed the same pattern as the breeding herds, which was to find a suitable home range that provided food and water without having to move large distances to achieve that.

Contrary to our predictions, there were no differences in the giraffe home range sizes during the different seasons. The feeding behavioural plasticity shown by the giraffe during the different seasons were responsible for the home range sizes observed. The bulls also did not have larger home ranges than the cows as predicted. This was likely because of herding strategies and dominance amongst individuals.

2.6 Acknowledgements

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2.7 References

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2.8 Supplementary information

Supplementary information Figure S2.1: GPS UHF transmitter fastened onto giraffe ear in the present study.

CHAPTER 3

Seasonal changes in habitat use by South African giraffe across a land-use mosaic in central KwaZulu-Natal, South Africa

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Running header: Habitat use of giraffe

3.1 Abstract

Animals occupy certain areas because of the availability of resources. This area is termed as their habitat and animals find different uses of the resources within their preferred habitats. We investigated seasonal habitat use of the South African giraffe (*Giraffa camelopardalis giraffa*) across a land-use mosaic in central KwaZulu-Natal, South Africa. The study area was ~5000 ha unfenced area near Weenen, with three land-use types namely the Zingela Conservancy (Thukela Valley Bushveld vegetation), the Kusa communal land (Thukela Valley Bushveld/ Thukela Thornveld vegetation) and the Emaweni Game Hunting Ranch (Thukela Thornveld vegetation). We assessed habitat use of the giraffe by fitting Ecotone transmitters on the ears of 12 giraffe. These transmitters sent Global Positioning System (GPS) geographical location coordinates for each tracked individual every 6 h following which we were able to map the giraffe' movements across the three land-use types, indicating the different areas used by the giraffe at different times of the year. We found that the giraffe selected an area of higher browse availability in the dry seasons. The giraffe also were observed in an area with higher possibilities of anthropogenic interaction. Giraffe habitat use was influenced by browse availability and quality more than anthropogenic interactions

Keywords: GPS tracking, habitat use, South African giraffe, land-use gradient, browse availability.

3.2 Introduction

A habitat has been described as available resources and optimum conditions that allow an organism to survive and reproduce, thereby leading to occupancy of the area (Hall et al. 1997; Krausman & Morrison 2016). These resources include food, water, availability of mates and in some cases are site-specific such as perches to sing on for birds (Bamford & Calver 2014). Due to the importance of finding a suitable habitat, habitat selection in animals is an on-going process of evaluating trade-offs (van Beest et al. 2012). The evaluation of trade-offs is based on maximising fitness which is largely influenced by maximising energy intake and ultimately avoiding mortality (Railsback & Harvey 2002). The animals follow a pattern of habitat use which relates to how the animal then uses the resources found in the habitat it has selected (Lele 2013).

Many factors influence habitat use, such as the spatial arrangement of resources and climate-induced environmental changes (Lawson & Rodgers 1997; Freitas et al. 2015). Climate-induced environmental changes mean that an animal's requirements may vary according to seasons, and this will affect habitat use (Krausmann 1999). Food quality and quantity control herbivore reproduction as peak maternal demands are aligned with peak plant nutritional output (Ogutu et al. 2014). Therefore rainfall has a direct influence on herbivore populations as it controls available plant biomass and nutrient concentration (Bartzke et al. 2018).

Giraffe (*Giraffa camelopardalis*) show variations in movement, home range size and habitat use which are controlled by rainfall amongst numerous other factors (Knusel et al. 2019). Seasonal rainfall also leads to changes in the phenology of plant species (Deacon 2017). Due to their high bioenergy needs, giraffe habitat use is then controlled by food availability and quality which leads to adaptations to their diet during different seasons (Fennessy 2009). Giraffe have shown different diet preferences in response to life stage changes (Muller et al. 2020). For example, they show a preference for *Vachellia* species and high protein content tree species during lactation and growing stages which influences their use of different habitats (Muller et al. 2020). Although they are mostly water independent, water availability can impact on giraffe habitat use by influencing herd distribution and structures as the animals will avoid habitats with watering holes overpopulated by other giraffes and predators (Deacon & Smit 2017; Muller et al. 2020).

Another factor affecting some giraffe populations' habitat use is human habitation (Knusel et al. 2019). Giraffe will avoid areas with human settlements, travelling longer distances to obtain resources in other habitats (Knusel et al. 2019). This is partly because human habitation of giraffe habitats has been shown to lead to a rise in giraffe poaching cases to supply the bushmeat trade (Okello et al. 2015). Anthropogenic habitat destruction and fragmentation are also part of the leading causes of giraffe numbers declining in Africa, and these have a direct impact on giraffe habitat use as trees are typically felled to clear space for farming practices and fuel (Muller 2018).

We investigated the habitat use of South African giraffe (*G. c. giraffa*) in a land-use and vegetation mosaic in central KwaZulu-Natal, South Africa. We predicted that the giraffe would avoid areas with the possibility of anthropogenic interaction, i.e. communal land. We also predicted that the giraffe would move to an area with higher browse availability in the dry season.

3.3 Methods

3.3.1 Study area

Our study was conducted in central KwaZulu-Natal, South Africa. It included three land-use types namely Zingela Conservation area (28º 43.035 S 30º 03.800 E; 1200 ha), Kusa Kusa Communal Area (24º 43.194 S 30º 00.093 E; 1500 ha), and Emaweni Game Hunting Ranch (28º 42.209 S 30º 01.0303 E, 2000 ha). The total study area was ~5000 ha of unfenced land between Weenen and Colenso. These three land-use areas are adjacent to each other but have different types of land-use and vegetation types. Zingela is a conservation area that is Thukela Valley Bushveld vegetation, dominated by *Vachellia* tree species and *Blepharis subvolubilis* undergrowth. Emaweni is a private game hunting that has Thukela Thornveld type vegetation which is dominated by a mix between turpentine (*Cymbopogon caesius*) grassland and *Vachellia* species. thorn land. Kusa Kusa is a communal area which is between the two farms and has vegetation that is a mixture of the two. The communal farmers in this area are mostly small-scale cattle and goat farmers. The area receives rainfall from October to March which is the wet season.

3.3.2 Sampling techniques

We captured 12 giraffe with the help of a qualified veterinarian and game capture pilot in July 2019 (Chapter 2). The giraffe were sedated with a 2 cc 6.35 cm 13G needle administering 15 mg of Etorphine hydrochloride (M99 Reckitt) (Wildlife Pharmaceuticals, White River, South Africa). When the animal had been sedated, a team of three people sat on the neck of the giraffe to prevent it from getting up. Ablindfold was put over the animal's eyes to protect them from direct sunlight. The veterinarian immediately injected it with 150 mg of Naltrexone (Wildlife Pharmaceuticals, White River, South Africa) to reverse the effects of the tranquiliser. We used plastic ear tags to fasten Ecotone Global Positioning System (GPS) Ultra High Frequency (UHF) transmitters (Ecotone Telemetry, Poland) weighing less than 25 g on the giraffe' ears. The transmitters recorded and sent the animal's GPS geographical location co-ordinates to a server over a cellular network (GSM). The *csv file containing this information was read through the Ecotone telemetry online panel. The game capture process took approximately 15 min. per giraffe from sedation to release. Five cows and seven bulls were selected from different herds, and vulnerable animals such as young calves and heavily pregnant females were avoided (Bennitt et al. 2019). Data were collected from July 2019 to July 2020.

3.3.3 Data analyses

We sorted the received GPS co-ordinates according to the months they were received. We split the data into two seasons, wet and dry seasons. A map of the vegetation types in the habitats was created using ArcGIS version 10.7 and the 2018 South African vegetation map. The 2018 South African land-use map was also used to create a map of giraffe movements in the land-use mosaic. The Ivlev Selectivity Index was used to evaluate the habitat selection where r_i is the percentage of habitat i used by one individual and n_i is the percentage of habitat i available in the study area (Ivlev 1961; Hanzen 2019). The selectivity index ranges from -1 (avoidance) through 0 (non-selection) to +1 (complete selection).

3.4 Results

We observed that the giraffe selected the Thukela Valley Bushveld in the dry season (0.000365) and avoided the Thukela Thornveld (-0.371) (Table 3.1). In the wet season, we observed the giraffe selecting the Thukela Thornveld (0.171) and avoiding the Thukela Valley Bushveld (-0.279) (Table 3.1). The giraffe used the Thukela Thornveld more in the wet season and the Thukela Valley Bushveld in the dry season (Figure 3.1). We observed the giraffe moving into areas with a high possibility of human interaction (Kusa Kusa) throughout the year (Figures 3.2 and 3.3).

Table 3.1: Habitat selectivity indices according to seasonality for the giraffe in the present study.

Habitat Type	Percentage use	Season	Selectivity index
Thukela Thornveld	0.262	Dry	-0.371
Thukela Thornveld	0.807	Wet	0.171
Thukela Valley Bushveld	0.738	Dry	0.000365
Thukela Valley Bushveld	0.193	Wet	-0.279

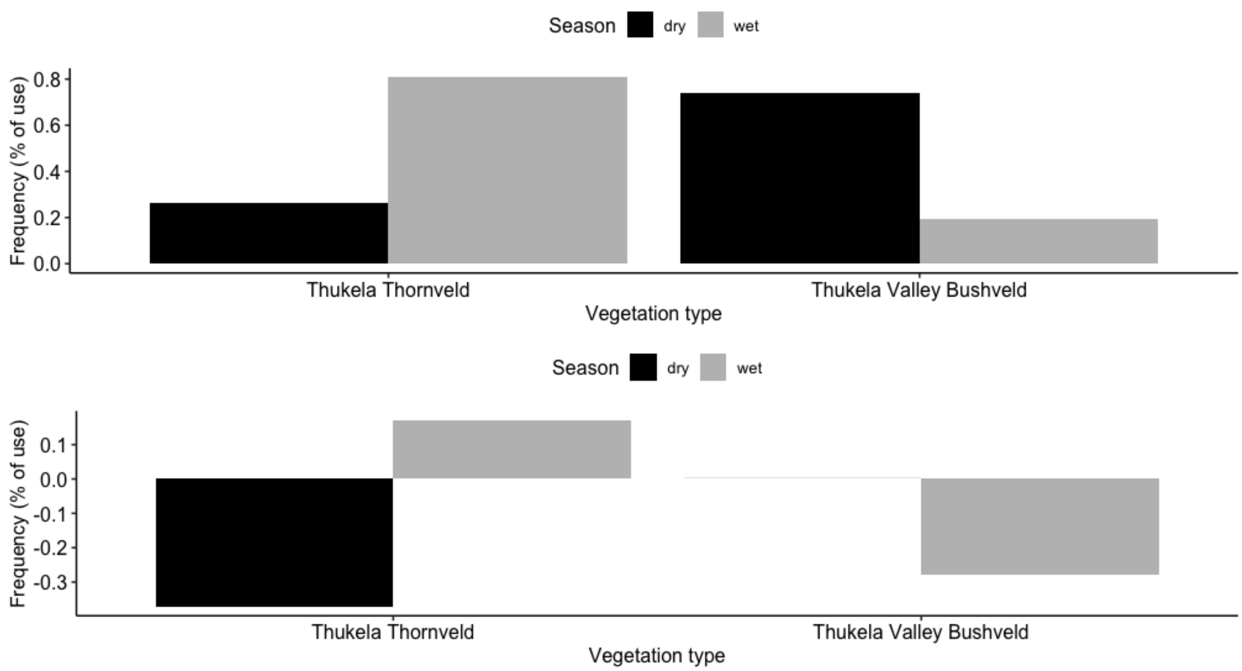

Figure 3.1: Habitat selection and avoidance by the giraffe in the present study as a consequence of seasonality.

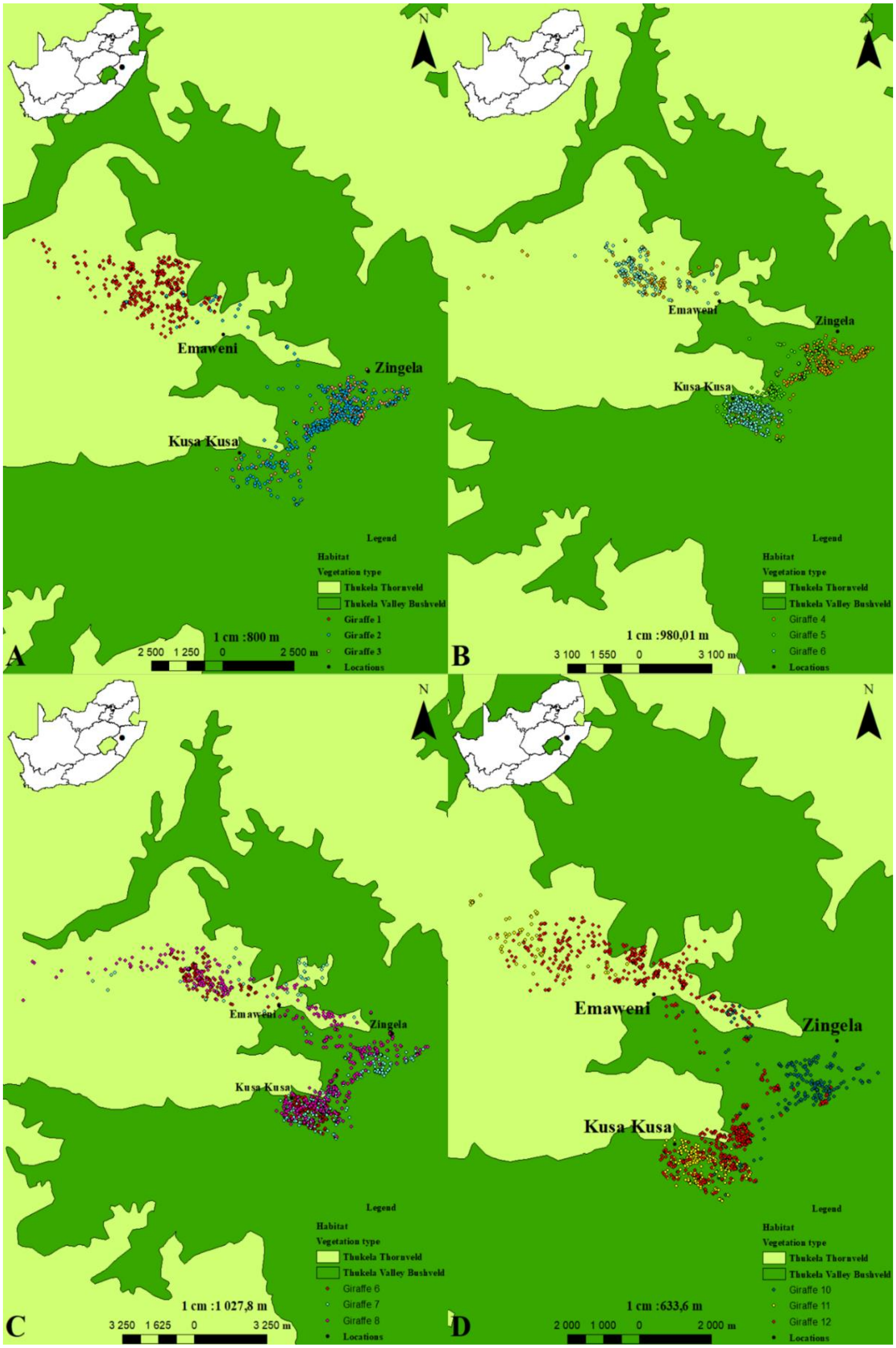

Figure 3.2: Giraffe habitat use in areas of varying land-use and vegetation in the present study.

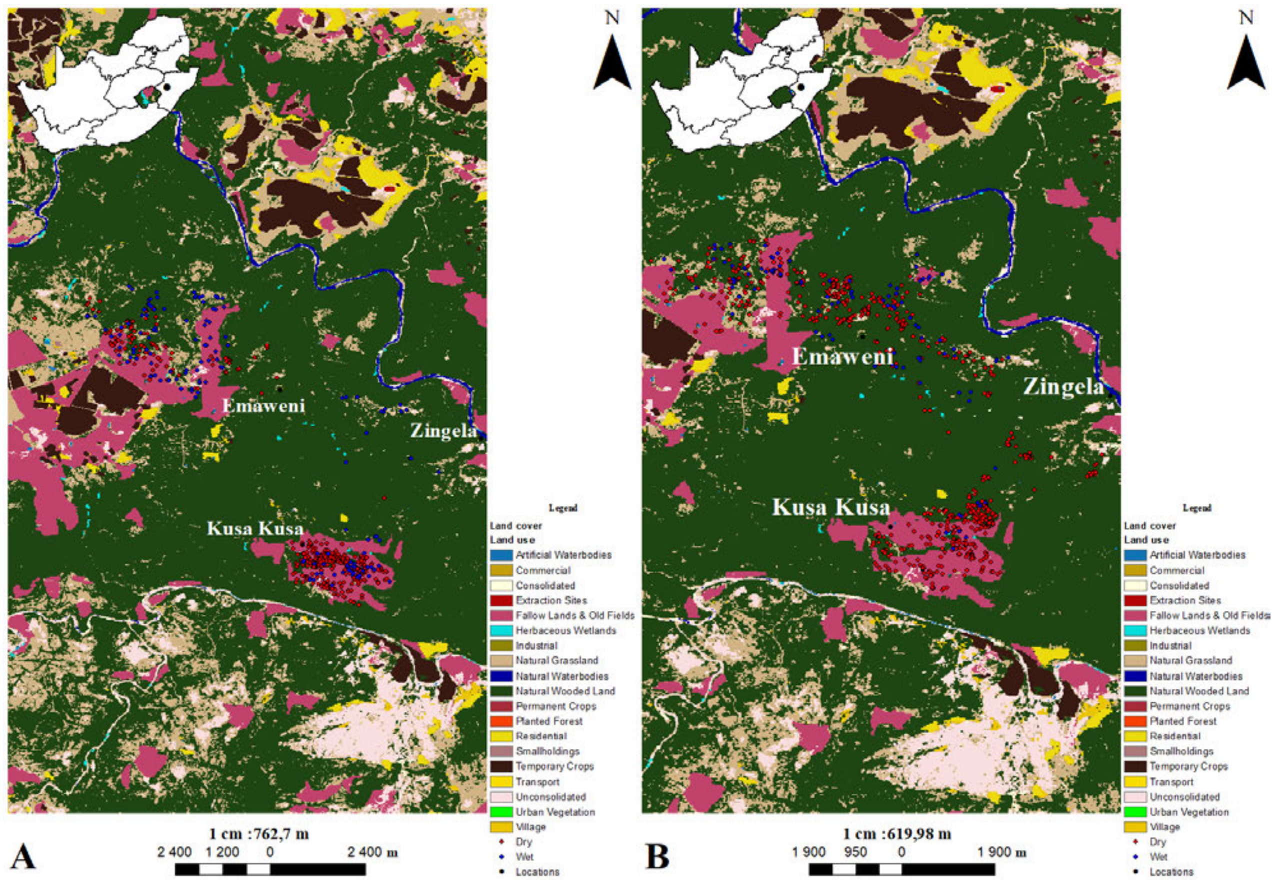

Figure 3.3: Giraffe habitat selection by land use during the different seasons in the present study.

3.5 Discussion

One of the reasons for a shift in giraffe habitat use is browse availability (Deacon and Parker 2016). Deciduous trees, including the giraffe' preferred *Vachellia* species, shed their leaves in the dry seasons which leads to a reduction in browse availability and quantity. Giraffe adapt to this shift in the browse nutritive value by adjusting their diet to cope with their bioenergy needs. The diet flexibility involves the inclusion of evergreen and semi-deciduous tree species (Berry and Bercovitch 2016).

Our study area was made up of areas with Thukela Valley Bushveld and Thukela Thornveld vegetation. The Thukela Valley Bushveld is dominated by *Vachellia* species of different heights and evergreen tree species such as *Boscia albitrunca* and *Olea europaea* subs. *africana* whilst the Thukela Thornveld is dominated by *Vachellia* species of varying densities and dense grassy undergrowth (Weenen 2013). We found the giraffe selected the Thukela Valley Bushveld in the dry seasons and avoided the Thukela Thornveld (Table 3.1). In the wet seasons, they selected the habitat in Thukela Thornveld vegetation more than habitat in the Thukela Valley Bushveld vegetation (Table 3.1). The less preferred habitat is noted by the negative selective indices (Kong et al. 2018). The giraffe probably selected the Thukela Valley Bushveld in the dry season because of the evergreen trees such as *O. europea* subs. *africana* and the semi-deciduous trees such as *Spirostachys africana* that are present in this vegetation type. The giraffe then used less of the Thukela Thornveld area in the dry season probably because of the decreased browse availability. However, they selected it in the wet season because of the availability of *Vachellia* species in leaf that dominate the Thukela Thornveld vegetation which provided them browse. The *Vachellia* trees at Emaweni Game Hunting Ranch started producing foliage earlier in the wet season than the populations in Zingela and Kusa Kusa, and the new higher quality browses available probably influenced the giraffe to change habitats (pers. obs.).

Hunting is a significant revenue generator in South Africa as hunters pay for licences to shoot animals with trophy characteristics such as large horns (Saayman et al. 2018). Emaweni is a Game Hunting Ranch where most of the hunting on the property is conducted in the dry seasons. The giraffe probably further avoided the area in the dry seasons because of the hunting activities. The probabilities of anthropogenic interaction are increased at Emaweni in the dry seasons. The absence of large carnivores meant that the only potential predation encountered by the giraffe was from human beings. This could be a further reason for the giraffe selecting the Thukela Valley Bushveld vegetated area in the dry seasons.

We also observed the giraffe choosing to use an area with the highest probability of anthropogenic interaction which was the Kusa Kusa communal area in our study area. The giraffe used this habitat throughout the year. This was likely because of the availability of water in the impoundments/ dams that supply water for the domestic livestock owned by the subsistence farmers in the area. The giraffe' used these water sources, which was supported by sightings of the giraffe at the dams. These dams are the only available water sources besides the river in the Thukela Valley Bushveld vegetation area which the giraffe preferred in the dry season. Although giraffe are not water-dependent, as is evidenced by populations in arid areas such as the Namib Desert, water availability is a factor in giraffe movements and therefore in habitat selection (Knusel et al. 2019).

The giraffe moved to areas with a high possibility of anthropogenic disturbances which was contrary to our first prediction. Our second prediction was supported as the giraffe chose to move to an area with higher browse availability in the dry seasons. Habitat selection by giraffe is influenced by browse availability and quality more than any other factor.

3.6 Acknowledgements

We are most grateful to the Calverley family for letting us conduct the study at Zingela and be based there. We would also like to extend our gratitude to the community of Kusa Kusa and the management at Emaweni Game Hunting Ranch for letting us conduct the study in their respective areas. We are most grateful to L. Ilizsko for awarding the grant that provided the 12 transmitters made by Ecotone Telemetry and partial costs of game capture. We thank the University of

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CHAPTER 4

Seasonal changes in South African giraffe feeding behaviour in central KwaZulu-Natal, South Africa

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Running header: Feeding behaviour of giraffe

4.1 Abstract

To survive, animals need to obtain sufficient food during different seasons. Seasonality influences food availability and quality. Animal feeding habits and diet change according to the changes in their food source. As browsers, South African giraffe (*G. c. giraffa*) must make feeding behaviour changes between wet and dry seasons. We investigated aspects of the feeding behaviour and habits of giraffe in Zingela Conservancy, in central KwaZulu-Natal, South Africa, during different seasons by conducting field observations during 2019-2020. We found that the giraffe fed on 11 plant species and chewed bones (osteophagy). Using the Shannon Weiner index, we found that giraffe showed significantly higher dietary diversity in the dry season than the wet season with significant differences in feeding habits between seasons. *Vachellia tortilis* leaves were fed on the most during both seasons whilst *Spirostachys africana* was fed on extensively during the dry seasons and not recorded during the wet seasons. Giraffe showed behavioural plasticity with seasonal changes in browse availability and quality by changing their diets to include more species in the dry seasons.

Keywords: Dietary diversity, preference, *Vachellia tortilis*, feeding habits, osteophagy

4.2 Introduction

Trees are typically divided into two categories according to strategies to cope with resource variations in the areas they are growing in (Hasselquist et al. 2010). Deciduous trees dominate areas where there is a marked seasonal difference in resource availability and quality (Bai et al. 2015). They shed their leaves in the less favourable seasons while evergreen trees retain their leaves throughout the year (Tomlinson et al. 2013). These changes undergone by trees during different seasons influence the herbivores that feed on the trees (Munyaka & Gandiwa 2018).

In 2015, giraffe (*Giraffa camelopardalis*) numbers had decreased by over 40% in 30 years, with extinctions in some African countries (Muller et al. 2018). Feeding behaviour studies are essential when considering conservation measures such as translocation of certain species and how the species would affect the ecosystem of the release site (Parker & Bernard 2005). Forage quantity and quality are crucial factors to be investigated concerning giraffe translocations (Muller et al. 2020). The vegetation found in the release area and giraffe feeding behaviour are two of the most important variables to be considered to improve translocation success rate (Muller et al. 2020).

South African giraffe (*G. c. giraffa*) are large herbivores that are exclusively browsers that prefer to feed mostly on *Vachellia* species. which are deciduous tree species (Deacon & Parker 2016). These trees lose their leaves in the dry season, reducing the availability of the giraffe' preferred food source and highlighting the effect seasonality has on them (Fennessy 2009). To achieve their large bioenergy needs, giraffe show plasticity in their diet diversity to maintain their fitness during different seasons (Berry & Bercovitch 2016). These ruminants widen their dietary range to include a variety of additional tree species in the drier season to meet their nutritional requirements, and the ranges generally vary according to the vegetation type that the giraffe occur in (Berry & Bercovitch 2016). For example, giraffe in the Kalahari Desert feed on 20 plant species while in the Serengeti, they feed on 45 plant species (Pellew 1984; Deacon 2015). Food quality is an important factor that as the giraffe choose alternative food sources to the deciduous trees which shed their leaves in the drier seasons (Munyaka & Gandiwa 2018). Giraffe diet has been observed to switch from deciduous trees to less nutritious evergreen trees in dry seasons to obtain moisture and maintain energy (Fennessy 2004; Gordon et al. 2016).

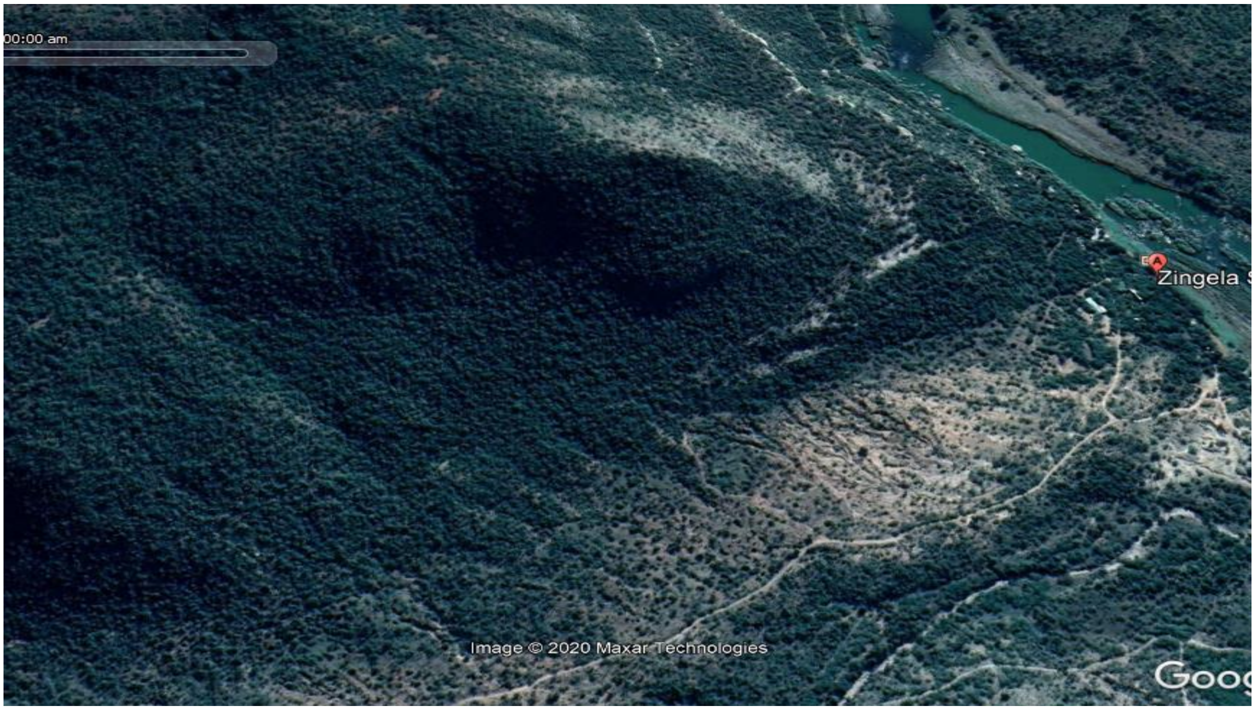
Therefore, we investigated differences in giraffe feeding habits in a study area in KwaZulu-Natal with a range of anthropogenic land-uses and with distinctive seasons. We predicted that the giraffe would have a wide-ranging diet in terms of tree species fed on during the dry seasons compared with the wet seasons.

4.3 Methods

4.3.1 Study area

We investigated the feeding habits of giraffe at Zingela Safari and River Company (28º 43.035 S 30º 03.800 E; ~2000 ha) which is a conservation area in central KwaZulu-Natal, South Africa (Fig. 4.1). The area receives seasonal rainfall between 600 – 1000 mm (Kleynhans et al. 2005). The wet season runs from October to March, with the dry season running from April to September. The vegetation in the study area is dominated by *Vachellia* trees which are preferred by the South African giraffe population (Gordon et al. 2016). Evergreen trees are also present, with Shepherd's trees (*Boscia albintrunca*) being strikingly evident in the drier months together with *Olea europaea* subs. *africana*. The area also has semi-deciduous tree species, with *Spirostachys africana* being the most dominant. Large populations of *Aloe marlothii* are scattered over the property. The movement of the animals in the conservation area is unrestricted because of the area not being fenced. The Tugela River acts as geographical border and water source, covering 8 km of the border of the conservation area.

a.



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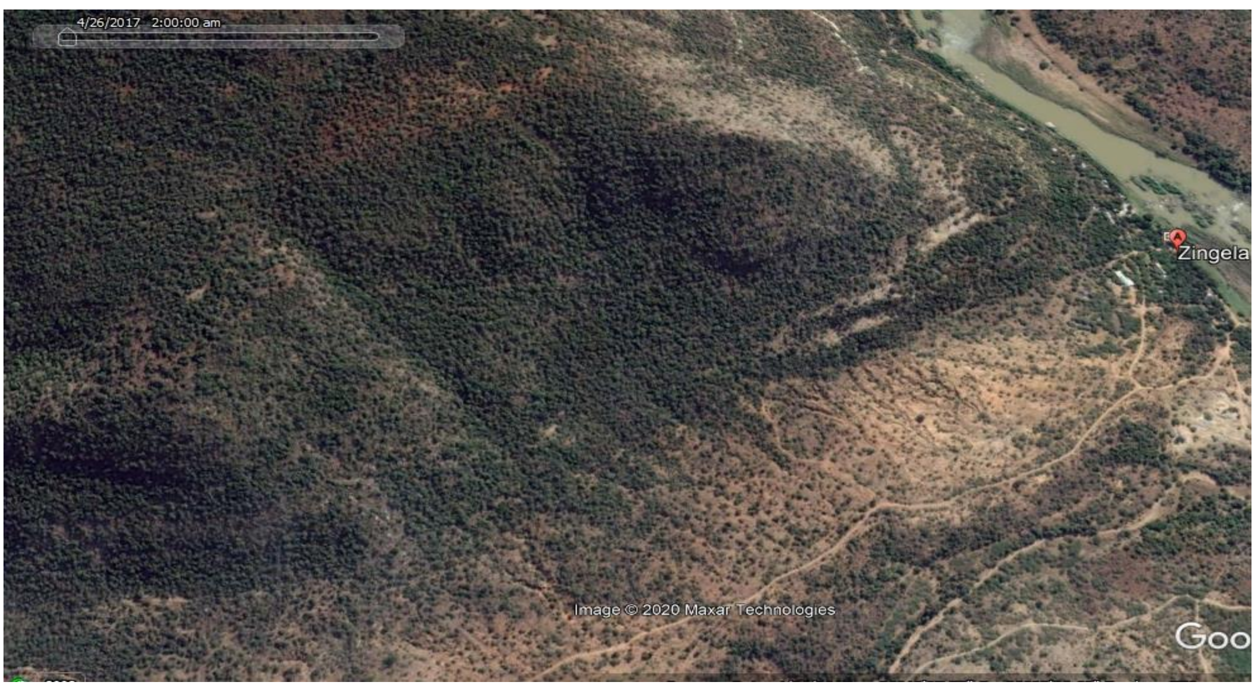

Figure 4.1: Aerial view of the study area in a. the wet season and b. the dry season.

4.3.2 Sampling techniques

To determine the forage selected by the giraffe, we located the animals on foot across the different sections of the property. Upon locating a herd, we conducted observations using binoculars (Nikon Aculon A211 8x42) from a distance greater than 20 m to avoid disturbing the animals. Observations were carried out from June 2019 to June 2020 for at least ten days each month. We found each giraffe herd randomly. We took the geographical location using a global positioning system (GPS Garmin eTrex 10 Handheld, Garmin, Lenexa, Kansas, United States). We noted and identified the trees fed on by the giraffe. Tree identification was confirmed using leaves and flowers (if available) from the trees the giraffe fed from. The trees were then identified using a guide tree book (Boon 2010). Individual giraffe were observed for 5 min. at a time which was considered a feeding behaviour (Makin et al. 2018). We also recorded any other feeding behaviours such as osteophagy.

4.3.3 Data analyses

We split the feeding observations into the two seasons, dry and wet, according to the months of observation. We calculated the Shannon Weiner dietary diversity index $\mathrm{H}' = -\sum_{i=1}^{n}[pi \times \ln(pi)]$ using Microsoft Excel for both seasons. Species found in one season and not the other were recorded as contributing 0% in the season they were not found in (Berry & Bercovitch 2016).

We used a Pearson's Chi-squared test with a simulated p-value was to investigate the frequency distribution of plant species between the two seasons. The statistical analyses were performed using the statistical programme R 3.6.0 (RStudio 2015).

4.4 Results

We found the giraffe in our investigation fed on the foliage of 12 tree species in the dry seasons and eight in the wet seasons (Table 4.1). We also observed osteophagy in both seasons and bones were noted as a '**plant species'**. The giraffe fed on *Vachellia tortilis* more than any other species in both seasons. *Spirostachys africana*, *Pappeas capensis*, *Cadaba natalensis* and *Maytenus heterophylla* were not fed on in the wet seasons but were used in the dry seasons (Fig. 4.2). Our calculated dietary diversity using the Shannon Weiner index of diversity was more pronounced in the dry seasons (H' = 2.039) compared with the wet seasons (H' = 1.628). There was a significant difference in the frequency distribution of the dietary species across the two seasons (Pearson's Chi squared test, $X^2 = 36.857$, df = 11, p = 0.0001218).

Table 4.1: List of plant species and other dietary items fed on by South African giraffe at Zingela conservancy, central KwaZulu-Natal, South Africa, in the present study and season of use. (Note: arranged in alphabetical order by family).

Family	**Species**	**Dry season**	**Wet season**
Asphodelaceae	*Aloe marlothii*	Yes	Yes
Capparaceae	*Boscia albitrunca*	Yes	Yes
	Cadaba natalensis	Yes	No
	Maeurua angolensis	Yes	Yes
Celastraceae	*Maytenus heterophylla*	Yes	No
Euphorbiaceae	*Spirostachys africana*	Yes	No
Fabaceae	*Cassia abbreviata*	Yes	Yes
	Vachellia robusta	Yes	Yes
	Vachellia tortilis	Yes	Yes
Oleaceae	*Olea europea* subs. *africana*	Yes	Yes
Sapindaceae	*Pappea capensis*	Yes	No
Bones*		Yes	Yes

*not a plant species

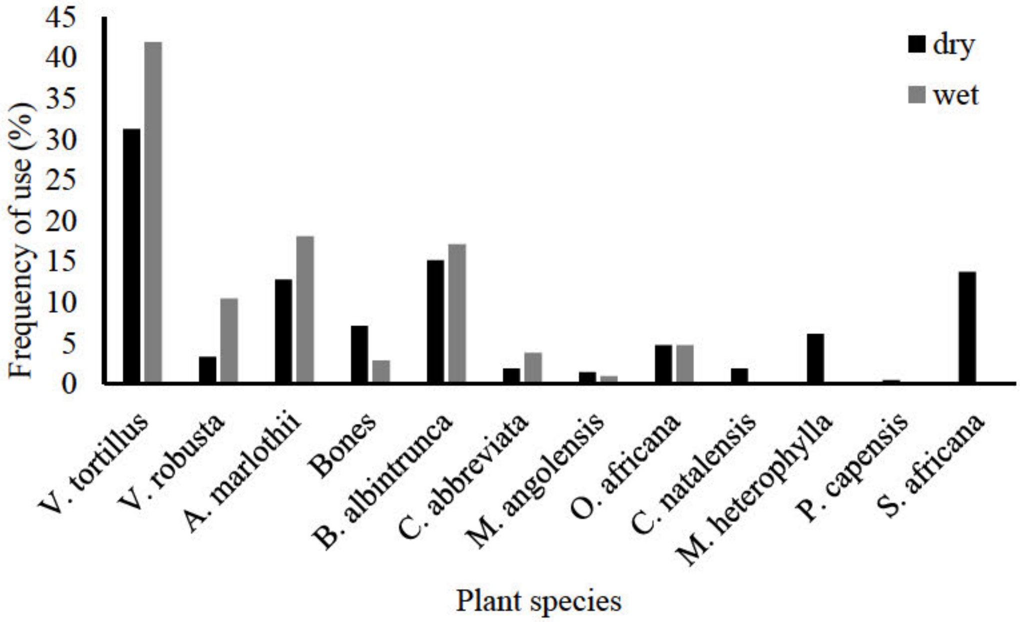

Figure 4.2: Frequency of tree species use and bone ingestion by giraffe in the wet and dry seasons in the present study. (See Table 4.1 for species names).

4.5 Discussion

We observed significant differences in giraffe feeding behaviour during the wet and dry seasons. Food availability has a direct impact on giraffe feeding habits (Fennessy 2009). The browse available to the giraffe is generally reduced in the dry seasons as deciduous trees shed their leaves (Thomlinson 2013). Giraffe are not specialist browsers, and their generalist browser behaviour is observed in the adaptations to their diet during different seasons (Berry & Bercovitch 2016). The animals increase their dietary diversity to maintain their fitness in the dry season when browse quantity and quality are reduced (Berry & Bercovitch 2016). The browse nutritive value is typically reduced in the dry season because of lower levels of growth and photosynthesis (Penderis 2012). The giraffe in the present study fed on more trees species in the dry seasons compared with the wet seasons, indicating the effort made to supplement the loss of browse from the plant species they fed on the most (Fig. 4.2). The giraffe included *C. natalensis*, *M. heterophylla*, *P. capensis* and *S. africana* in their diet in the dry season but did not feed on those species in the wet season. The tree species added to the diet allowed the giraffe to cater to their bioenergy needs in the dry seasons. Semi-deciduous trees like *S. africana* show high nutrient concentrations, especially for crude protein (Penderis 2012). Giraffe use this tree species to supplement the reduction of nutrients in their diet.

We also observed the giraffe feeding exhibiting higher levels of osteophagy in the dry seasons than in the wet seasons. Osteophagy refers to the eating of bones by herbivores and has thought to supplement calcium and phosphate in the giraffe' diet (Seeber et al. 2012). The mineral deficiency has been attributed to the low-quality foliage available in the dry seasons (Bredin et al. 2008). *Vachellia* tree species provide giraffe most of their required nutrients, including calcium whilst *B. albintruca* has relatively high magnesium levels (Ditlogo et al. 2020). These nutrients function as components of the bones in the animal's skeletal system and are essential to giraffe because of their size and structure (Bredin et al. 2008). In the dry season, a reduction in available browse from these trees may lead to deficiencies of these nutrients. The higher levels of osteophagy observations in the dry seasons compared with the wet seasons was probably a response by the giraffe to these deficiencies.

Seasonality has a direct influence on available browse as deciduous trees shed their leaves in the dry seasons. The lack of water leads to reduced photosynthesis and growth. Giraffe showed behavioural plasticity with seasonal changes in browse availability and quality by changing their diets to include more species in the dry seasons. This was as predicted. These changes in the diet of giraffe is a vital part of conservation efforts as a variety of tree species are required to support giraffe during different seasons.

4.6 Acknowledgements

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CHAPTER 5

Seasonal changes in South African giraffe social behaviour in central KwaZulu-Natal, South Africa

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Running header: Social behaviour of giraffe

5.1 Abstract

Social behaviour in animals looks at interactions between animals of the same species as they secure territories, find mates, raise their young and communicate. These interactions influence animal movements, and herd composition. South African giraffe (*Giraffa camelopardalis giraffa*) typically move in herds, adopting a fusion-fission system which leads to variable herd size and structure. Our study aimed to observe interactions between giraffe in the Zingela conservation area in central KwaZulu-Natal, South Africa, to explain the different sizes and structures of their aggregations. We conducted field observation between 2019-2020. We found that herd sizes differed significantly during the wet and dry seasons. Herd sizes were significantly larger during the dry seasons compared with the wet seasons. We found that adult bulls joined the herds more frequently in the wet seasons than in the dry seasons. We concluded that food quantity and quality in the different seasons was the main influence of giraffe social behaviour.

Keywords: Social behaviour, aggregations, herd sizes, adult bulls, interactions, fusion-fission.

5.2 Introduction

Animal social structures and behaviour have been an area of interest for scientists in past decades (Hughey et al. 2018). Animal social structures are built on various relationships between pairs of in a population (Carter et al. 2013a). This leads to the establishment of animal herdings for reasons such as to increase mating chances, increasing vigilance and improving foraging efficiency (Jolles et al. 2020). The herd sizes differ according to animals, species and even between populations of the same species, and it is still not understood why some of the differences are observed (Herbert-Read 2016). Several models have been put forward to try and explain observed differences in population dynamics by linking them to individual animal movements (Herbert-Read 2016).

Factors such as territory, food provision, encounter rates and energy balance have been suggested as an influence on the fluctuating animal herd sizes (Morales et al. 2010).

Giraffe (*Giraffa camelopardalis*) are large herbivores that live in herds for the duration of their life span of 20 – 30 years (Carter et al. 2013b). The herds show flexible fission-fusion dynamics which enable the animals to deal with any biotic or abiotic changes in their habitat (Van der Waal et al. 2014). Fission-fusion dynamics refers to the changes in herd size as members leave or rejoin the herd because of changes in certain resources utilised by the animals (Aureli et al. 2008). The temporary consolidation and breaking down of subherds is based on the kinship of the female members of the herds as closely related animals will associate with each other when joining or breaking away from the herd (Godde et al. 2015).

South African giraffe (*Giraffa camelopardalis giraffa*) also form herds that are typically based on strong bonds between females, with the dominant males adopting a roaming reproductive strategy (Berry and Bercovitch 2014). Non-dominant bulls generally leave herds to form all-male bachelor herds (Bercovitch and Berry 2014). Seasonality affects food resources which in turn influences social dynamics (Deacon and Bercovitch 2018). Dominant bulls move between herds seeking mating opportunities whilst cows are more influenced by familiarity and kinship in their fission-fusion dynamics (Bercovitch and Berry 2014; Deacon and Bercovitch 2018; Wolf et al. 2018). Giraffe herds typically increase in size during the wet season as there is an increase in food availability (Deacon and Bercovitch 2018).

We investigated differences in giraffe herd sizes and structure in a study area in central KwaZulu-Natal with distinctive seasons. We predicted that herd sizes would increase significantly during the wet seasons and decrease in size during the dry seasons. We also predicted that the bulls would be observed with the females in the wet seasons more than in the dry seasons.

5.3 Methods

5.3.1 Study area

We conducted the study between 1 June 2019 and 8 July 2020 at Zingela Safari and River Company (28º 43.035 S 30º 03.800 E) which is a 1200 ha wildlife conservation area. This area is unfenced and is bordered by the Tugela River. The vegetation at Zingela is Thukela Valley Bushveld (SVs 1) which is dominated by *Vachellia* species and *Aloe malorthii*. The area has large populations of tamboti (*Spirostachys africana*) and shepherd's tree (*Boscia albitrunca*) which are easily identifiable in the dry season by their strikingly colourful foliage. The hills in the area also have large populations of *Olea europaea* subs. *africana*. The area receives an average of 500 mm of rain every year between October and March, which is the wet season (Weenen Nature Reserve: Management Plan 2013). The dry season is between April to September.

5.3.2 Sampling techniques

We located the giraffe herds on foot in different parts of the conservation area. Observations were carried out ransomly three times a week. Individuals within an estimated 1 km radius were considered as being part of the same herd. We carried out a physical count from a distance greater than 20 m using binoculars (Nikon Aculon A211 8x42) so as not to interfere with the giraffe' feeding habits or to scatter the herd. We took the geographical location using a global positioning system (GPS) (Garmin eTrex 10 Handheld, Garmin, Lenexa, Kansas, United States). The adult males were noted in every herd, and the rest of the individuals were counted as a collective regardless of age. Individuals were identified using well known distinguishable features and their unique pelages, which remain unchanged through the giraffe's life (Shorrocks and Croft 2009).

Pictures of the giraffe' shoulders were captured, and we used Interactive Individual Identification System software (I3S Pattern version 4.02) to identify individuals (Calmanovici et al. 2018). The software maps out a triangular section of the pelage on the shoulder from the provided image. When the pattern had been saved in the database, it was used to compare to new images to establish the identity of the individual.

5.3.3 Data analyses

The data were split according to seasons, wet and dry. To test the differences in herd sizes during the different seasons, we herded all the individuals together regardless of sex. We conducted a Mann-Whitney U test to establish whether there was a significant difference between herd sizes.

We investigated the effect of the seasons on the social interactions between adult bulls and the rest of the herd members. The data on the number of bulls observed with each herd were split according to seasons, wet and dry. We used a Wilcoxon test to test whether there was a significant difference in adult bull numbers in herds between the seasons. All the tests were conducted using the statistics programme R 3.6.0 (RStudio 2015).

5.4 Results

5.4.1 Herd social behaviour

We found a significant difference between giraffe herd sizes in the wet and dry seasons (Mann Whitney test; $p = 0.01747$). We found that herd sizes were significantly larger in the dry seasons with the largest herd of giraffe comprised of 31 individuals (Fig. 5.1). The mean (± SD) herd size in the dry seasons was 13 ± 6 individuals and in the wet seasons 10 ± 3 individuals (Fig. 5.1). In the wet seasons, we observed the largest herd comprised of 16 individuals. The smallest giraffe herds we observed comprised of five individuals in the wet seasons and four individuals in the dry seasons.

Most of the giraffe in the study area gave birth in the wet seasons (pers. obs.). We observed the cows forming small temporary herds with their offspring from previous years together with the new calf. These temporary herds influenced the results as herds in the wet seasons were significantly smaller. These smaller herds were temporary until the giraffe calf was old enough to re-join the rest of the herd.

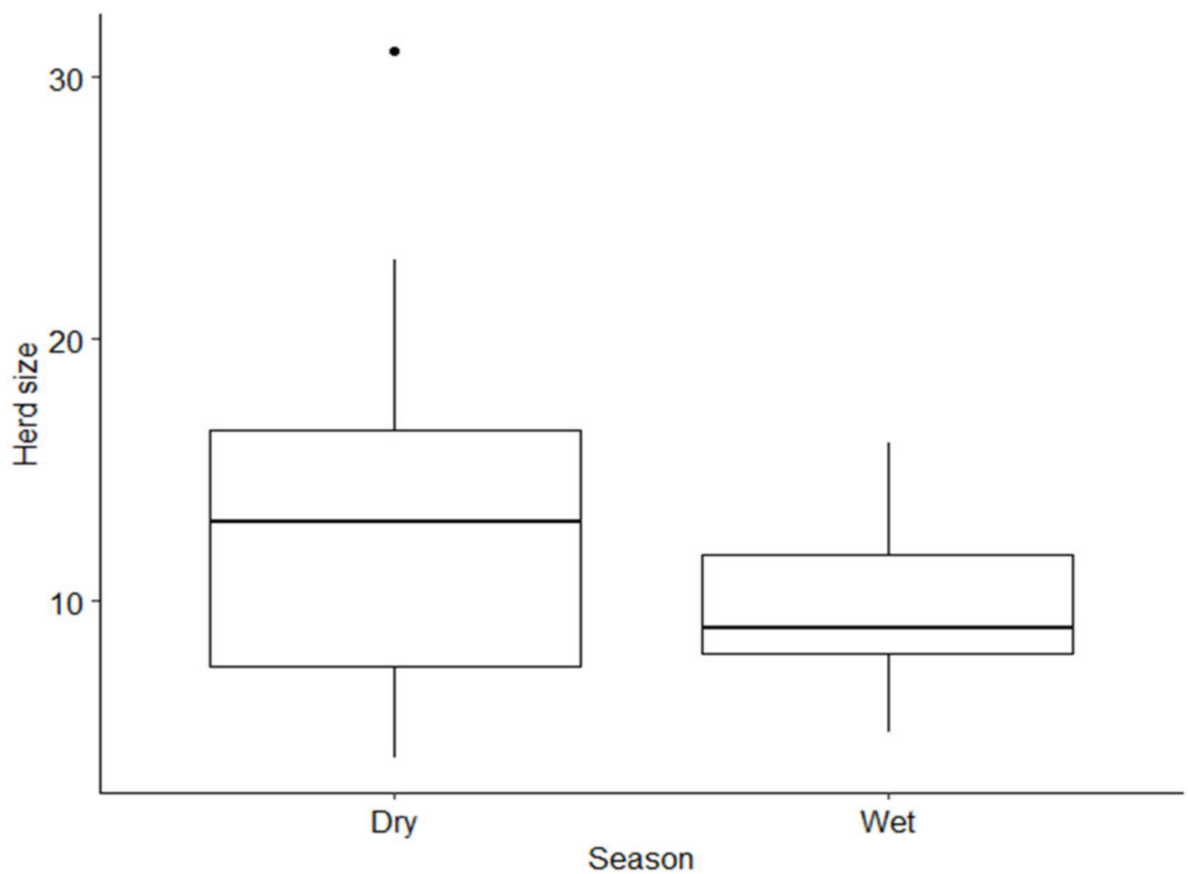

Figure 5.1: Giraffe herd sizes in the wet and dry seasons in the present study.

5.4.2 Bulls social behaviour

We found a significant difference in adult bulls interacting with the breeding herds between the two seasons (Wilcoxon test; $p = 0.009791$). We observed more adult bulls moving with herds in the wet season than in the dry season (Fig. 5.2). We observed six bulls moving with a herd in the dry season, which was the highest number observed across the two seasons.

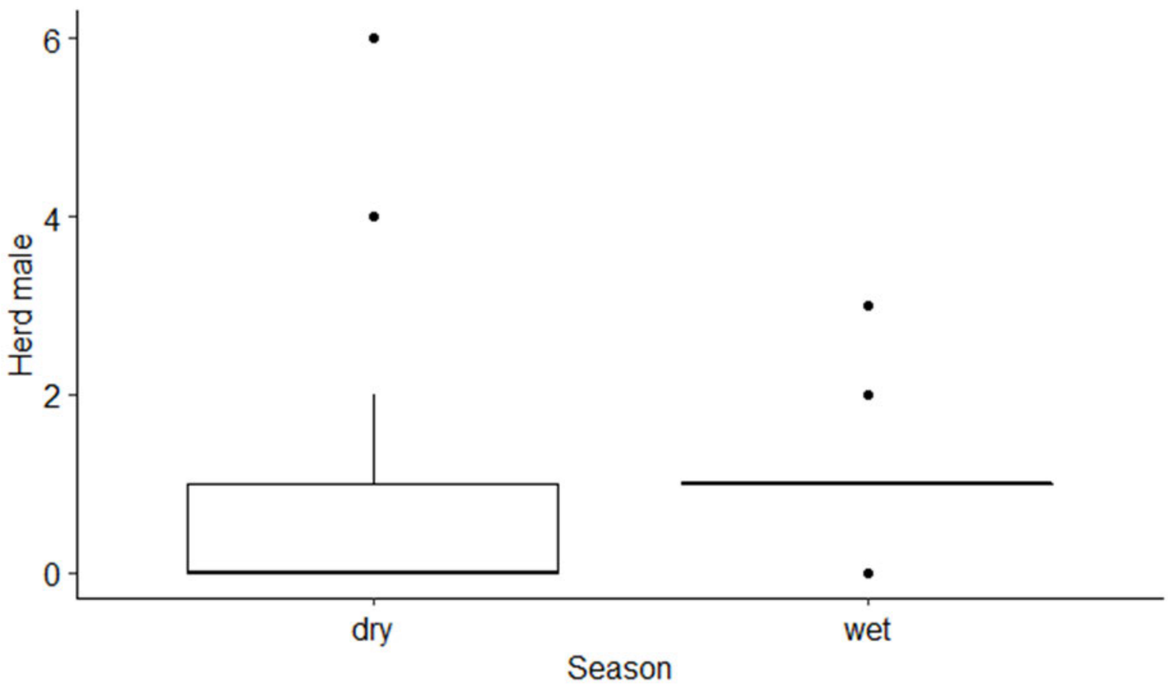

Figure 5.2: Number of giraffe males present in herds during the dry and wet seasons in the present study.

5.5 Discussion

South African giraffe move in herds whose sizes change because of different reasons, such as seasonality (Deacon and Bercovitch 2018). We found there was a significant difference in herd sizes during different seasons. Giraffe herd sizes on average were larger in the dry seasons compared with the wet seasons. The study area has relatively large populations of evergreen tree species such as *B. albitrunca* whilst the semi-deciduous *S. africana* trees in the study area do not shed all their leaves in the winter (Weenen Nature Reserve: Management Plan 2013). These trees provided most of the giraffe' food during the dry season, and individuals typically aggregate at these protein-rich food sources (Fennessy 2004). Giraffe increase their dietary plant diversity and utilise nutrient-rich food sources to supplement their diet in the dry season (Fennessy 2004; Berry and Bercovitch 2016). The conservation area in our study is bordered by 8 km of Tugela River frontage which provides the animals on the property with drinking water in the dry season. Access to a water source and a protein-rich food source in the dry season is probably the reason we observed larger herds in the dry seasons as found in other studies (Fennessy 2004). Giraffe follow fusion-fission social dynamics which means that herds continuously change in size as members join and leave the herd (Carter et al. 2012a). We observed this when the giraffe joined large herds during the dry season to forage on the best available browse in the area.

Giraffe give birth all year round after a gestation period of 15 months (Lee et al. 2017). A pregnant cow will move away from the herd for one to three weeks to give birth and on some occasions, have been observed to return to previously used birthing sites (Langman 1977; Muller 2018). We observed most of the giraffe in our study area giving birth in the wet seasons (pers. obs.). The cows formed small, temporary herds with their previous offspring and the new calf. We found that these temporary herds influenced the size of giraffe herds in the wet seasons, which were significantly smaller. These smaller herds were temporary until the giraffe calf was old enough to re-join the rest of the herd.

Giraffe show sexual segregation with dominant adult bulls employing a roaming mating strategy (Berry and Bercovitch 2014). The bulls move through herds searching for females that are in oestrus (Van der Waal et al. 2014). We observed more bulls moving with the herds in the wet seasons compared with the dry seasons because of most of the cows gave birth in the wet season (pers. obs.). The bulls moved between herds looking for females in oestrus even after they had recently given birth as giraffe are known to initiate reproductive cycling even in the early stages of lactation (Bercovitch and Berry 2009a,b). The bulls joined the herds as many of the females had given birth. The numbers of adult bulls in the same area was an indication of a relatively large number of females available for mating. A bull will typically find a receptive female and guard the cow, preventing other males from mating with this female (Bercovitch et al. 2006). This behaviour allowed other adult males to come into the area to find receptive females.

Adult giraffe bulls need high energy reserves as foraging time is generally reduced when they encounter a receptive female (Bercovitch et al. 2006). A bull will follow a receptive female to prevent other males from mating with the female (Bercovitch et al. 2006). The bull will eat with less frequency; therefore, a high-quality diet is required. The wet seasons in our study area typically have higher quality browse because of water availability (Penderis 2012). This mating behaviour explained the increased male numbers with the herds in the wet seasons as there were more receptive females with young calves. The increase in food availability and quality in the wet season probably enabled more bulls to move between more herds without losing fitness.

The giraffe in our study showed larger herd sizes in the dry seasons with a higher number of males observed with the females in the wet seasons. These observations were influenced by food resources. To implement effective conservation management strategies food availability and quality during seasons must be noted. Earlier studies showed giraffe herds increasing in size in the wet season (Bercovitch and Berry 2009a,b). Our study showed the herds being larger in the dry season, and this was because of food quality with individuals forming larger aggregations around protein sources. This showed that nutrient and vegetation assessments are important in shaping giraffe management decisions as they influence giraffe social dynamics.

5.6 Acknowledgements

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CHAPTER 6

Conclusions

6.1 Introduction

This chapter presents my research findings in relation to the objectives set out at the beginning of the study. Additionally, it provides management recommendations and directions for future research.

Anthropogenic land-use changes have been observed globally in response to the growing human population (De Fries et al. 2010; Nuissl and Siedentop 2020). These land-use changes are directly linked to changing large sections of natural land for the building of human settlements and agricultural purposes (Patra et al. 2018).). The clearing of land has a direct influence on wildlife as it is a form of habitat degradation (Symes et al. 2018). Habitat degradation is one of the main causes of wildlife extinctions and has led to many species being listed as vulnerable by the Internation Union for Conservation of Nature (IUCN 2010, Symes et al. 2018).

Globally, protected areas are at the forefront of conservation with wildlife protection from poaching and habitat degration a priority (Barnes et al. 2016). This conservation strategy has seen an increase in the population densities of threatened and protected species (Barnes et al. 2016). Besides protected areas, trophy hunting is another management tool that has been used to conserve wildlife (Muposhi et al. 2016). Hunters pay a fee to hunt animals for trophies such as horns with the money being used to maintain the areas in which these animals are kept and to sustain surrounding communities (IUCN 2016; Angula et al. 2018). The surrounding communities are usually communal land areas with subsistence farmers (Angula et al. 2018). In these areas wildlife, humans and domestic livestock share resources often leading to human-wildlife conflict (Gemeda and Meles 2018).

Giraffe are listed as a vulnerable species because of decreasing numbers across Africa (Muller et al. 2018). Habitat degradation, poaching and disease outbreaks are the leading causes of a reduction in the global giraffe population numbers (Strauss et al. 2015). The South African giraffe subspecies is listed as of "Least concern" because of increasing numbers (Muller et al. 2018). This subspecies has population numbers that are more easily accessible for investigations to be carried out on them to improve management strategies for the other subspecies. Home range sizes, habitat use, feeding behaviour and social behaviour are important aspects of giraffe ecology that require investigation to formulate management strategies especially in light of closed environments or areas with limited movements like in some of the areas of South Africa.

6.2 Research findings

The present study found that home range sizes did not show a significant differences between seasons nor sexes (Chapter 2). In similar studies, giraffe home range sizes have been influenced by factors such as food and water availability, food quality and proximity to human settlements (Fennessy 2009). The giraffe in the present study adjusted their home ranges with the food quality and quantity changes in their habitat. Deciduous trees lose their leaves whilst the general browse nutritive value decrease in the dry seasons (Penderis 2012). The giraffe in the present study maintained relatively similar home ranges during the wet and dry seasons (Chapter 2). This was because of the giraffe aggregated in areas with natural water sources and the vegetation required to satisfy their bioenergy needs during the different seasons. The animals likely minimised the sizes of their home ranges as much as possible to improve their fitness. Bulls and cows did not show a significant difference in home range sizes (Chapter 2). Although dominant bulls employ a solitary roaming strategy, they utilised home ranges that were similar to the cows. Management strategies for giraffe conservation should focus on browse availability and quality during the dry season. An area with evergreen and semi-decidous trees is important for the giraffe in the dry season (Chapter 2). The giraffe will have home range sizes that allow them to feed on this browse. The proximity of a water source to this area is important in order to reduce the home range sizes of the giraffe.

Changes in giraffe habitat used seasonally across a land-use mosaic were investigated (Chapter 3). The results indicated that habitat use is influenced by vegetation type, which influences browse availability and that giraffe will move to areas with the possibility of anthropogenic interaction (Chapter 3). Previous studies showed a shift in the diet in the dry seasons because of browse availability (Deacon and Parker 2016). Food quality and quantity are the main drivers in giraffe habitat use. Management strategies must focus on land-uses in areas that are part of the giraffe habitats or that border these habitats in closed environments. These browse availability during different seasons must be evaluated in order to predict the animals' habitat use to improve their fitness.

Seasonal changes in the feeding habits of South African giraffe were investigated (Chapter 4). There was a significant difference in giraffe feeding habits during the wet and dry seasons (Chapter 4). These results supported the findings that giraffe increased their diet breadth in the dry season to cope with the lower browse quality and quantity (Berry and Bercovitch 2016). The giraffe added more tree species to their diet including the semi-decidous *Spirostachys africana* (Chapter 4). The use of evergreen and semi-deciduous tree species in the dry season showed behavioural plasticity to cope with the decreased browse nutritive value. Vegetation assessments are important in giraffe management as the animals diversify their diets in the dry season. The classification of tree species that provide browse in the dry season will give insight into the survival of the animals. High availability of evergreen and deciduous tree species helps giraffe maintain their levels of fitness in the dry seasons.

Furthermore, seasonal changes in South African giraffe herding behaviour were investigated (Chapter 5). The giraffe showed a significant difference in herd sizes between the wet and dry seasons. These differences were influenced by food availability and quality. The animals aggregated at sources of high protein food sources with semi-deciduous and evergreen trees (Chapter 5). Giraffe follow fusion-fission social dynamics and this was evident as the animals formed temporary herds to use the best available food and water sources in the dry seasons (Deacon and Bercovitch 2018). Significantly more bulls were observed with the females in the wet seasons than in the dry seasons (Chapter 5). The availability of receptive females and high quality browse influenced the number of adult bulls joining the female herds. The availability of higher quality browse in the wet season allowed the bulls to follow their roaming mating strategy and also ensured theys had sufficient energy to guard the receptive females they encountered, as found in other studies (Bercovitch et al. 2006; van der Waal et al. 2014). Management strategies would therefore have to focus on the carrying capacity of areas as there would be an increase of numbers in certain areas during the dry seasons. Areas with higher quality browse during the dry seasons would experience an increase in giraffe numbers. The ability of an area to cope with an increased carrying capacity is important in formulating management strategies. The size of the giraffe' habitat is also important in management efforts. Older giraffe bulls are typically solitary animals, and a large area is needed to allow them to roam when they are not part of the breeding herds such as in the dry season in the present study. Giraffe bull numbers increased in the wet season, which implied that the bulls had different areas of foraging in the dry season (Chapter 5).

Management strategies in giraffe conservation should look to investigate giraffe ecology to establish optimum resource use and resource availability that supports viable populations.

6.3 Recommendations

Although a number of questions have been answered by the present study, there are still more questions that can be answered with improvements to the present study.

1. What is the average foraging distance from an available water source and what is the frequency of visits to the water source? A compilation of GPS co-ordinates from giraffe around the water source would help provide information on the effect of water availability on giraffe ecology.
2. What are the factors that influence calving site choice? Giraffe move away from their herds to give birth, and some have been observed to use the same calving sites across multiple birthing seasons. An investigation of these sites would help in allowing management strategies to be formed that would provide the giraffe with optimum calving conditions.
3. A survey of the attitude of communities in communal areas towards wildlife. This information would help explain the characteristics of giraffe ecology around communal areas.

6.3.1. Conclusions

This thesis provides information on aspects of the the ecology of South African giraffe across a land-use mosaic. The study sheds more light on habitat use, home ranges, social and feeding behaviours. These factors are important in formulating management strategies. The results are a reflection of the effects of seasonality on the ecology of the large herbivores. The recommendations of the study provide more information for current and future management solutions.

6.4 References

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