THE SPATIAL ECOLOGY, HABITAT PREFERENCE AND DIET SELECTION OF GIRAFFE (GIRAFFA CAMELOPARDALIS GIRAFFA) IN THE KALAHARI REGION OF SOUTH AFRICA

by

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ABSTRACT

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Key terms: giraffe**;** spatial ecology, diet selection, habitat preference, carrying capacity**;** management**;** seasonal movements.

The research project was conducted within two separate study areas. The main research project was conducted in the Khamab Kalahari Nature Reserve (KKNR) in the North West Province of South Africa. The main research project only commenced after the completion of a preliminary study that was conducted on the Woodland Hills Wildlife Estate in the Free State Province of South Africa. KKNR is situated in a remote portion of the Kalahari savanna and is 95 537.56 ha in size with an average rainfall of 333 mm. Vegetation types present are grassland, open thickets, dense thickets and areas that were previously treated with arboricides. In total, 11 plant communities were described, which were grouped into three major plant communities. Little is known of the environmental impacts on giraffe in this ecological region, and concern has been expressed regarding population numbers declining in KKNR.

The first objective of the research project was to develop and design efficient and safe GPS collars for giraffes. During a second phase of the study, a giraffe population in KKNR was studied with the objective of assessing their habitat selection and spatial ecology as influenced by season, habitat resources (browse and water) and plant species composition. The diet selection of giraffe in relation to browse availability, and changes in daily activities (feeding and non-feeding) over seasons were also studied. The final objective of the study was to establish management guidelines for giraffe in arid regions to ensure sustainability and to aid in future decisions to promote population growth amongst other sub-species in the rest of Africa.
Although the giraffe in the KKNR have free reign within the reserve of 95 653 ha and appears to have adapted well to their new surroundings, their numbers are still on the decline since their re-introduction. The distribution patterns of giraffe in the reserve were found to be strongly influenced by seasonal effects on vegetation, deciduous nature of woody species, provision of water and human impact on habitat persecutions and available browse for giraffe.

With the aid of the GPS collars it was established that the average daily distance travelled was 5.1 km, with females travelling for longer hours and distances during the winter months compared to other seasons. Average distances travelled fifer between seasons, with the lowest in autumn (5.05 km / day), and the highest in winter (5.75 km / day) with an average speed of 0.21 km / h. Giraffes in KKNR utilized an average home range of 206.0 km² (20

602 ha) to find sufficient forage to sustain their daily requirements. In the wet, hot season (summer) when food was abundant, giraffes frequented smaller areas (average 177 km²), while in the dry, cool season (winter) they extended their home range (average 245 km²) to fulfil their daily needs. Giraffes clearly favoured areas (53% of all recorded locations) that were selectively treated (more than 13 years ago) with arboricides, but avoided untreated bush thickened areas (underutilizing these areas by 62% compared to availability). Giraffes also avoided areas where most of the woody plants were cleared (underutilizing these areas by 233% compared to availability).

Giraffes in the KKNR preferred tree densities of 744 to 1 084 plants ha^{-1}, combined with a high (> 5 600) Total Evapotranspiration Tree Equivalent (ETTE ha^{-1}), where they can select very specific woody species to browse. *Acacia erioloba, Z. mucronata, B. albitrunca* and *A. mellifera* were the tree species most preferred, and are considered to be critical resource species, especially the evergreen *B. albitrunca*. These four woody species, combined, represent 93% of the giraffe diet of giraffe in KKNR, suggesting that giraffe are preferentially searching for these woody species, although they are not always the most abundant woody species available (36.2%).

Female giraffe feeds predominantly at a height of 3.0 m or higher, but this differed between tree species due to differences in size and growth from: 99% of female feeding occurred ≥3.0 m on *A. erioloba* (89%), ≥3.0 m on *A. mellifera* (70%), ≥3.0 m on *Z. mucronata* (90%) and >3.0 m on *B. albitrunca* (94%). Male feeding occurred ≥ 4.0 m on *A. erioloba* (90%), ≥4.0 m on *A. mellifera* (92%), ≥4.0 m on *Z. mucronata* (95%) and >4.0 m on *B. albitrunca.* Male and female giraffes were browsing on levels that largely excluded direct competition from other browsers (>2.0 m), especially during the dry season. Only 7% of all female feeding occurred below 2.0 m and only 19% of all male feeding occurred below 4.0 m.

Giraffes were further influenced by the seasonal cycle of tree phenology due to the winter deciduous nature of the majority of the tree species influenced. Results demonstrated that giraffes experienced difficulty finding preferred browse material during the critical dry period from July – October and they increase their home range in response. During this time (July – October), the availablility of areas that can be described as “critical resource areas”, such as *B. albitrunca*-abundant areas, had a significant ($P<0.05$) effect on the survival of giraffes during the pre-season dry period.

Giraffes also favour areas with high shoot availability (<2.0 mm in diameter) within the high preference areas (1 545 kg ha^{-1}), which is two times more than in the low preference areas (873 kg ha^{-1}), indicating that this is one of the main criteria influencing habitat selection other than tree species. Osteophagia as an activity of all giraffes was common during the winter (>500 recordings), indicating that the giraffes were in need of supplementary minerals during the dry season and that they were under nutritional stress.

Activity budgets indicated that 39% of time was spent related to non-feeding activities for all observations with female 36%, male 44%, sub-adult male 54%, sub-adult female 34% and juvenile 51% of time devoted to non-feeding activities. The key to the survival of giraffe in the Kalahari is proper management principles which are based on the habitat’s carrying capacity and by keeping numbers accordingly. The results indicate KKNR can sustain 4 512 browser units (BU) based on the biomass available below 2.0 m and 9 765 BU if browse between the 2.0 m and 5.0 m strata are included.

DECLARATION

I declare that the dissertation hereby submitted by me for the partial fulfilment of the requirement for the degree of Doctor of Philosophy (Wildlife Science) at the University of the Free State is my own independent work, and has not been submitted by me to any other university/faculty. I further cede copyright of the dissertation in favour of the University of the Free State.

Francois Deacon

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Firstly my Lord Jesus Christ in whom I find my daily strength and faith. Holding on to Psalm 8: *"O LORD, our Lord, how majestic is your name in all the earth! You have set your glory above the heavens. From the lips of children and infants you have ordained praise because of your enemies, to silence the foe and the avenger. When I consider your heavens, the work of your fingers, the moon and the stars, which you have set in place, what is man that you are mindful of him, the son of man that you care for him? You made him a little lower than the heavenly beings and crowned him with glory and honour. You made him ruler over the works of your hands; you put everything under his feet: all flocks and herds, and the beasts of the field, the birds of the air, and the fish of the sea, all that swim the paths of the seas. O LORD, our Lord, how majestic is your name in all the earth."*

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CHAPTER 1: INTRODUCTION

The family Giraffidae consists of two genera, each with a single species. Namely the giraffe (*Giraffa camelopardalis*) and the okapi (*Okapia johnstoni*, Lankester) of the lowland forests in central Africa (Nowak & Paradiso, 1983). Although several species of giraffes were recognised in the past, the genus is now considered monospecific (Dagg, 1971; Grzimek, 1990).

The giraffe is a unique mammal endemic to the African continent and comprises the following nine known subspecies: with *Giraffa camelopardalis giraffa* (Lesson) and *G. c. angolensis* (Lydekker) occurring in southern Africa; *G. c. rothschildi*, *G. c. tippelskirchi*, *G. c. reticulata, G. c. camelopardalis, G. c. antiquorum* and *G. c. thornicrofti* occurring in East Africa; and *G. c. peralta* in West Africa (Dagg, 1962; Bothma *et al.,* 2010; Carnaby, 2010; Tutchings *et al.,* 2013). Of the two southern subspecies, *G. c. giraffa* is considered iconic of the Southern African savanna and is commonly found in national parks, provincial reserves and wildlife ranches across southern Africa. Many animals of this species have been introduced into areas where they did not historically occur. *Giraffa camelopardalis giraffa* (Lesson) historically occurred in the Mpumalanga Province of South Africa, south-western Mozambique and southern and south-eastern Zimbabwe, while *Giraffa camelopardalis angolensis* (Lydekker) occurred in north-west Zimbabwe, northern Botswana and northern Namibia (Skinner and Smithers, 1990). These two southern subspecies differ primarily in their markings. *G. c. angolensis* has larger patches than *G. c. giraffe* (Kingdon, 1979) and though both subspecies have numerous patches with jagged outlines, the patches of *G. c. giraffe* have firmer outlines than those of *G. c. angolensis* (Kingdon, 1979, Thutchings *et al.,* 2013).

Although the giraffe is considered to be a common species, little research has been done on the *G. c. giraffa* subspecies and even less information relative to the other subspecies of giraffes has been published. Privately owned giraffes are kept on game farms, game ranches or private game reserves that can vary in size from only a few hectares to a few thousand hectares. Regardless of the size of the property, the movement of giraffes to adjacent populations and habitats is restricted by fences.

The wildlife ranching industry is unique to southern Africa (Deacon & Smit, 2013). Legally, after compliance with certain regulations, the owners of wildlife ranches, private game reserves and game farms are allowed to keep giraffes on their land for commercial purposes such as eco-tourism, live sales and hunting. On the almost 10 000 farms and reserves throughout the country (WRSA, 2013), little research has been done to evaluate the natural resources that are necessary to sustain the animals. And, as a result, few of these privately owned wildlife species receive proper attention regarding their needs in extensive farming practices. The wildlife ranching industry of southern Africa has expanded significantly over the past few decades and has become a lucrative enterprise, driven mainly by live animal sales, trophy hunting and sport hunting (Damm, 2005; Bothma & Von Bach, 2010; Van Zyl & Sartorius-Von Bach, 2010; Cloete, 2012).

Boshoff & Kerley (2004) investigated the conversion of stock- to game farming and reported that an increasing number of farmers were replacing their stock with game or combining stock- and game farming. The reason for this conversion can largely be ascribed to the increased production costs of stock farming that often exceeds the value of sales, combined with reduced government subsidies. To increase their return on capital, these farms are converted into hunting-, tourism- or wildlife breeding farms with the added aesthetic value of popular species such as giraffes and rhinos. According to Dagg & Foster (1976), due to their height, the giraffe is one of the few game

species that can utilize a wide range of browse material and in this way can add economic value to a food resource that is under-utilized.

The sustainability of these farm conversions has an ecological impact, as land owners often introduce game species on their farms that did not historically occur in the area. Indigenous animal species and the environment may therefore be threatened or damaged or the available habitat may not suit the introduced species. In sub-optimal habitats, extra-limital species may compete with indigenous species for space and food and subsequently impact the vegetation negatively. Except for the scientific studies of Kok & Opperman (1980, 1985) and Kruger (1994), the adaptation success of relocated giraffes is largely unknown. In a rapidly expanding game ranching industry, where inter-provincial translocation of game is a common occurrence in South Africa, non-endemic species like the giraffe, are often subjected to severe feeding stress.

Because giraffes have traditionally been considered to be of less economic importance compared to species traditionally hunted for their meat or for trophies, such as plains game or the 'big five', there has been little incentive to study these animals. This is also emphasised by the limited information on giraffes in the literature compared to other species. However, the giraffe is an important species in the tourism industry, in view of the growing importance of eco-tourism to the economy of southern African countries (Blomqvist & Renberg, 2007; De Beer, 2009). The importance of giraffes from an economic perspective has increased in more recent times (Blomqvist & Renberg, 2007). The GCF (Giraffe Conservation Foundation), in collaboration with the International Union for Conservation of Nature (IUCN) and IGWG (International Giraffe Working Group), have concluded that only limited systematic monitoring or research has been conducted on any giraffe population (Tutchings *et al*., 2013). In recent years, few formal research studies have been conducted in South Africa on key *G. c. giraffa* populations (Hirst, 1966; Lambrechts, 1974; Hall-Martin, 1974; Hall-Martin & Basson, 1975; Sauer, 1975; Van Aarde & Skinner, 1975; Kok & Opperman, 1980 & 1985; Furstenburg, 1991; Furstenburg, 2003; Parker, 2004) that could have increased our limited knowledge of key populations. Due to the fragmentation of conservation areas, the South African giraffe has been biologically isolated and is now not only genetically distinct from other subspecies, but even its ecology may differ. In view of the fact that the giraffe is uniquely African and an iconic species of South Africa with a high tourism value, a better understanding of its spatial ecology, habitat preference, feeding behaviour, ecology and conservation status is essential. As a general rule, (except for a few populations in southern Africa) giraffe numbers appear to be declining across Africa Habitat loss, poaching and conflict with a growing human population can be cited as possible reasons for this dramatic decline during the past decade (Rija, 2013; Bothma *et al*., 2010; Tutchings *et al*., 2013). Giraffes still occur in several conservation areas in their African countries of origin, and the species as a whole is currently listed by IUCN as "least concern" (Tutchings *et al.* 2013).

During 1998 giraffe numbers were estimated to exceed 140 000 individuals throughout Africa, while a decade later the numbers are estimated to be less than 80 000 (almost 40% reduction). These figures are less than 20% of the current estimates of African elephants, which is classified as 'endangered', yet the conservation status and profile of the giraffe are very different (Fennesy, 2009). In the 2008 and 2010 Red List update for the giraffe, the GCF and IGWG have managed to have the West African subspecies (*G. c. peralta*) and the Rothschild's giraffe (*G. c. rothschildi*) listed as "endangered", highlighting the importance of giraffe research across the continent (Fennessy & Brown, 2008; Fennessy & Brenneman, 2010).

It has, therefore, become increasingly important to conserve the existing gene pool of giraffe populations. Conservation of the South African population (*G. c. giraffa*) and development of sound management principles for natural populations, will also contribute to the conservation of giraffes elsewhere in Africa.

Although it is assumed that the numbers of privately owned giraffes are increasing, there has been no accurate estimate of the South African (*G. c. giraffa*) population in recent times. No rigorous assessment of the numbers, status and distribution of *G. c. giraffa* has ever been undertaken within South Africa.

Though Lynch (1983) mentioned the possibility of giraffes historically occurring in the semi-arid western areas of South Africa, there is no undisputed evidence of giraffes ever occurring in these areas (Anseli, 1968; Anon, 1972). Due to its water scarcity and possibly because of the dominance of winter deciduous trees, the broader Kalahari region in South Africa and bordering countries of Namibia and Botswana's southern Kalahari were not included in the distribution area of the giraffe (Dagg, 1962; Sydney, 1965). However, in recent times, many giraffes have been introduced to the Kalahari region of South Africa, regardless of the suitability of the available habitat, which originally included the savanna biome in the eastern lowveld of South Africa. In the past, the re-introduction of giraffes had been conducted by the former Transvaal Nature Conservation (Hirst, 1966; Lambrechts, 1974). In 1970, the demand for giraffes was mainly for provincial and private nature reserves, while in more recent times giraffes are also in demand by private land owners throughout the country. Relocations are mostly based on aesthetic, rather than conservation considerations.

There is some uncertainty as to the historical and natural distribution range of the giraffe in southern Africa. As seen from Figure 1.1 their distribution range in South Africa is predominantly the savanna areas of the Limpopo Province, KwaZulu-Natal and the North West Province (Skinner and Smithers, 1990; Walker 1996). Since 1991, giraffes have also been successfully re-introduced to the Kgalagadi Transfrontier Park (trans-located from Etosha National Park in Namibia), Northern Cape (Kruger, 1994). Yet little is known of the impact of this population on the vegetation. Once occurring widely and continuously in savanna habitats south of the Sahara, giraffes are now fragmented into numerous isolated populations scattered throughout West and East Africa. As seen in Figure 1.1 they are absent from forest areas and the central and western parts of the country.

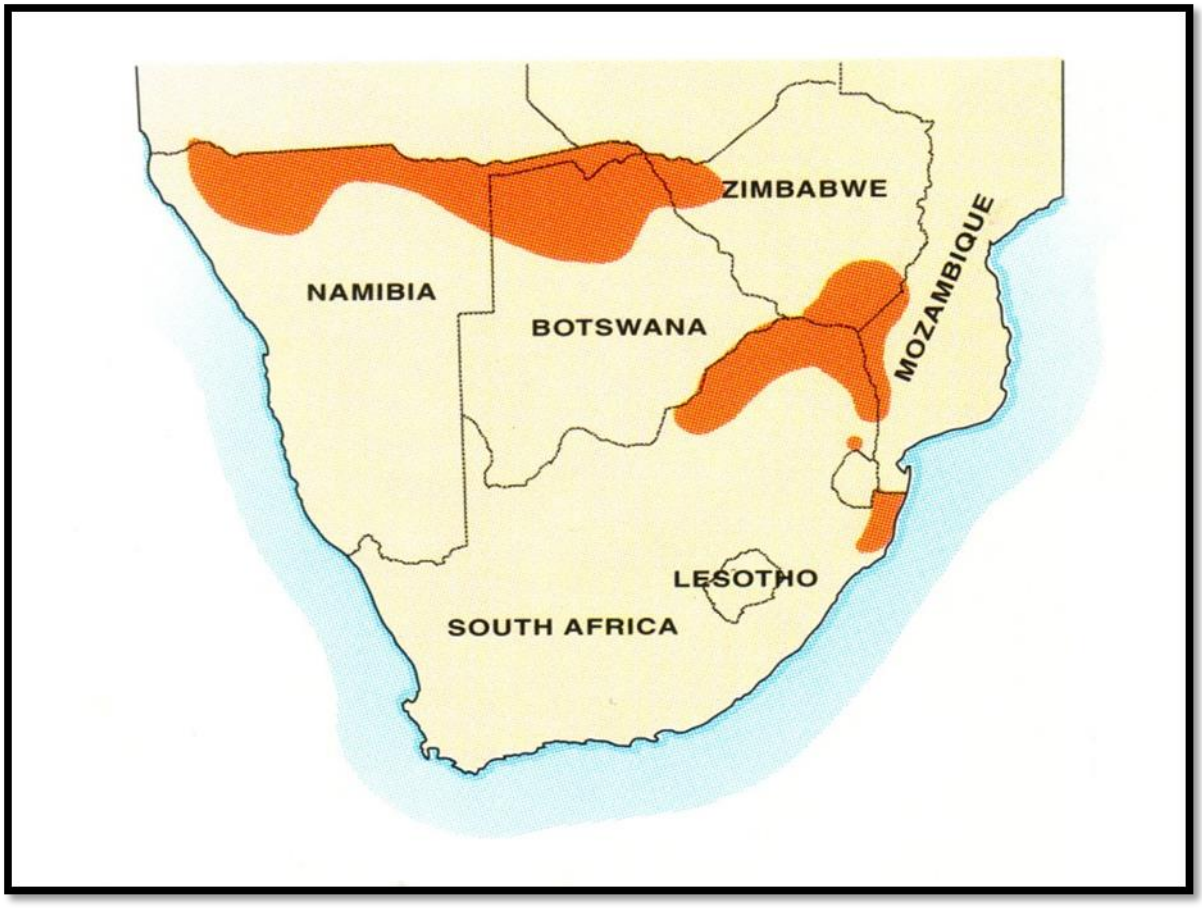


Figure 1.1 Distribution range of the giraffe (*Giraffa camelopardalis giraffa*) in southern Africa (Walker, 1996).

Giraffe populations have since been widely introduced to numerous private game ranches and provincial game reserves throughout South Africa (Figure 1.2). A distribution map (Theron, 2005) of giraffes was compiled by Wildlife Ranching South Africa, in collaboration with the Department of Environmental Affairs. The compilation of this map was motivated by the pending biodiversity law and translocation policy that would govern which game species may be introduced or moved to specified areas (Theron, 2005). These maps indicate the natural distribution range of the giraffe, as well as all additional areas in which particular sub-species are well established. Figure 1.2 represents the most recent figures for giraffes in South Africa. The dark green areas represent areas where historical records show that giraffes occurred naturally, while the light green areas are outside its natural distribution range, where giraffes have become well established through introductions.

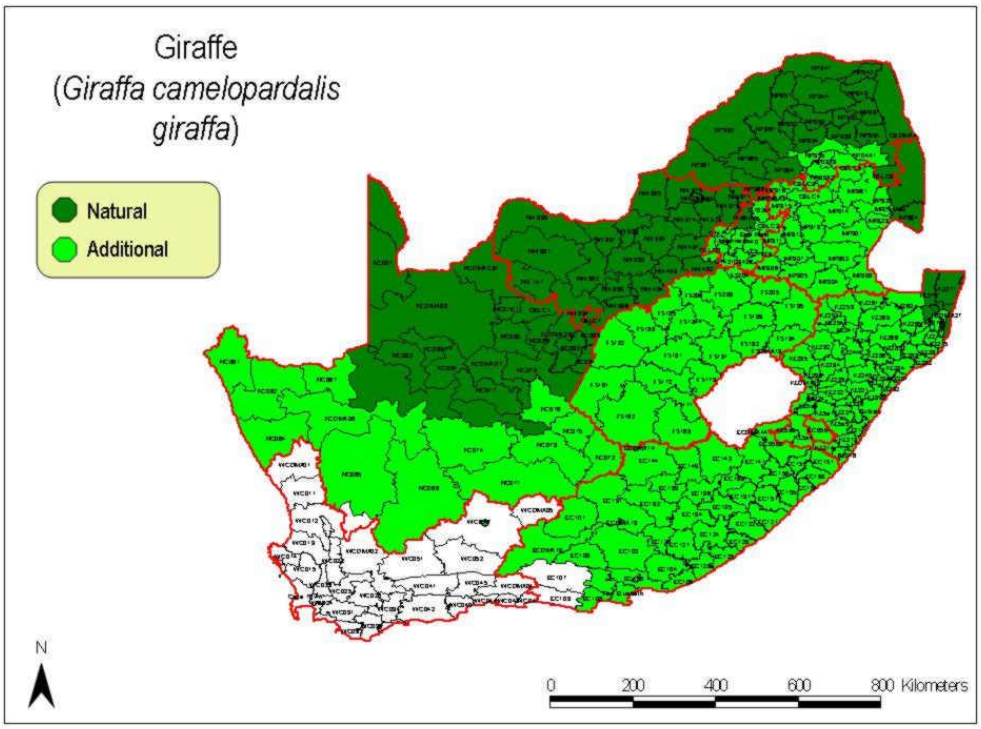


Figure 1.2 Distribution map of the giraffe (*Giraffa camelopardalis giraffa*) in South Africa according to Wildlife Ranching South Africa in collaboration with the Department of Environmental Affairs (2000).

Within the arid western areas of South Africa, Kruger (1994) could find no official literature records of giraffes existing in the southern Kalahari, including the Kgalagadi Transfrontier Park (KTP), which is currently a National Park hosting a re-introduced giraffe population. During April 2004, Castley *et al.* (2004) did a preliminary investigation as a follow-up report on Kruger (1994), who in 1994 studied the feeding ecology and behaviour of re-introduced giraffes in the former Kalahari Gemsbok National Park (now the Kgalagadi Transfrontier Park). Both these studies brought to the attention of scientists that giraffes might be having a negative impact on the *Acacia* tree species within the KTP.

A large part of South Africa is covered by grasslands and a quantitative description of the woody plants is usually required to evaluate whether giraffes truly influence the vegetation. In order to evaluate the habitat, certain ecological implications occur. Before the introduction or re-introduction of any giraffes, an evaluation based on the following three aspects should be conducted: (i) does the area fall within the natural distribution range of the giraffe; (ii) is the habitat suitable for giraffes; (iii) will the impact of giraffes be negative on the environment?

Based on old records and historic eyewitness accounts of giraffes being present in the Kalahari (Backhouse, 1844; Smith, 1849; Bain, 1949) it was decided by the management of the study area to include giraffes within the fenced property. Though the giraffes have free rein within the reserve of 95 653 ha and seem to have adapted well to their new surroundings, their numbers are still on the decline since their re-introduction.

The lack of long-term studies, which remains the limiting factor in understanding the home range, spatial ecology and movement of giraffes, motivated the decision to investigate the possibility of using appropriate technology, such as tracking devices for research purposes. Equipping animals

with radio transmitter collars has aided ecological research by allowing remote collection of data on animal movements and home ranges. More recently, advances in satellite technology have enabled the miniaturisation of GPS transmitters to fit into collars. The ability to transmit data from a collar via satellite has improved the scope and efficiency of field-based research, allowing collection of accurate data on home ranges, seasonal movements, human-wildlife interaction zones and preferred habitats. Though this system is expensive, the cost is justified by its convenience and reduced disturbance compared to aerial surveying and tracking on the ground. Giraffes in the study area have been relocated and re-introduced from Limpopo, Mpumalanga and the North West provinces. No investigation was done concerning the suitability of vegetation and environmental variables for giraffes. There is the assumption that distribution patterns of giraffes are strongly influenced by environmental variables, human persecution, roads and location of waterholes (Bolger *et al.,* 2008). Most animal distributions are also influenced by extrinsic factors such as weather conditions, food supply (deciduous plants for browsers), vegetation and human disturbance of the landscape (Dagg, 1962; Pratt & Anderson-Pratt, 1982; Goodman & Tomkinson, 1987; Bond & Loffell, 2001).

This research project aims to provide a tool for conservation that will support wildlife authorities and researchers in identifying suitable management programs that suit the habitat needs of giraffes. With little known about the giraffe throughout the continent, and specifically in arid environments, this research project will be invaluable for better understanding the species, to the benefit of their conservation and to establish a baseline for their long-term conservation management. The project aims to make a significant contribution towards informed ecological decision-making; expanding the applicability of the findings to other areas of wildlife management; tourism development; education and community involvement, enhancing international co-operation between the University of the Free State and other interested role players, and improving collaboration in securing the future of giraffes in Africa.

The first objective of the research project was to develop and design efficient and safe GPS collars for giraffes. As a second phase of the study, a population of giraffes in the arid Kalahari region of South Africa was studied with the objective of assessing the following:

1. The habitat selection and spatial ecology of giraffes based on the effect of seasonal changes;
2. The habitat selection and spatial ecology of giraffes based on the effect of habitat resources (browse and water) and plant species composition;
3. Diet selection of giraffes in relation to browse availability;
4. Daily behaviour of giraffes with feeding and non-feeding activity budgets.

The final objective of the study was to compile management tools for giraffes in arid regions to ensure sustainability and to aid in future decisions to stimulate population growth amongst other giraffe sub-species populations in the rest of Africa.

CHAPTER 2: STUDY AREAS

This research project was conducted within two separate study areas. The main project was conducted in the Khamab Kalahari Nature Reserve in the North West Province of South Africa, but only commenced after the completion of a preliminary study that was conducted in the Woodland Hills Wildlife Estate in the Free State Province (secondary study area).

2.1. Main Study Area

2.1.1. Location

The Khamab Kalahari Nature Reserve (KKNR) (coordinates: -25.484939, 23.254035) is situated in a remote portion of the Kalahari savanna in the north-western region of the Republic of South Africa (Figure 2.1).

Prior to their incorporation into KKNR, the individual farms that now form part of the reserve were all in private ownership. This involved a total of 10 different owners with an average property size of 9 553 ha, ranging from the smallest property of 1 498 ha to the largest of 28 434 ha (
Table 2.1). The total fenced area of the KKNR is currently 95 000 ha (Collinson, 2008). The reserve was initiated during 2007 and the fencing was finally completed during 2008. Several indigenous wildlife species occurred naturally on some of these farms, while some that were operated as game ranches were stocked with game of various species brought in from elsewhere.

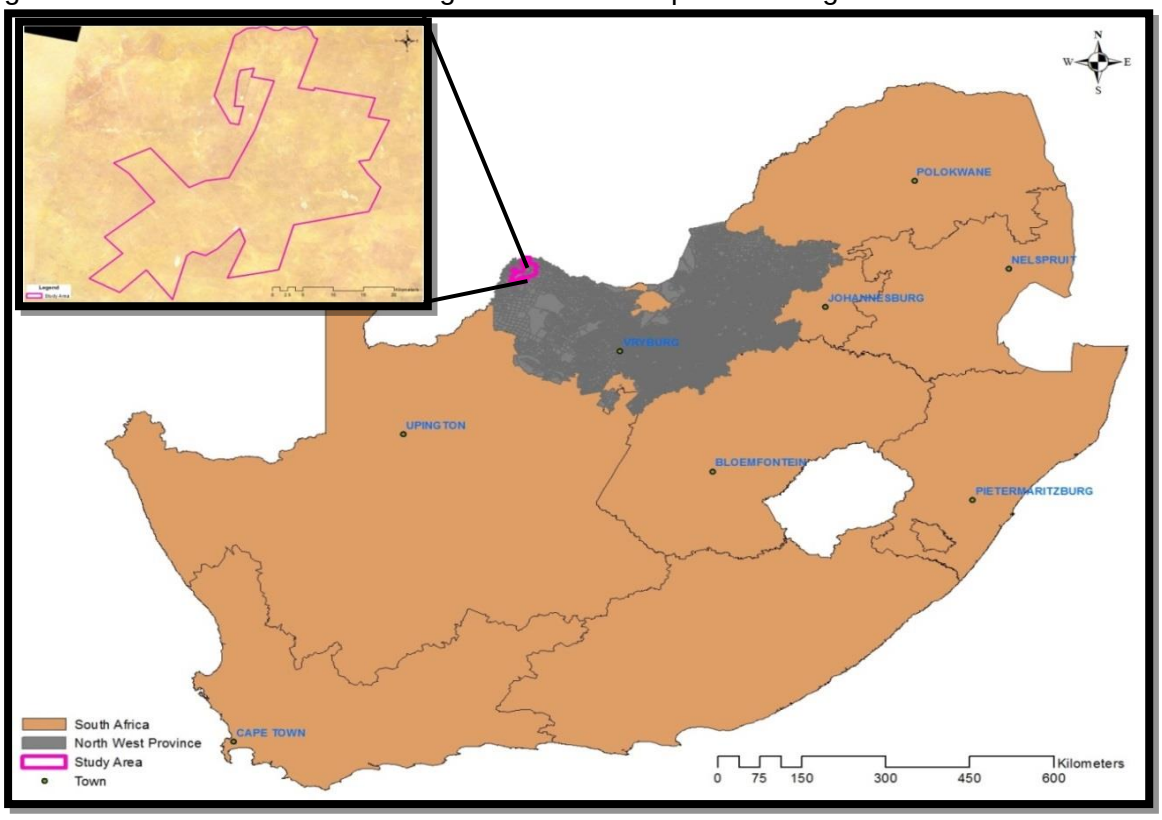


Figure 2.1 Location of Khamab Kalahari Nature Reserve (KKNR) within the North West Province of South Africa

The main forms of land use prior to incorporation into the KKNR were commercial livestock production comprising extensive rather than intensive grazing systems and wildlife-based conservation, hunting and ecotourism.

Table 2.1 and 2.2 provide a summary of the size of farms and the land use that was being practised on the farms purchased for the formation of KKNR at the time of acquisition (Collinson, 2008; EES, 2012).

Table 2.1 Privately owned farms purchased for inclusion into the larger Khamab Kalahari Nature Reserve (KKNR)

	Farm	Title Names	Ha	Total Area
1	Werda	Werda Portion 4	1498.931	1498.931
2	Lorraine	Lorraine portion 52	6172.3934	6172.393
3	Esperance	Suiderkruis	2569.596	2569.596
		Alberta	1284.798	
		Dakota	1070.665	
		Dakota	3842.7761	
		Omega	3111.7811	
		Colorado	3237.2076	
		Portion 138 of 53	2217.5613	
		Portion 15 of 3	1731.4795	
		Portion 3 of Portion 3	1731.4795	
			18227.7481	18227.75
		Esperance Portion 2	3821.8458	3821.846
			24619.1899	
4	Wilzenau 2	Portion 155	5050.5054	5050.505
	Wilzenau 2	Portion 151	4953.7504	4953.75
5	Wilzenau 3	Wilport Ranch 152	5111.8665	5111.867
6	Sweetwater	Portion 36	4065.9531	
		Portion 38	3351.8231	
		Portion 43	5139.1898	
		Portion 40	13690.2119	
		Portion 126	2187.2043	
			28434.3822	28434.38
7	Wilzenau 1	Portion 160	5851.8457	5851.846
		Portion 150	3634.7494	3634.749
8	Allegheny	Portion 34	2984.2082	2984.208
9	Omega	Portion, 53, 139, 141, 5	5084	5084
10	Ella	Farm 1033	2141.7334	2141.733
				95,537.56

Table 2.2 Summary of the previous land use of the farms purchased for the formation of KKNR

Farm name	**Land use**
Werda	Extensive commercial livestock (cattle) ranching with many small fenced paddocks
Donkerhoek	Extensive commercial livestock (cattle) ranching with larger fenced paddocks
Esperance	Extensive commercial livestock (cattle) ranching, separate paddocks for game ranching (mainly trophy hunting) and “canned lion hunting” operations
Lorraine	Extensive commercial livestock (cattle) ranching with few paddocks and a severe problem of bush thickening
Ella	Extensive commercial livestock (cattle) ranching with fenced paddocks
Dakota	Extensive commercial livestock (cattle) ranching with fenced paddocks
Saratoga	Extensive commercial livestock (cattle) ranching with many small fenced paddocks
Colorado	Extensive commercial livestock (cattle) ranching with fenced paddocks
Omega	Extensive commercial livestock (cattle) ranching with fenced paddocks and large game camp in the north
Wilzenau 1, 2, 3	Extensive commercial livestock (cattle) ranching with two game paddocks on separate sections of the farm
Sweetwater	Extensive commercial livestock (cattle) ranching with large fenced paddocks and established water points
Allegheny	Extensive commercial livestock (cattle) ranching with many fenced paddocks and established water points
Glen Devon	Extensive commercial livestock (cattle) ranching with large fenced paddocks
Simmenthal	Extensive commercial livestock (cattle) ranching with large fenced paddocks and water points
Eldorado	Extensive commercial livestock (cattle) ranching with many large fenced paddocks and water points

2.1.2. Climate

KKNR falls within the summer rainfall region with the majority of rain occurring between October and April. The mean annual rainfall for the study area is estimated at 333 mm, (calculated from 2007 – 2014 using three individual weather stations located within KKNR), with a high annual coefficient of variation (CV) of 34%. Due to the low rainfall the area is considered semi-arid with a rainfall pattern that is erratic and unpredictable for any one year or series of years. The consequences of this are that the mean annual rainfall is an unreliable measure for the management of cattle ranching and wildlife conservation projects, especially with respect to the calculation of herbivore carrying capacities and stocking rates (Smit, 2000; Collinson, 2008; EES, 2012).

The area is subject to thunderstorms and experiences between two and three lightning strikes per year per 100 ha, which can be considered low in the context of South Africa as a whole. Mean minimum and maximum daily temperatures are respectively 0°C and 22°C in July and 18°C and exceeding 34°C in January. Summer temperatures are, therefore, generally high. Frost occurs in winter with a mean number of 27 days of frost (Collinson, 2008; EES, 2012).

2.1.3. Geology and Soils

The most visible geological feature of KKNR is the substrate of red wind-blown sands (Hutton and Clovelly soil forms) of the Kalahari Group which occur uniformly over most of the reserve at depths which exceed 1.2 m in some parts. These Kalahari sands are underlain by tillites, sandstones, mudstone and shales. However, these rock formations are not visible on the landscape surface due to the depth of the sand substrate. Localised areas of exposed limestone (calcrete) occur along the Molopo River and in and around the edges of the pans. The Molopo river course is underlain by quartzites (Collinson, 2008; EES, 2012).

The soil can be described as generally well-aggregated and freely drained with a high base status which is the result of limited leaching under an arid climate. Soils of the river beds and pans are more alluvial in nature and their fertility status is higher than that of the surrounding red sands. Occasional patches of lighter coloured sands (whitish to grey) are found in small depressions that are interspersed with the sea of red sands (Collinson, 2008; EES, 2012).

2.1.4. Topography

Elevation for the region ranges from 1 054 m above sea level near Bray to 992 m to the west of Molopo Nature Reserve. This is a difference of 62 metres over a distance of 95 kilometres. The overall difference in elevation is therefore almost insignificant across this vast area. Accordingly, the topography of KKNR for the most part can be described as flat to slightly undulating. The Molopo River has a very gentle gradient along the northern border of the Molopo district with an altitude of 1 030 m at Bray in the northeast and 990 m for the Molopo Nature Reserve. (Collinson, 2008; EES, 2012).

2.1.5. Water

According to Collinson (2008) and EES (2012), the key feature of the area is the complete absence of perennial surface water. This phenomenon has been the most important influence on the presence, abundance and distribution of indigenous plant and animal species. Today it poses the most important challenge to the planning and future management of KKNR, a challenge that is compounded by the more recent practice of sinking boreholes for the provision of permanent surface water for cattle and its concomitant more recent influence on the ecosystem.
Another significant feature of the area is the presence of endorheic pans (pans that do not possess an outflow). A number of large pans are present on the farms acquired for the formation of KKNR. After heavy thunderstorms they may hold water for some time. For this reason these pans are invaluable to a wildlife conservation project such as the KKNR (Berry 1991; Collinson 2008; EES, 2012).

2.1.6. Vegetation

KKNR falls within the Savanna Biome of South Africa (Mucina & Rutherford, 2006). This biome, which covers one-third of the country, is the most widespread of the biomes found in South Africa. KKNR is located within the Eastern Kalahari Bushveld Bioregion, and more specifically the Molopo Bushveld (SVk11) vegetation unit, which forms part of the Savanna Biome that extends westwards from Mafikeng to the Botswana border in the west and the Orange River in the south. This bioregion is the second most arid of the bioregions of the Savanna Biome (Collinson 2008; EES, 2012).

It is proposed by some scientists that prolonged severe overgrazing of the grass layer by cattle, especially in drought years, has contributed to an almost complete replacement of the grass layer by a dense stand of woody plants over an extended area. Many of the cattle farmers responded to this bush encroachment by applying intensive bush clearing interventions using both chemical and mechanical techniques. Fortunately, not all farmers applied indiscriminate and unselective bush control measures and thus have left some areas with natural ecosystems still intact (Collins 2008, EES, 2012).

In the vegetation study done by EES (2012) the Braun-Blanquet survey technique was used to identify, classify and describe vegetation communities and ecological units on the KKNR (Figure 2.2).

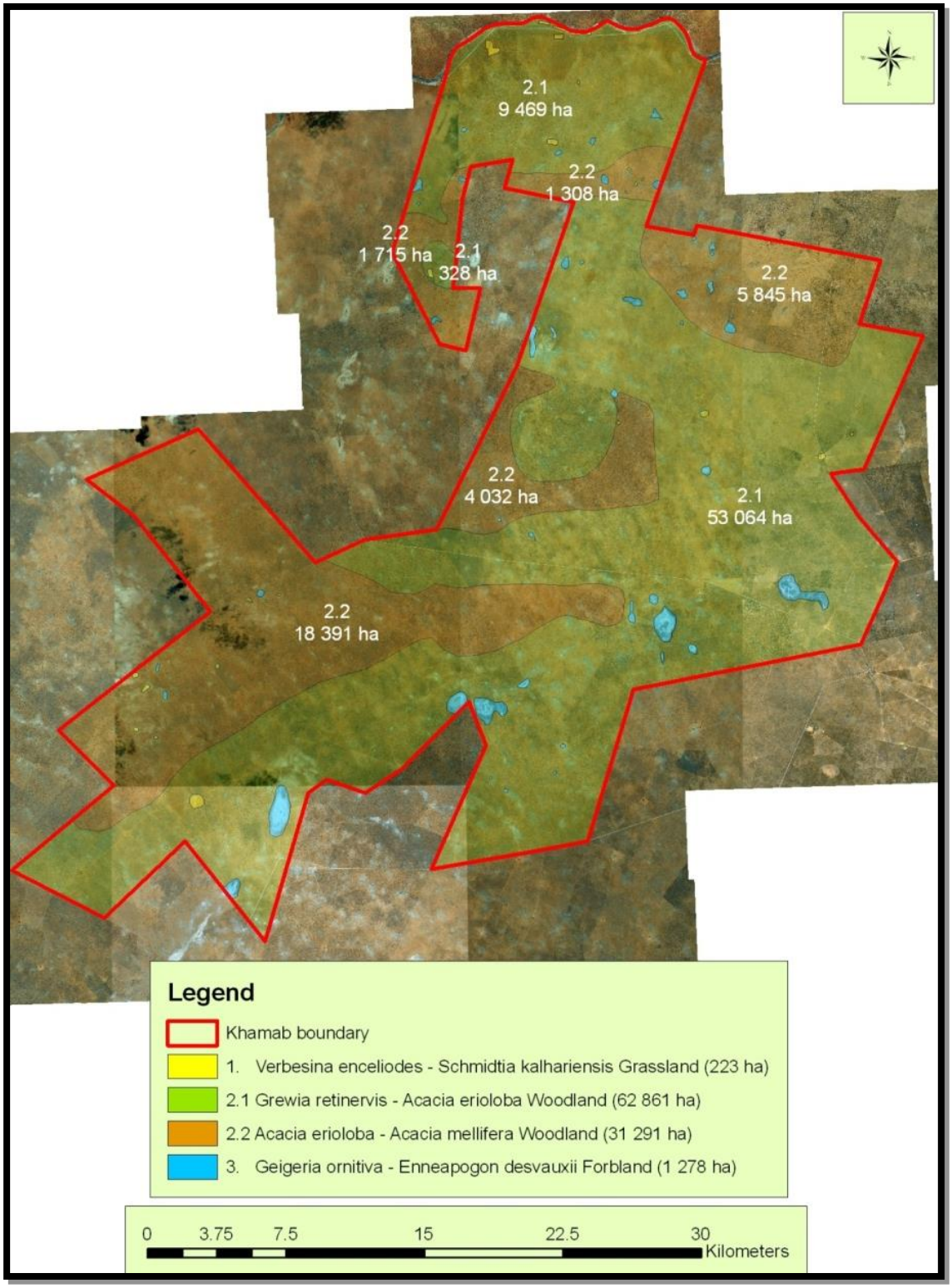


Figure 2.2 Vegetation units within Khamab Kalahari Nature Reserve (EES, 2012)

The study area was stratified into relatively homogeneous physiographic-physiognomic vegetation units on a 1:5 000 scale. Homogeneous units form the basis of this classification method, derived either from large-scale aerial photographs or known environmental parameters (geology, topography, climate, soil etc.).

2.1.6.1. Plant Communities

From the EES (2012) report, the analysis resulted in the description of the following eleven plant communities, which can be grouped into three major plant community types with their own sub-communities:

1. *Verbena encellioides-Schmidtia kalahariensis* Grassland

2. *Schmidtia pappophoroides-Acacia erioloba* Woodland

    2.1 *Grewia retinervis-Acacia erioloba* Woodland

        2.1.1 *Eragrostis trichophora* variant

        2.1.2 *Acacia haematoxylon* variant

        2.1.3 *Diospyros lycioides* variant

        2.1.4 *Terminalia sericea* variant

    2.2 *Acacia erioloba-Acacia mellifera* Woodland

        2.2.1 *Boscia albitrunca* variant

        2.2.2 *Acacia luederitzii* variant

    2.3 *Eragrostis lehmanniana-Cenchrus ciliaris* Grassland

3. *Geigeria ornitiva-Enneapogon desvauxii* Forbland

    3.1 *Monechma incanum-Enneapogon desvauxii* Forbland

        3.1.1 *Rhigozum trichotomum* variant

        3.1.2 *Plinthus karooicus* variant

    3.2 *Eragrostis bicolor-Enneapogon desvauxii* Grassland

Due to the relatively homogeneous nature of the vegetation, as well as the image quality of the satellite photos available, only community 1, sub-community 2.1, sub-community 2.2 and community 3 could be mapped as presented in Figure 2.2.

2.1.6.2. Description of plant communities (Figure 2.2)

1. *Verbesina encellioides-Schmidtia kalahariensis* Grassland

The soil type for this vegetation unit is a clovelly soil form with 6 – 15 % clay and with deep yellow-brown sand (>1.2 m). The vegetation structure is open grassland on disturbed sandy patches with prominent species such as *Schmidtia kalahariensis*. The diagnostic species are *Schmidtia kalahariensis, Verbesina encellioides and Amaranthus praetermissus.* The grassland is characterised by disturbed patches and water points within the sandveld. As expected, these areas vary between bare open patches due to trampling and improved cover with mainly pioneer weedy species. Some of the pans contained water while others are currently used as water points for the

animals. The grass layer covers between 15 - 60% of the area, though in some areas cover of only 1% is visible. The tree layer covers 1 - 12% of the area varying from 5 - 9 m tall. Less than 5% of this plant community consists of shrubs.

The vegetation is dominated by the annual tuft grass *Schmidtia kalahariensis,* which is a characteristic of disturbed areas. This grass grows relatively fast and protects the soil against wind erosion. The forb *Verbena encellioides* is present and sometimes dominant throughout this grassland.

Other species that are locally prominent include the trees *Acacia erioloba* and *Boscia albitrunca* and the forb *Chenopodium album*. Most of these species are indicative of overgrazing or disturbance by browsers.

2. *Schmidtia pappophoroides-Acacia erioloba* Woodland

The diagnostic species for this vegetation unit include *Stipagrostis uniplumis, Grewia flava, Schmidtia pappophoroides, Aristida congesta* and *Lycium cinerium.*

This open woodland makes up the largest part of the study area, with the vegetation dominated by valuable grazing grass species such as *S. uniplumis, S. pappophoroides* and the shrub *G. flava.* The tree *Lycium cinerium* and the pioneer grass *Aristida congesta* subsp. *congesta* with the grass *Eragrostis lehmanniana* are also present in the vegetation unit. The latter also provides some grazing for animals.

Although this plant community is very homogeneous, it is characterised by small variations in plant species composition due to previous bush clearing or thinning activities. This community is therefore divided into three sub-communities: (2.1) *Grewia retinervis-Acacia erioloba* woodland, (2.2) *Acacia erioloba-Acacia mellifera* woodland and (2.3) *Eragrostis lehmanniana-Cenchrus ciliaris* grassland.

2.1 *Grewia retinervis-Acacia erioloba* Woodland

The soil type for this vegetation unit is clovelly (>1.2 m deep) with red to yellow-brown sand with <6% clay. The vegetation structure is open woodland with a well-developed grass layer and diagnostic species such as *Leonotis ocymifolia; Aristida stipitata.* and *Sesamum triphyllum* are prominent. Plant species also include the shrubs *Grewia retinervis and G. flava*, the grasses *Aristida stipitata, Stipagrostis uniplumis and Schmidtia pappophoroides* and the forb *Leonotis ocymifolia*. The tree species *A. erioloba* is prominent within this community with the tree *B. albitrunca* also present.

This community consists of four variants due to previous management practices:

2.1.1 *Eragrostis trichophora* variant

The most prominent plant species in this sub-community include *Stipagrostis uniplumis, Schmidtia pappophoroides, G. flava, A. erioloba and B. albitrunca*. This vegetation unit is characterised by the presence of the grass *Eragrostis trichophora.* The tree cover percentage is no more than 4% and the shrub cover percentage 12%. It has a well-developed grass layer covering up to 70% of the area and occurs on deep yellow-brown sand.

The tree *A. mellifera* is present in low numbers because it has mostly been destroyed through previous applications of herbicides. Only single individuals of other *Acacia* species are still present.

2.1.2 *Acacia haematoxylon* variant

The most prominent plant species include *Stipagrostis uniplumis, Schmidtia pappophoroides, A. erioloba, A. mellifera and A. haematoxylon*. This vegetation unit has a tree cover percentage of 2.5%, shrubs 7% with the herbaceous layer covering 62% of the area, while trees up to 10 m tall cover 2.5%. It is characterised by the presence of species such as the shrub *A. haematoxylon* and the forbs *Phyllanthus maderaspatensis* and *Sesamum triphyllum.* Also, the tree *A. mellifera* that may become dense under poor veld management is locally prominent in patches, while *A. erioloba* is ever present.

Arboricides have been used in most areas of this variant to kill a large number of trees, with only solitary large individuals remaining. Fire has also been used in other areas, together with the arboricides. Thus, some form of degradation or disturbance of the environment has taken place. Although large numbers of *A. mellifera* trees have been killed, they are still present and have become locally dominant despite the various treatments. In certain areas re-growth of the woody species has occurred, especially in areas where arboricides were applied a long time ago. These trees are 1 –2 m tall, covering an average of 7% of the area.

2.1.3 *Diospyros lycioides* variant

The most prominent plant species in this sub-community include *Stipagrostis uniplumis, Schmidtia pappophoroides, G. flava, A. erioloba, A. mellifera and D. lycioides* with the shrub and herbaceous layers of this variant being dominant, and covering an average of 62% and 14%, respectively. The tree layer covers only 2.7% of the area with an average height of 7.2 m. Some trees are up to 10 m tall within this vegetation unit. This variant is also characterised by the presence of the shrub *D. lycioides* and the forbs *Vernonia poskeana* and *Cucumis africanus*. The vegetation is dominated by the tree *A. erioloba,* while sections are overgrown by the tree *A. mellifera.*

Even though the shrub layer has an average cover of 14%, the cover of the sections where *A. mellifera* shrubs are present can be as high as 30%. This vegetation variant was treated with arboricide by hand in the past and the vegetation is showing signs of woody re-growth, as is evident in the shrub layer being dominant. Other parts of this variant have not been treated at all.

2.1.4 *Terminalia sericea* variant

The most prominent plant species for this vegetation variant include *Stipagrostis uniplumis, Schmidtia pappophoroides, G. flava, A. erioloba and T. sericea.* The woody layer covers 4.3%, the shrub layer 10% and the grass layer an average of 62% (ranging from 50% to 80%).

As its name suggests, this variant occurs on deep sand with the presence of the tree *T. sericea* and the shrub *Dichrostachys cinerea* characteristic. The trees *A. erioloba* and *B. albitrunca* are prominent throughout, with smaller areas where the tree *A. mellifera* is prominent.

The vegetation of these areas varies from sections where arboricides have been selectively applied, mostly to *A. mellifera* trees, to sections where no arboricides have been applied, but which have become moribund.

2.2. *Acacia erioloba-Acacia mellifera* woodland

The soil for this vegetation unit can be described as clovelly (> 1.2 m deep) with red to yellow-brown sand and < 6 -15% clay. The vegetation structure can be described as open woodland with a well-developed grass layer and diagnostic species such as *Solanum incanum* and *Pavonia senegalensis.*

This vegetation unit comprises the second largest section of the reserve (31 291 ha) and mainly occurs on the western part of the reserve with other smaller areas scattered over the rest of the KKNR (Figure 2.2). The terrain of this unit is flat with deep (> 1.2 m), yellow brown sandy soil with a dominance of the clovelly soil formation. No rock cover was noted.

The vegetation is characterised by the dominance of the woody species *A. erioloba, B. albitrunca, A. luederitzii, A. mellifera* and *G. flava* with the grass species *Schmidtia pappophoroides, Stipagrostis uniplumis* and *Eragrostis lehmanniana* dominant in the herbaceous layer.

This vegetation unit is described as open woodland with the trees evenly scattered throughout the community. In some areas the woody species had become denser than the rest of the surrounding vegetation, but no bush thickening or encroachment has been noted (La Grange, 2010).

This vegetation unit has been impacted by chemical treatment of mostly *A. mellifera,* but the other *Acacia* species also show signs of arboricide treatment. Fire also plays a major role in this ecosystem.

Because of the chemical treatment impact on the *Acacia* plant species, this open woodland vegetation is divided into two variants, namely (2.2.1) an unnatural savanna with sparse *Boscia albitrunca* trees scattered in the community and (2.2.2) a natural woodland with woody *Acacia* plant species dominant in the unit.

2.2.1 *Boscia albitrunca* variant

This variant is considered to be the degraded woodland, which was a result of arboricides applied to *A. mellifera* and has poor biodiversity in terms of species composition. The most prominent species include *Boscia albitrunca, Acacia mellifera, Grewia flava, Schmidtia pappophoroides* and *Stipagrostis uniplumis.* The average estimated canopy cover is very low (<3%), but the herbaceous cover is much higher (> 65%) than in the other variant of this woodland. Although there are *Acacia* plant species noted in this variant, the conspicuous woody plant species is *B. albitrunca*. This vegetation is characterised by the dominance of the woody species *A. erioloba, B. albitrunca, A. luederitzii, Z. mucronata, L. cinereum, Rhigozum brevispinosa* and *G. flava,* with the grass species *Schmidtia pappophoroides, Enneapogon cenchroides, Stipagrostis uniplumis* and *Eragrostis lehmanniana* being dominant in the herbaceous layer. The percentage of the tree cover is 3%, with shrubs 16% and the grass layer at 67%, being the most dominant.

This is one of the areas most negatively influenced by arboricides and a great deal of damage has been done to the *Acacia* tree layer. The impact that this clearing of mainly *A. mellifera* has had on this ecosystem has been devastating and it will take decades to recover.

2.2.2 *Acacia luederitzii* variant

This variant is the natural undisturbed vegetation of this woodland, which comprises a typical woody stratum with a well-developed tree (height 6 m and canopy cover of 5%) and shrub stratum (height 2 m and canopy cover 16%) in the study area. The typical herbaceous stratum for this variant has a height of 0.6 m and canopy cover of 50%. The height and canopy cover of the

herbaceous stratum will vary due to the erratic and relatively low rainfall. The description of the habitat aspects, species composition and vegetation structure are the same as that of woodland unit (2.2). The most prominent species include *Acacia luederitzii, A. mellifera, Eragrostis lehmanniana, Stipagrostis uniplumis and Schmidtia pappophoroides.*

The vegetation is characterised by the dominance of the woody species *A. erioloba, B. albitrunca, A. luederitzii, Z. mucronata, A. mellifera, Ehretia rigida, L. cinereum* and *G. flava* with the grass species *Schmidtia pappophoroides, Stipagrostis uniplumis* and *Eragrostis lehmanniana* dominant in the herbaceous layer.

2.3. *Eragrostis lehmanniana-Cenchrus ciliaris* grassland

This moderately tall open grassland occurs in association with the scattered pans (Figure 2.2, Unit 3) in the study area. It is characteristically found in isolated patches around the pan edges. This is an area with no trees, but 50% shrubs up to 1.8 m tall. The most prominent and conspicuous grass species is *Cenchrus ciliaris* (> 70% of the total species composition). The soil is moderate deep (0.8 – 1.2 m) dark brown clayey (15 – 20%) soil (Oakleaf soil form) with the prominent plant species such as *A. mellifera, E. lehmanniana*, and *Schmidtia pappophoroides* dominant in the herbaceous layer.

3. *Geigeria ornitiva-Enneapogon desvauxii* forbland

This forbland is strongly associated with the “Panveld” of KKNR and occurs scattered in the study area (Figure 2.2). The poorly drained greyish soil with a clayey texture is moderately deep. This unit comprises 1 278 ha of the reserve with diagnostic species such as *Geigeria ornativa, Enneapogon desvauxii* and *Eragrostis obtuse.*

The vegetation is characterised by the dominance of the grass species *Enneapogon desvauxii* and *Eragrostis obtuse,* together with the forbs *Geigeria ornativa* and *Pentzia globosa*. No or only sparsely distributed woody species such as *Z. mucronata* and *B. albitrunca* are present in this community. The herbaceous layer of this forbland is well-developed.

The “Panveld” has two vegetation communities associated with it. It can be zoned into the (3.1) pan (which could be bare or grassy) and (3.2) pan edges (sandy substratum or stony with mostly calcrete). The pan edges can be divided into two variants.

3.1. *Monechma incanum-Enneapogon desvauxii* forbland

The soil for this vegetation unit can be considered as moderate deep yellow brown sandy soil with a vegetation structure of open dwarf woodland and grassland, with diagnostic species such as *Rhigozum trichotomum, Eriocephalus aspalathioides* and *Monechma incanum.* This forbland is associated with the pan edges of the study area. Two variants have been identified and will be described in more detail, namely the *Rhigozum trichotomum* variant and the *Plinthus karooicus* variant.

3.1.1. *Rhigozum trichotomum* variant

The vegetation structure for this variant is a tall closed forbland with prominent species such as *Rhigozum trichotomum* and *Enneapogon desvauxii.* The terrain is undulating and mostly north-facing. Rock cover ranges between 2% and 5%. No trees are present in this variant, but 42%

consists of shrubs up to 0.5 m tall with 23% grasses in this area. The soil is relative moderate deep yellow, brown sandy soil.

3.1.2. *Plinthus karooicus* variant

The soil of this variant is deep yellow, brown sandy soil with a vegetation structure of open dwarf woodland with a good grass cover including prominent species such as *Plinthus karooicus and Enneapogon desvauxii,* with 8% shrubs up to 0.2 m tall and 43% grasses.

3.2. *Eragrostis bicolor-Enneapogon desvauxii* Grassland

This vegetation structure is open grassland with a good grass cover and with prominent species *Eragrostis bicolor* and *Enneapogon desvauxii* and with diagnostic plant species such as *Eragrostis bicolor, Walafrida saxatilis, Salvia runcinata, Chloris virgate, Cullen obtusifolia, Hibiscus pussilus, Blepharis integrifolia* and *Panicum coloratum*. The soil for this variant is deep yellow, brown sandy soil.

This forbland is associated with the pans of the study area. Some of these pans are bare, although some of them have a good herbaceous cover. The bare pans are not described because of the absence of the woody layer.

Due to the homogeneous nature of the vegetation, as well as the image quality of the aerial photos available, only community 1, sub-communities 2.1 and 2.2 and community 3 could be mapped and are indicated in Figure 2.2.

2.1.7. Mammals currently within KKNR

A standard 2.4 m electrified game fence demarcated the borders of the reserve to restrict the movement of the wide variety of wildlife species it contains. These species include white rhinoceros (*Ceratotherium simum*), black rhinoceros (*Diceros bicornis*), gemsbok (*Oryx gazella*), eland (*Tragelaphus oryx*), kudu (*Tragelaphus strepsiceros*), red hartebeest (*Alcelaphus buselaphus*), springbok (*Antidorcas marsupialis*), giraffe (*Giraffa camelopardalis giraffa*), Burchell's zebra (*Equus burchelli*), blue wildebeest (*Connochaetes taurinus*), warthog (*Phacochoerus africanus*), African buffalo (*Syncerus caffer*), lion (*Panthera leo*), leopard (*Panthera pardus*), cheetah (*Acinonyx jubatus*), black-backed jackal (*Canis mesomelas*), wild dog (*Lycaon pictus*) and brown hyena (*Parahyaena brunnea*). A wide variety of small mammals including springhare (*Pedetes capensis*), ground squirrel (*Xerus inaurus*), suricate (*Suricata suricatta*), pangolin (*Smutsia temminckii*), aardvark (*Orycteropus afer*) and several wild cats, as well as a great variety of bird species.

The most recent game count showed that there were approximately 111 giraffes. The ratio of males to females was currently 2:3. There has been no obvious predation on giraffes by predators in the reserve, although a few dead giraffes have been found that died of unknown causes.

2.2. Secondary Study Area

2.2.1. Location

The study area is situated just north of Bloemfontein (29º02'50.94"S; 26º11'25.80"E) in the central Free State Province of South Africa (Figure 2.3). It is part of a developed residential area named

Woodland Hills Wildlife Estate (WHWE), which was initiated in 2005. The study area is located at 1 398 m above sea level.

2.2.2. History

Woodland Hills Wildlife Estate is located on the northerly outskirts of Bloemfontein. The Estate offers residents the opportunity of living in an exclusive security area, close to nature, with the convenience of the city just around the corner. The combination of modern homes inside a nature reserve where animals roam wild among the houses, makes Woodland Hills a very sought-after residential area in Bloemfontein. The natural Free State flora in the large communal areas and the nature reserve, an abundance of water and dams and more than 20 species of game already established on the Estate, offer a unique lifestyle to its residents. Several walking – and bicycle trails on the 1 000 ha Estate and Game Reserve provides a unique opportunity to residents to safely enjoy their environment.

Woodland Hills Wildlife Estate was developed on a farm with a rich history. At one stage the land on which the estate was developed belonged to Abraham Fischer. He was the first and only prime minister of the Orange River Colony before the country became a union in 1910. Another snippet of history is that the Canadian regiment was stationed on the farm during the Anglo-Boer War. Guard posts were erected and even today various spent cartridges, horses' hoofs and bombshells can be seen here (http://www.whestate.com).

2.2.3. Current wildlife species

The WHWE includes natural Free State vegetation, abundant water and more than 20 species of wildlife that is already established. Some game species include: buffalo (*Syncerus caffer*), kudu (*Tragelaphus strepsiceros*), giraffe (*Giraffa camelopardalis*), springbok (*Antidorcas marsupialis*), zebra (*Equus burchelli*), steenbok (*Raphicerus campestris*), sable antelope (*Hippotragus niger*), duiker (*Sylvicapra grimmia*), roan antelope (*Hippotragus equinus*), impala (*Aepyceros melampus melampus*), nyala (*Tragelaphus angasii*), gemsbok (*Oryx gazella*) and waterbuck (*Kobus ellipsiprymnus*).

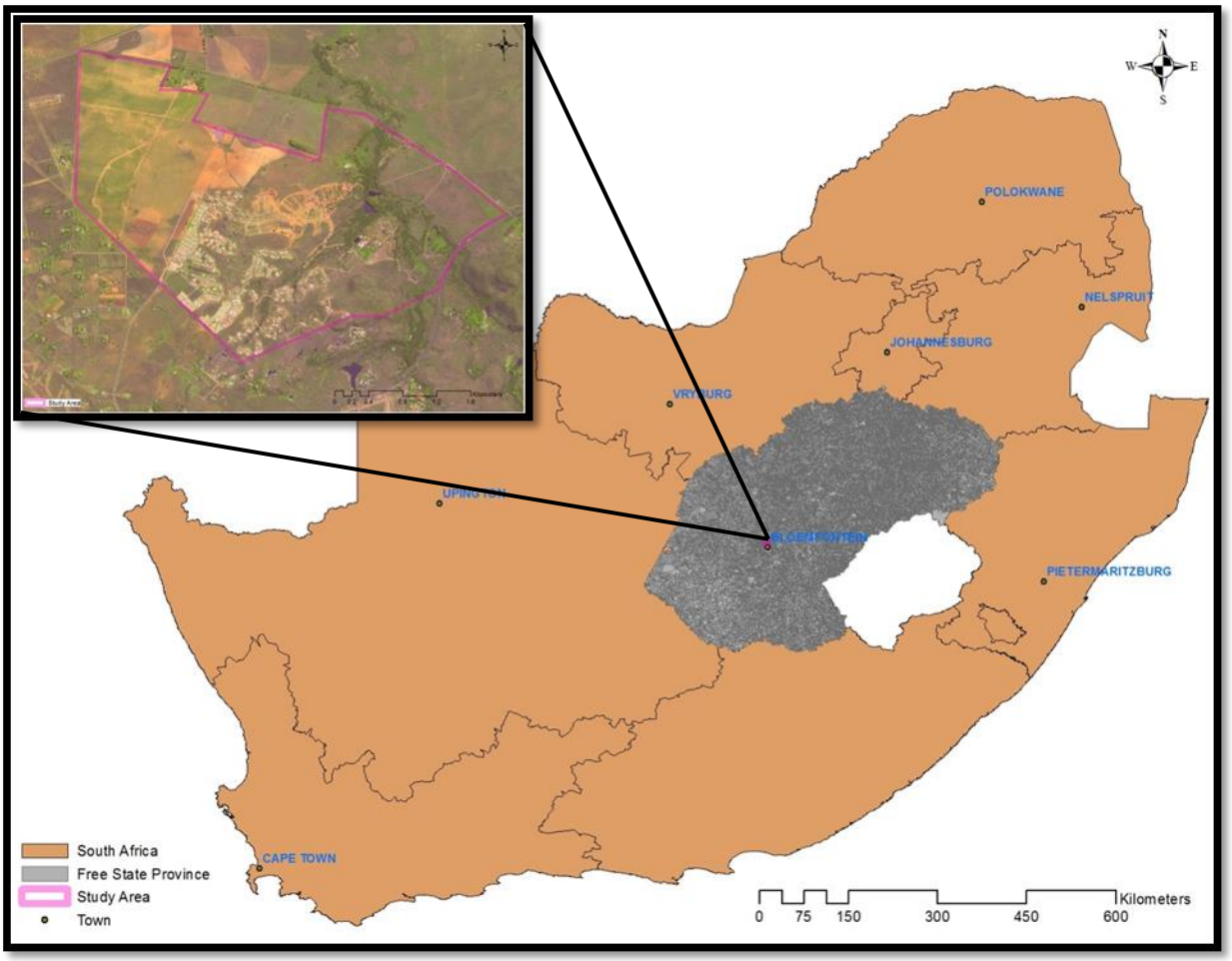
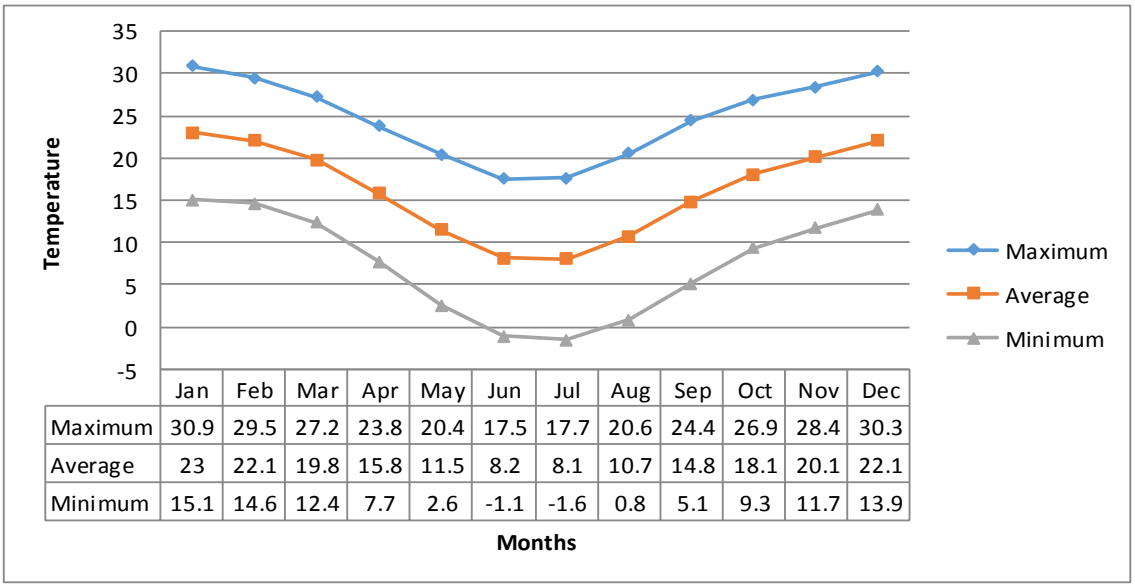


Figure 2.3 Location of Woodland Hills Wildlife Estate (WHWE) in relation to the Free State Province

2.2.4. Climate

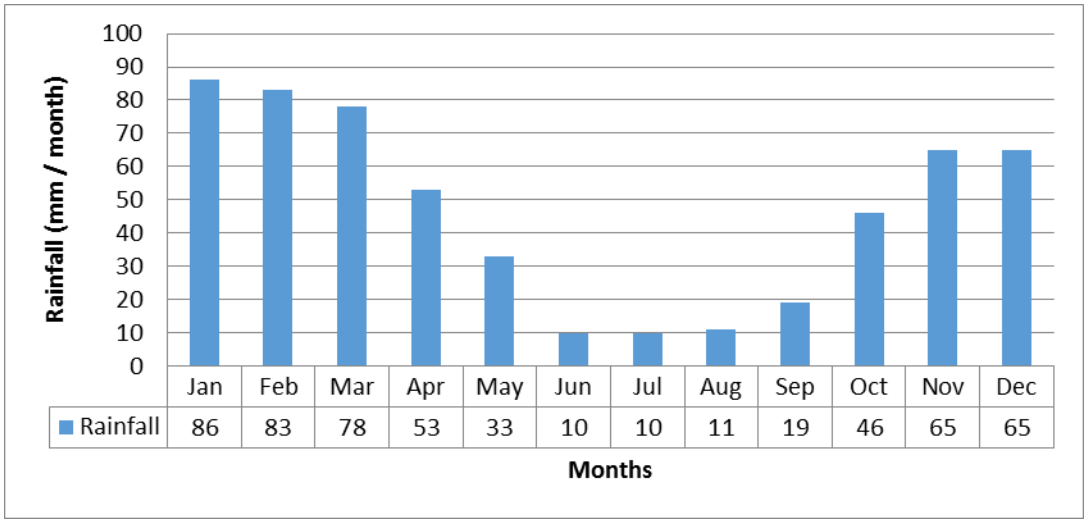
According to Dingaan (1999) one of the features of the Bloemfontein area is a climate where great extremes of temperatures are experienced. The average annual temperature has a relative wide range of 17.2°C. The highest temperatures are experienced during the summer months of December and January. The minimum temperatures are sometimes liable to extremes, and the local weather bureau notes that the winter climate of Bloemfontein can provide some of the lowest readings for the entire country. During the months of June and July, temperatures below zero are often recorded. The annual mean maximum temperature for the region is 24.8°C and the annual mean minimum temperature is 7.5°C. The mean annual temperature range for Bloemfontein for the period 1977- 1993 is presented in Figure 2.4.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	30.9	29.5	27.2	23.8	20.4	17.5	17.7	20.6	24.4	26.9	28.4	30.3
Average	23	22.1	19.8	15.8	11.5	8.2	8.1	10.7	14.8	18.1	20.1	22.1
Minimum	15.1	14.6	12.4	7.7	2.6	-1.1	-1.6	0.8	5.1	9.3	11.7	13.9

Figure 2.4 Mean annual monthly temperature for Bloemfontein for the period 1977- 1993 (Dingaan, 1999).

Bloemfontein has an average annual rainfall of 548 mm, which mainly precipitates during the summer months by way of thunderstorms. The long-term average rainfall is presented in Figure 2.5. For the period of 1977- 1993, the long-term average rainfall was 493.8 mm per annum. With the exception of the 1988 floods, the annual rainfall was often less than the long-term averages.



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfall	86	83	78	53	33	10	10	11	19	46	65	65

Figure 2.5 Mean annual monthly rainfall for Bloemfontein for the period 1977- 1993 (Dingaan, 1999).

The winds that prevail over the Bloemfontein area are generally northerly. In summer, the resultant air movement is from a northerly direction with a slight north-westerly predominance. The latter pattern is somewhat more prominent during the winter. The windiest period in Bloemfontein is mainly in spring during October and November. Autumn and winter seem to be the seasons with the least wind. The average velocity of the wind varies between 6.8 and 13.7 km/h. The average long-term monthly wind speed is presented in Figure 2.6.

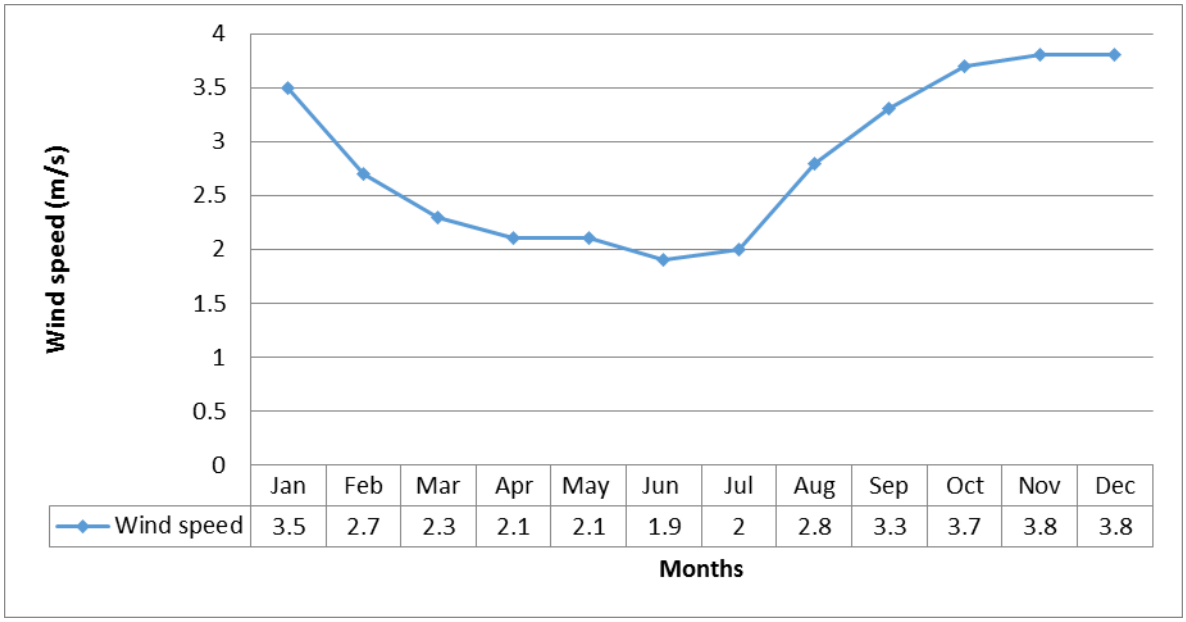


Figure 2.6 The mean wind speed for Bloemfontein for the period 1977-1993 (Dingaan, 1999).

2.2.5. Vegetation description

Bloemfontein and the rest of the Free State, except for the western third, is part of the grassland biome (Rutherford & Westfall 1994), which is South Africa's second largest biome. The biome is found mainly on the central plateau of South Africa and the inland areas of Kwazulu-Natal and the Eastern Cape (Low & Rebelo, 1998).

Low and Rebelo (1998) in turn divided the grassland biome into 15 different vegetation types. Bloemfontein is located in the Dry Highveld Grassland, which has an approximate surface area of 56 924 km². This area is agriculturally important, both in terms of intensive crop production and extensive stock farming. However, the widespread ploughing of arable land coupled with livestock grazing pressure resulted in the destruction or degradation of large portions of pristine vegetation.

The Dry Highveld Grassland is also poorly conserved (approximately 0.28% of the total 56 924 km²). Therefore, the importance of conserving a representative sample of this vegetation type is emphasised (Low & Rebelo, 1998).

Woodland Hills Wildlife Estate is situated on the southern border of the Highveld with the semi-desert area of the Karoo adjoining this area. The area is level in most places with a few peaks. The general vegetation of the area includes various grassland types with a number of tree species present in more sheltered southern parts of the hills. Due to the increasing presence of *Acacia karroo,* the veld type tends to be changing to a more savanna type of vegetation. This vegetation is suitable for grazing (livestock and game species). According to Acocks (1988), the veld type is classified as veld type 50 and includes dry *Cymbopogon-Themeda* veld. According to Low & Rebello (1996), the area was described as dry, sandy highveld grasslands and known as veld type 37.

According to Mucina & Rutherford (2006), there are three prominent vegetation types that need to be considered when describing this study area and the adjacent region.
(i) The Bloemfontein Dry Grassland (Gh 5) (ii) the Winburg Grassy Shrubland (Gh 7) and (iii) the Bloemfontein Karroid Shrubland (Gh 8).

(i) The Bloemfontein Dry Grassland is within the dry Highveld Grassland Bioregion with a distribution extending from Petrusburg in the west to the Rustfontein Dam in the east and from Reddersburg in the south to the Soetdoring Nature Reserve in the north. The conservation status is endangered with only a small portion statutorily conserved in the Soetdoring Nature Reserve. More than 40% is already transformed, e.g. for crop production (mainly Ae and Ca land types) as well as for urban (and related) development (the largest part of this vegetation unit on the Ae land type is situated in the Genl De Wet military training area, west of Bloemfontein). Especially those grasslands on shallow, gravelly soils as well as the low-lying areas on clayey soils are prone to karoo-bush encroachment when overgrazed. Erosion is considered low (50%), very low (37%) or moderate (13%) (Mucina & Rutherford, 2006).

(ii) The Winburg Grassy Shrubland has a conservation status description of least threatened within the dry Highveld Grassland Bioregion. This vegetation type has a series of larger patches between Trompsburg through Bloemfontein and Winburg to Ventersburg with more than 10% transformed for cultivation and by urban sprawl. Erosion low (57%), very low (24%) and moderate (18%) (Mucina & Rutherford, 2006).

(iii) The Bloemfontein Karroid Shrubland also has a conservation status description of least threatened. The distribution ranges from the Free State and Mpumalanga (only in the southwest) Provinces with an archipelago of isolated patches found on koppies (such as within the study area), butts and ridges embedded mainly within dry highveld grasslands in the region extending over large distances between Bloemfontein in the southwest, Verkeerdevlei and Lindley in the southeast, Standerton in the northeast as well as Heilbron and Bultfontein in the northwest. When looking at the conservation status, some sites of this vegetation are exposed to considerable urban developmental pressures, especially within the borders of the Mangaung Municipality. One small area is, however, conserved in the premises of the Free State National Botanical Garden in Bloemfontein. About 10% already transformed, mainly by cultivation. Erosion low (66%) and very low (24%) (Mucina & Rutherford, 2006).

CHAPTER 3: LITERATURE REVIEW

3.1. Diet Selection and Habitat Preferences of Giraffes

3.1.1. Diet selection

Giraffes typically prefer feeding in areas where *Acacia* species dominate the vegetation (Du Toit, & Bryant, 1990; Furstenburg, 1991; Furstenburg & Van Hoven, 1994; Skinner & Chimimba, 2005; Bothma *et al*., 2010). They are also classified as concentrate feeders (Hoffman, 1973; Kok, 1980; Pellew, 1984). Concentrate feeders have small reticulo-rumens in relation to body size and, in order to remain active, require more energy per kg body mass than other types of ruminants (Hoffman, 1973). This means that giraffes will select specific species of plants and highly nutritive plant parts. This in turn allows giraffes to browse frequently throughout the day on plant parts such as new shoots, pods and flowers (Hoffman, 1973, Pellew, 1984; Bothma *et* al., 2010). Giraffes are also highly selective concerning the browsing of specific plant species (Fourie, 1977; Furstenburg, 2003), but only partially selective with regard to plant parts and can therefore be viewed as concentrate feeders to a certain extent. The leaves from deciduous plant species formed the dominant component of their diet, but plant parts like flowers, fruits and pods were also regularly utilized when available (Kok & Opperman, 1985; Theron, 2005).

In a study by Blomqvist & Renberg (2007) it was shown that southern giraffes in the Mokolodi Nature Reserve spent 36% of their time on browsing and between 10% and 20% of their time ruminating. The study also showed that adult cows spent more time actively feeding, whereas males spent more time ruminating; juveniles spent more time browsing than adults. Blomqvist & Renberg (2007) deduced that the difference in time spent browsing between males and females was due to the fact that males browsed more efficiently by selecting more nutritious plant parts at higher browsing levels. Males also spent more time on vigilance scanning. In a study on the time allocation of *G. c. tippelskirchi* in the Serengeti National Park, Pellew (1984) found that females devoted more time to feeding throughout the day and attributed this to the fact that males tend to walk around more in search of females in oestrus.

With regard to plant species preferences, Blomqvist & Renberg (2007) found that giraffes in the Mokolodo Reserve preferred *Acacia* zones and also showed a strong preference for deciduous species such as *Ziziphus mucronata*. It was also concluded that there was a seasonal variation in the diet of the giraffes.

A total of 25 plant species were utilized in the study of Furstenburg & van Hoven (1994) in the Kruger National Park, South Africa. In the study by Theron (2005) a total of 28 plant species are listed, which were browsed in the Willem Pretorius Nature Reserve, South Africa. Apart from the prickly pear (*Opuntia ficus-indica*) and the barley sugar bush (*Pollichia campestris*), all the rest could be classified as woody plant types. It is noteworthy that the most intensively browsed species were all thorny, and that nearly half of the species were browsed only occasionally during six or fewer months. Though supplementations and grasses are not included in this plant list, they had a relatively important contribution during the dry season. According to the various criteria applied, *Acacia karroo*, *Asparagus laricinus* and *Ziziphus mucronata* constituted by far the most important components of the giraffe diet. Together these three species constituted almost 74% of all observations from Theron's (2005) study. This agreed with the finding of Furstenburg (2003) in the Kruger National Park that 60% – 70% of the diet of giraffes normally consisted of their preferred

plant types, with 30% – 40% of diet formed by 25 to 35 other species, which agreed with the 31 noted plant species from the study of Blomqvist & Renberg (2007).

Grasses of various species comprised nearly 2% of the total diet of the animals in the Willem Pretorius Game Reserve (Kok & Opperman, 1980, 1985). Grasses were especially utilized during August and September, the most critical period of the year and could possibly be related to an imbalance in the diet, associated with calcium deficiencies (Theron, 2005).

Seasonal variations in the diet of giraffes were seen in the findings of Leuthold & Leuthold (1972), Van Aarde & Skinner (1975), Sauer *et al*. (1977), Kok & Opperman (1980) and Theron (2005). Based on the findings of Theron (2005), no significant difference ($p > 0.05$) was found in the variety of plant types utilized in the various seasons (wet: 23; dry: 25), and could possibly be ascribed to the generally low abundance of the preferred food plants. As expected, the deciduous *A. karroo* exhibited a higher importance value in the wet season (44%) than during the dry season (33%). As *Asparagus laricinus* retains its leaves until late in the season, their importance value was identical for the various seasons (16%). Apart from *Z. mucronata* being deciduous, the dry leaves and leaves damaged by frost, as well as shoots and available fruits were continually utilized. The relative importance of the plant is therefore the same for both seasons, namely 19%, as is the case for *A. laricinus*. The importance value for the rest of the feeding plants combined was 20% for the wet season versus 32% for the dry season. This means that fewer dominant plants were utilized during the dry season, which is also the time when the nutritive value of plants declined (Kok & Opperman, 1980; Heitkonig, 1993).

Similarly, Sauer *et al*. (1977) found in the former arid Transvaal in South Africa that *Searsia lancea* was often utilized in the dry season, regardless of the strong aroma and bitter taste of the leaves. During the study done by Theron (2005), *S. lancea* trees in the Wag-'n-Bietjie Nature Reserve in the central Free State were browsed to such an extent during the dry season that large parts started dying off. Riparian plant species were conspicuously utilized more in the dry season. The quality of the preferred plant types tended to decrease during the dry season (Heitkonig, 1953). To maintain a balanced diet, less digestible species were therefore browsed (Macandza *et al*., 2004). *Buddleja saligna,* an evergreen shrub seldom browsed during the wet season, was continually utilized by giraffes in the Franklin Nature Reserve in South Africa (Parker *et al*., 2003). As described by Berry (1973), Dagg & Foster (1976) and Sauer *et al*. (1977), mainly the young shoots on the canopy perimeter of the trees and shrubs were eaten by giraffes. Signs of heavy browsing occurred commonly at the end of the dry season as demonstrated, amongst others, by the high leaf lines of *Salix babylonica* in Weltevreden Nature Reserve in South Africa.

Similar heavy browsing was also described by other authors (Foster, 1966; Foster & Dagg, 1972; Leuthold & Leuthold, 1972; Van Aarde & Skinner, 1975), when browsing damage in the form of broken branches caused by giraffe bulls was especially evident during the dry season. By this means leaf material also becomes available to cows and younger individuals, which would otherwise have been out of their reach. Giraffes have a seemingly significant effect on the deformation of the crown structure of trees and shrubs during the dry season (Spinage, 1968; Fourie, 1977; Kok & Opperman, 1985; Furstenburg, 2003).

There was a conspicuous increase in the utilization by giraffes of evergreen trees and shoots during the dry season in nature reserves in the Free State Province (Theron, 2005). Similar findings were also noted by various authors in other areas (Hall-Martin, 1974; Hall-Martin & Basson, 1975; Sauer, 1975; Van Aarde & Skinner, 1975; Kok & Opperman, 1980; Furstenburg,

1991). Except for the leaves of *A. karroo*, the flowers were preferred during the flowering period at the beginning of the wet season. In the autumn, *A. karroo* pods, *Z. mucronata* and *A. laricinus* fruits were preferred (Kok & Opperman, 1980). Large quantities of *A. karroo* racemes were consumed with little effort in some areas (Spinage, 1968; Du Toit, 1990), giving rise to a clearly distinguishable flowering line (Hall-Martin, 1974).

The exceptional utilization of alien plant species and the regular occurrence of osteophagia supported the opinion that giraffes were subject to mineral deficiencies, primarily during relative food shortages. Both of these phenomena suggest that giraffes were subject to sub-optimal habitat conditions, aggravated by the constraints of limited movement due to fencing. When comparing the results of different studies (Hall-Martin, 1974; Hall-Martin & Basson, 1975; Sauer, 1975; Van Aarde & Skinner, 1975; Kok & Opperman, 1980 and Furstenburg, 1991), the animals not only utilized a notably higher percentage of the available trees and shrubs, but also made use of herbaceous and alien plant species. Overbrowsing and preferred plant species gave rise to abnormal growth forms, in turn leading to lower browsing heights of the giraffes (Theron, 2005).

3.1.2. Feeding levels

O'Connor (2013) found that resource and diet overlap between different species can potentially be an additional stress factor for browsers. According to Leuthold & Leuthold (1972) from a study done in Tsavo National Park, Kenya, giraffes browsed at levels higher than two metres in 63% of the observations in the dry season, compared to 33% in the wet season. In the former western Transvaal (now North West Province) South Africa, Sauer *et al*. (1977) found that 67.4% of the browsing took place above two metres.

Blomqvist & Renberg (2007) illustrated six different height classifications during a feeding behaviour study on giraffes in the Mokolodi Nature Reserve in Botswana. The first level was below the knees; the second level was from the knees to the belly; the third level from the belly to the back; the fourth level form the back to the middle of the neck; the fifth level from the middle of the neck to the head; and the sixth level above the head. They found that males and females showed a difference in relative browsing height, because males preferred foraging on a higher level than females. Level five was the most common browsing level for males with 49% of the browsing records, whereas the female's most common browsing level was level four with 40.4 % of the browsing records. In total, more than 80% of browsing records from both sexes were between levels four and six. This corresponds with the findings of Sauer *et al*. (1977), but differs somewhat from the findings of Leuthold & Leuthold (1972), where 67% of feeding was below two metres, and from the results of Wyatt (1969) in Nairobi National Park, Kenya who also found most browsing occurred below two metres. Sauer *et al*. (1977) used a similar, but slightly modified height stratum classification with different name codes added. They found that the tree strata above two metres contained 67.4 % of all the browsing records, and 32.6 % of the records were from 0.5 – 2.0 m above ground. It was found that the vegetation below 0.5 m was apparently of no importance. O'Connor (2013) has done comparative studies to compare the browsing of giraffes and domestic camels (*Camelus dromedaries*) and found that camel feeding does not overlap with giraffe feeding. O'Connor (2013) used only four browsing levels during his studies done in northern Kenya, namely: feed high 180°, feed medium 135°, feed level 90° and feed low 45°.

Cilliers & Kok (1994) who did studies in the Franklin Nature Reserve in South Africa, initially used six classifications of feeding levels, rather than five levels. They used general browsing levels based on the body orientation and height of the mouth above ground level. They described level one: ground - feeding from the ground level; knee height – head lower than the stomach, the knee itself is not bent; chest height – neck horizontal or lower but not lower than the stomach; neck height – neck with an angle smaller than 45° to the horizontal, but not lower than the shoulders; head height – normal posture with neck position at an angle of 45° to the horizontal; head extension – mouth higher than the horn base. They found that 40% of the diet was below 2.0 m and that 31.4% in the dry and 28.3% in the wet season was at head level and only 1.7% in the dry and 1.6% in the wet season was at the extended level.

Young & Isbell (1991) did some feeding ecology studies in southern Kenya on a wildlife ranch. In contrast to the study of Pellew (1984b), they did not find that males preferred habitats with taller trees, as the average height of trees in the *Acacia drepanolobium* savanna was well below the average height preference of males and females. They found the preferred feeding level of females to be 1.0 – 2.0 m with few feeding records above 3.0 m.

Kok & Opperman (1980) used five feeding levels browsed by giraffes in the Willem Pretorius Nature Reserve in South Africa. They also included certain neck angles (e.g. 45°) when the giraffes were browsing. They established that many tree species preferred by giraffes were not above two metres in height, but 45% of all their recordings were at the height between the knees and the torso. This was also found by Van Aarde & Skinner (1975) in the Jack Scott Nature Reserve, where 17% of the diet and 33% of diet in the Koos Meintjies Nature Reserve (Sauer *et al*., 1977) and 50% of some species in Tsavo National Park (Leuthold & Leuthold, 1972) were below two metres. Kok & Opperman (1980) found that females fed 49% of the time at lower levels than males (35%).

3.1.3. Habitat characteristics and qualities

Browsing capacity of an area is its potential to support a specific number of browsers in good reproductive condition over an extended period of time, without deterioration of the habitat (Pellew, 1983a, b; Van Rooyen, 2010; Janeke, 2011). For impalas and elands, which are intermediate feeders, this implies availability of both grass and browse (Meissner *et al.,* 1996). Interpreting from Trollope (1990), carrying capacity is primarily a function of the grazing and browsing capacity of the veld, thus a principal factor in such calculations is foliage and foliage intake (Snyman, 1997). The difference between the stocking rate and browsing capacity can be described as stocking rate being a production decision, while browsing capacity is a habitat characteristic that is primarily a function of vegetation condition (Van Rooyen, 2010). Stocking rate or density refers to the number of animals that feed on a specific land area without necessarily considering the carrying capacity. It reflects a management decision regarding the number of animals to be put on the veld (Fourie *et al.,* 1985; Smit, 2006; Van Rooyen, 2010).

When browsing and the availability of browse are taken into consideration, four major environmental variables are thought to influence savanna structure and regulate woody cover and thus play a role in browse production, namely: herbivory, fire, water and nutrient availability (Skarpe, 1990; Chirara *et al.,*1998; Augustine & McNaughton, 2004; Smit, 2004; Sankaran *et al.,* 2008; Janeke, 2011). It is also known that fire and herbivory act partly by influencing availability of,

and competition for, water and nutrients (Skarpe, 1990). Scotcher (1979) noticed that the selection of plants by herbivores will depend, amongst other factors, on the choice and acceptability of available plant species. Results of food studies can therefore only realistically be interpreted by comparing the species in the diet with some quantitative values concerning the availability of the species in the habitat (O'Connor, 2013). Owen-Smith & Cooper (1987) concluded that among the favoured species of browsing ungulates there was no relation between the acceptability of a plant and its relative abundance along the foraging pathway. This is relevant to what is considered to be preferred food species and what are principal food species.

According to Smit (2001, 2006), the determination of browse availability is further influenced by height distribution of browse material, phenology of the plant species, whether they are evergreen, early- or late winter deciduous and the seasonal presence of flowers, fruits and seed pods with a high nutrient content. Scotcher (1979) indicated that historically this is probably one of the most difficult parameters to measure, as availability of food is governed by a host of factors such as age, growth form, proximity to water, soil conditions, rainfall, the feeding behaviour of the animal itself and position of plants in relation to others.

Tree-on-tree competition, that determines the position of trees in relation to each other, is often species specific (Furstenburg, 1991; Furstenburg & Van Hoven, 1994; Smit, 2006). In several woody species a significant positive correlation exists between size of the tree and distance to its nearest neighbour of the same species (Smit *et al.,* 1999; Smit, 2001).

Plant defences against herbivory or host-plant resistance (HPR) describes a range of adaptations, where plants have evolved to improve their survival and reproduction by reducing the impact of herbivores (Bothma *et al.,* 2010). Plants use several strategies to defend against damage caused by herbivores and this can have a great influence on the actual amount of browse utilized, as well as the browsing capacity. Many plants produce secondary metabolites, known as allelochemicals that influence the behaviour, growth or survival of herbivores. These chemical defences can act as repellents or toxins to herbivores, or reduce plant digestibility (Owen-Smith & Novellie, 1982).

Plant defences can be classified generally as constitutive or induced. Constitutive defences are always present in the plant, while induced defences are produced or mobilized to the site where a plant is injured (Owen-Smith & Novellie, 1982). There is wide variation in the composition and concentration of constitutive defences and they range from mechanical defences to digestibility reducers and toxins. Many external mechanical defences and large quantitative defences are constitutive, as they require large quantities of resources to produce and are difficult to mobilize (Carwardine, 2007).

Condensed tannins are especially important as a defence mechanism in woody plants (Haslam, 1974; Waghorn, 1990; Ward & Young, 2002). Tannins are a diverse group of compounds, widespread among dicotyledonous forbs and trees, which precipitate protein (Asquith & Butler, 1985; Caister & Shields, 2003) and sometimes act as a toxin rather than a digestion inhibitor (Hagerman *et al.,* 1992).

Leaves of trees are not always accessible or acceptable to browsers, in contrast to grasses where most dry material that is produced during the wet season is still available during the dry winter, as standing hay (Smit, 1989a). Gowda (1997) states that there are two variables that are important in influencing consumption of leaf tissue by herbivores, namely nutritional value and accessibility. Accessibility will further be determined by the terrain, climatic factors, openness and convenience

(O'Connor, 2013). According to Owen-Smith & Cooper (1985), the habitat carrying capacity for specialist browsers like the kudu or giraffe is limited by two factors: (i) most of the foliage produced by woody plants is out of reach in the higher levels of tree canopies and though much of this potential food material falls to the ground during the dry season, it becomes too dispersed to be ingested efficiently by an ungulate as large as the kudu or in this case for giraffes; (ii) the evergreen species providing browse during the dry season form only a very minor vegetation component in most savanna regions.

According to Waghorn (1990) and Topps (1997), browse has a medium to high crude protein value and the protein in browse is less subject to seasonal changes than in grasses. Enhanced nutritional value of foliage may lead to higher preference of the plant by browsers (Cooper & Owen-Smith, 1985). The increasing concentration of nitrogen in leaves is related to a reduction in concentration of secondary substances, like tannins (Furstenburg, 2005). Twigs and foliage of woody plants, the edible parts, are normally restricted to tips of branches. It is difficult to define, especially in the case of twigs, what portion of the plant is edible. According to Owen-Smith (1979), large herbivores generally consume only a small fraction of the vegetation components that they can eat. Thus, assessment of food availability by direct measurement of the vegetation can be a poor reflection of food availability as experienced by the animals (O'Connor, 2013). Further, larger animals often feed at the same level as smaller animals (Du Toit, 1990), in addition to feeding at heights not available to small animals. Production and utilization are therefore more difficult to measure than in the case of herbaceous plants (Barnes, 1976; Smit, 2006).

On average, impalas browse at heights of up to 1.5 m, elands and kudus up to 2 m and giraffes up to 5 m (Table 3.1). As demonstrated by Milewski & Madden (2006) on a wildlife ranch in Kenya, the collective browsing heights of giraffes, elands and impalas feeding on thorny plants, ranged from near-ground level to a maximum of 5 m on average. Giraffe bulls can reach up to between 5.6 m and 6 m when using their prehensile tongue.

Abule *et al.* (2007) calculated in the Awash National Park, Ethiopia, that 60% of giraffe browse occurred above 1.5 m. Dekker & Smit (1996) found the same in the mopane savanna in South Africa. Research in the Masai Mara, Kenya by Van Essen *et al.* (2002), indicated that the majority of leaves were above 2 m and therefore out of reach for smaller browsing ungulates. According to Grant *et al*. (1995), giraffes in the Kruger National Park should only rarely experience a limitation of food availability, especially in the absence of deciduous trees. This is because there is little or no competition at their browsing height and they should not experience a limitation in food quality.

Hofmann (1973) observed that giraffes move slowly through their habitat as long as food is sufficiently available. There are also different ways of feeding by browsers. Field & Ross (1976) and Milewski & Madden (2006) identified browse feeding techniques as either: i) strip - when tongue, lips, or the inside of the mouth were used to rip leaves off a section of a branch; ii) pull - where a branch was pinioned between palate and lower teeth and tugged entirely free from a plant; iii) nibble - when the lips cropped leaves from branches without the distinctive head movement associated with pulls and strips. When browse becomes scarce in the case of dominance of deciduous trees, then leaf litter as well as other sources of food are included in the winter diet of browsing animals.

Table 3.1 Summary of height strata utilized by different browser and mixed feeder game species (Bothma, 2010).

Species	Plant material 0 - 1.5 m	Plant material ➢ 1.5 - 2 m	Plant material ➢ 2.0 - 5 m
Giraffe	Yes (♀ & sub-adult ♂)	Yes (♀ & sub-adult ♂)	Yes (adult ♂ and ♀)
Kudu	Yes	Yes	No
Eland	Yes	Yes	No
Impala	Yes	No	No
Nyala	Yes	No	No
Springbok	Yes	No	No

The available production per ha plays an important role in the spatial distribution of giraffes. According to Pellew (1983a & b; 1984a & b) and Janeke (2011), browse production is limited in certain areas and differs due to variations in soil, terrain, season, climate, vegetation types and management, to list only a few factors. When calculating browse availability, it should include leaf material and young shoots (Smit, 2002). Most authors did not include shoots as part of the browsable material and only evaluated the leaf mass. Rutherford (1982) reported a leaf dry matter (DM) production of 1 100 kg/DM/ha in *Burkeya africana – Ochna pulchra* savanna. Scholes (1987) reported a yield of 801 kg/DM/ha for *Colophospermum mopane* veld and Walker (1980) found a yield of 600 – 2 100 kg/DM/ha in *C. mopane* veld in Zimbabwe. In relation to production, Smit (2002) reported a production ranging between 1 500 – 1 700 kg/DM/ha in different growing seasons for mopane veld in Limpopo Province and Dekker & Smit (1996) reported a range of 1 224 – 2 672 kg/DM/ha in another area of the mopane veld in Limpopo Province, South Africa. Abule *et al.* (2007) calculated peak biomass produced across different rangeland sites in Ethiopia to be 196 – 3 311 kg/ha. Van Essen *et al.* (2002) worked in south-western Kenya and determined browse production to differ between communities in the Kiloriti plain from 52 – 8 042 kg/ha, with a range of 56 – 1 452 kg/ha below a 2 m browsing height.

Larger browsers often remove shoot ends while feeding and hence have a trimming effect (Du Toit *et al.,* 1990; Augustine & McNaughton, 2004). Du Toit *et al.* (1990) proposed that severe browsing of *Acacia* trees not only stimulated shoot production, but also induced a physiological response that increased palatability, leading to a feedback loop of further browsing.

The energy cost of browsing may be influenced by a reduction in accessibility due to increased spinescence (spine length and density) (Gowda, 1997). Milewski *et al.* (1991) showed that spinescence in *Acacia seyal* and *Acacia xanthophloea* increased with an increasing density of giraffes. Sankaran *et al.* (2008) found a clear negative relationship between woody cover and biomass of browsers. Augustine & McNaughton (2004) also concluded that browsers have significant effects on species composition of the shrub community in central Kenya, especially when shrubs lacked thorn defences. Milton (1987) found that *Acacia karroo* sustained heavy losses of its soft green shoots to browsers in cases where it was the first species to sprout in spring. *A. karroo* will be most sensitive to defoliation in September and October when rapid extension of shoots occurs. Shoots produced in late summer, in response to damage during the growing season, remain leafier in winter (Omphile, 1997). In this way browsing may increase browse availability for browsers, but repeated damage reduces regrowth in the following season.

Stuart-Hill & Tainton (1988) confirmed that frequent intense browsing of *A. karroo* might reduce vigour and have a depressing effect on growth in the long-term. When leaves of a tree are damaged, a chemical activator, ethylene, is released through stems and twigs which stimulates tannin production in leaves. This reaction can also spread to other plants in the area before they are damaged, as a preventative measure, by means of chemicals released into the air (Van Hoven, 2010). The studies of Van Hoven (2010) on kudus indicated that concentrated tannin levels in leaves of *A. caffra* increased by 94% within 15 minutes after feeding commenced. Kudus adapted to this by browsing only for a short while on a specific tree, before moving on to the next tree (Omphile, 1997). Smit (2006) described a case of *A. nigrescens* leaves that displayed a 70% increase in tannin concentration two minutes after disturbance, followed by a delayed response of 30 to 100 minutes after the disturbance. In this instance the giraffes were forced to select plants with lower tannin content. Baldwin & Schultz (1983), Van Hoven (1984) and Janeke (2011) described cases where browsing resulted in increased chemical defence from the plants. Negative impacts of browsers and mixed feeders have been reported in some browsing ecosystems (Owen-Smith, 1985; Pietersen *et al.,* 1993; Bond & Loffell, 2001; Birkett, 2002; Augustine & McNaughton, 2004; Bezuidenhout, 2005; Sankaran *et al.,* 2008; Deacon & Smit, 2012). No damage was, however, recorded in other cases (Kok & Opperman, 1980; Owen-Smith & Cooper, 1985; Du Toit, 1990a; Van Rooyen, 1992; Dörgeloh, 2001a; Watson & Owen-Smith, 2002; Matson *et al.,* 2006).

According to Bezuidenhout (2005) crude protein and moisture content of leaves seem to be the deciding factors when giraffes select food. Browsers in general will specifically select flushing shoots that have a high protein content. This might explain why browsers tend to defoliate everything in a selected small proportion of a reserve rather than browsing over a wide area (Deacon & Smit, 2013). When stocking rate is correct and the browsing impact is acceptable, animals help maintain biodiversity (Deacon & Smit, 2012). Dominant, preferable trees may eventually be eradicated at densities of 1.23 giraffes/km² (Bezuidenhout, 2005). The results of Bond & Loffell (2001) and Deacon *et al*. (2012) indicated major long-term browsing impacts of giraffes on some *Acacia* species. Bond & Loffell (2001) found that *Acacia davyi* has almost disappeared from areas of high giraffe concentration in Ithala Game Reserve (Kwazulu Natal) and *A. caffra* might suffer a similar fate. *A. karroo* showed high mortality in heavily browsed areas of Ithala, although some trees still produced foliage on heavily browsed branches. They predicted heavy mortality of these trees, should the population experience drought, disease or other stress in coming years. Bond & Loffell (2001) suspected that the available browse resource was too small relative to giraffe numbers, with few alternative feeding areas available to spread the browse load. Birkett (2002) found that giraffe browsing, at a density of 1.9 giraffes / km², along with low rainfall of <600 mm per year reduced tree growth in Kenya. Growth retardation was height specific and giraffe impact was greatest at 3 – 5 m in the *Acacia* woodland, as was confirmed in the study of Pellew (1983).

At increased densities in small confined areas, browsers such as kudus and giraffes could also have a more severe impact on woody plant growth and recruitment than they do naturally (Owen-Smith, 1985). Normally bush encroachment and tree thickening are detrimental to grazers only, but it may also be detrimental to browsers (Smit, 2004; Janeke, 2011). According to Smit (2001), trees in low density stands display a better distribution of browse and have leaves in younger phenological states over an extended period compared to high densities. Abule *et al.* (2007) recognized a variation in leaf dry matter (DM) for similar species across rangelands with the same ecological conditions and attributed it to differences between vegetation types.

Different types and condition of the available habitats as well as management objectives, such as trophy hunting, venison production, sport hunting or game viewing determine the stocking density of the ranch by management (Trollope, 1990). Trollope (1990) defines ecological carrying capacity as follows: “The maximum population of animals that an area can support without deterioration of the habitat.” A possible solution for higher stocking rates is to base the number of breeding stock of game on the mean annual rainfall (Janeke, 2011). This will provide a viable strategy for coping with drought periods (Trollope, 1990). Failure to consider the spatial components of herbivory in calculations of carrying capacity and assessments of ecosystem persistence can contribute to overutilization, failed economic development efforts and declines in wildlife populations (Smit, 1990; Dekker *et al.,* 1996; Bothma, 2010). Du Toit (1995a) noted that larger species are able to feed in a wider range of habitats due to their wider feeding tolerance. Smaller species are more evenly spread through the ecosystem, are habitat specialists and their populations are clumped in suitable habitat types (O’Connor, 2013).

3.2. Activity Budgets of Giraffes

Different activities and patterns of behaviour have been documented by Seeber *et al.* (2012) in Zimbabwe and in South Africa. Kok (1980) and Kok & Opperman (1985) studied the daily activity patterns of giraffes and described them by means of the moment-scanning method, (Altmann, 1974). The specific activity of every giraffe in the herd was noted at a given moment, regardless of the activities of the individuals prior to that (Altmann, 1974). Observation intervals of five minutes during the day and ten minutes at night were determined by using a wristwatch. The data for every hour were grouped so that different activities were expressed as percentages per hour of the day or night. Four activity categories were noted by Kok (1980), namely movement (including walking and running), standing, lying down and eating. The measure of shade utilization - whether none, partially or fully, was noted simultaneously. Total activities were calculated as the number of activity records per category expressed as a percentage of all observations. Pellew (1984) did some activity budgets in the Serengeti National Park and concluded that energy-consuming activities were minimized and that energy was conserved at the most demanding times of the day.

Pellew (1984) included a total of 8 553 observational records and Kok & Opperman (1985) made a total of 12 794 observational records. Leuthold & Leuthold (1972) made 4 024 observational records in Tsavo National Park (East) in Kenya, focusing mainly on feeding habits between seasons. This is in comparison with the food preference study of Oates (1972) in the Transvaal Lowveld mopane woodland, who made 494 feeding records, only two of which were grasses. In comparison, Van Aarde & Skinner (1975) in the Jack Scott Nature Reserve, made 548 observational recordings during seven months from February to August 1974. Langman (1978) only focused on the frequency of osteophagia and geophagia during observations in the Timbavati Private Nature Reserve in South Africa and identified some shortages and imbalances that existed in that area for browsers. Few of the authors distinguished between sexes and age groups. Ginnett & Demment (1997) identified some sex differences in Masai giraffe foraging behaviour in Mikumi National Park, Tanzania and collected 1 884 observations in total. They found that males spent less time foraging than females, but allocated a greater proportion of their time to ingestion as opposed to travel between feeding patches. They also found no sex difference in rumination time, although males spent more time on non-feeding activities such as walking. This was also noted by Leuthold & Leuthold (1978) in Tsavo East and by Young & Isbell (1991) on the Athi Plains in Kenya. Feeding ecology and observations done by Furstenburg & van Hoven (1994) showed

supportive evidence of differences between sexes, with 2 730 observations made in the Kruger National Park.

Many comparisons can be made from the methodology used by Blomqvist & Renberg (2007), who used the 5 minute scan interval to construct time budgets. A total of 153 sampling observations were done, 89 and 64 of males and females, respectively, in the Mokolodi Nature Reserve in Botswana. Seeber *et al*. (2012) evaluated 65 different behavioural patterns and grouped them in seven categories, while recording 272 hours of observations and making a total of 1 264 recordings. They also cited a total of 104 giraffe publications to make comparisons with data derived from studies done all over the world. Van der Waal *et al*. (2013) identified social cliques from 1 089 recorded observations amongst the reticulated giraffes in Kenya and concluded that giraffes are non-random in their pattern of activities. O'Connor (2013) did 290 hours of fieldwork using a two-minute group scan interval and analysed 8 696 giraffe observations within the Mpala Research Centre in Laikipia Province in north-central Kenya and identified several activities.

3.2.1. Standing

The specified standing activity is noted when the giraffe is standing still and not feeding, ruminating, moving or performing any other activity. The standing category was also noted by Ginnett & Demment (1997), Leuthold & Leuthold (1978) and Blomqvist & Renberg (2007). From the study of Theron (2005) in the Free State, it represented the second most important daily activity of the giraffes. Aspects like resting, social interaction and drinking were included in this category by most authors. The first-mentioned standing position was seen as a typical resting position and characterized by the neck being held at an angle of approximately 45° while ruminating (Innes, 1958). It was also noted that heavy rain accompanied by lightning caused a temporary cessation of activities, while the animals stood around restlessly (Innes, 1958).

3.2.2. Walking (movement)

Theron (2005) found that a relatively small percentage of total daily activity was spent in movement, which was different from the findings of Kok & Opperman (1985) and Pellew (1984). The movement category played a less important role at night and only comprised 6% of total nocturnal activity. Most of the animals' movement took place during the early evening (17:00 - 20:00), possibly due to some restlessness accompanying the onset of twilight. The giraffes were often found the following day at almost the same place observed the previous night – as was also mentioned by Foster & Dagg (1972). During the day, movement peaked during the early morning (07:00 – 10:00) and late afternoon (14:00 – 17:00). The least movement took place during the heat of the day. Theron (2005) found that both sexes spent equal time (17%) during the day in movement. However, cows seemed to move more during the dry season during food shortages, than during the wet season when more food was available. From the observations of Theron (2005), there was a significant difference in the movement of giraffes during the various seasons.

3.2.3. Browsing

Giraffes spent most of their time feeding (Innes, 1958; Dagg, 1960; Ferreira, 1970; Dagg & Foster, 1976) and according to Furstenburg (2003), up to 70% of their day is spent browsing. In a study conducted in the Free State (South Africa), Theron (2005) observed that active browsing was responsible for more than half (53%) of the daily activities of the animals. During the day, browsing

activities mostly took place in direct sunlight. Minimal time was spent in full or partial shade. During light rain showers, their ears were only flattened and browsing continued undisturbed. More intense rain showers usually caused a temporary cessation of browsing. Though individuals sometimes smelled the leaves of trees prior to browsing, especially in the Franklin Nature Reserve in South Africa with its unusual composition of potential feeding plants, no relation was found between wind and browsing direction (Theron, 2005). The simultaneous browsing of the same plant by more than one giraffe was observed regularly by most authors. In contrast to the assumption of Dagg (1960) and Spinage (1968) that the feeding activities of giraffes also dominated at night, browsing was responsible for less than a third (31%) of the total time budget during the night. In the early evening (17:00 - 20:00) and the early morning hours (01:00 - 05:00), the browsing frequency was high (84%), but it dropped to a low frequency (16%) in the middle of the night. Throughout the day, browsing, however, took place at a relatively constant rate with an initial increase of 20% in the early morning and again in the late afternoon (Theron, 2005).

When the sexes were viewed separately, the browsing category remained high for both sexes (Theron, 2005). The fact that mature bulls browsed significantly less than the cows was also supported by the findings of Du Toit (1990) and Pellew (1984). Young calves normally spent less time browsing, as mothers' milk largely fulfils their nutritive requirements, leaving them needing only to nibble on plant parts. On a seasonal basis, browsing still represented the dominant activity of adult giraffes in both the wet and dry seasons. Though it initially seemed that there was little difference between the different seasons (Theron, 2005), there was still a significant difference. Over all the observations, browsing was found to be the highest during the dry season. In both sexes, the browsing time during the period of food scarcity slightly increased. The way ungulates adapt to fodder may be influenced by certain seasonal changes and fluctuations in environmental conditions that will characterize ranging patterns (Morrison & Bolger, 2012). Browsing will also be influenced by competition due to seasonal fluctuations of food resources (Carter, 2013).

3.2.4. Lying down

Contrary to popular belief, giraffes do lie down (Sicks, 2011). When they lie down to ruminate, their necks are normally held up straight, whereas their necks are curled backwards with their heads resting on their flanks when they sleep (Carnaby, 2010; Sicks, 2011). Blomqvist & Renberg (2007) found that giraffes in the Mokolodi Nature Reserve on average spent less than 5% of time lying down (lying-and- ruminating or lying and sleeping). They also noted that females lay down more often than males and adults more often than sub-adults and juveniles. Giraffes in the Serengeti National Park, Tanzania only devoted between 0% and 10% to this activity during daytime, but a significant amount of time was spent lying down during the night (Pellew, 1984). Moreover, he found that adult bulls lay down the most during the day, whereas all recordings of males lying down were made between 10:00 and 16:00. Some recordings of cows, calves and bulls lying down, especially during midday, were therefore expected.

Theron (2005) found that only 4% of the total daily time was spent lying down. With some exceptions, all animals were found in direct to partial shade in relatively open, grass-covered areas. Similar observations were made by Kok & Opperman (1980) in the Willem Pretorius Game Reserve. During the day, resting periods with the head on the stretched out hind leg, only lasted for three to five minutes. In contrast, lying down with the head high took place for up to 60 minutes. As initially presumed by Dagg & Foster (1976), more than half of the total time during the night was

spent lying down as described in the category from Theron's (2005) study. For all individuals, peak times of lying down took place long before and shortly after midnight, alternatively with browsing. During the day, giraffes mostly lay down between 11:00 and 14:00, when the environmental temperatures increased. Though the lying down category during the day did not play any significant role among the sexes, bulls lay down somewhat more than cows. Obvious differences were observed between the seasons, as the animals spent more than double the amount of time lying down during the wet season than during the dry season. This has also been noted by Ginnett & Demment (1997) for G. c. *tippelskirchi* giraffes in Tanzania.

3.2.5. Galopping (running)

Giraffe have a unique gait, i.e. both right legs or both left legs are moved forward simultaneously with each step when they walk (Innes, 1958). However, when these animals gallop their gait changes to the back- and forth swing of both their front and hind legs like a horse, so that they are capable of reaching high speeds. According to the literature, giraffes can gallop at speeds of up to 55 $km.h^{-1}$ when fleeing from danger (Carnaby, 2010).

3.2.6. Osteophagia

Osteophagia (eating of bones) is a form of pica (the ingestion of non-food items), which is behaviour expressed as the result of an underlying health problem, such as a mineral deficiency. The most common cause of osteophagia is a phosphorus deficiency. This most typically occurs in grazing and browsing mammals in areas where soil contains very low levels of phosphorus (De Waal & Koekemoer, 1997). Giraffes are similarly highly susceptible to calcium and potassium imbalances (Langman, 1978), which can also lead to a phosphorus deficiency. According to Langman (1978), Blomqvist & Renberg (2007) and Bothma *et al.* (2010), osteophagia is a common feature in the feeding routine of the southern giraffe, especially during the months from April to November. Langman (1978) found that osteophagia occurs at more or less the same frequency in both adult and sub-adult giraffes.

Osteophagia was observed in Willem Pretorius Nature Reserve among cows and younger individuals during the dry season (Theron, 2005). Pregnant, lactating and growing individuals were found to be more sensitive to mineral deficiencies in their diet (Kok & Opperman, 1980). The ground was also repeatedly licked when the phosphorus and calcium content of the diet was insufficient (Furstenburg, 2003). Animals on phosphate-poor grazing develop a major need to chew on bones (De Waal & Koekemoer, 1997), although it is speculated that this could be due to an eating deficiency. In this way they can contract botulism-poisoning. By having phosphate licks available as seen in Nairobi National Park in Kenya (Evans, 1970), osteophagia can be overcome to a large extent (Mitchell & Skinner, 2003) and the lick can attract large numbers of giraffes, as seen with the Rothschild's giraffe.

3.2.7. Other activities

a) Herd structure

Several studies on their social behaviour and social structure have concluded that giraffes associate randomly and only form loose social bonds, with group membership changing frequently (Dag & Foster, 1976; Leuthold & Leuthold, 1978; Pellew, 1984). However, recent studies using more sophisticated methods to analyse the social networks of animals suggest otherwise (Bercovitch & Berry, 2013a). Studies by Bashaw *et al*. (2007) and Shorrocks & Croft (2009) both indicated that relationships between individuals are established and maintained for long periods, but that these relationships are "obscured" by the frequent changes in group size and membership. Bashaw *et al*. (2007) concluded that social relationships between adult females and between mothers and their offspring are maintained long-term, after studying the structure of social relationships among captive female giraffes. This strong social structure between mothers and daughters within the herd composition was also seen amongst Thornicroft's giraffes (Bercovitch & Berry, 2013a). Shorrocks and Croft (2009), on the other hand, identified individuals in several giraffe herds who "joined smaller groups into one social network." Bothma *et al*. (2010) state that the mean herd size of giraffes is 5.7 individuals, but herds of up to 25 individuals can be found. Shorrocks & Croft (2009) found that herd size ranged from 2 to 19 individuals. Male giraffes are solitary most of the time, but are frequently observed in all male herds (Bercovitch & Berry, 2013b).

b) Grooming and scratching / rubbing

According to Berry & Bercovitch (2012) it is a common occurrence for giraffes to groom and scratch themselves against branches and tree trunks. He explains that these large animals have the disadvantage of not being able to reach their head and neck with their hind legs, or their bellies with their mouths; areas where parasites, especially ticks, congregate and cause irritation.

c) Geophagia

Like osteophagia, geophagia (eating of soil) is a form of pica and often forms part of the feeding routine of the southern giraffe (Langman, 1978). Soils are also supplements of nutrient-poor diets and, according to Stark & Slabach (2012), have the added advantage of binding toxins and counteracting the effects of endo-parasites. They found that animals especially prefer clay-like soils as the negatively charged clay molecules easily bind to positively charged toxin molecules and even bacteria or viruses. Langman (1978) found that geophagia was most often exhibited by juveniles in the Timbavati Private Game Reserve adjoining the Kruger National Park.

d) Drinking water

Because their front legs are longer than their necks, giraffes must splay their front legs when drinking so that their mouths can reach the water. According to Berry & Bercovitch (2012), a giraffe is most vulnerable during this activity, as these movements take time and can effectively reduce the animal's reaction time (when, for instance, attacked by a predator). Furthermore, Bothma *et al*. (2010) state that, although giraffes can consume up to 47 litres of water per day, they can cope for relatively long periods without surface water in arid regions and are generally classified as water independent. In fact, it is so unlikely to find a giraffe drinking water in arid regions that this activity was not accounted for in giraffe time allocation and behavioural studies by Pellew (1984) and Blomqvist & Renberg (2007).

e) Necking

According to Berry & Bercovitch (2012) this behaviour is typically exhibited during courtship, when young males play and "practise" for later in life or when two adult males fight, in which case it is more appropriately referred to as 'sparring'. In the first case the male and female would typically intertwine their necks with no intent of hurting one another, whereas in the latter case males will swing their necks to deliver painful blows with their horn-like ossicones to the bodies of their opponents. Berry & Bercovitch (2012) explains that giraffe bulls do not fight to establish a territory like the males of most other ungulates, but "develop a social hierarchy by fighting one another, the reward for the highest ranked male being access to females is oestrus." Such a fight over dominance may continue for several hours, until one bull becomes submissive and backs away. Darker males tend to neck more aggressively and male coat colour darkens with age. Necking starts to play a role when the male pelage colouration darkens at 1.8 – 2 years of age (Berry & Bercovitch, 2012). Necking and aggressive fighting is most probably the main reason why the average age of death of males is at 16 years. Maximum age for males is 22 years, compared to females that may live for up to 28 years (Berry & Bercovitch, 2012).

f) Urinating and defecating

Giraffes are concentrate selectors with a digestive system distinguished by the high fermentation rate and quick passage of food, as well as the increased absorptive surface as a result of even papillation throughout the various portions of the rumen (Hoffman, 1973; Van Hoven, 2010). Because of the rapid digestion of food it is expected that giraffes would defecate and urinate often. There are, however, no records available of how often they defecate or urinate.

g) Calves suckling

Giraffe calves are weaned at an age of 12 to 16 months. It was therefore expected to see calves younger than this age suckling from their mothers throughout the day. It was also expected to see weaned calves with their mothers, as giraffe mother-offspring relationships are often maintained into adulthood (Bashaw *et al*., 2007).

h) Sniffing cows / flehmen

It is a common feature for males of several species of ungulates to sniff and lick the urine of females, and afterwards to tilt their heads backwards and curl the upper lip so that their teeth and vomero-nasal organs are exposed, in a posture called 'flehmen' (Carnaby, 2010). The exposure of this organ allows the male to chemically analyse the scent signal (mainly pheromones) and thus determine the oestrus state of a female. Flehmen often occurs during courtship by males, or in males and females when "investigating" new odours. Because female giraffes reach sexual maturity between the ages of three to five years, can breed throughout the year and can produce up to 8 calves in a lifetime (Hall-Martin & Skinner, 1978), it was expected that flehmen would occur often in males as the probability of females being is oestrus was high. Females can become

pregnant while lactating (Bercovitch & Berry, 2010b) and, because breeding is non-seasonal (Bercovitch & Berry, 2010a), flehmen can take place at any time during the year when males travel and seek female herds. Male mating behaviour was investigated by Bercovitch *et al.* (2006) and showed that male movement patterns are strongly influenced by female distribution.

i) Predator vigilance

Vigilance can be defined as the action or state of keeping careful watch for possible danger and is, according to Cameron & Du Toit (2005), mainly considered to have an anti-predator function in ungulates. Ecological factors such as predator pressure have a pervasive impact on animal population sizes and structure (Bercovitch & Berry, 2010). Vigilance behaviour in ungulates includes scanning the surroundings and maintaining a certain feeding posture for maximum visibility of the area. Cameron & Du Toit (2005) found that adult cows monitored in the Kruger National Park scanned more frequently, whereas males scanned less often, but for longer periods at a time, resulting in no significant difference in total time devoted to vigilance scanning. Cameron & Du Toit (2005) also observed that both cows and bulls interrupted their browsing to scan more often when foraging at lower and high neck angles. This suggests that it is costly (in terms of browsing efficiency) for the animals to browse at these heights. It was therefore expected that giraffes would spend a significant amount of time throughout the day scanning their environment and would maintain a feeding height that also allowed maximum visibility while feeding. Giraffe herds tend to be smaller in woodland and thicket areas than in open areas (Bercovitch & Berry, 2010).

With regard to anti-predator behaviour Carnaby (2010) states that, “although clearly curious, sometimes advancing to investigate predators or strange movements, shapes, etc., they [giraffes] usually flee from danger at up to 55 $km.h^{-1}$.” All the predators known to catch and kill giraffes, including lions, leopards, cheetahs and spotted hyenas, occur in the Khamab Kalahari Reserve. Predators might play a big role, as giraffe calf mortality was found to be extremely high in other studies and half of all calves born died before the age of one year (Bercovitch & Berry 2010a).

3.2.8. General activities

Blomqvist & Renberg (2007) and Pellew (1984), concluded that giraffes spent most of their time browsing, followed by walking and standing-and-ruminating. Blomqvist & Renberg (2007) more specifically found that giraffes, on average, devoted 36% of their time to browsing, 20% to walking and 16% to standing-and-ruminating, with the rest of their time devoted to standing, looking around, walking-and-ruminating, lying-and-ruminating, galloping and other activities. Blomqvist & Renberg (2007) and Pellew (1984) therefore agreed that giraffes spent between 0% and 10% of the time on ‘other’ activities not related to feeding (i.e. browsing and moving from plant to plant).

3.3. Management of Giraffes

From all the information available, the management of non-captive giraffes is the most limited. Most information available is from giraffes in captive environments and zoos (Zellmer, 1960; Jarboe, 1965; Fowler, 1978; Junge & Bradley, 1993; Bercovitch *et al*., 2004; Castillo *et al*., 2005;

Clifton-Bumpass, 2013; Roberts & Gorsuch, 2013; Sicks, 2013; Freiheit, 1970). Little information exists on giraffe conservation management (Oates, 1969, 1971; Brenneman *et al*., 2009; Block *et al.* 2014). Realizing giraffe social relationships are very complex (Bashaw, 2007), giraffe management should be carefully planned. Something as simple as artificial watering points for browsers can affect the pastoral production, the density of plants and the composition of plant communities (Katjiua & Ward, 2007). Giraffe conservation and management are complex tasks and too little information is available (Block *et al.* 2014) despite recent efforts (Fennessy, 2008).

In South Africa, however, no giraffe can be considered completely "free roaming" (Bothma, 2010). In most cases giraffes are either managed in National Parks and Provincial Nature Reserves or in private reserves and game ranches. A game ranch owner in South Africa can, within the limits of certain regulations, own giraffes, breed with giraffes, buy and sell giraffes and hunt or consume giraffes (WRSA, 2012). This ownership is driven by economic reasons in order to improve ecotourism (Bothma, 2010; WRSA, 2012; NACSO, 2012). Giraffes are therefore reliant on humans for trans-locations to new environments. These introductions have led to many giraffes being transported to areas in the country where they did not historically occur. For this reason, there is newly developed legislation and regulations for owning giraffes or transporting them in South Africa (NAMC, 2006).

The following information on the legislation for keeping giraffes demonstrates that very little is known or available concerning giraffe management on private ranches.

Western Cape: Provision for the introduction of giraffes in the Western Cape Province is made in the Cape Nature Game Translocation and Utility Policy where private game farm owners with sufficient fencing may apply. The Western Cape is out of the range as per IUCN definition for the keeping of giraffes (www.capenature.co.za).

Northern Cape: In the Northern Cape a study of the potential impact of giraffes on a reserve or farm is required before giraffes can be introduced. According to the Northern Cape they are not endangered and not indigenous to this area.

Free State: In the Free State, giraffes are seen as normal wildlife and only a transfer permit is required. All giraffes coming into or leaving the Free State require a permit. The Nature Conservation of the Free State is currently working on this regulation to control giraffe numbers more efficiently (Personal communication, Johan Watson[1]).

Wildlife ranching as a whole has to function in a specific legislative framework within the National Legislation context. NAMC (2006) lists the following 18 Acts that affect wildlife management, depending on the kind of activities that take place on the ranch: Agricultural Product Standard Act, No. 119 of 1990; Animal Health Act, No. 7 of 2002; Animal Improvement Act, No. 62 of 1998; Animal Identification Act, No. 6 of 2002; Animals Protection Act, No. 71 of 1962; Conservation of Agricultural Resources Act, No. 43 of 1983; Environment Conservation Act, No. 73 of 1989; Fencing Act, No. 31 of 1963; Firearm Control Act, No. 60 of 2000; Marketing of Agricultural Products Act, No. 47 of 1996; Meat Safety Act, No. 40 of 2000; National Environment Management Act, No. 107 of 1998; Perishable Products Export Control Act, No. 9 of 1983; National

[1] Johan Watson, Principal Nature Conservation Scientist, DETEA head office, Bloemfontein.

Environmental Management: Biodiversity Act, No. 10 of 2004; National Environmental Management: Protected Areas Act, No. 57 of 2003; South African Abattoir Corporation Act, No. 120 of 1992; Tourism Act, No. 72 of 1993; and Veterinary and Para-veterinary Professions Act, No. 19 of 1982**.** The Fire Act, No. 101 of 1998 is also applicable (Cheney, 2005). The National Environmental Management: Biodiversity Act in combination with the National Environmental Management: Protected Areas Act constitute a set of laws within which the full range of conservation efforts are recognised, regulated and empowered (NAMC, 2006).

Legislation on the management of giraffe populations throughout the African continent will continue to be very difficult and in most cases of real concern. The continuing conversion of savanna to agricultural land and the fast growing human population have two major consequences: an increased impact of human activity on natural habitats; and increased number of conflicts between wildlife and humans (Galanti *et al.,* 2000).

3.4. Collars and Spatial Ecology

Tracking animals with Global Positioning Systems (GPS) has opened new and unique opportunities for research (Verlinden, 1998; Verlinden & Gavor, 1998; Gelanti *et al*., 2000; Rodgers, 2001; Rumble *et al*., 2001; Springborn & Meahr, 2001; Kumpala *et al*., 2001; Licoppe & Lievens, 2001; Lindzey *et al*., 2001; Zimmermann *et al*., 2001; Sibbald *et al*., 2001; Kliskey & Byrom, 2001; Hulbert, 2001; Haller & Filli, 2001; Fennessy, 2009). The first telemetry based on the GPS system was developed in the 1990s (Rodgers, 2001). Since commercial development of GPS-based telemetry systems for tracking animals began in 1991, a variety of configurations have been designed for use by researchers in different situations. In addition, numerous improvements have been made to the size and performance of GPS systems and their cost has been dramatically reduced over the years (Hulbert, 2001). Initially the enormous quantities of data generated by these systems clearly presented a challenge to data management and analytical procedures (Springborn & Meahr, 2001). Given the variety of configurations and features of current GPS systems, researchers must carefully plan and select an appropriate system to address particular biological issues (Rodgers, 2001). Since the very first field trials of the first GPS unit, it demonstrated an observation success rate of 97% (Rodgers, 2001).

GPS systems allow researchers to improve the ability to distinguish between habitats used and not used by animals, as they provide highly accurate position estimates that have the same or better spatial resolution than habitat mapping data, such as that derived from satellite imagery (Zimmerman *et al*., 2001). As a result there is a decreased chance of incorrectly assigning animal locations to habitat categories when these data are plotted on a habitat map in GIS (Rodgers, 2001). GPS collars as such allow biologists to collect systematically scheduled data, where the VHF telemetry data derived from yagi antennae are mostly difficult and sometimes impossible to collect (Rumble *et al*., 2001).

Kumpala *et al*. (2001) tested GPS tracking systems with satellite image data for the pasture use of reindeer (*Rangifer tarandus*) in northern Finland from 1996 – 1997. They succeeded partially when one collar worked for fourteen months, but the others only worked for three and a half months. Kumpala's *et al*. (2001) recordings varied from three to eight loggings per day. Of all the location logging attempts, 79% were successful. They also added a radio transmitter in each GPS collar that could be detected with a yagi antenna. Licoppe & Lievens (2001) studied red deer (*Cervus elaphus*) with GPS collars in the Saint-Hubert forest in Ardenne, Belgium in 2000, and could only get data for 85 days at a rate of four loggings per day. Both Kumpala *et al.* (2001) and Licoppe &

Lievens (2001) showed that GPS technology is a possible tool to evaluate habitat use by wild angulates. This was also demonstrated with mountain lions (*Puma concolor*), elk (*Cervus elaphus nelson*) and mule deer (*Odocoileus hemionus*) in the United States by Lindzey *et al*. (2001). It was demonstrated in the latter study that accurate locations of most terrestrial mammals can be obtained with GPS collars, regardless of weather and daylight patterns. Zimmerman *et al*. (2001) showed that remote downloadable data from GPS fitted collars are very useful and they had 97–99% success rate with data transferred from studies done on moose (*Alces alces*) and wolves (*Canis lupus*) in southeastern Norway in 2000.

Sibbald *et al*. (2001) specifically used ArcView software from ESRI in California in the USA to analyze GPS data from red deer collars used in Scotland in 1998 and 1999. They calculated average distances and used nearest point differentiations on vegetation GIS based maps. They discovered that GPS collars can follow movements with great detail, and also that distances travelled by individuals can vary immensely. This was also noticed in the study done by Bolger *et al*. (2008), where they investigated ungulate migration and seasonal variations with integrative approaches. Feeding, resting, movement and travelling can all be accurately timed in order to get some idea of how ungulates make daily changes.

Rodgers & Carr (2001) developed specific home range extension software that extends ArcView to analyze home ranges of animals. This is accomplished entirely within a geographic information system (GIS), which provides a common and relatively familiar interface for analyses performed on telemetry fixes and subsequent home range polygons. ArcView has the ability to use large data sets and carry out all required home range analysis within a single software environment. Rodgers & Carr (2001) developed two types of home range analysis models: minimum convex polygons and kernel methods.

Kliskey & Byrom (2001) did some research on smaller mammals and discovered that the size and weight of GPS units are a particular constraint when animals are smaller than 20 kg in size. Janeau *et al*. (2001) found that the performance of GPS collars become inaccurate within very forested environments and may also limit the effectiveness and performance of GPS receivers when smaller units are used.

GPS telemetry has broadly been used in mammal research throughout the world, especially for mammal species like elephants (*Loxodonta africana*) and lions (*Panthera leo*) in Africa (Verlinden & Gavor, 1998; Galanti *et al*., 2000). Galanti *et al*. (2000) captured five elephants in Tarangire National Park in Tanzania and fitted them successfully with GPS collars to establish their home range and seasonal migration routes.

Previous attempts to fit GPS collars on giraffes had limited success. Only a pioneer conservation project in Niger in 2010 by a team of researchers in West Africa proved to be partially successful (Vaughan, 2010). Fennessy (2009) collected three months of data by collaring giraffes in northwestern Namibia with a design mounted on the torso and lower neck. They managed to gather a few months' data from the transmitters fitted around the shoulder and front legs, as the collars did not stay on the animals very long (Vaughan, 2010). McQuater (2013) fitted four giraffes with satellite head- arness collars, following the design of Deacon & Smit (2013), which provided location data to deduce home ranges, daily movements and habitat preferences in northern Botswana.

CHAPTER 4: DEVELOPMENT AND TESTING OF CUSTOM MADE GPS COLLARS FOR GIRAFFES

4.1. Introduction

Understanding the factors that determine the distribution and movements of giraffes around the landscape is often a major objective for any giraffe scientist, conservationist or wildlife manager. Giraffe populations can only be conserved through developing the required knowledge. Haller *et al*. (2001) described the concept of tracking wild animals as the best method to understand the interaction between the animal and its environment. Scientists have a long history of attempting to resolve the logistics of gathering information on the movements and distribution of giraffes, which until recently relied mainly on tedious visual observations and in some cases the use of conventional VHF (Very High Frequency) radio telemetry (Gordon, 2001). The limitations of visual observations include the disturbance of the animal and tracking during the day only. Global Positioning System (GPS) devices fitted to a collar allow biologists to collect systematically scheduled data, when VHF telemetry and visual observations are very often difficult, inaccurate or practically impossible (Haller *et al.,* 2001; Rumble *et al*., 2001). The development of GPS collars for giraffe has offered the opportunity to overcome a number of previous limitations. This enables biologists to meet the sample size requirements for assessing habitat selection of animals, to track animals at night or during periods of poor weather, receive data by remote transfer, and collect considerable amounts of information about animals without disturbing them (Rumble *et al*., 2001).

According to Africa Wildlife Tracking[2] in South Africa, there has been a growing interest in the use of GPS collars amongst biologists, but the high cost of these units limited their application. GPS satellite telemetry offers many opportunities that can contribute to the understanding of habitat use at different time intervals as well as on spatial scales. The quality and quantity of data potentially available are perhaps the greatest assets, combined with an ability to quantify the data, unlike any other tracking tool (Hulbert, 2001).

The use of GPS tracking devices and the potential for conducting field-based research could open a vast field of research opportunities - not only for the giraffe, but also in the broader wildlife environment. This is the first study of its nature in the world, based on giraffe spatial ecology using the latest GPS technology, that should aid in ecological research by allowing remote collection of data on animal movements and home ranges.

The objectives of this study are:

i) To design a GPS equipped collar for specific use on giraffes,
ii) To fit and evaluate different designs of such a GPS collar on a giraffe,
iii) To assess the influence of the fitted GPS collar on all aspects of the behaviour and welfare of the giraffe,
iv) To conduct a preliminary value assessment of the prototype collars in terms of their application,
v) To ensure that the application of a GPS collar complies with all the requirements of the animal ethical committees of the University of the Free State (UFS) and the Free State Department of Nature Conservation (DETEA) (see Addendum 1).

[2]African Wildlife Tracking, 106 Nuffield Street, Rietondale, 0084, Pretoria

4.2. Procedure

4.2.1. Designing prototype GPS collars for fitment on giraffes

Two separate collars were designed, using the same giraffe bull as the experimental animal, to assess whether it is possible to use a GPS collar on this species for future studies. The first collar and also the main design, is named the “head harness collar” and is intended to be fitted over the head and ossicones. The second collar is intended to be fitted around the neck (like the most commonly found collars for herbivores) and is named the “neck collar” (Figure 4.1).

Figure 4.1 Two prototype GPS designs tested during the preliminary study with the top one to be the first initial head harness design.

The development of the first head harness collar was done in collaboration with Africa Wildlife Tracking (AWT), who helped with the planning and measurements of the initial design (Figure 4.3). The measurements of all possible dimensions of female giraffe (*G. c. giraffa*) skulls and craniums were collected. It was further refined by fitting the prototype harness on 48 different giraffe skulls, taxidermy artistry and live specimens (live animal auctions and zoos) during the development phase in 2011. The GPS unit also included a VHF transmitter that added extra weight to the collar design. The model used was the GPS/VHF software where data in near real time were transmitted via Iridium satellites. The batteries included within the GPS unit were two ‘D’ cells and the VHF transmitter included two ‘C’ cells with a duty cycle of 12 hours ON/OFF (Figure 4.2). The initial phase included two important factors: firstly, to determine the outcome of the physical design and its success, and secondly, the functioning of the software and transmitter.

The sensors used within the tracking device have an on-board temperature sensor that measures temperature to 0.5-degrees C accuracy (Figure 4.2). An additional external sensor can be added on request, but was not necessary as the sensor was calibrated with the nearest weather station. The hardware had the required interfaces to integrate accelerometers and activity sensors (some development will be required for this integration in future and will be discussed further in section 4.5).

Figure 4.2 Compaction of batteries and VHF monitor transmitter inside the collar

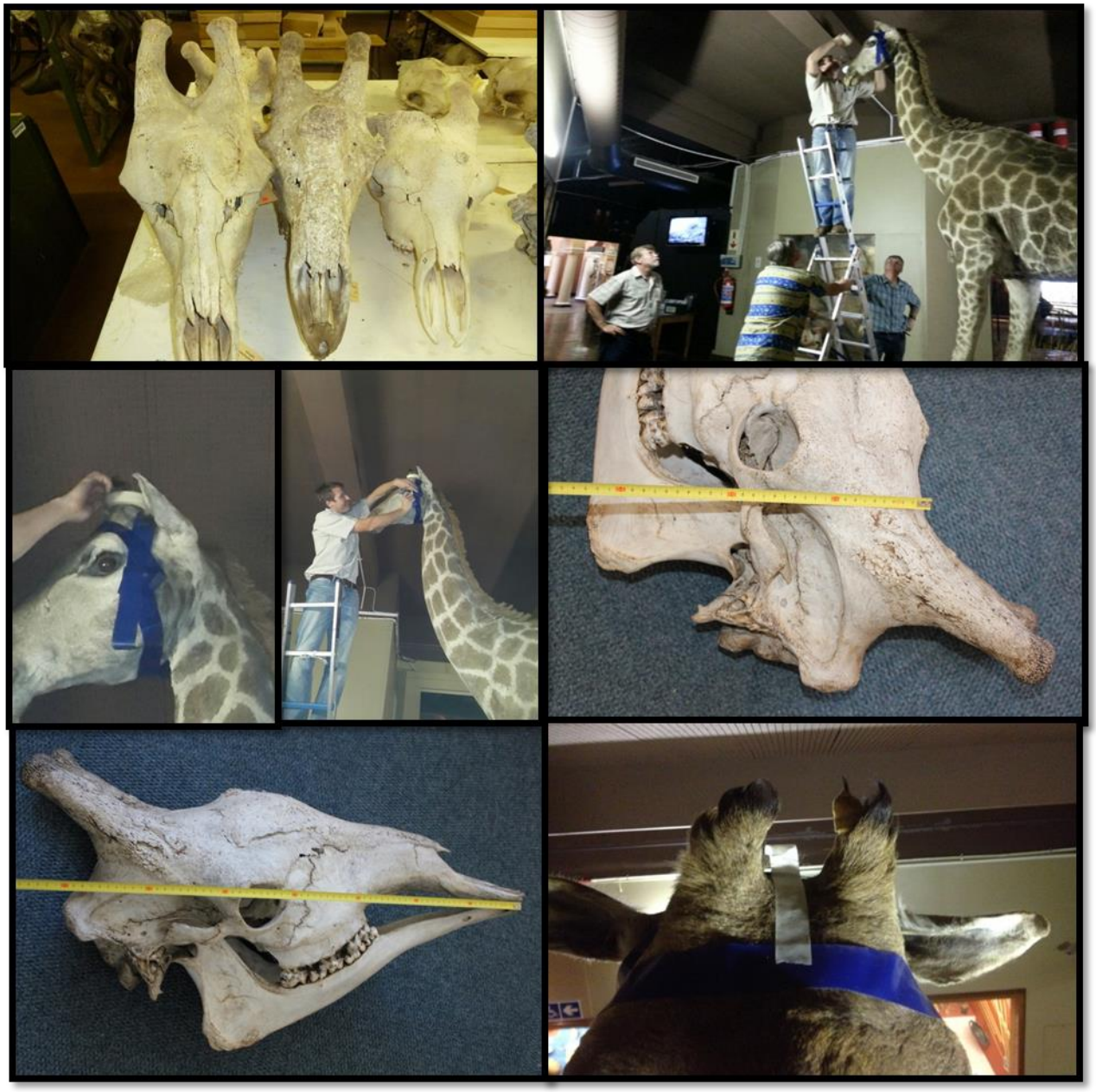


Figure 4.3 Selected measurements of giraffe skulls used in the design of the head harness collar.

The coverage with the Iridium satellite constellation consists of 66 satellites that orbit the earth over the poles in six equidistant orbits, each orbit containing 11 satellites. There are numerous satellites trailing each other in each orbital path. At any point on earth, if a good sky view is possible, there should be at least three satellites in view. The orbital paths cross above the poles, dividing the orbital sphere into 12 segments, similar to the segments of an orange. Since the earth is always rotating under the satellite paths, they do not move over the same spot on earth during each orbit. The signal strength varies according to obstructions in line of sight, and antenna orientation in relation to those satellites. The signal strength also varies in time, because the satellites are always moving. A satellite moves from horizon to horizon in a few minutes. In short, if there are no obstructions (like a dense plant canopy) there should be no problem uploading points anywhere on the globe. The challenge is that under plant canopies the line of sight to the satellites is obstructed

which will result in poor performance, as with any other satellite service. Another advantage of Iridium is that the satellites are only 780 km above the earth, compared to Inmarsat at a distance of 37 786 km, which reduces the power requirements to transmit and it also simplifies the antenna requirements.

The GPS unit works in the following manner: it receives the current GPS position and attempts to transmit that point to the satellite system; if no uplink occurs, it will retransmit a number of times in an attempt to transmit the data; when an uplink takes place, the unit determines whether previously stored points still need to be uploaded and if this is not the case, it switches off. In the case where the maximum number of retransmit attempts occurred without uplink, the unit stores the position in a retransmit buffer. When the unit eventually logs a point where it manages to make an uplink, it attempts to upload previously stored points if the network coverage is good enough. The maximum number of retransmit attempts for the current log can be remotely set between 0 and 15. When uploading previously stored points, it is not registered as a retransmit attempt. The number of points stored in the buffer for retransmit can also be set between 4 and 64.

By setting retries to zero, the unit will not expend energy trying to transmit the current point when coverage is insufficient (HDOP < 2). Instead, it will transmit missed logs when conditions are favourable. This provides better data as there will be fewer missed logs than when transmitting points in unfavourable conditions, and it will be more efficient as retries are not required. If, however, it is required to receive the current positions logged in real time, retransmit attempts may still be set.

The logging schedules work in a standard operation. The tracking device uploads its location to the database immediately after position acquisition. This means that data are available in near real time, eliminating the wait for bulk uploads and allowing the scientist to know the current position of the animal immediately. The tracking device and logging schedules can also be remotely set and/or changed. Two options were available: a range of fixed logging intervals, or user defined logging times. In the GPS unit used for the project the fixed logging interval options were 5 min, 30 min, 1 hour, 2 hours, 4 hours, 8 hours or once per day. Alternatively, the tracking device could be set to log on 2, 4, 8 or 16 specific times during the day.

The information transmitted by the tracking device was accessed by an online application via a standard internet browser. Locations were plotted on an online mapping application (like Google maps), which provides a map, a satellite image and topographic terrain backdrops. Searches were often done based on date and time to find specific information. Data were downloaded into an Excel file for use in GIS applications and in this project, ArcView 10.2 from ESRI was used for most of the analysis and map designs.

4.2.2. Fitting of the prototype collars on an experimental animal

When the first collar prototype was ready for fitment permission was obtained to test it on a sub-adult bull at Woodland Hills Wildlife Estate (WHWE) (see Figure 2.1, Chapter 2). For the purpose of observation and monitoring, a relatively tame sub-adult bull giraffe was selected, which could be closely observed for any change in behaviour or discomfort. Two separate designs (Figure 4.1) of the GPS collars were fitted and a bull was chosen,as bulls tend to be more aggressive and more

likely to fight. The intention was to test the ruggedness of the collar to function reliably under harsh conditions.

The animal capture and fitment of the collars was done during June 2011. The tranquilization involved darting the animal with a pheudart-dartgun from a distance of no more than 40 m. The dart included 8 mg of the drug A30-80 (Phianil), 4 mg Etorphine (M99) and 70 mg Azaperoon (Stressnil) (Figure 4.4). A detailed discussion of the different chemicals and drugs suitable for tranquilizing giraffes is presented in Chapter 10. After the giraffe was tranquilized and while under the influence of the drugs, the two collars were fitted on the animal. The head harness collar was fitted and adjusted on the giraffe's head with straps to the horns (Figure 4.5), preventing it from moving up and down the neck. The neck collar was fitted to the upper part of the neck (Figure 4.8). Both collars were also fitted with GPS transmitters to test if the activity monitor built inside the collar is suitable for future designs (Figure 4.2) without influencing the animal negatively at any stage. The weight of the head-harness collar was 670 g and of the neck collar was 635 g. The average weight of a sub-adult giraffe is less than 900 kg (Bothma, 2010). This meant that a single collar was less than 0.07% of the total weight of an average giraffe.

4.2.3. Assessing the influence of the fitted collars

After the fitting of the collars, the giraffe was monitored daily for a period of 45 days, whereafter the collars were removed and the animal observed for another 35 days to ensure its wellbeing. The physical designs of both collars were not only tested for durability, but more importantly, they were evaluated in terms of the comfort to the giraffe. The collars were each evaluated based on potential chafing, hair loss, discomfort, tightness and hindering to see if they might cause any inconvenience or abnormal behaviour.

The observations were conducted by following the giraffe on foot or by vehicle. Daily observations included whether the giraffe displayed normal behaviour in terms of movement, social interaction, feeding and drinking, etc. The bull was part of a herd with three adult females, one adult bull, one sub-adult female and two juveniles. The collared sub-adult bull was observed several times necking with the adult bull in the herd in a playful manner rather than being aggressive. During the study period all eight giraffes moved together and were never observed splitting into two herds. Canon SLR camera equipment and Bushnell binoculars were used while following the herd to detect any abnormal behaviour by the collared bull, such as might be due to rubbing or chafing.

Figure 4.4 Tranquilizing darts prepared for use in the dartgun.

Figure 4.5 Physical fitting of the head harness collar on the giraffe.

Figure 4.6 Double checking the fitment of the two collars and preparing to remove ear buds and eye cloth.

Figure 4.7 Assisting the giraffe to stand up after the fitting of the collars was completed.

Figure 4.8 Giraffe after the tranquilization with the two designs of GPS collars (one around the neck and one as a head harness).

4.2.4. Preliminary value assessment of the prototype collars

4.2.4.1. Nature and scope of data collected

In addition to the geographical location coordinates collected by the GPS device attached to the collars, they were also able to collect the following data every 30 minutes: ambient temperature (°C), speed (km/h), altitude (m), the quality of signal (HDOP) and the distance between locations (m). These measurements might provide valuable information on the effectiveness and quality of data gathered by the collars. The accuracy as well as the quality might provide information about whether it is worth using GPS collars for giraffes. The value assessment will include whether GPS collars are a possibility for future research on giraffes and whether the data gathered by the collars are valuable.

As soon as the giraffe was fitted with the GPS collar, it started to log information programmed into the built-in transmitter and stored on-board the logger. The data were sent via satellite to a computer logged onto the AWT server. It was then downloaded from the server using a specified password. After collecting all the recorded data, it was downloaded into an Excel worksheet.

4.2.4.2. Approach to data analyses

The data received from the transmitter in the collars were analysed using Microsoft® Excel by making use of the Analysis ToolPak (Raubenheimer, 2012). The parameters for each analysis

were provided by the program, and the built-in tool used the appropriate statistical or engineering macro functions to calculate and display the results in an output table based on the provided data. After the usable data were filtered within Excel, regression analysis was done between different parameters. The same data were also used in the GIS application for ArcView 10.2 (ESRI, 1996) to evaluate spatial distribution and space use over the 45-day period. ArcView was also used to determine how speed, altitude and temperature might play a role in giraffe daily movements and distribution. Overall distance and daily distance recorded by the transmitter was also analysed with ArcView, as well as habitat preference and avoided areas.

4.2.5. Ethical compliance

Ethical approval had to be obtained before the research project could commence. This approval required the following procedures. First, a formal project proposal had to be submitted to the animal welfare committee based in Bloemfontein in South Africa, which was evaluated by representative members from the Department of Nature Conservation (DETEA) and the Society for the Prevention of Cruelty to Animals (SPCA) who serve on the committee. Secondly, the proposal had to comply with the rules and regulations of the animal ethics committee of the University of the Free State (Appendix 4A), which is part of the same committee and follows the same prescriptions as DETEA and SPCA. Compliance with this procedure ensures the welfare of the giraffe and adds the necessary endorsement to the research project of the Faculty of Natural and Agricultural Sciences at the University of the Free State. At the end of the investigation a report must be submitted on the conclusions regarding the experimental collars, and the status and wellbeing of the animals and this report must be accompanied by photographs.

4.3. Results and Discussion

4.3.1. Collar design

The design of the head harness collar and relevant measurements can be seen in Figure 4.9. This figure demonstrates how much detail there is in developing such a design for giraffes. The extensive database of dimensions and measurements of a large number of giraffe skulls and taxidermy artistry proved to be invaluable in the design and development of this collar

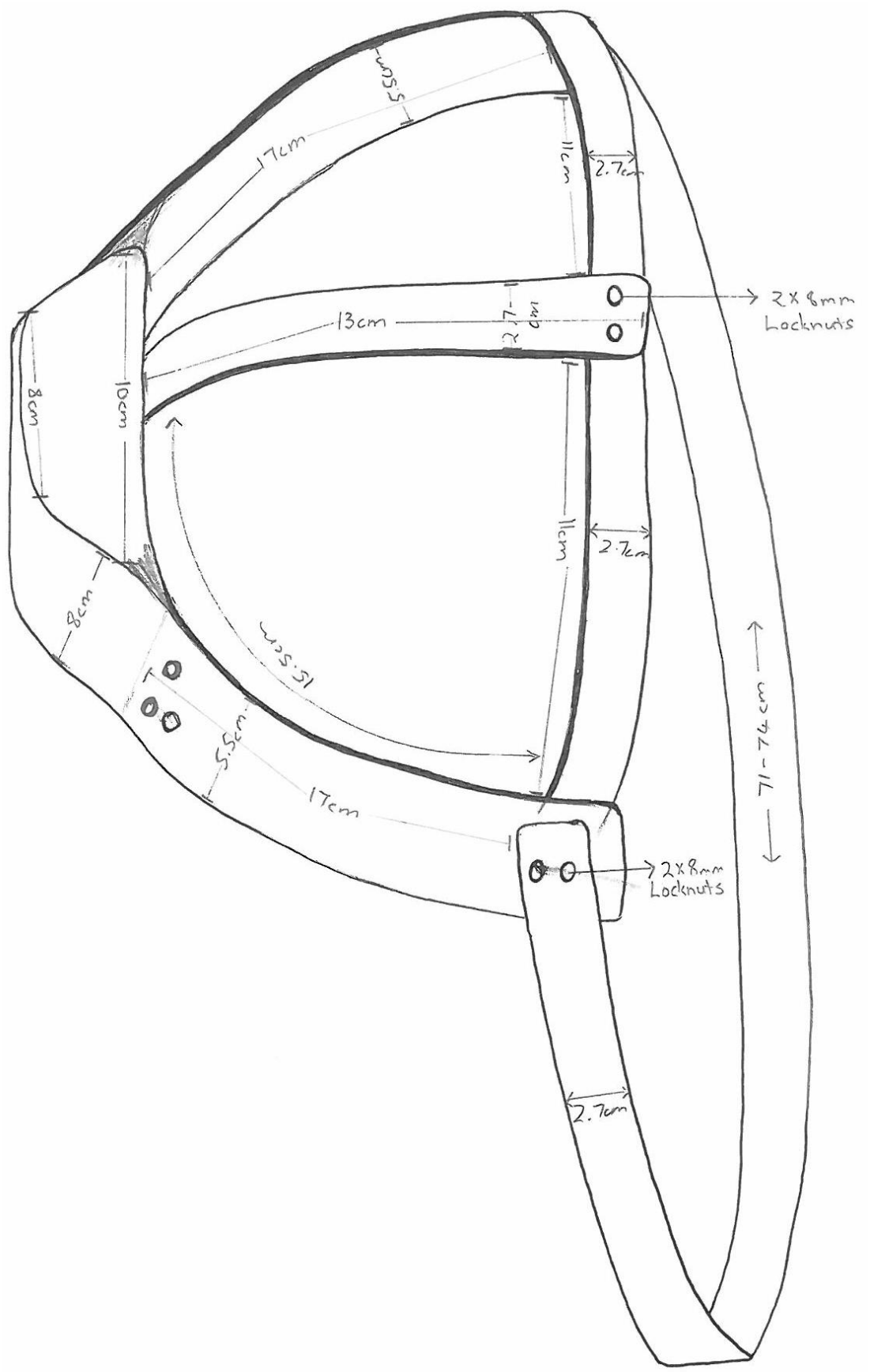


Figure 4.9 Final design with measurements for the head harness collar

4.3.2. Practical fitting and problems associated with the collars

Before the collars could be fitted, the giraffe had to be sedated with the tranquilizing dart; the effect of the chemicals took an average of 4.37 minutes to start working effectively. The head harness collar was fitted first and took 4.14 minutes, followed by the fitting of the neck collar which took 2.47 minutes. Fitting of the collars involved two technicians from Africa Wildlife Tracking, two veterinarians (monitoring the heartbeat, body condition and breathing), four people from the game capture team to put weight on the neck and keep the giraffe down, and three people that assisted with tools, covering the eyes and ears and keeping the head from the ground. When the collars were properly fitted, the capture team swiftly moved away from the animal, which then stood up with some assistance and little difficulty, and walked away with no ill effects from the capture procedure. From start to finish, the whole procedure took 14 minutes to complete.

The data transmitters of both collars functioned well and provided all the necessary data and information that was required. Physically the head harness collar did not cause any chafing, hair loss or discomfort to the giraffe, but the neck collar did experience some problems with design and durability. Both collars did show some problems with the physical design, (Figure 4.10 and Figure 4.11).

Figure 4.10 shows that the neck collar was a failure. It was noticed during the daily observations that the collar had moved downwards during the last period (40 days) of monitoring (Figure 4.10). The collar started tightening around the neck to such an extent that it could not freely move upwards again (Figure 4.10). The collar also caused some swelling (Figure 4.10). The figure illustrates that the neck collar can be life threatening and should be avoided in future.

The head harness collar demonstrated to be the better collar, although some modifications were still required (Figure 4.11). The fitting demonstrated that each collar needs to be modified to each individual's circumference, not too tight, but with enough space to avoid hair loss and chafing. Merely measuring skulls does not provide enough information as to the correct size or shape of the collar, although it aided with the initial design seen in Figure 4.3. The head harness collar also illustrated the importance of custom-making each collar for the different sexes and age groups. This statement is also true for each sub-species, if future research is to be done with head harness collars. Figure 4.10 demonstrates that the head harness collar is clearly the better option, although it takes more time to custom fit.

4.3.3. The influence of the collars on the giraffe

The daily observations demonstrated little abnormal behaviour. The giraffe bull showed no chafing or rubbing that could indicate discomfort or attempts to remove the collars. He moved freely, fed and ruminated without any uneasiness and could drink water without limitations. The herd did not avoid moving with the collared bull and did not seem to notice anything being different about him. He was often seen drinking water and could browse at any level he preferred. He was habituated to the presence of humans and the vehicle and it did not seem to bother him or the other animals in the herd.

After the 45-day period the bull was again tranquilized in August 2011 and the two collars were removed. The removal procedure took only nine minutes to finish and the giraffe stood up with little difficulty. During the time the bull was held down, observations and inspections were done on both positions where the collars were fitted. Mr. Martin Haupt from Africa Wildlife Tracking was also present to take photographs and to inspect the collars for future reference and modifications. On closer inspection it was noticed that the head harness collar also showed some need for modification (Figure 4.11). The collar started to thrust into the back of the ossicones (Figure 4.11) and hair-loss was visible after removal of the collar, although no physical damage to the skin or the ossicones was observed. Following the day of removal the bull was monitored for the next 35 days, whereafter field observations commenced for another six months once a month. During these months no abnormalities were noticed.

Figure 4.10 Downward movement of the neck collar (red line indicating the original position)

Figure 4.11 Position of head harness collar during the removal procedure (red circle demonstrating the thrusting at the back of the ossicones)

4.3.4. Type of data gathered by the GPS collars

The 45-day experiment with the two GPS collars was enough to collect valuable information and the head harness collar recorded the expected set of day and night locations, temperatures, speeds and altitudes for every 30-minute interval.

The recorded results totalled 2 127 loggings over a period of 45 days (06/04/2011 to 07/18/2011) from the transmitter built into the head harness collar (for practical reasons only one set of data from one collar was used). From the 2 127 recorded loggings, we can calculate that the giraffe bull travelled a total of 180.5 km. On average this represented a distance of 84.9 m for every 30 minute interval and 2 037.6 m for every 24 hour period. The maximum recorded speed for this giraffe was 50.1 km/h and the longest distance travelled within a 30 minute interval was 1 183 m. The maximum temperature recorded during this period was 31.5 C°, the lowest temperature being -1 C°.

Table 4.1 illustrates a sample from the datasheet retrieved from the GPS collar. This table illustrates the data that the GPS logger recorded and downloaded every 30 minutes via satellite. The GPS collar showed 95% accuracy, which increases with an increase in the HDOP (satellite signal quality, where >1 is good and <1 is less good) measurement. Recorded distances are in a straight line from point A to B and not the actual tracking distance of the animal. The collars were calibrated to limit unnecessary variations in speed, temperature and altitude.

During the study period sunrise was at 07:10 and sunset at 17:28. As the daily temperature increases after sunrise and decreases after sunset (indicated by Figure 4.12), the average speed of movement of the giraffe bull also started to increase as the day progresses, with considerable variation in speed after sunset (Figure 4.13). On average, the least variation in the speed of movement was during the early hours from 00:28 until 6:28, and again during the mid-day hours from 10:58 until 13:28 (Figure 4.13).

Collar design illustrates that the giraffe bull preferred higher altitudes at night-time from sunset until sunrise. Collar design also indicates that from sunrise until sunset the giraffe preferred to move to lower slopes. The average movement distances increased marginally as the day progressed, with considerable variation in distances just before and after sunset (Figure 4.14). The least variation in distances travelled was from sunset until sunrise (Figure 4.14).

Table 4.1 Sample of a datasheet with 30 minute intervals

Local Date	Local Time	GMT Date	GMT Time	Lat	Lon	Temp	True Speed	Dir	Alt	Cov	HDOP	Distance	Count
2011/06/04	00:28:29	2011/06/03	22:28:29	-29.04067	26.197925	8.5 C	0.56 km/h	0	1393. m	5	4.8	0 m	1
2011/06/04	00:58:04	2011/06/03	22:58:04	-29.04021	26.195927	7 C	0.7 km/h	0	1387. m	5	4.5	201 m	2
2011/06/04	01:28:35	2011/06/03	23:28:35	-29.04234	26.195258	85 C	2.38 km/h	12	1392. m	5	1.32	246 m	3
2011/06/04	01:58:04	2011/06/03	23:58:04	-29.04034	26.198686	6 C	5.85 km/h	244	1377. m	5	1.34	401 m	4
2011/06/04	02:28:05	2011/06/04	00:28:05	-29.03784	26.198177	0 C	0.25 km/h	0	1372. m	5	1.53	282 m	5
2011/06/04	02:58:05	2011/06/04	00:58:05	-29.03785	26.198234	0 C	0.34 km/h	0	1379. m	5	1.97	6 m	6
2011/06/04	03:28:05	2011/06/04	01:28:05	-29.03785	26.198195	4.5 C	0.38 km/h	0	1372. m	5	1.78	4 m	7
2011/06/04	03:58:35	2011/06/04	01:58:35	-29.03784	26.198222	4.5 C	0.02 km/h	0	1372. m	5	1.2	3 m	8
2011/06/04	04:28:04	2011/06/04	02:28:04	-29.03783	26.198222	4 C	0.05 km/h	0	1375. m	5	1.26	1 m	9
2011/06/04	04:58:04	2011/06/04	02:58:04	-29.03753	26.198207	3.5 C	0.13 km/h	0	1383. m	5	1.52	34 m	10

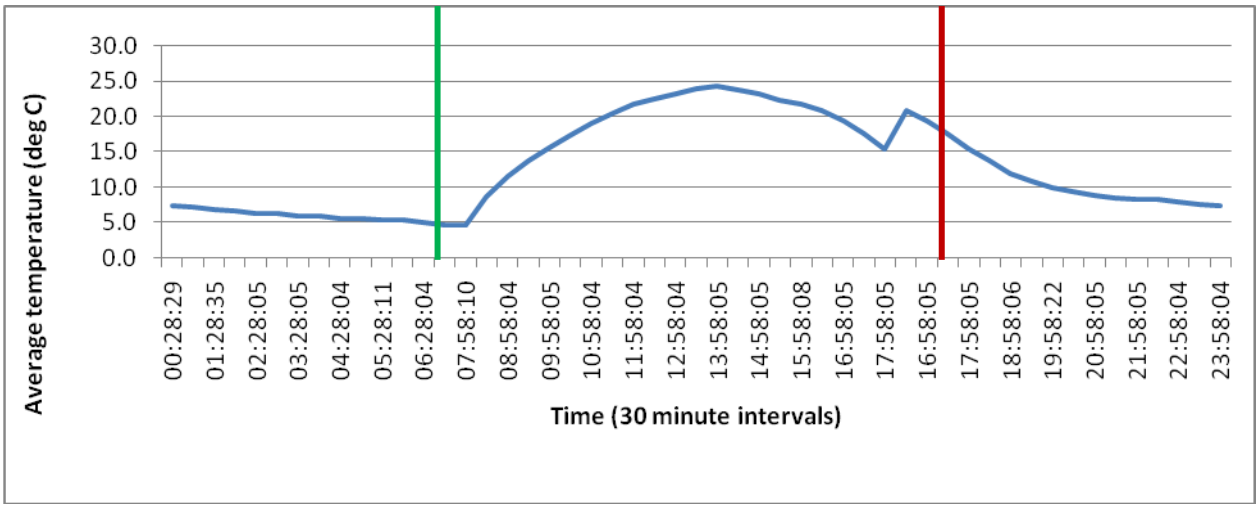


Figure 4.12 Average temperature versus time, gathered from the GPS collars, with the green line indicating sunrise at 07:10 and the red line indicating sunset at 17:28

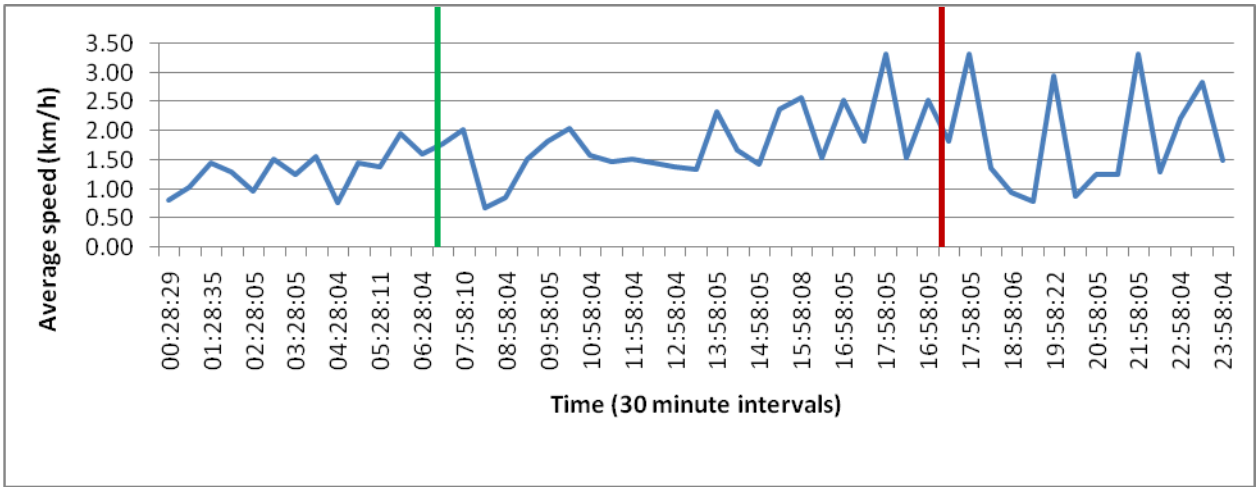


Figure 4.13 Average movement speed of the giraffe versus time, gathered from the GPS collars, with the green line indicating sunrise at 07:10 and the red line indicating sunset at 17:28.

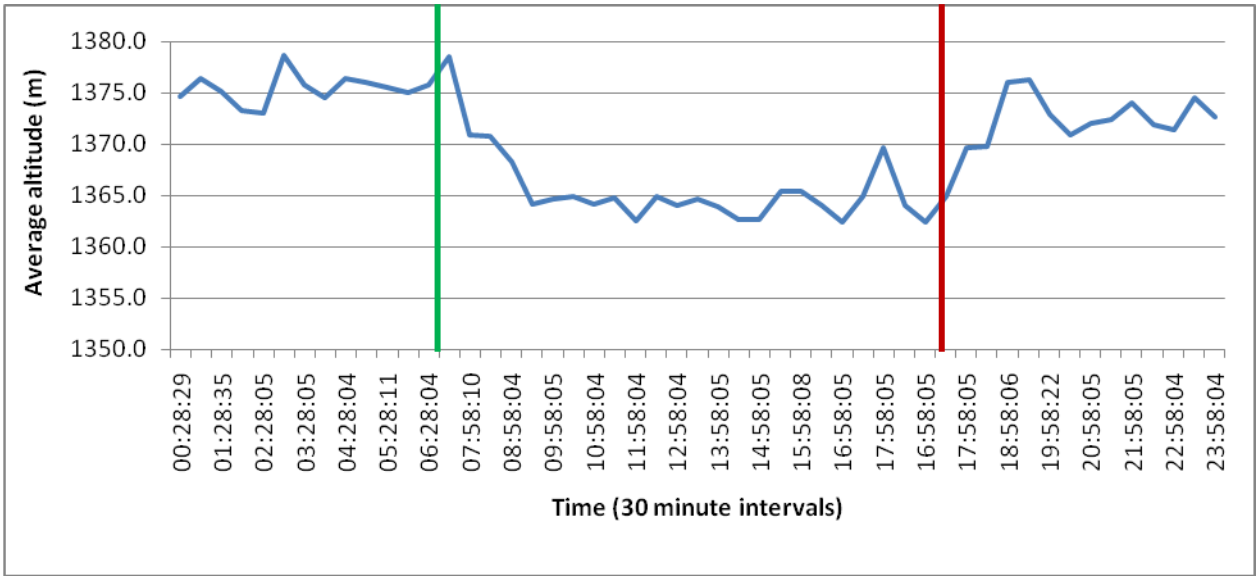


Figure 4.14 Average altitude versus time, gathered from the GPS collars, with the green line indicating sunrise at 07:10 and the red line indicating sunset at 17:28.

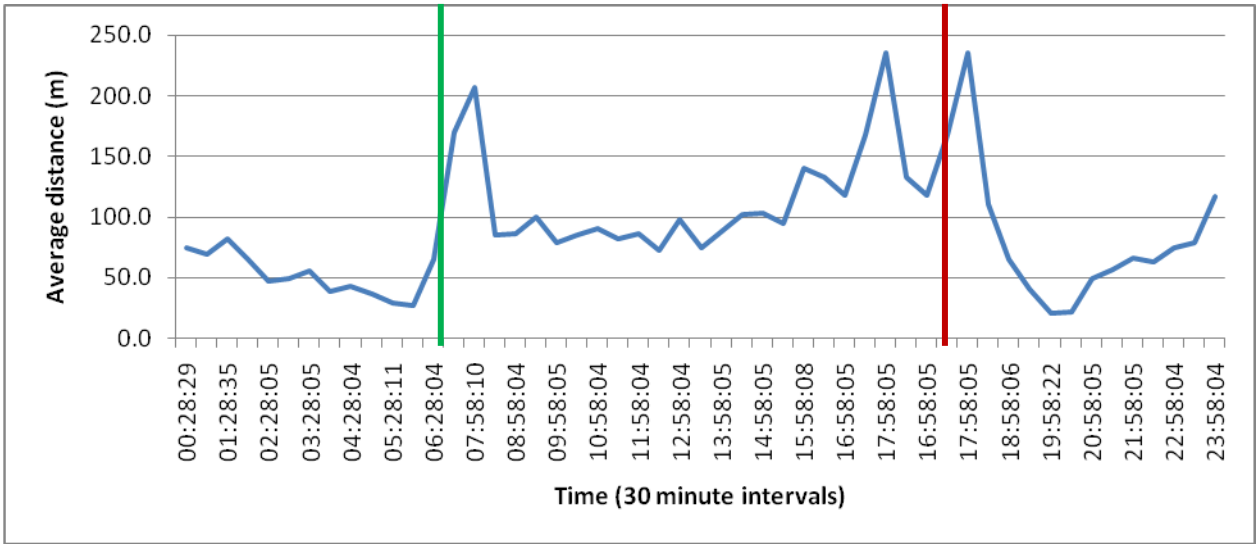


Figure 4.15 Average distances travelled by the giraffe versus time, gathered from the GPS collars, with the green line indicating sunrise at 07:10 and the red line indicating sunset at 17:28.

When the speed of movement (km/h) of the bull is compared with the altitude (m), it further indicates how it changed over a 24-hour period (Figure 4.16). Figure 4.16 illustrates how the giraffe moved slower at higher altitudes. It also illustrates that after sunset there were bigger variations in speed of movement. Figure 4.17 illustrates how the giraffe moved longer distances during sunrise and sunset, but also illustrates longer distances travelled after sunrise (07:10) compared to night-time after sunset (17:28). This figure also illustrates a sudden decrease in distances travelled when the temperature decreases.

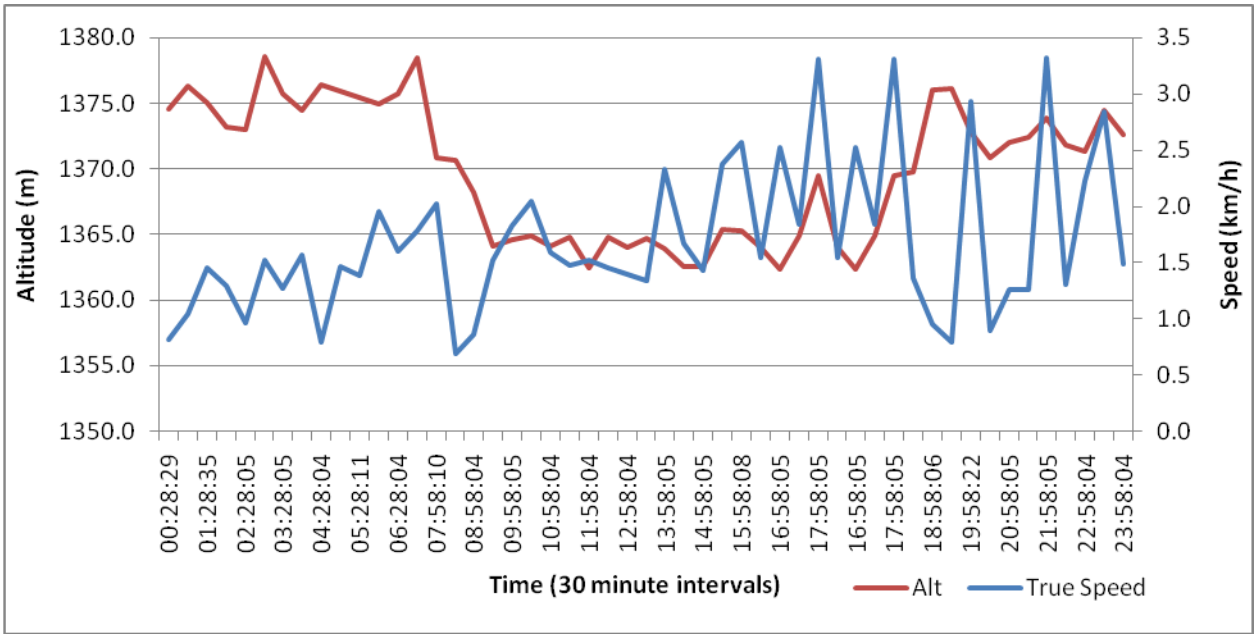


Figure 4.16 Speed of movement of the collared giraffe bull at different altitudes during every 30 minute period.

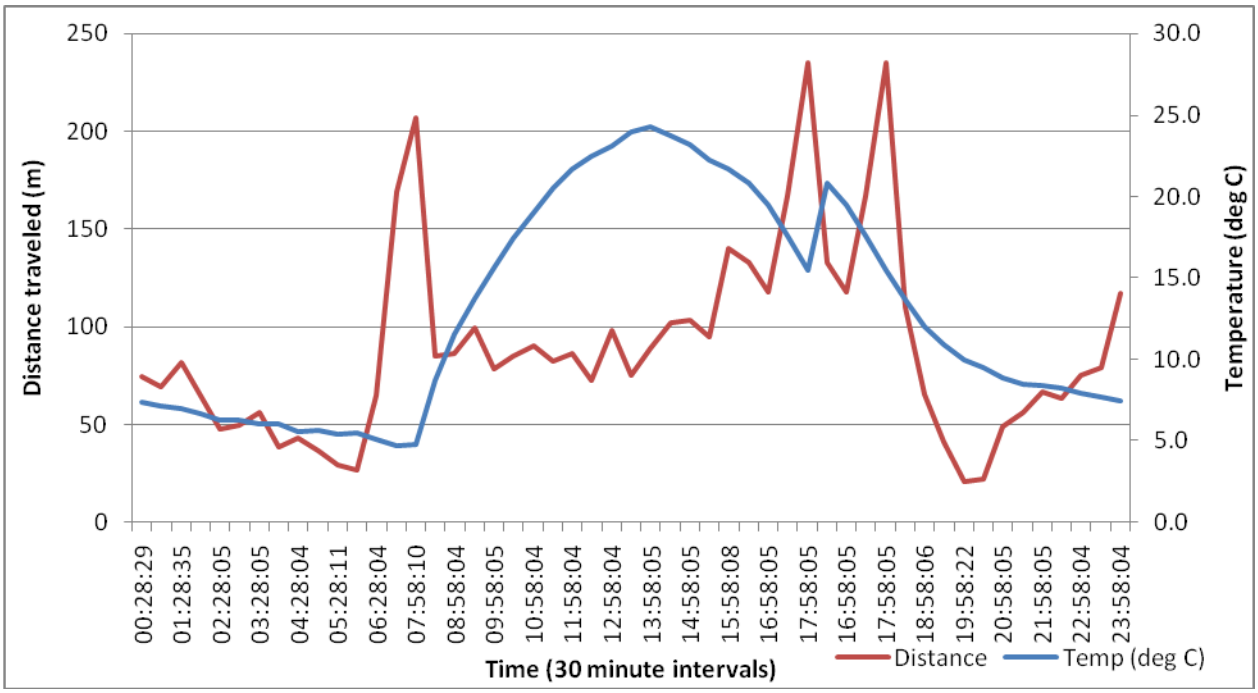


Figure 4.17 Distances the collared giraffe travelled in relation to the ambient temperature recorded every 30 minutes.

Figure 4.18 illustrates how the giraffe preferred to be at higher altitudes during colder periods. Only when the temperature started to increase, did the giraffe move to lower altitudes. The giraffe moved to higher altitudes after sunset (17:28) and lower altitudes after sunrise (07:10). Figure 4.19 illustrates how the speed travelled gradually increased as the day progressed, with much variation in speed after sunset 17:28.

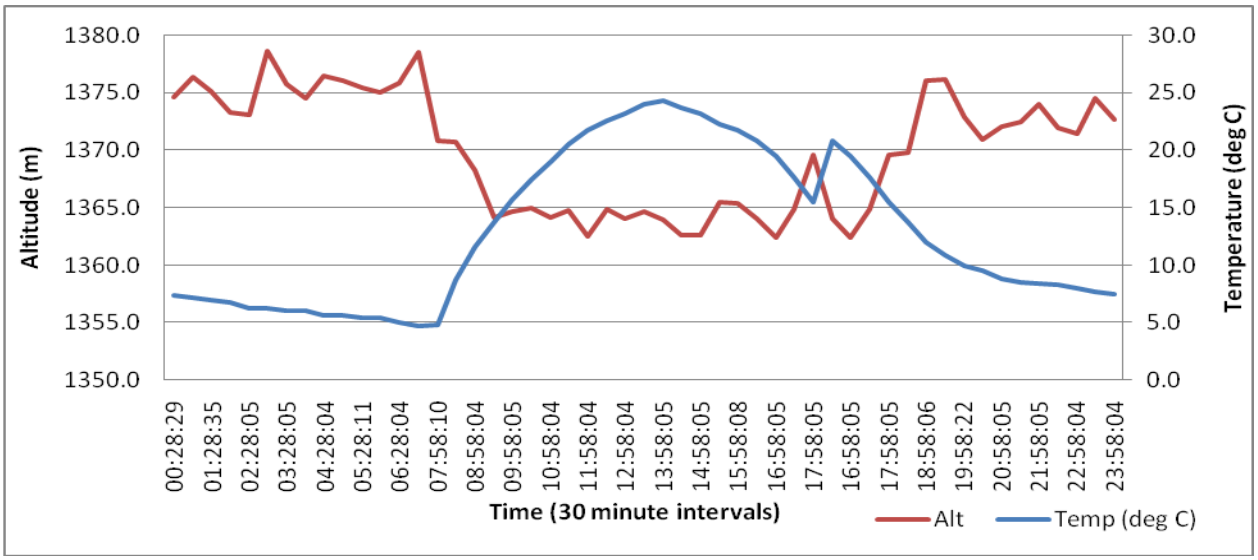


Figure 4.18 Altitude of the collared giraffe in relation to temperature recorded every 30 minutes.

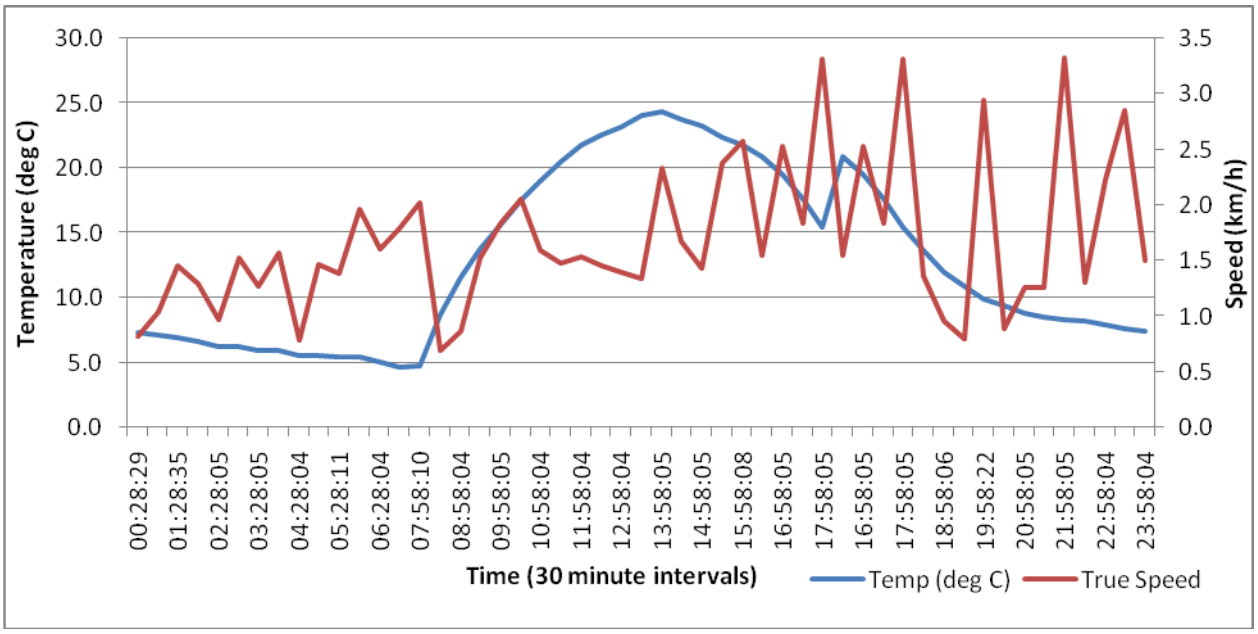


Figure 4.19 Speed of the collared giraffe at different temperatures recorded every 30 minutes.

A test for correlations with significant relationship ($r = 0.83$, $P<0.01$) between altitude and temperature can be seen in Figure 4.20**.** The linear line has a gradient of 0.704 m for every 1°C temperature increase. This regression implies that when there is a 1°C decrease in temperature, the giraffe will move on average 0.704 m higher in altitude. Daytime 07:10 to 17:28 is the preferred time for the giraffe to be at lower altitudes (Figure 4.20).

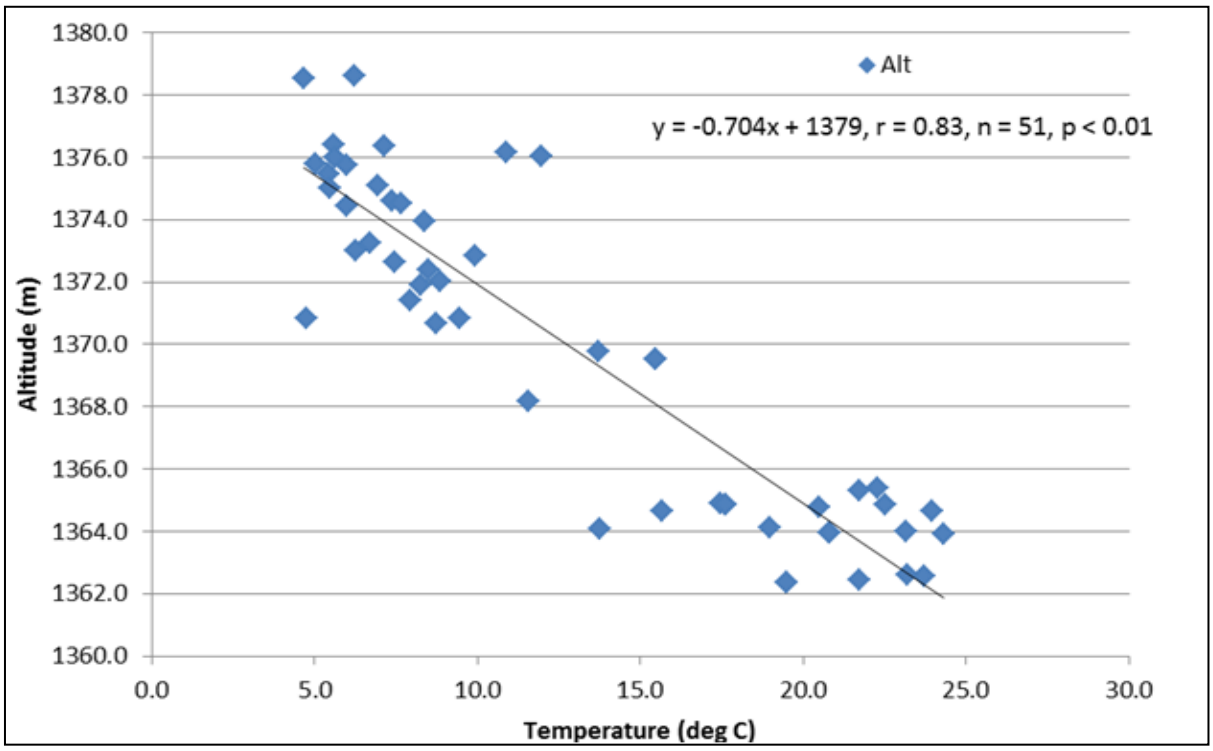


Figure 4.20 Regression analysis demonstrating a linear negative relationship between temperature and altitude.

Figure 4.21 illustrates how the giraffe utilised only a small section of the total area available. The giraffe also avoided the human influenced areas and the residential areas (Figure 4.21). Figure 4.21 also illustrates the giraffe movement at different times of day (PM, AM and nocturnal hours). In view of the fact that temperature may influence behaviour, Figure 4.12 to 4.14 demonstrate how activities and movement changed during daytime hours to night-time hours. These figures show that the giraffe was less active during colder temperatures and his activities started to increase when there was an increase in temperature. This can also be seen from Collar design Figure 4.14 to 4.20, which show that the giraffe moved to higher altitudes during colder hours. Therefore, the assumption can be made that giraffes will actively seek warmer areas during colder temperatures. Unfortunately, only one animal in the herd had been collared, and data received from the collar cannot be regarded as the norm for all the giraffes in WHWE, so in this regard information based on the individual should be used as a case study based on the rest of the herd. This giraffe are therefore representing the whole herd, regardless (known from observations) that the herd always moved closely together. It might also be true that giraffes are less active during colder temperatures with the reduction of speed and distances during colder hours of the night.

It is noteworthy how little of the total area the giraffe utilised, only 251.6 ha from the available 1 000 ha. From the spatial distribution layer over the aerial photograph, it is clear that the giraffe preferred to be close or within the vicinity of the tree cover and that open areas were avoided. This may probably be due to the disturbance created by residential development within the bigger study area.

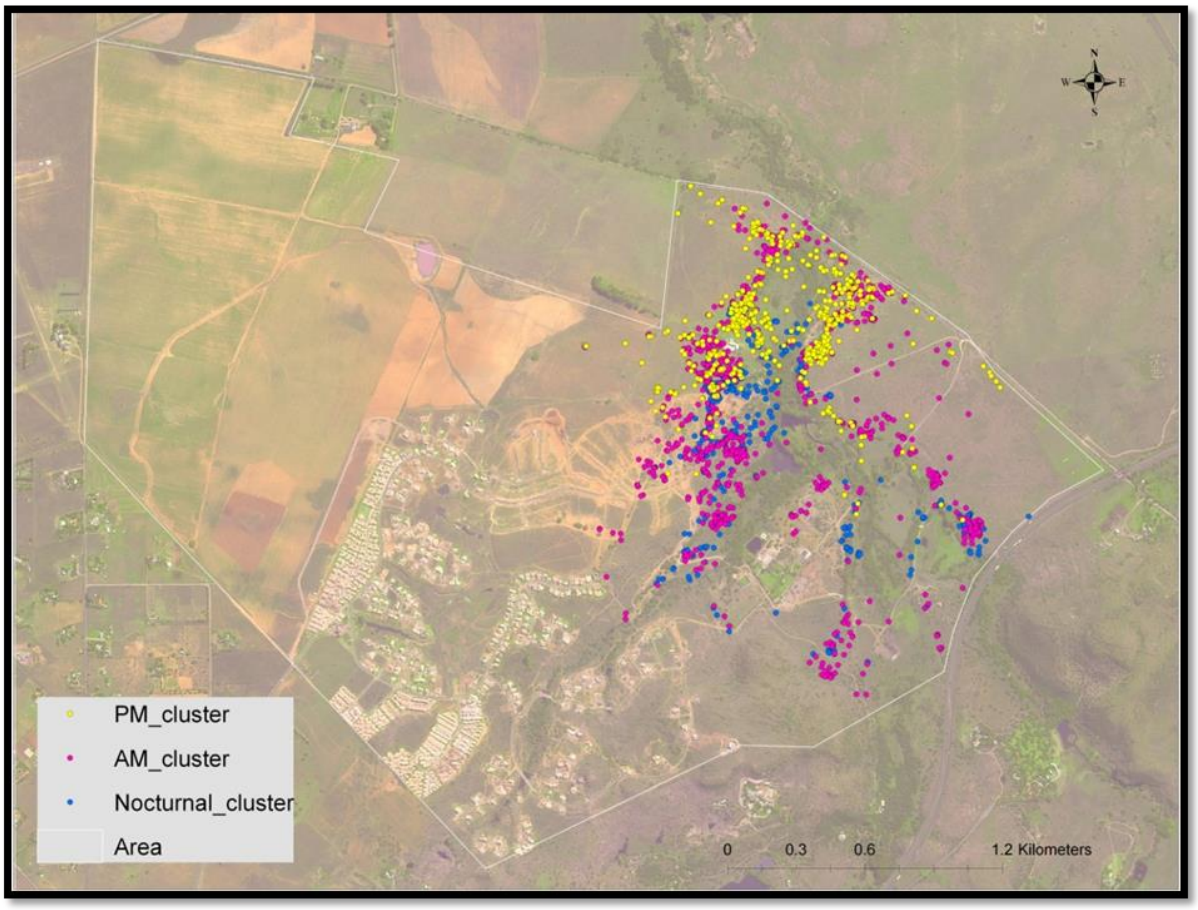


Figure 4.21 Woodland Hills Wildlife Estate boundary and the residential development illustrating the recorded locations of the collared giraffe bull.

Spatial patterns are visible (Figure 4.21) and there are definite spatial differences between the different times of the day. Time of day can be linked to the temperature and altitude (Figure 4.18 and 4.19). As seen from the digital elevation map (DEM) the giraffe tended to avoid the steep slopes (Figure 4.22) and preferred to move within the lower slopes during daytime. At night-time the giraffe tended to move to higher altitudes but not onto steep slopes (Figure 4.22). The mean centres during the time of day (morning, afternoon and nocturnal data) are displayed as the most central point for each time of day combined. Afternoon locations clearly differ from morning and night-time, with a difference in habitat preference and also in range size (Figure 4.22).

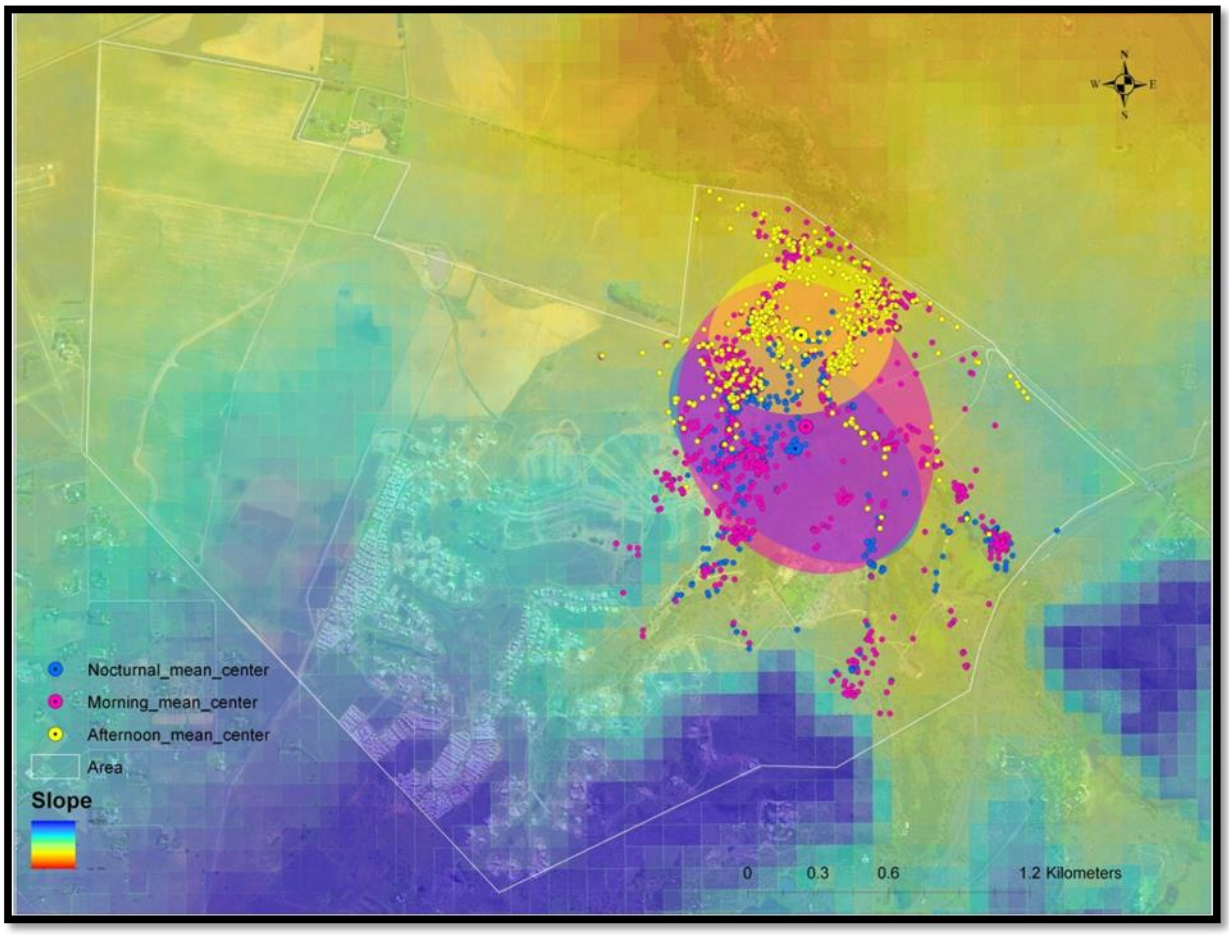


Figure 4.22 Illustration of the Digital Elevation Map overlaid with giraffe locations recorded on the GPS collar, indicating the morning (pink), afternoon (yellow) and nocturnal (blue) locations.

The giraffe home range and spatial distribution for daytime (109.5 ha) and night-time (189.5 ha) differ significantly in size (Figure 4.23). The total home range determined with ArcView 10.2 during the 45 days was an estimated 251.6 ha. Figure 4.24 demonstrates how the giraffe bull's spatial distributions differ in relation to altitude. Altitude also varied during the time of day and with different temperatures (Figure 4.24). This is in relation to the regression analysis done with altitude and temperature. The giraffe altitude preference versus day or night-time are demonstrated in Figure 4.25. The giraffe bull had a definite preference for higher altitudes during colder times (night-time), but *vice versa* for the warmer times of the day (Figure 4.26).

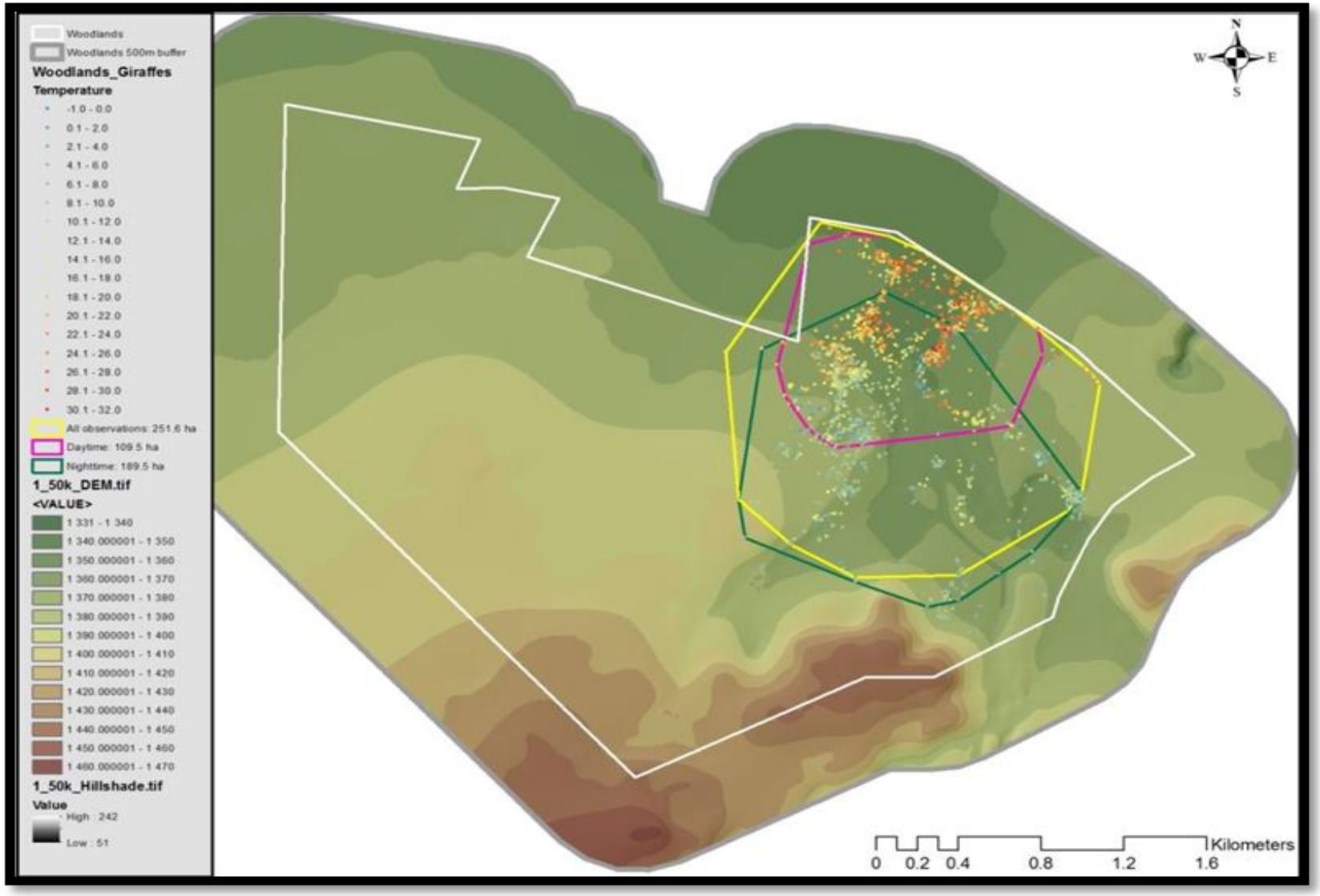


Figure 4.23 The giraffe home range and spatial distribution for daytime and night-time.

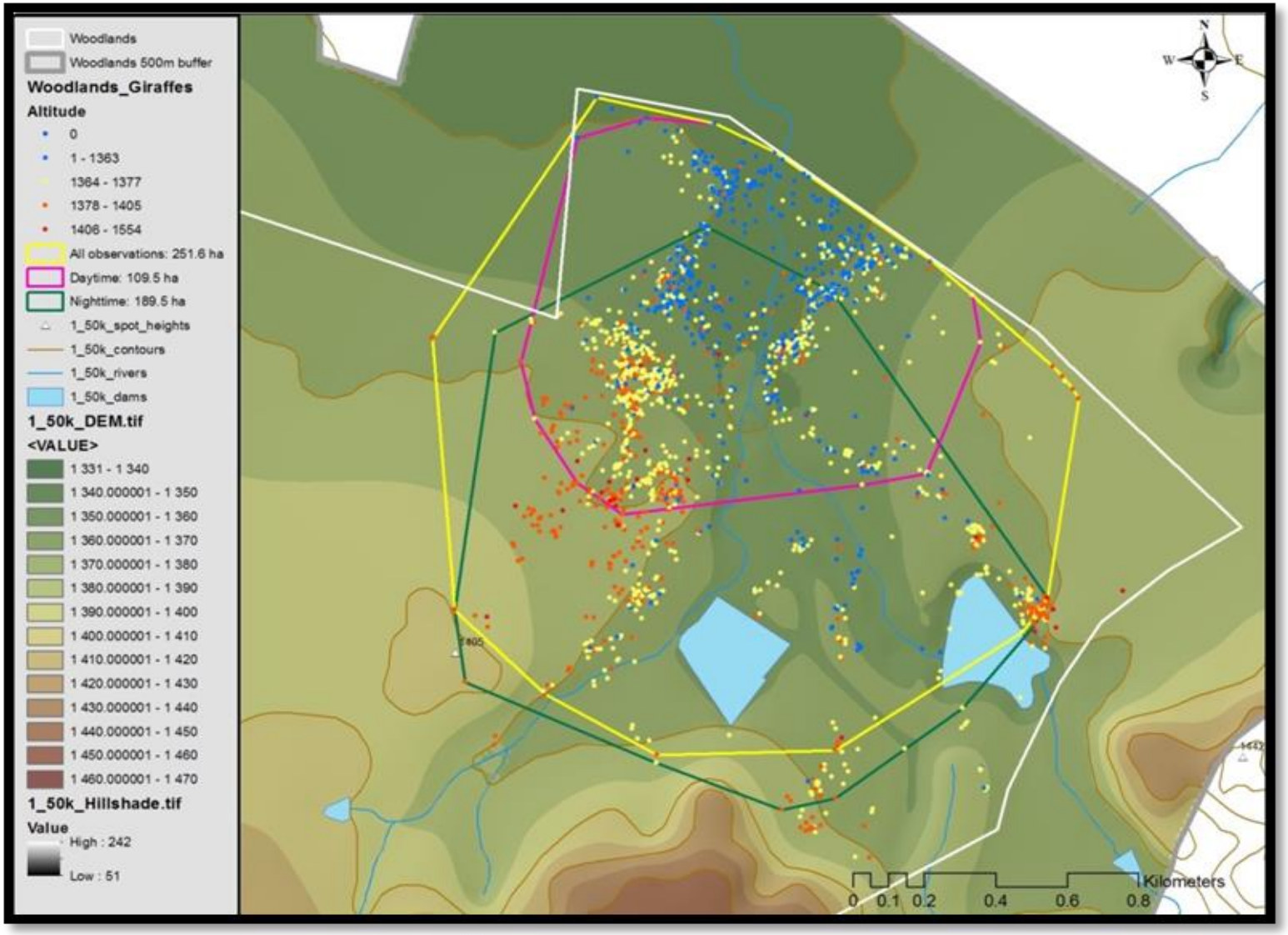


Figure 4.24 The giraffe spatial distribution in relation to altitude with the contours and availability of permanent water

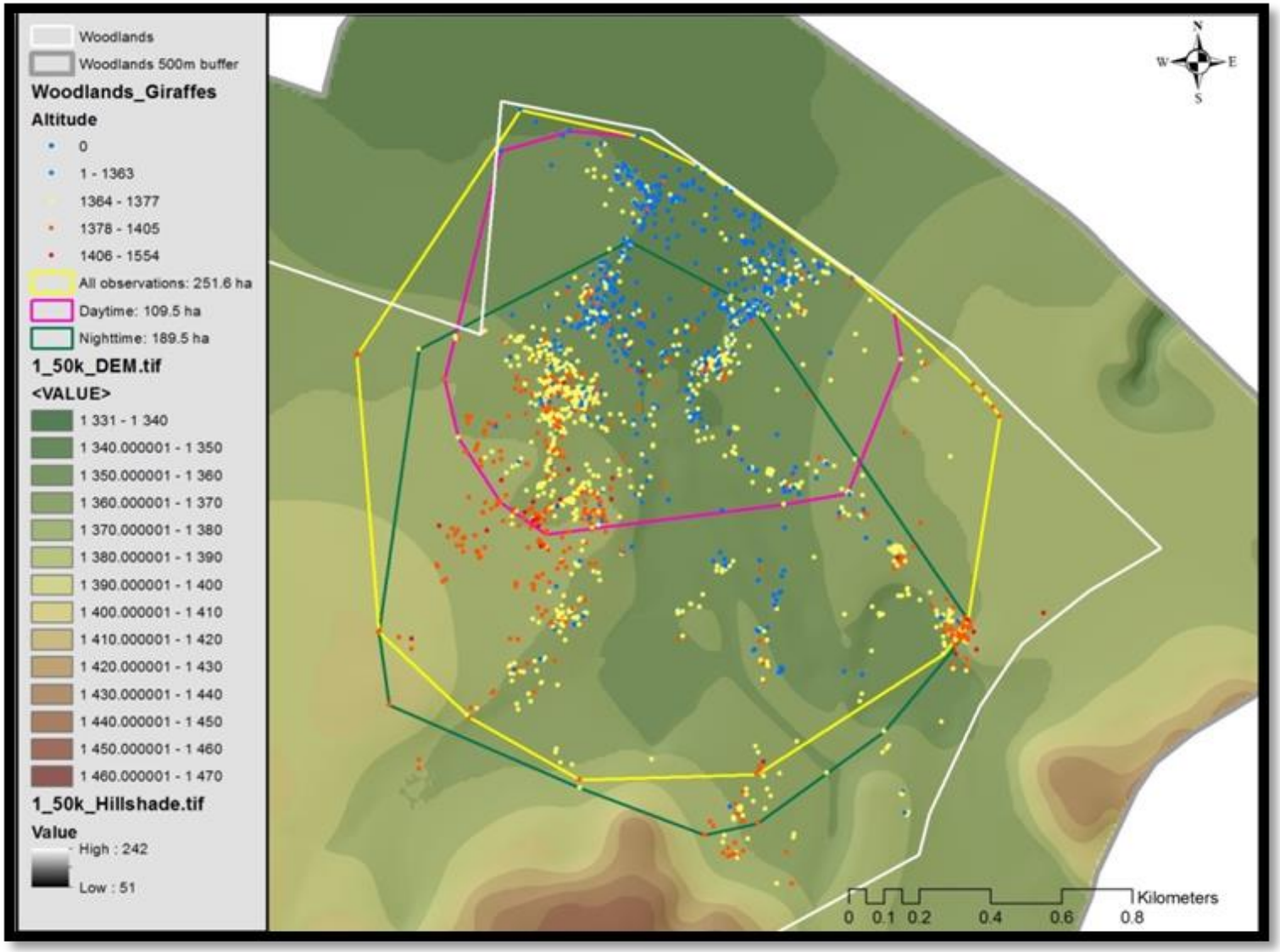


Figure 4.25 The giraffe altitude preference day vs night-time

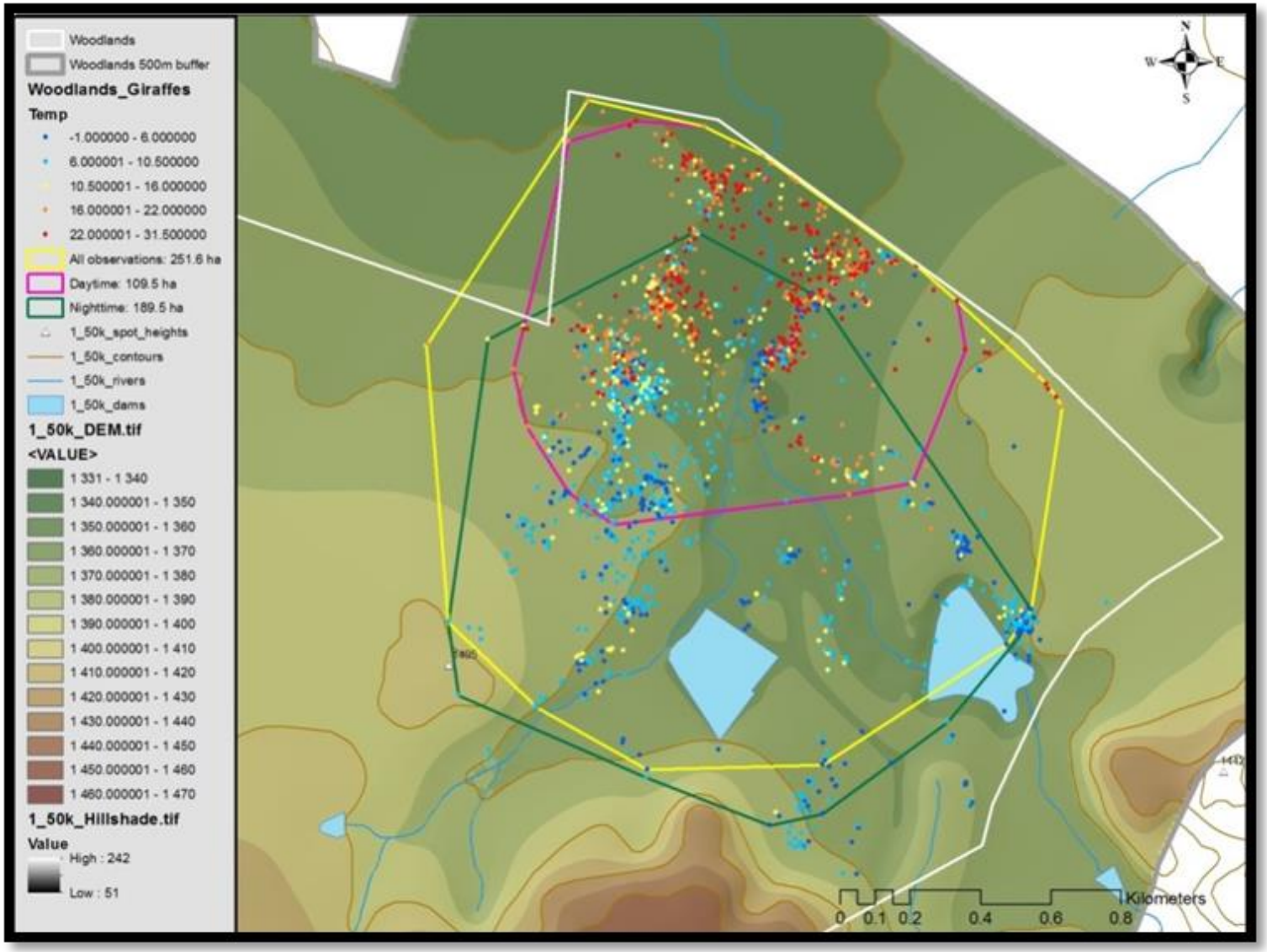


Figure 4.26 The movement of the giraffe in relation to temperature variations between the day and night

4.4. Conclusion

It can be concluded that the head harness collar is preferred to the neck collar. The head harness collar can be fitted on giraffes effectively if the necessary precautions regarding measurements have been taken. If the design, shape and size for each giraffe are not planned with care, there can be negative effects, such as were caused by the neck collar. The preliminary investigation on giraffe skulls, taxidermy artistry and live specimens proved to be very valuable in the development and design stage. Without this proper investigation, the giraffe's life might be threatened and it is advisable before any future collaring takes place to ensure that the collar has been correctly designed and that all measurements are accurate. Time must always be allowed for final minor adjustments to be made in the field.

The information gathered by the head harness collar enabled biologists to gain a better understanding of the spatio-temporal use of habitat by giraffes and to study interactions between giraffes and the terrain. The preliminary influence and value assessments of the head harness collar done in this study demonstrated that the designed GPS collar can be very valuable for monitoring giraffes in the future.

From the observations made in this study, it can be concluded that the collar did not pose any threat or cause a change in natural behaviour. Thus the GPS collar can confidently be used in future research regarding giraffe natural behaviour. The advantages of using this GPS collar include less labour-intensive fieldwork, higher position accuracy, collection of data in the winter time and at night, better control of sampling schedules and less disturbance to the animals. Another advantage is that the use of the collar is creating opportunities to address biological questions that could never previously have been answered for giraffes, such as the accuracy of location, altitude, temperature and distances travelled.

Additional benefits of this GPS collar are the built-in transmitters that record temperature, speed and movement. Continuous logging and storing of temperature and activity information can allow a comprehensive understanding of certain activities and movements of giraffes over seasons.

Current negative factors are that these collars are expensive ($2 500 each). They are also not equipped with a remote release mechanism, which should be considered for inclusion in future projects involving giraffes. A release mechanism would further minimise risks of harm to the animal. However, this will add another $600 to the total cost of the collar.

Future prospects for using GPS collars are regarding the location-based alerts, such as geo-fence areas that can be defined for specific tracking devices. Alerts can be triggered when a specific tracking device enters and/or leaves the defined areas. These alerts can be delivered via SMS or email. This feature is another advantage of near real time data up-linking.

In future, the logger from AWT will use a MEMS (Micro Electro Mechanical System) 3-axis accelerometer, which can detect acceleration in three dimensional space. It uses nanotech silicon substrate to detect acceleration. The level of detection is adjustable in increments of +-2 g from 2 g - 8 g. The device is capable of detecting interrupt or free-fall states which can be user defined. The functionality of the accelerometer is currently limited by power supply

constraints – more readings require more power usage. Therefore, the current head harness collar was set at 30 minute intervals and not at shorter intervals. The future system uses a high inertial wake up on high frequency activities, and is also scheduled not to wake up on low frequency applications. This is to avoid premature battery drain due to low frequency events such as vibrations caused by animal behaviour. Thresholds can be set which, if not managed correctly, can cause battery drain. Furthermore, the future accelerometer data will be augmented by an ultra low power GPS positioning system to define spatial position and heading when possible. Raw accelerometer data may not be useful without a point of reference, so biologists might use unique techniques to try to create a point of origin, so that data may be interpreted more easily.

Currently, data transfer is costly on a satellite system. Thus, accelerometer data which are sent, need to be usable and rich or else the cost versus usable data becomes exorbitant. Loggers can log a far greater quantity of data, but will not be able to provide real-time data in the field. The data can be downloaded remotely in the proximity of the animal or manually once the unit has been removed. The logger will also have the capability of taking temperature readings more efficiently.

Fewer uplinks and the firmware will allow multiple positions to be transmitted in a single satellite uplink. The number of points will be user-defined and can be set on the unit remotely. This should aid in conserving the battery life of the unit, as fewer uplinks will be required, although data will not be available immediately and changing unit settings will take much longer, since these require satellite communication.

This experiment on the giraffe bull proved successful and showed promise for the future fitment of head harness collars on giraffes in the Kalahari to gather data remotely via satellite. The Kalahari giraffe would be the main study and focus for this project, using these pre-tested GPS devices. The software built into the head harness collar can, therefore, also provide the necessary information from giraffes in remote areas such as the Kalahari.

CHAPTER 5: SPATIAL ECOLOGY & HOME RANGE PATTERNS OF THE GIRAFFES

5.1. Introduction

Giraffe home range sizes are highly variable and population structures and number of individuals may vary considerably within home ranges. It also varies between environments differing in size, food availability, seasonal rainfall and frequency of predation (Fennessy, 2009). This, in turn, will often result in different species congregating in the same area, when they favour the same landscapes due to factors such as predation, competition, habitat size, climatic elements and resource quality (Scheepers, 1992). Resource quality includes the quality and availability of forage, shelter and cover (Schamberger & O'Neil, 1986). According to Fabricius (1994), resource richness and home range (HR) depend on the spatial arrangement of habitat patches (the same vegetation type), i.e. how closely spaced patches are within an animal's home range. The relationship between animal density and resource quality is also scale dependent. At a fine resolution, foraging group size varies according to within-patch richness. With a coarse resolution, an animal's home range is determined by spatial arrangement of resource patches within the home range, if not restricted by a fence. A herbivore will expand its home range until all its resource requirements are met within the smallest possible area. Landscapes with densely packed habitat patches may contain many small home ranges, whereas landscapes with sparsely distributed habitat patches may contain few large home ranges. As habitat patches become very sparsely distributed, the animals show a net energy loss in moving between patches to forage (Fabricius, 1994). Resource patches can be restricted by a fence that limits movement and would influence the natural distribution and home range size of animals. Naturally, resource requirements would expand outside the borders of a fence and by restricting the movement of animals, the feeding pressure on the vegetation would be higher.

Little is known regarding the minimum resource and space requirements for giraffe populations to function efficiently within a specified area. This is a concern for wildlife and nature conservation managers, as these minimum standards have never been determined for management purposes. This is a problem for prospective owners who wish to obtain giraffes for game ranching purposes, since nature conservation officials cannot enforce regulations regarding minimum requirements for giraffes. Defining the home range of giraffes within the KKNR might provide the necessary information regarding the requirements for giraffes to be self-sufficient in the Kalahari region. Determining the seasonal variation in home range can assist game managers and nature conservation officials to make informed decisions regarding the wellbeing of giraffes during critical periods. There is little information in the literature on giraffe spatial ecology (in fenced game reserves and game ranches), such as daily distances covered, home ranges and the influence that temperature, rainfall and altitude may have on them.

In general, the movements and home range size of giraffes are strongly linked to seasonal browsing and/or water availability (Hall-Martin, 1974; Berry, 1978; Pellew, 1984b; Fennessy, 2009). Seasonal movements have specifically been associated with phenological changes (see chapter six) of preferred plant species (Hall-Martin & Basson, 1975; Leuthold & Leuthold, 1978) with shifts in forage preferences leading to seasonal expansion or contraction of ranges (Ciofolo & Le Pendu, 2002; Fennesy, 2009).

According to the literature, giraffes are mostly diurnal, but may also be active after dark (Hofmann, 1973; Kok & Opperman 1980). Fennessy (2009) mentioned that giraffes are very biphasic throughout a 24 h period and most of the distribution of their nocturnal activities remains unknown.

Kok & Opperman (1980) found that the giraffes in the Willem Pretorius Nature Reserve, South Africa, increased their home range during the dry season. The average distance moved also increased in the same study area from 2.2 km per day in the wet season to 3.7 km per day during the dry season.

The objectives of this study are:

i) To identify suitable female giraffe representatives of the various family groups in the study area to be captured and collared,
ii) To assess if the collared females are genetically related,
iii) To evaluate the seasonal and annual home ranges of the giraffes by means of the locations recorded by the GPS collars,
iv) To determine daily, seasonal and annual distances travelled by the female giraffes,
v) To investigate whether the home ranges of the different herds overlap and whether the overlap varies between seasons,
vi) To investigate the spatial distribution patterns during the day and night,
vii) To evaluate how much time each herd spent in each vegetation type.

5.2. Procedure

5.2.1. Identification and collaring of representative female giraffes

It was decided to capture and collar eight female giraffes in different parts of the study area, which preferably belonged to different populations, in order to obtain data on giraffe herd movements, The limiting factor that determined the number of animals that could be collared was the high cost of the collars.

The giraffe capture operations were conducted in KKNR study area from 4 – 8 April 2012. At the time of collaring, the herds were widely dispersed over the study area as indicated in Figure 5.1. A representative female was selected for collaring from each herd. The selection involved examining and evaluating the physical condition of all the animals with a team of experts, including two veterinarians. The selection criteria stipulated that the selected animal must be a healthy, fully grown female without any deformities of the ossicones and the skull.

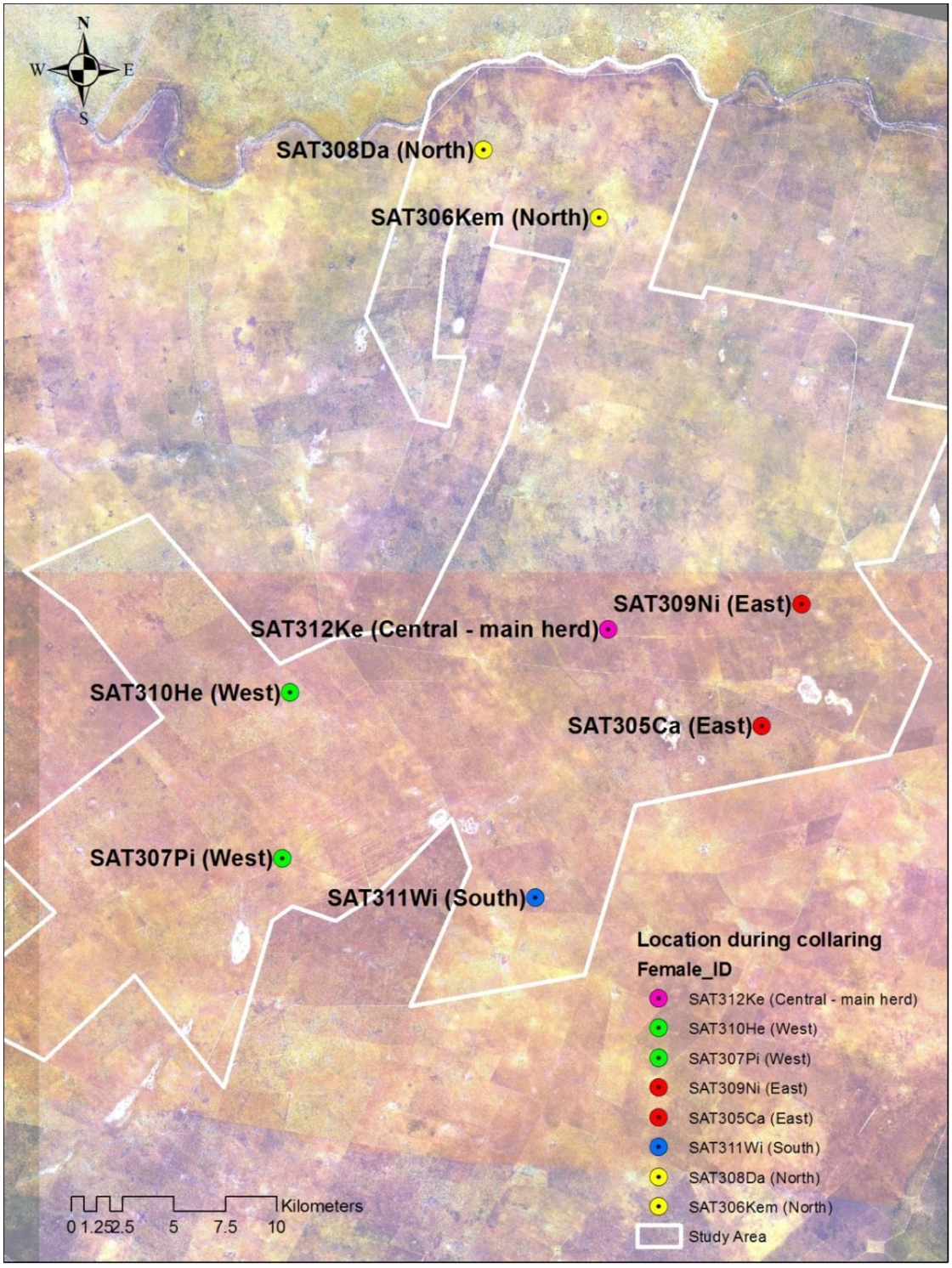


Figure 5.1 Distribution of the giraffe herds from which one individual per herd was selected for collaring during April 2012

Figure 5.1 shows the location where each female was captured. Two animals captured in the northern section of the reserve (SAT308Da and SAT306Kem) were approached and darted from a R44 helicopter. Two were captured in the eastern section of the reserve (SAT305Ca and SAT309Ni). Another two were captured in the western section of the reserve (SAT307Pi and SAT310He). One was captured in the southern section (SAT311Wi) and one in the central section (SAT312Ke) of the reserve. All the individuals accompanying the latter female were classified as belonging to the main herd, and this was the herd followed for daily social and feeding observations for the next fifteen months. All the females were darted from a helicopter, except SAT307Pi and SAT305Ca which were darted from a vehicle. The same dartgun-propelled syringes were used as described in chapter four.

Once the females had been captured, the research team followed the procedure described by Galanti *et al*. (2000) and vital signs such as heart rate, respiration rate, body temperature and physical condition were continuously monitored during the time the giraffes were sedated. A physical examination was carried out and biological samples (blood, faeces, hair and ecto-parasites) were collected from each female to compile a database for management purposes. Biometric measurements that included back length, tail length, ossicone length and width, teeth condition and neck girth were also taken. During the sedation, each female was given the reversal drug (described in chapter four) by the veterinarian. The age of each captured giraffe was estimated, based on tooth wear, skin colour and body size. Following the experience gained during the collaring process with the giraffe bull at Woodland Hills Wildlife Estate (see chapter four), the head harness collar was custom fitted on each female with the assistance of Martin Haupt, the AWT technician responsible for manufacturing the collars.

Each collared female was given a distinctive code name which initially referred back to the sponsor for that collar. The first two letters of the sponsor's name are the two letters used at the end of the code name e.g. SAT312Ke. This was unique for each collar and used to simplify the code names and to limit confusion. The number used within the code name was the same as registered on the AWT server and satellite link. The code names were used throughout the study for all the datasets and spatial analysis.

The collars have a range accuracy of 5 metres. The data recorded by the GPS collars included: date, time, ambient temperature and animal activity, (i.e. speed of movement) as described in chapter four. The GPS collars were scheduled to record coordinates every four hours to conserve battery life and thereby extend the active life of the collars for as long as possible.

The GPS collars fitted to some of the giraffes were active for nearly two years, from April 2012 to February 2014 (SAT312Ke and SAT305Ca), while others stopped functioning in November 2013 (SAT307Pi and SAT306Kem). The details of the performance of each collar are presented in Table 5.1. For statistical purposes, only the data collected from 8 April 2012 to 31 December 2013 (21 months) were used for analyses, as these were the months for which most of the collars provided sufficient information.

Only one herd (SAT312Ke) was considered as the main herd. This herd with the collared female (SAT312Ke) was used as representative for all field observations and was followed for 15 months to gather information on giraffe feeding preferences (see chapters six to eight)

and non-feeding activities (see chapter 9) to assist in making decisions for management purposes (see chapter ten).

For the full duration of the study, regular observations of behaviour were carried out to determine the condition of the eight collared females. The animals were tracked using radio tracking (yagi antennae) to locate the VHF transmitters that were built into the GPS collars. This was achieved by both aerial (R44 helicopter) and ground surveys. This monitoring continued as frequently as possible to evaluate the physical condition and status of each collared giraffe. The main herd in the central area of the reserve (SAT312Ke) was followed monthly for 15 consecutive months from June 2012 to August 2013 in order to collect data on daily activity budgets (see chapter nine) and notes on feeding behaviour (see chapter seven).

Table 5.1 Summarised information for each of the eight-collared females.

Female ID	Location within the reserve	Date collared	Herd structure during collaring	Time to ground during fitting. Time to ground during removal	Time to stand during fitting. Time to stand during removal	Pregnancy (date conceived) and lactation	Date collar was removed	Collar technical performance	Collar physical performance
SAT312Ke	Central	4 April 2012 at 07:30	7 adult ♀ 2 sub-adult ♂ 2 sub-adult ♀ 1 juvenile	4.20 min 21.30 min	18.23 min 27.05 min	Test was negative. Conceived in July 2012. Gave birth 6 November 2013. When collar was removed she had a calf of 3 months and 3 days	14 February 2014 at 07:55	GPS functioning 100% and still had 23% battery life remaining. The VHF functioned perfectly	No chafing, no hair loss and no damage to the skin that was visible
SAT311Wi	South	7 April 2012 at	7 adult ♀ 1 sub-adult	3.28 min	13:45 min	Test was negative. She	# Female died	GPS functioning 100% and still had	Could not be determined

		07:07	♂ 3 sub-adult ♀ 2 juvenile	No time	No time	had a 4 month old calf and was lactating		5% battery life remaining. The VHF only functioned partially	
SAT310He	West	4 April 2012 at 16:23	1 adult ♀ 1 juvenile	5.10 min 4.55 min	17.48 min 7.30 min	Lactating with 2 month old calf	13 February 2014 at 16:47	Stopped functioning, last GPS coordinates: 05 December 2013. VHF 100%	Did have some chafing and minor hair loss, but no physical damage to the skin
SAT309Ni	East	6 April 2012 at 07:42	2 adult ♀ 1 juvenile	No times	No times	Had 5 month old calf. Conceived again September 2012. Gave birth on 14 December 2013.	* Dropped off	Collar sent the same coordinates from 31 October 2013 to 10 November 2013, but functioned 100%. VHF 100%	Could not be determined
SAT308Da	North	6 April 2012 at 07:55	5 adult ♀ 2 juvenile	No time 3.55 min	No time 6.13 min	Lactating with 6 month old calf	13 February 2014 at 10:30	GPS functioning 100%. The VHF also functioned perfectly	No chafing, hair loss or any damage caused
SAT307Pi	West	5 April 2012 at	3 adult ♀	No time	No time	Pregnancy test was negative	^ 31 October	GPS worked 100%. VHF never worked	Twisted collar. Female in a very

		08:17	1 sub-adult ♂ 1 sub-adult ♀ 1 juvenile	4.17 min	11.24 min	and this female was not lactating	2013 at 10:15	from the beginning.	good physical condition despite the collar being a little tight with minor skin damage
SAT306Kem	North	6 April 2012 at 09:15	6 adult ♀ 2 sub-adult ♂ 4 sub-adult ♀ 2 juvenile	No times	No times	Lactating with calf of 5 months at removal	14 February 2014 at 09:45	Last coordinates from this collar were sent 17 December 2013. VHF never worked from the beginning	No problems such as chafing or hair loss caused by the collar
SAT305Ca	East	5 April 2012 at 06:48	4 adult ♀ 2 sub-adult ♂ 4 ♀	6.56min 18.48 min	16.23 min 23.41 min	Positive for pregnancy during collaring	14 February 2014 at 11:30	GPS functioning 100%. The VHF gave problems to the end	No problems such as chafing or hair loss

 # This female died five days prior to the date scheduled for the removal of the collar (14 February 2014) of unknown causes (as she was still active on 9 February 2014). During the examination and physical inspection, it was noted that this female did seem to have an injury of some sort on her right-side hind hoof. The vultures consumed the carcass to such an extent that no assumptions on predation could be made nor could any signs of damage caused by the collar be ascertained. This female was seen in a herd browsing and ruminating on 15 December 2013 by Francois van der Merwe (personal communication, section ranger within KKNR) with no apparent injuries. The GPS collar was recovered eight metres from the carcass. Lightning as cause of death can also not be ruled out, as there were heavy thunderstorms recorded for that period.

***** *It was noticed on the server that the GPS collar repeatedly sent the same coordinates from 31 October 2013 to 10 November 2013. Upon investigation, the collar was discovered and retrieved where it was hanging in a tree. One of the straps was broken, demonstrating that the collar would rather tear before strangling or injuring the giraffe. This female was again seen on 2 December 2013 and she was in a good condition and heavily pregnant with no physical indications of injury.*

^ *This female was in very good physical condition and was considered to be the youngest of the eight collared females. This, however, was considered as a disadvantage, as the collar had to be removed earlier than planned. The collar twisted underneath the lower jaw, resulting in it tightening underneath the jaw. Although she was an adult female, she was not fully developed in size, and being smaller than the other females she grew into the collar, to such an extent that the collar became very tight. Continuous and monthly monitoring proved valuable, as the problem could be detected early enough for correctional action to be taken. The veterinarian considered the tightening not to be a serious problem or life threatening. Even before tranquilizing to remove the collar, it was noted that she browsed and ruminated with ease. She was part of a herd consisting of 11 other animals during the removal of the collar.*

5.2.2. DNA relationship between collared females

Following standard procedures; blood and tissue samples of each female were collected while anaesthetized. The collected samples were sent to a laboratory in Germany (Senckenberg Research Institute) for the DNA analysis. The DNA analysis was done to determine whether collared females might be genetically related. The DNA sequence data of the mitochondrial genome (mtDNA) from the giraffes also forms part of the effort to help clarify previous confusion regarding the genetic homogeneity of southern African populations. This DNA will in turn also contribute to a better knowledge of unstudied giraffe populations and refine the distribution map of the southern African *G. c. angolensis* and *G. c. giraffa* populations in particular.

MEGA software v5 (Tamura *et al*., 2011) was used to find the model of nucleotide substitution that best fits the available data. A phylogenetic tree was constructed using maximum likelihood procedures in MEGA v5, to identify the relationships between the collared females blood sampled. Phylogenetic testing was done using the bootstrap method, with 1 000 bootstrap replications. To root trees during phylogenetic analysis, we used the

control region portions of *G. c. thornicrofti* located in South Luangwa National Park in Zambia (GenBank accession numbers HF571176.1 and HF571177.1).

5.2.3. Data analysis of giraffe movements

The Excel Analysis ToolPak (2012) was used to demonstrate the descriptive statistics and data recorded by the GPS collars. This included the tools used for the data analysis, such as Standard Deviation (SD) and Standard Error of the mean (SEM) descriptions (Raubenheimer, 2012).

Data were further statistically analysed with GenStat® (Payne *et al*., 2012) for each dataset recorded by the GPS collars for each giraffe. The use of Generalized Linear Mixed Models (GLMM) extends the usual analysis to cater for non-normal distributions, for example, the Poisson distribution for counts and the gamma distribution for positively skewed data, such as the total distance as response variate. They also incorporate a link function that defines the transformation required to ensure the linearity of the model. For example, logarithm (base e) is used for counts and for the gamma distribution. GLMM additionally allowed for the inclusion of random effects, such as the hour of day, to account for the variation within time effects.

In other words, GLMM is used for data that do not agree with the assumptions for normality and homogeneous variances. The GLMM analyses were used to test for differences between time spent travelling and season effects, as well as the time x season interaction (fixed effects). The random effect was specified as hour. Treatment means were separated using Tukey's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran, 1980).

5.2.4. Evaluating locations recorded by the GPS collars

5.2.4.1. Determining the home range of the collared giraffes

Home range determination was done using the QGIS version 2 AniMove plugin (1991) and ArcView (ESRI, 1996). Minimum Convex Polygons containing 95% of the giraffe position fixes were generated by season and time of day for each collared giraffe. Tables and figures unrelated to spatial templates were used to summarise home range size, home range overlap and distance moved, using Excel and ArcView 10.2.

To determine the total home range size using 100% of the point fixes, only six fixes on the GPS collar were used per day (every four hours), using the Minimum Convex Polygon (MCP) method (ArcView 10.2, ESRI, 1996). Home ranges were calculated for each individual female separately and also for each season and time of day.

The data recorded by the collars were organized in Excel spreadsheets, with one sheet per giraffe. In order to facilitate the conversion to GIS format, the columns were renamed to conform with the 10 character limit imposed by the shapefile format from ESRI (2006). The conversion to shapefile required the spreadsheets to be exported as comma separated text

files (csv), which were imported into QGIS (1991) and converted to shapefile format for further use in ArcView 10.2. The re-projection of shapefiles was also necessary in order to facilitate the calculation of distances and areas. Shapefiles were reprojected to the WG23 South African Coordinate Reference System (CRS). This CRS, sometimes known as Lo23, uses the Hartebeesthoek94 datum, a Transverse Mercator projection and a central meridian of 23° East.

For each giraffe the collar readings were grouped according to year, season and time of day:

Years:	Year 1: 2012
	Year 2: 2013
Seasons:	Winter: June, July, August
	Spring: September, October, November
	Summer: December, January, February
	Autumn: March, April, May

Seasons were also weather dependent and were labelled: summer (wet hot), autumn (wet cool), winter (dry cool) and spring (dry hot). Time of day was divided into four time schedules, morning: 06h00 to 10h00, midday: 10h00 to 14h00, afternoon: 14h00 to 19h00, night: 19h00 to 06h00.

5.2.4.2. Determining distances travelled by the collared giraffes

Linear distance (m) between successive radio-locations was determined by logging the GPS coordinates every four hours. Total season distance covered was calculated by summing all the linear distances between successive fixes gathered within that season. Minimum speed was estimated by dividing linear distance between subsequent locations by the time taken (km/h per four hours). The calculated speed was categorized in one of six hour-intervals and a one-way analysis of variance was used to compare mean speed at different hours of the day for each giraffe. Influences on distances such as time of day and different seasons were also evaluated.

5.2.4.3. Determining the home range overlap of the collared giraffes

Home range (home range scale based on 1 km² = 100 ha) overlap, expressed as a percentage overlap of a giraffe's home range with the home range of each of the other giraffes, was calculated using the total recorded coordinates during each of the four seasons, using QGIS (1991) and ArcView 10.2 (ESRI, 1996). In relation to home range overlap, the number of days each of the collared females spent together was also calculated (females counted as together when they were in the vicinity of <300 m from each other). Days were summed to reveal how often the same collared females were together.

5.2.4.4. Investigating each collared female's day and night spatial patterns

The same time schedules were set for each collared female by using the same description for all datasets, which included time of day, set out as the total recordings within the morning, midday, afternoon and night-time hours (as described in 5.2.4.1 above). These time schedules were then evaluated using ArcView 10.2 (ESRI, 1996) and QGIS (1991).

5.2.4.5. Evaluating the time each collared female spent in each vegetation type

The area within which each female roamed overlapped with the vegetation communities (discussed in chapter three) and was expressed as a percentage overlap of a giraffe's time spent within each of the vegetation communities. The total number of recorded positions within each vegetation community was analysed with the Crosstab tool developed for ESRI (1996).

5.3. Results and Discussion

5.3.1. Identification and collaring of representative female giraffes

Within each discrete giraffe herd, a suitable female was identified to be fitted with the GPS head harness. The different herds were distributed throughout the reserve with representatives within each of the main vegetation units. The eight collared females were all in good condition and matched the selection criteria, namely that the selected animals should be healthy, full grown and without any deformities of the ossicones and the skull.

5.3.2. Performance of the GPS collars

No serious problems were experienced with the collars during the study period. Some of them had technical malfunctions from time to time, but the data were stored on-board the logger and could be retrieved afterwards. Only one of the collars had to be removed earlier than planned (SAT307Pi) and one collar fell off due to a broken attaching strap (SAT309Ni). The sum of locations recorded and estimates of distances moved for each female through the duration of the monitoring period are presented in Table 5.2, which also shows variations in average distance travelled by each female over 24 h. All data used for analysis were transmitted from 8 April 2012 to 31 December 2013, though some of the collars were still functioning up to February 2014, when the data were downloaded for the last time. The transmitted data showed that all the females remained inside the reserve and mostly roamed in areas surrounding the location where they were initially collared. It is possible that factors such as terrain, altitude, utilisable vegetation, water availability, rainfall and temperature are important determinants for the movements of giraffes in the KKNR, as was reported in the Kgalagadi Transfrontier Park in South Africa (Kruger, 1994).

5.3.3. Genetic relationships between the female giraffes

DNA was amplified successfully from all samples and sequenced from both ends for the cytochrome b (cytb) gene. DNA analysis would normally indicate some relationship between individuals if there are home range overlaps (Estes, 1997; Frandsen, 1998). The DNA results obtained from the eight females indicated some relationship between some of them (Figure 5.2).

The pattern of substitution in the dataset was best described by a Hasegawa-Kishino-Yano (HKY+G) model of nucleotide substitution. In the HKY-ML tree, populations are grouped into three broad clusters. Haplotypes supported by a bootstrap value of 94%, females

SAT306Kem, SAT305Ca, SAT310He and SAT311Wi were closely genetically related, but females SAT307Pi, SAT306Da, SAT312Ke and SAT309Ni were unrelated to them (Figure 5.2).

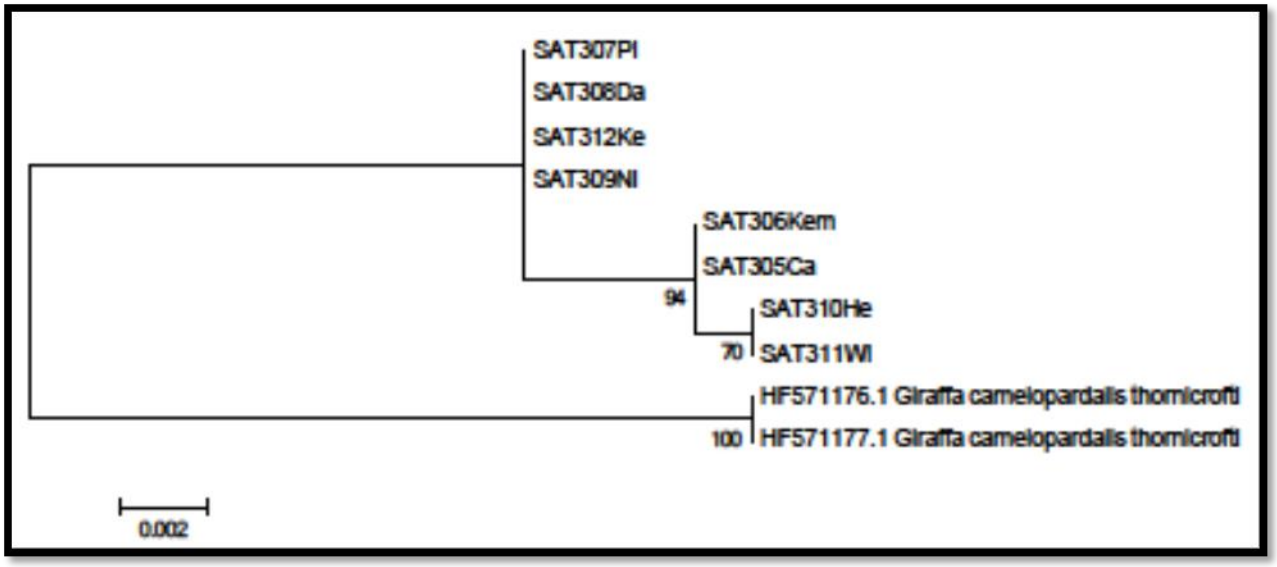


Figure 5.2 Tree grouping from the eight collared female giraffes with two control samples.

These DNA records will also assist with the global objective to understand better the genetic architecture of giraffe populations in South Africa and to help resolve their taxonomic status in comparison with populations across the continent. The DNA results of this study will also be assisting the broader giraffe conservation and management efforts to understand and maintain the genetic health of the South African populations. This will contribute to the identification of their genetic structure and health that are essential for their on-going survival. It will also be useful for the translocation of animals in the future in order to maximise genetic diversity and to reduce the potential for inbreeding, which may occur if populations from different genetic units are not mixed, as happened historically in southern Botswana (Fennessy, 2009). The giraffes within KKNR were translocated from the North West and Limpopo Provinces. The initial origin of many of these animals is from neighbouring provinces and possibly from neighbouring countries. Unfortunately, it is unknown whether these giraffes from neighbouring countries are Angolan or Cape giraffes, but they were recently 'clumped' into the Southern giraffe group (Block, 2014). Essentially little is known of the differences between these sub-species, and therefore the DNA samples gathered within the KKNR will assist wildlife ecologists to gain a better understanding of giraffe herd structures by determining how intimate individuals might be if they are not genetically related.

5.3.4. Descriptive statistics on giraffe movements

5.3.4.1. Distances travelled

As expected, the daily movements varied markedly between all collared females. The average daily distance moved for the eight females was 5.1 km per 24 hours, with a range of 4.2 to 6.6 km (Table 5.2).

Table 5.2 Summary of distances that were logged on the GPS collars

Collar ID	Period during which data were gathered	Max distance in 4 h (m)	Ave distance/4 h (m)	Average distance over 24 h period (km)	Total distance (m)	Number of recordings	Number of days recorded
SAT312Ke	04/08/2012 -12/31/2013	10 218	1044.4	6.3	41 775	3 821	633
SAT311Wi	04/08/2012 -12/31/2013	8 635	893.6	5.4	31 991	3 580	633
SAT310He	04/08/2012 -12/5/2013	9 914	705.4	4.2	25 731	3 648	607
SAT305Ca	04/08/2012 -12/31/2013	9 461	931.9	5.6	36 699	3 938	633
SAT307Pi	04/08/2012 -10/31/2013	7 342	866	5.2	29 964	3 460	573
SAT309Ni	04/08/2012 -11/1/2013	17 176	814.5	4.9	28 165	3 458	572
SAT306Kem	04/08/2012 -12/17/2013	18 886	729.2	4.4	27 278	3 741	620
SAT308Da	04/08/2012 -12/31/2013	18 592	739.8	4.4	28 237	3 817	633
Standard deviation			***116.42***	***4.87***			

The average daily distance moved (5.1 km calculated from the average of the eight females) was higher than was found for cows elsewhere: e.g. 2.9 km in South Africa (Langman, 1973), ≤ 2.3 km in Zambia (Berry, 1978) and 1.87 km in Namibia (Fennessy, 2009).

The maximum distance (SAT306Kem) travelled by one individual in four hours was 18 886 m and the average distance between points in four hours varied between 705.4 m (SAT310He) and 1044.4 m (SAT312Ke) (Table 5.2). The total distance travelled over the entire study period varied greatly from individual to individual. The highest (SAT312Ke) being 4 177 km recorded over 633 days with an average of 6.6 km per day. This is considerably higher than the 2 573 km (average 4.2 km per day) recorded by SAT310He. Berry (1978) found that giraffes never exceeded 2.3 km per day in Zambia and Fennessy (2009) found the average daily movements of bulls were 5.64 km compared to 1.87 km for cows in Namibia.

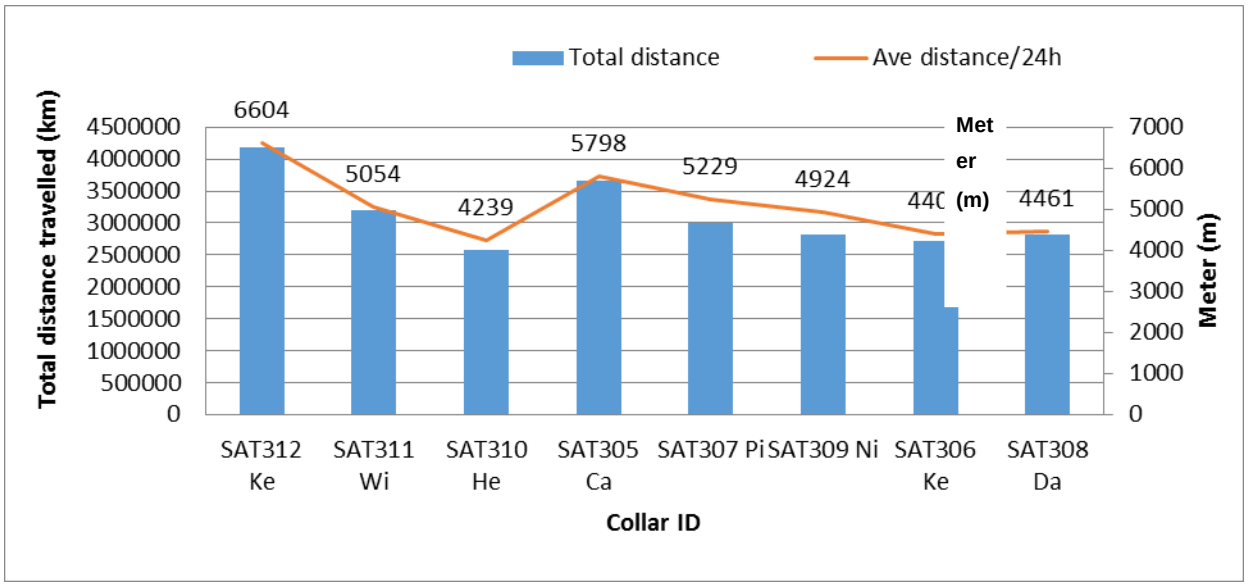
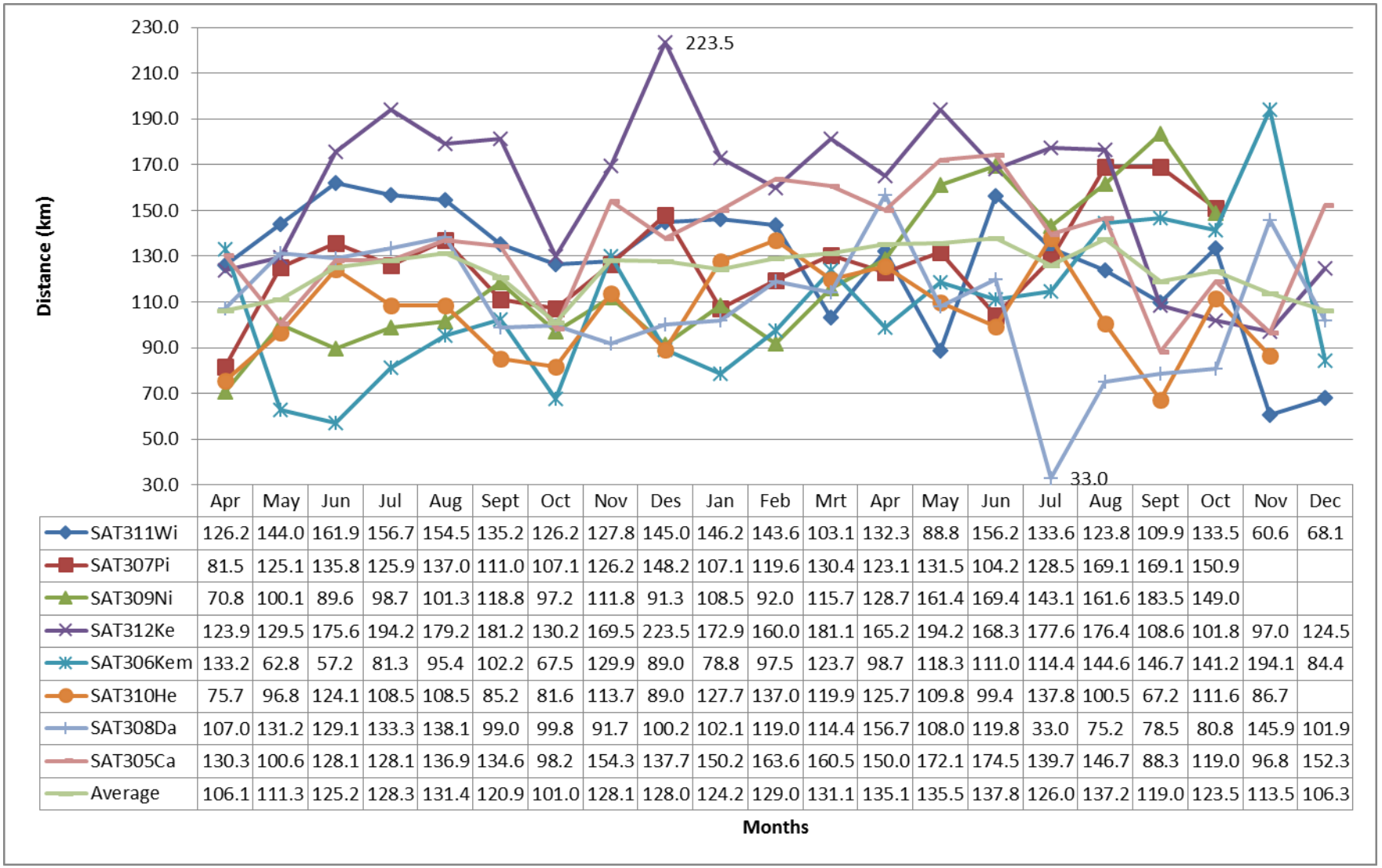


Figure 5.3 Total distance and average distance per 24 h travelled by each collared giraffe



	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Des	Jan	Feb	Mrt	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
SAT311Wi	126.2	144.0	161.9	156.7	154.5	135.2	126.2	127.8	145.0	146.2	143.6	103.1	132.3	88.8	156.2	133.6	123.8	109.9	133.5	60.6	68.1
SAT307Pi	81.5	125.1	135.8	125.9	137.0	111.0	107.1	126.2	148.2	107.1	119.6	130.4	123.1	131.5	104.2	128.5	169.1	169.1	150.9		
SAT309Ni	70.8	100.1	89.6	98.7	101.3	118.8	97.2	111.8	91.3	108.5	92.0	115.7	128.7	161.4	169.4	143.1	161.6	183.5	149.0		
SAT312Ke	123.9	129.5	175.6	194.2	179.2	181.2	130.2	169.5	223.5	172.9	160.0	181.1	165.2	194.2	168.3	177.6	176.4	108.6	101.8	97.0	124.5
SAT306Kem	133.2	62.8	57.2	81.3	95.4	102.2	67.5	129.9	89.0	78.8	97.5	123.7	98.7	118.3	111.0	114.4	144.6	146.7	141.2	194.1	84.4
SAT310He	75.7	96.8	124.1	108.5	108.5	85.2	81.6	113.7	89.0	127.7	137.0	119.9	125.7	109.8	99.4	137.8	100.5	67.2	111.6	86.7	
SAT308Da	107.0	131.2	129.1	133.3	138.1	99.0	99.8	91.7	100.2	102.1	119.0	114.4	156.7	108.0	119.8	33.0	75.2	78.5	80.8	145.9	101.9
SAT305Ca	130.3	100.6	128.1	128.1	136.9	134.6	98.2	154.3	137.7	150.2	163.6	160.5	150.0	172.1	174.5	139.7	146.7	88.3	119.0	96.8	152.3
Average	106.1	111.3	125.2	128.3	131.4	120.9	101.0	128.1	128.0	124.2	129.0	131.1	135.1	135.5	137.8	126.0	137.2	119.0	123.5	113.5	106.3

Figure 5.4 Total distance travelled each month by each collared giraffe

Distances recorded by the GPS collar indicated the three longest distances travelled by female SAT311Wi were 161.9 km (June 2012), 156.7 km (July 2012) and 156.2 km (June 2013) (Figure 5.4). This indicates that she travelled for longer distances during the winter months compared to other seasons. The two months when the least travelling occurred were November 2013 (60.6 km) and December 2013 (68.1 km). However, this was not the case for the same period the previous year (November and December 2012), when she moved more than twice as far (Figure 5.4).The longest distances travelled by female SAT307Pi were 169.1 km in August and September 2013 (Figure 5.4).

The distances travelled by female SAT309Ni were highest in September 2013 (183.4 km) and lowest in June 2012 (89.6 km) (Figure 5.4). It is significant that this female considerably increased the distance travelled from the first year (605.7 km, May 2012 – October 2012) compared to the second year (968.1 km, May 2013 – October 2013). Female SAT312Ke (Figure 5.4) travelled the longest distances of all the collared females, e.g. 194.2 km (July 2012) being the month when she conceived, 223.5 km (December 2012) and 194.2 km (May 2013). Her shortest distances travelled were 108.6 km (September 2013), 101.8 km (October 2013) and 97.1 km (November), which is on average much longer than the other collared females, possibly because of her physiological stage or her age. It is interesting to note that she gave birth on 6 November 2013, and the relatively short distance travelled in that month probably indicates that her movements were restricted by having a new-born calf.

Female SAT308Da (Figure 5.4) travelled the longest distances in April 2013 (156.7 km) and November 2013 (145.9 km), and the least during July 2013 (33.1 km). She gave birth in July/August 2013, as she had a six to seven month old calf and was lactating when the collar was removed in February 2014. The three months that followed the birth (August 2013 – October 2013) were the months when she travelled the least, indicating that her movements were restricted by her new calf.

For female SAT305Ca (Figure 5.4), the months when the longest travelling distances were noted were May 2013 (172.1 km) and June 2013 (174.5 km), and the three months with the least travelling were October 2012 (98.2 km), September 2013 (88.3 km) and November 2013 (96.8 km).

When tested with GLMM (GenStat®, 2012) temperature was demonstrated to have little effect on the majority (six collared females) of daily distances travelled ($p<0.05$) (see Appendix C). However, temperature was shown to exert a significant effect ($p<0.05$) on the daily movements of females SAT306Kem and SAT309Ni.

Average monthly distances travelled by all females were calculated from the monthly distances of the individuals (Figure 5.4). Lowest speeds were recorded for the summer months (1.50 km/h), followed by autumn (1.69 km/h) and the highest speeds were recorded for the winter (1.92 km/h) months, followed by spring (1.73 km/h) (Figure 5.4). These figures reveal that giraffe moved faster on average during the colder periods of the year (Figure 5.4). The graph illustrates how giraffe moved slower in the summer months than in the other months. (Figure 5.4).

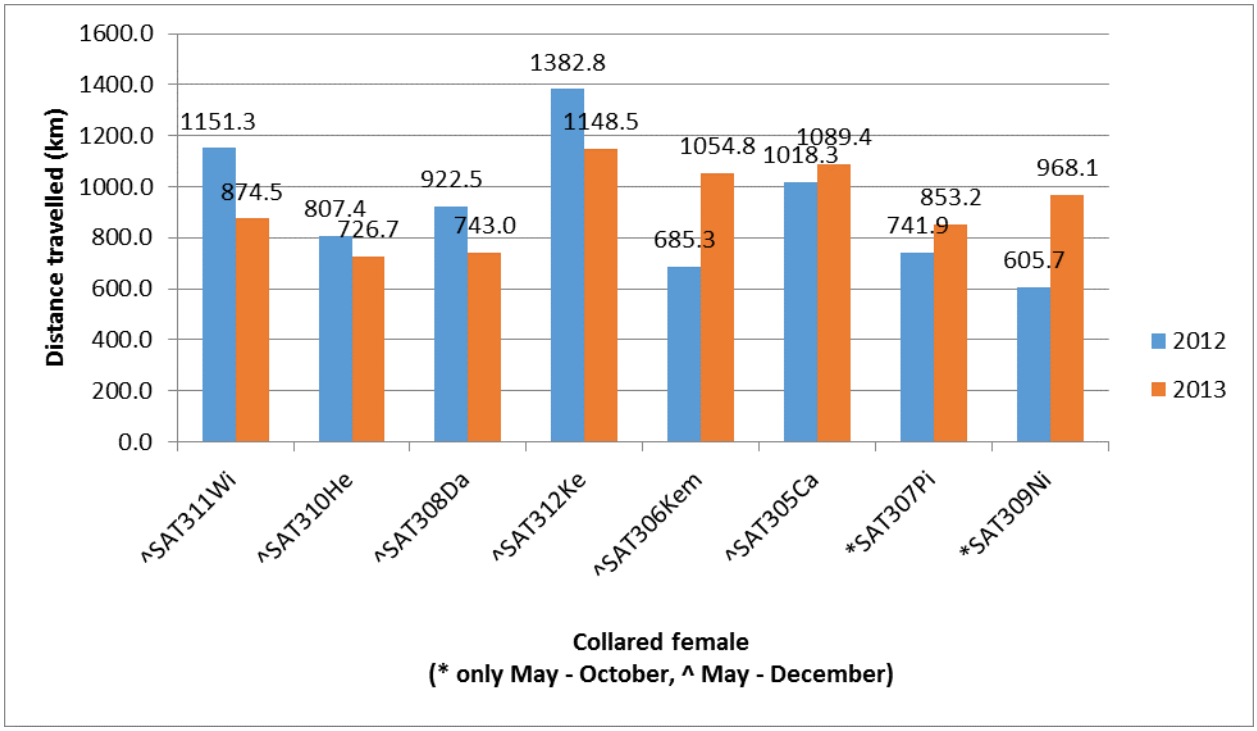


Figure 5.5 Total distance travelled by each collared giraffe comparing year one (2012) with year two (2013)

If recorded distances (n = 29 463 over 4 904 days) are added together the giraffes travelled 31 230 km (average of 5 088 km per day) in total. This illustrates an average speed of 0.21 km/h over the study period.

On average year one (2012) the giraffes moved 1 695.2 km (recorded over nine months) in total and in year two (2013) only 1 542.8 km in total over 12 months (except SAT309Ni and SAT307Pi only ten months) (Figure 5.5). The reason for this could possibly be the lower rainfall recorded in year 2013 (178.8 mm) compared to the year 2012 (268.5 mm) (Figure 5.7).

5.3.4.2. Seasonal changes in distances travelled

Seasonal distances travelled by the collared females (Figure 5.6) demonstrate that the longest distances were travelled during the winter (959.4 km) months, followed by spring (864.8 km), summer (852.0 km) and autumn (842.8 km) on average, however, the 2 years were not consistent with only summer in both years low together. It also indicates that the giraffes did not travel longer distances during the warmer months of the year (Figure 5.6).

According to Kok & Opperman (1980), the average daily distance moved by giraffes in the Willem Pretorius Nature Reserve in South Africa increased from the dry to the wet season (2.2 km/day in the dry season to 3.7 km/day in the wet season). This study found the opposite with an increase of average distances moved over the autumn season (5.05 km/day), summer season (wet) (5.1 km/day), spring season (5.2 km/day), and the winter season (dry) (5.75 km/day) (Figure 5.6 and Table 5.2).

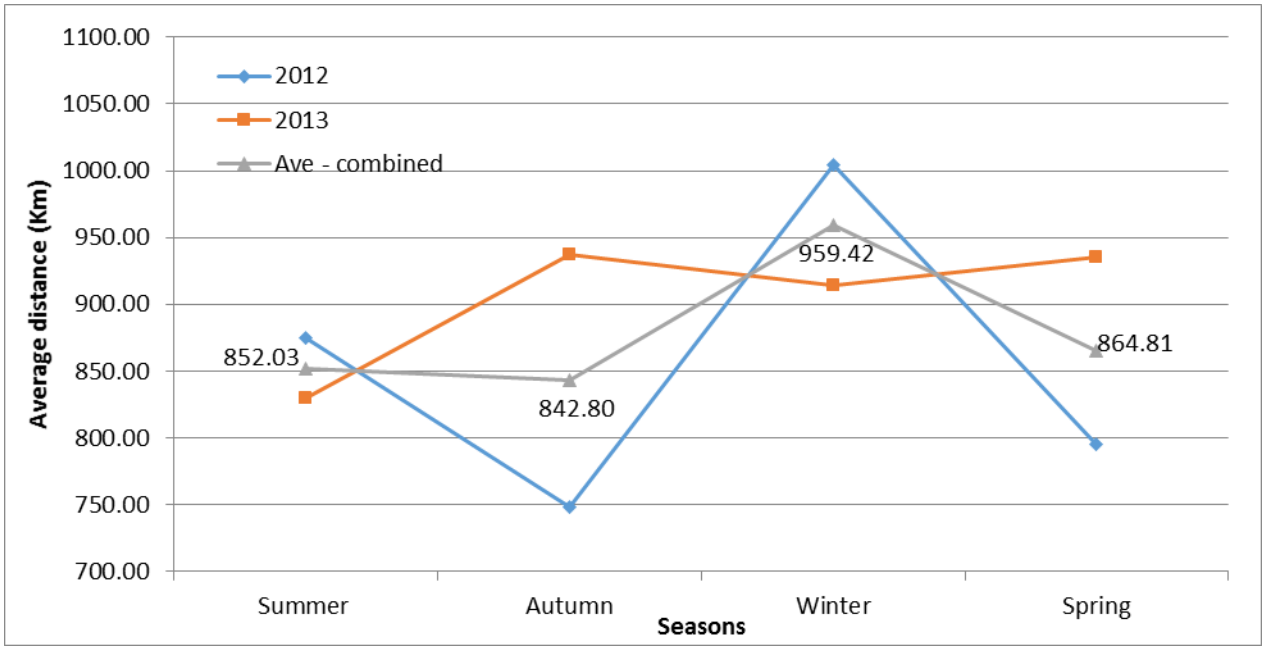


Figure 5.6 Combination of all average distances travelled by collared giraffes over seasons for 2012 and 2013

5.3.4.3. Rainfall

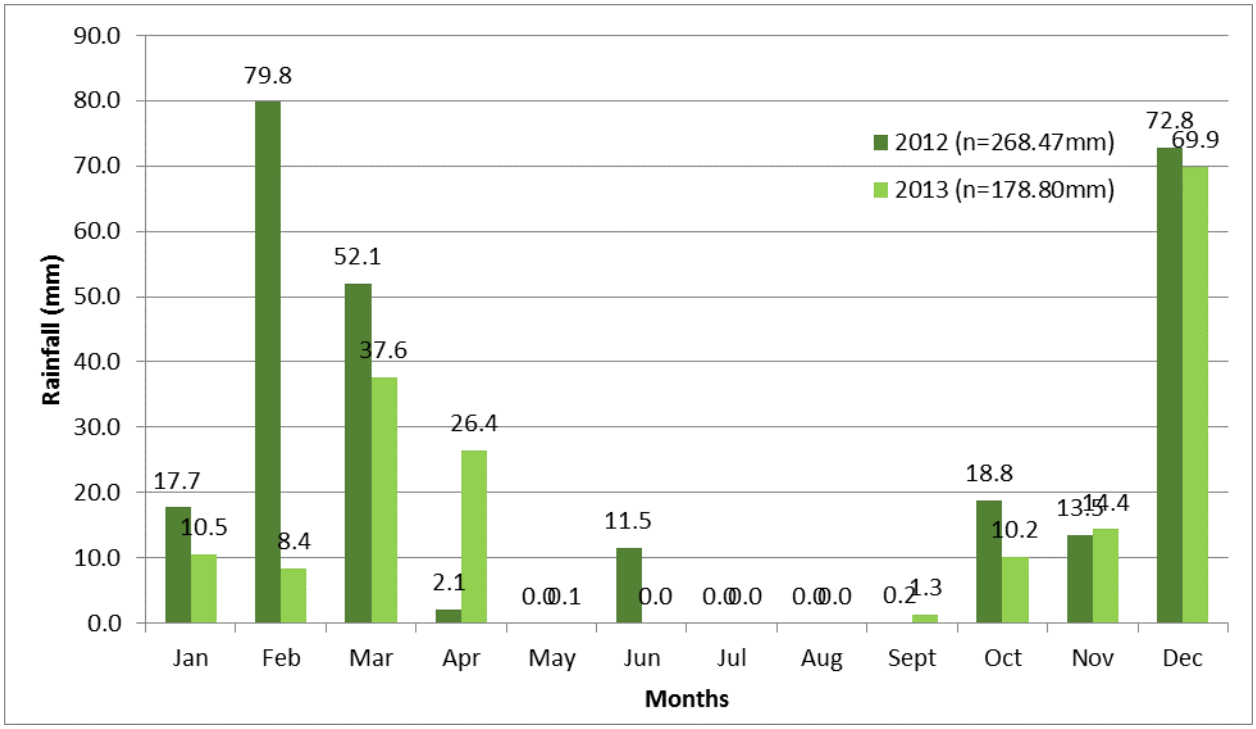


Figure 5.7 Average rainfall recorded over two years (2012 & 2013) from three weather stations located within KKNR

Seasonal distances travelled in 2013 were lowest in the summer months, followed by spring, for the eight collared females, with the majority of longer distances travelled in the autumn

(four females) and in the winter (four females) months. This could possibly be attributed to the late rainfall in April 2013 (Figure 5.7). These data could possibly indicate that giraffes move longer distances during less-rainy seasons than in rainy seasons. This possibility might be due to the availability of drinkable water (open pans) from rainfall, which creates opportunities for giraffes to roam further afield. The rain in the middle of 2012 (June 2012) could also have contributed to the longer distances giraffes travelled in 2012 compared to 2013 (Figure 5.7)

5.3.4.4. Distances travelled during day and night

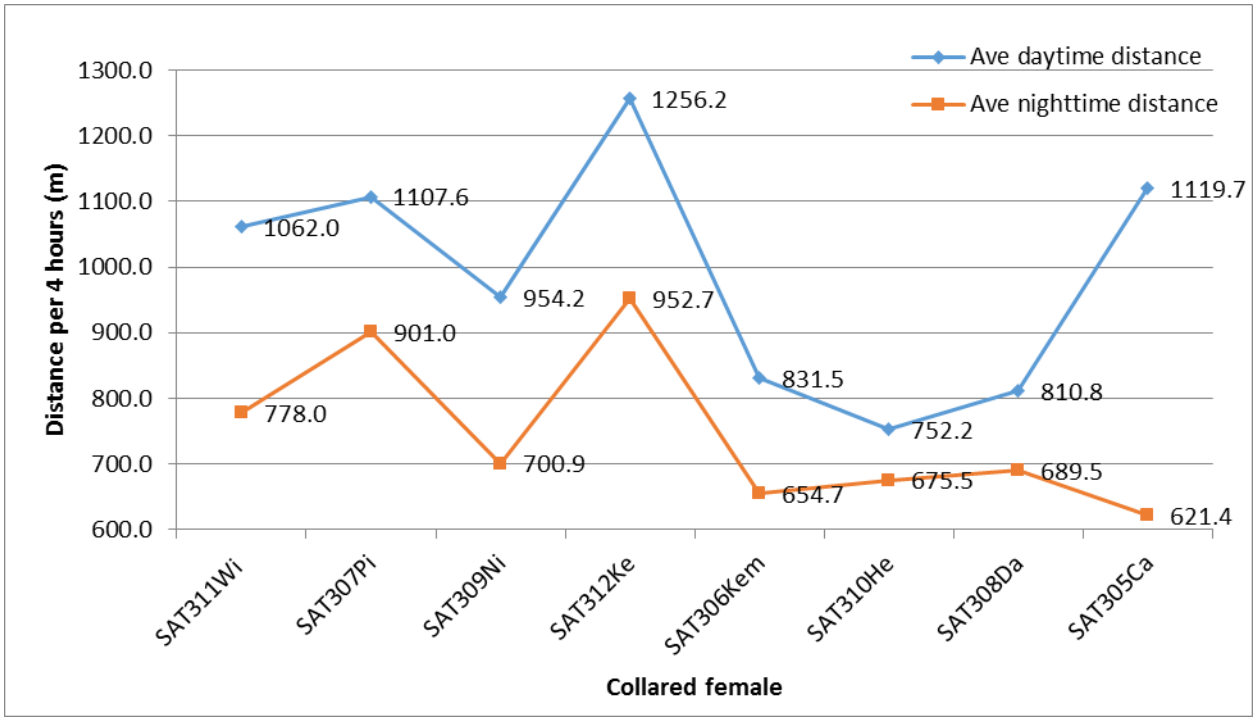


Figure 5.8 Average distances travelled during day and night recorded for each collared giraffe

The average distance travelled per 4 h period during the day by each collared giraffe was further than any of the night-time distances (Figure 5.8). The total distance travelled by all collared giraffes during the day (13 652 km) was greater than travel during the night (10 510 km) (Figure 5.8).

5.3.4.5. Statistical results regarding influences on distances travelled

The results were tested statistically for time and seasonal effects that might influence distances travelled for each collared giraffe. Appendix C demonstrates the true value of each observation presented as back-transformed means from the untransformed means. These means varied substantially between each collared female for time of day and during seasons.

The GLMM analysis for female SAT305Ca indicated during the tests for fixed effects (Appendix B) that there were significant differences ($p<0.05$) between time effects, season

effects and the time x season interaction effects. The Wald statistic indicated that time effects accounted for most of the variation, followed by the time x season interaction.

The same was seen for female SAT306Kem, except temperature also had a significant effect ($p<0.05$). However, the Wald statistic for season effects (10.91), time effects (0.03) and time x season interaction effects (4.87) was very low, but still significantly different ($p<0.05$). Temperature was added as a possible covariate to improve the estimated distances and adjust the estimates. For some of the females, temperature was significant and for others not, but for most it did not improve the model.

For female SAT307Pi there were significant differences between time x season interaction effects ($p<0.05$), with the Wald statistic indicating that time x season (80.67) effects accounted for most of the variation, while the effect of season (2.63) and time (22.68) was not high.

Female SAT308Da demonstrated significant differences between time effects and season effects ($p<0.05$). The Wald statistic indicated that time effects (42.22) accounted for most of the variation, followed by season (29.79). The Wald statistic for time x season (9.25) was very low.

Female SAT309Ni demonstrated that there were significant differences only between temperature effects ($p<0.05$) and season effects ($p<0.05$). The Wald statistic showed that temperature was the highest (281.81), while the influences of season (20.83), time (13.55) and time x season (15.68) were very low.

Distances travelled by female SAT310He showed that there were significant differences between time x season effects ($p<0.05$) and also season effects ($P<0.001$), but not for time ($p<0.733$). The Wald statistic indicated that time x season effects (77.61) accounted for most of the variation, followed by season (27.01). The Wald statistic for time (11.29) and altitude (7.35) was very low.

Distances travelled by female SAT311Wi showed that there were significant differences between time x season effects ($p<0.05$). The Wald statistic indicated that time x season effects (61.29) accounted for most of the variation. The Wald statistic for season (8.11) and time (3.58) was very low.

Distances travelled by female SAT312Ke showed that there were significant differences ($p<0.05$) between time x season effects, and altitude and season effects, but not for time ($p<0.597$). The Wald statistic indicated that time x season effects (65.43) accounted for most of the variation, followed by season (23.96) and then altitude (16.52). Altitude was added as a possible covariate to improve the estimated distances and adjust the estimates. For some of the females altitude was significant and for others not, but for most it did not improve the model.

5.3.4.6. Interactions influencing distance travelled

I. Effect of time of day on distance as fixed model (Appendix B)

GenStat® (Payne *et al*., 2012) was used to determine if there were variations in distances travelled during certain times of the day. Distance travelled during different times of the day differed significantly ($p<0.05$) in three of the eight giraffes, while the other five giraffes

showed no significant differences. Distance remained the response variate in the analysis and the fixed model used was time of day (hours), analysed with the biometrika method (Schall, 1991).

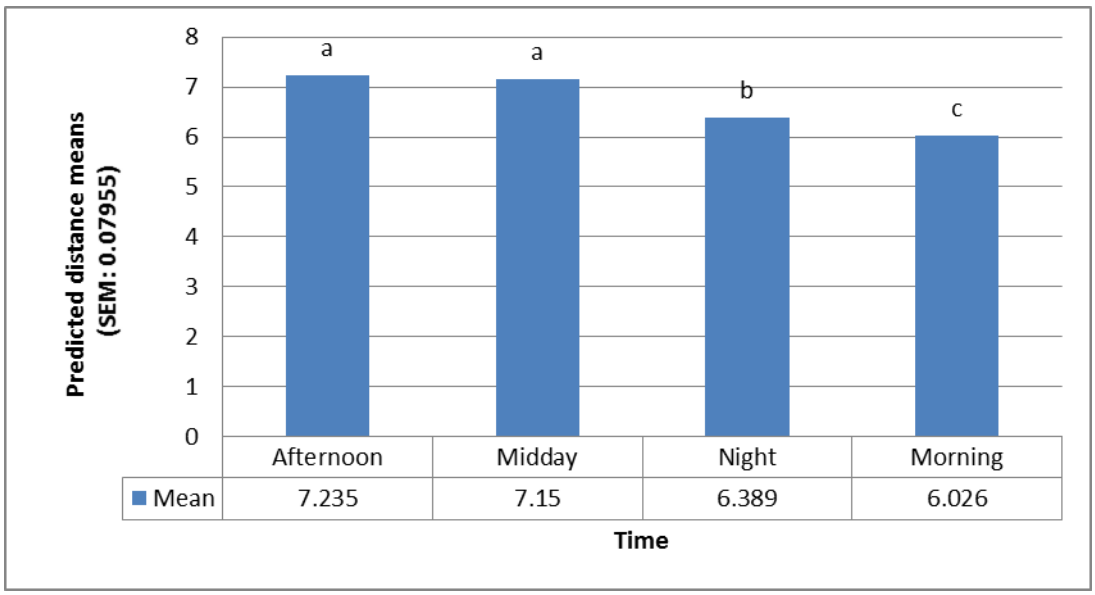


Figure 5.9 Effect of time of day on daily distance travelled for female SAT305Ca (transformed means)

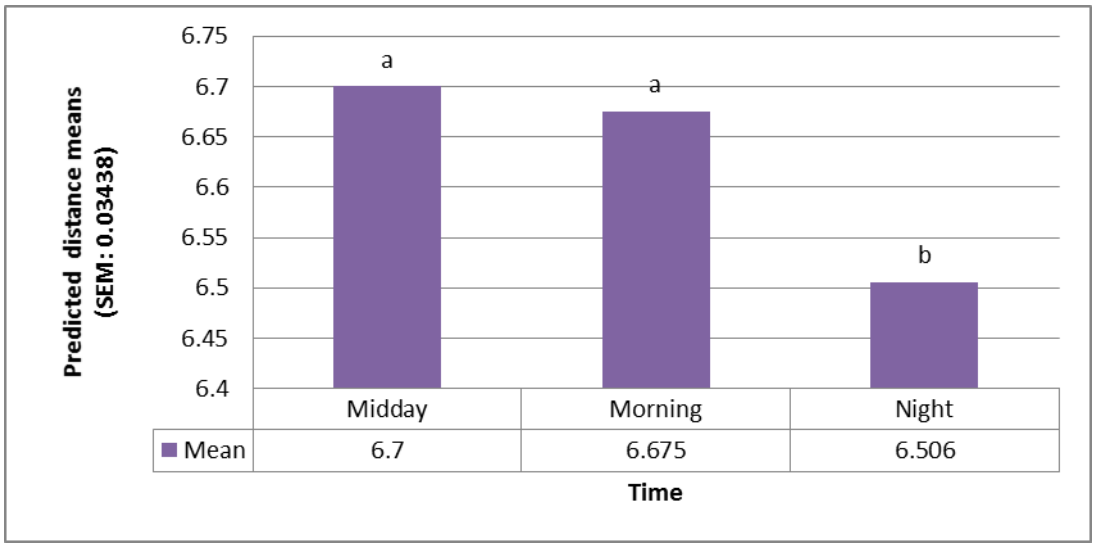


Figure 5.10 Effect of time of day on daily distance travelled for female SAT309Ni (transformed means)

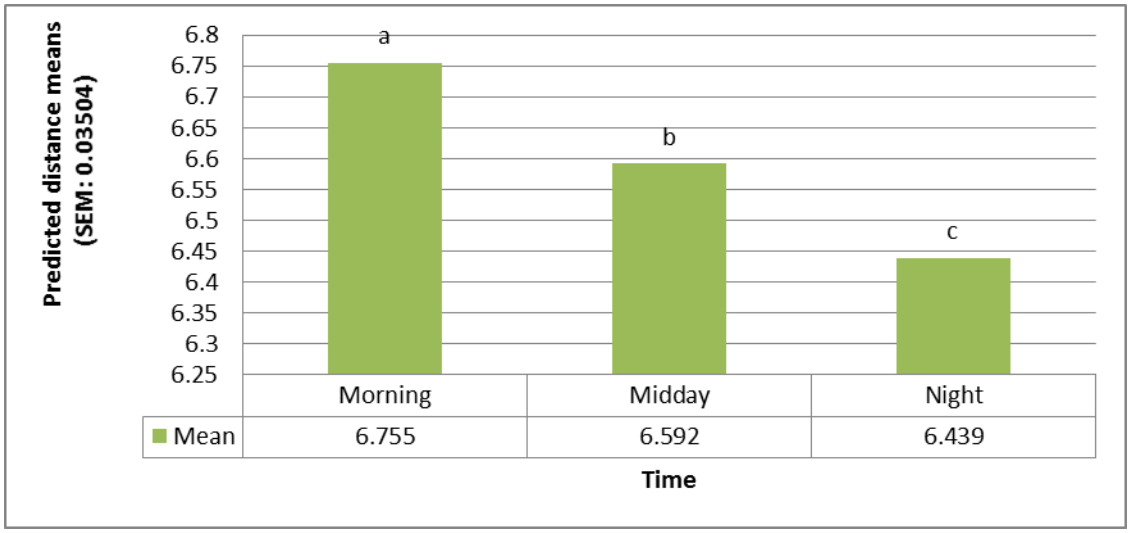


Figure 5.11 Effect of time of day on daily distance travelled for female SAT308Da (transformed means)

The GLMM showed significant differences in distance travelled for female SAT305Ca between afternoon (7.235), midday (7.15), night-time (6.389) and morning (6.026) (Figure 5.9) with SEM = 0.08 (untransformed scale). This would mean this female on average travelled the longest distances in the afternoon (1 387.4 m) compared to morning (414.2 m) and night-time (595.3 m) (transformed scale). This indicates that this female travelled three times longer distances in the afternoon and midday hours (1273.6 m) compared to the morning. The GLMM also showed that night-time (b) and morning (c) were significantly different, but afternoon (a) and midday (a) were not.

The GLMM showed significant differences in distance travelled for female SAT309Ni between midday (6.7), morning (6.675) and night-time (6.506) (Figure 5.10) with SEM = 0.03 (untransformed scale). This would mean this female on average travelled the longest distances in the midday (812.6 m) compared to morning (792.7 m) and night-time (669 m) hours (transformed scale). The GLMM also showed that there was a significant difference between each time of day, with night-time (b) being significantly different from midday (a) and morning (a).

The GLMM showed significant differences in distance travelled for female SAT308Da between midday (6.592), morning (6.755) and night-time (6.439) (Figure 5.11) with SEM = 0.04 (untransformed scale). This would mean this female on average travelled the longest distances in the morning (858.6 m) compared to midday (729 m) and night-time (625.6 m) hours (transformed scale). The GLMM also showed that there was a significant difference between each time of day, with night-time (c), midday (b) and morning (a) being significantly different from each other.

The GLMM analyses indicate that time of day had an influence on distances travelled for only four giraffes – namely the three discussed above plus SAT307Pi. Hence, for the other half of the sample of eight giraffes, the time of day the giraffes travelled had no significant effect on daily distances.

II. Effect of season on distance as fixed model (Appendix C)

GenStat® (Payne *et al*., 2012) was also used to determine if there were significant variations in distances travelled during each of the seasons. Analysis showed that for four of the eight giraffes distance travelled during the different seasons differed significantly ($P<0.05$). Distance remained the response variate in the analysis and the fixed model used was season, analysed with the biometrika method (Schall, 1991).

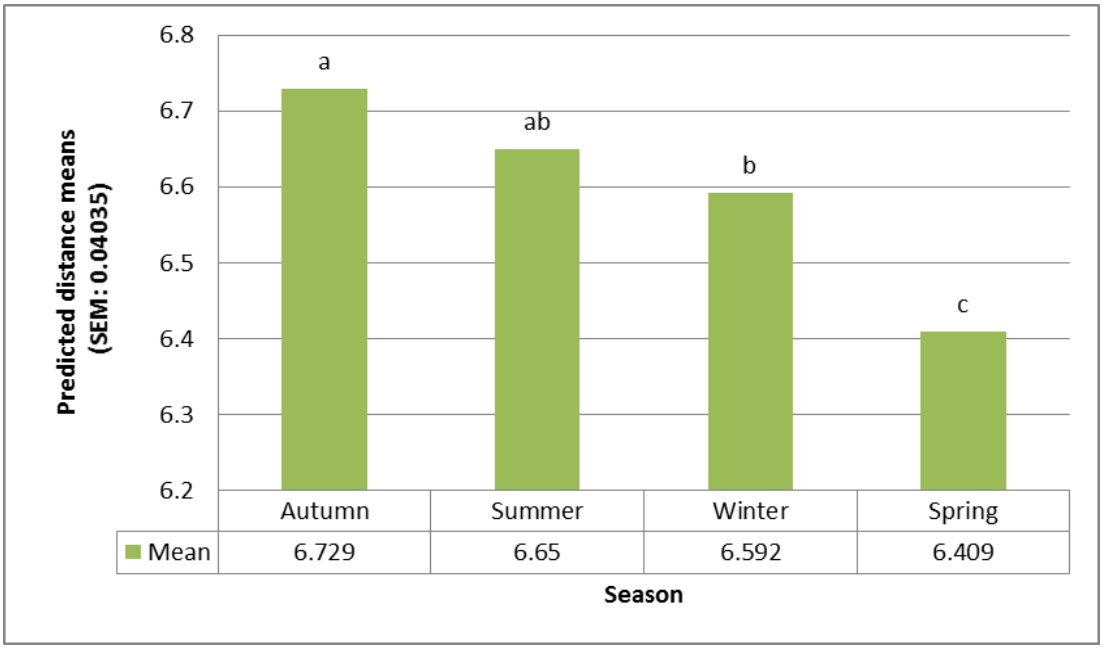


Figure 5.12 Effect of season on daily distance travelled for female SAT308Da (transformed means)

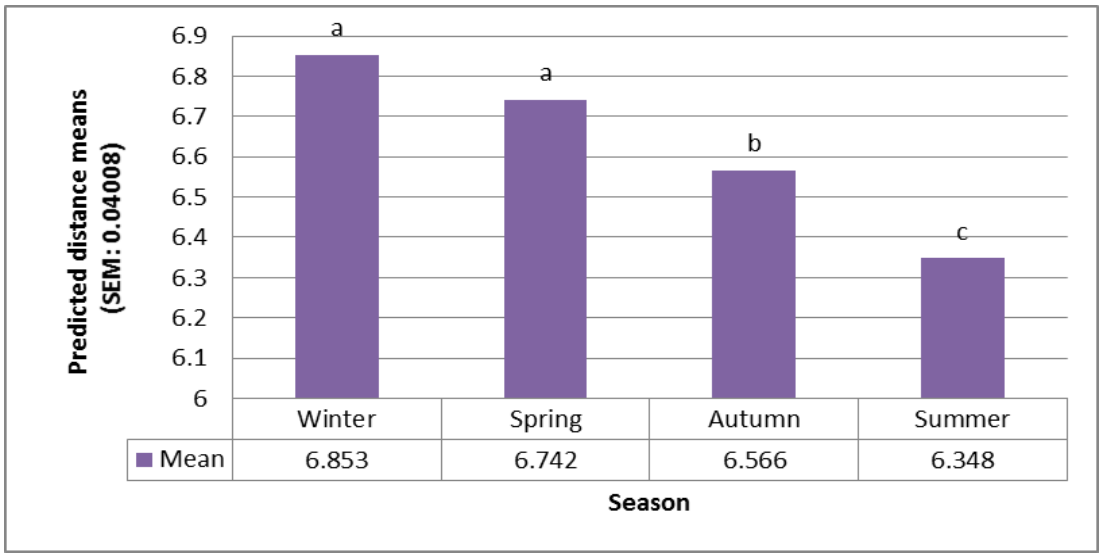


Figure 5.13 Effect of season on daily distance travelled for female SAT309Ni (transformed means)

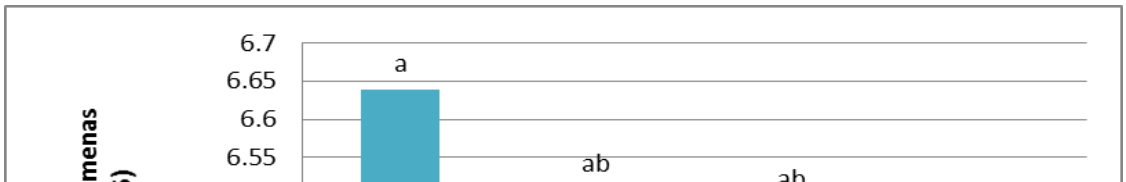


Figure 5.14 Effect of season on daily distance travelled for female SAT310He (transformed means)

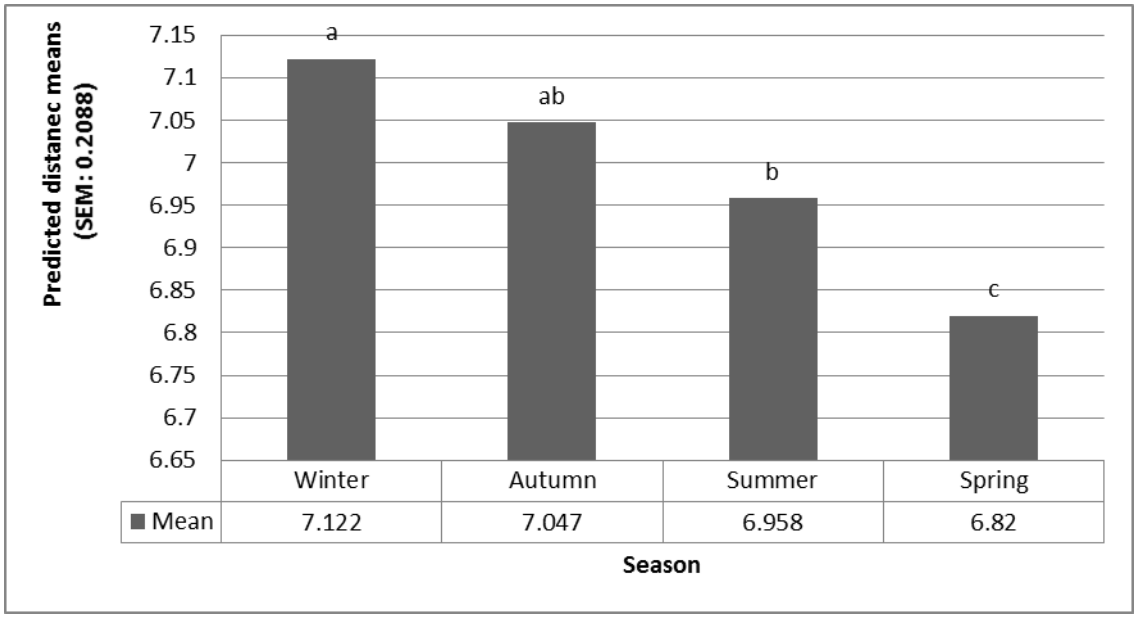


Figure 5.15 Effect of season on daily distance travelled for female SAT312Ke (transformed means)

The GLMM analysis showed significant differences in distance travelled due to season for female SAT308Da between means for autumn (6.729) and summer (6.65), with spring (6.409) the lowest (Figure 5.12) (untransformed scale). This would mean this female on average travelled the longest distances in the autumn (836.7 m) compared to spring (607.4 m) (transformed scale). These figures also indicate that the winter (b) and spring (c) seasons were significantly different from autumn (a), summer (ab).

The GLMM analysis showed significant differences in distance travelled due to season for female SAT309Ni with the mean for winter (6.853) the highest, followed by spring (6.742) and summer (6.348) had the lowest value (Figure 5.13) (untransformed scale). This would mean this female on average travelled the longest distances in winter (947 m) compared to the summer season (571.4 m) (transformed scale).These figures also indicate that the

autumn (b) and summer (c) seasons were significantly different (P<0.05) from winter (a) and spring (a).

The GLMM analysis showed significant differences in distance travelled due to season for female SAT310He with the mean for winter (6.638) the highest, followed by summer (6.506) and spring had the lowest value (6.346) (Figure 5.14) (untransformed scale). This would mean this female on average travelled the longest distances in winter (763.5 m) compared to spring (570 m) (transformed scale). These figures also indicate that the spring season (b) was significantly different (P<0.05) from winter (a), autumn (ab) and summer (ab).

The GLMM analysis showed significant differences in distance travelled due to season for female SAT312Ke with the mean for winter (7.122) the highest, followed by autumn (7.047) and spring had the lowest value (6.82) (Figure 5.14) (untransformed scale). This would mean this female on average travelled the longest distances in winter (1238 m) compared to spring (916m) (transformed scale). These figures also indicate that the spring season (c) was significantly different (P<0.05) from winter (a), autumn (ab) and summer (b).

In addition to the above four giraffes which showed highly significant differences for season effect at the level (p<0.001), another three showed significance at the level (p<0.05), namely females SAT305Ca, SAT306Kem and SAT311Wi. This demonstrates that there were significant variations in travel distance between the different seasons. Therefore, we can conclude that during the spring (five collared females) and summer (three collared females) (wet season) the giraffes travelled the shortest distances, whereas during the winter (five collared females) and autumn (two collared females) months (dry season) the giraffes travelled the longest distances.

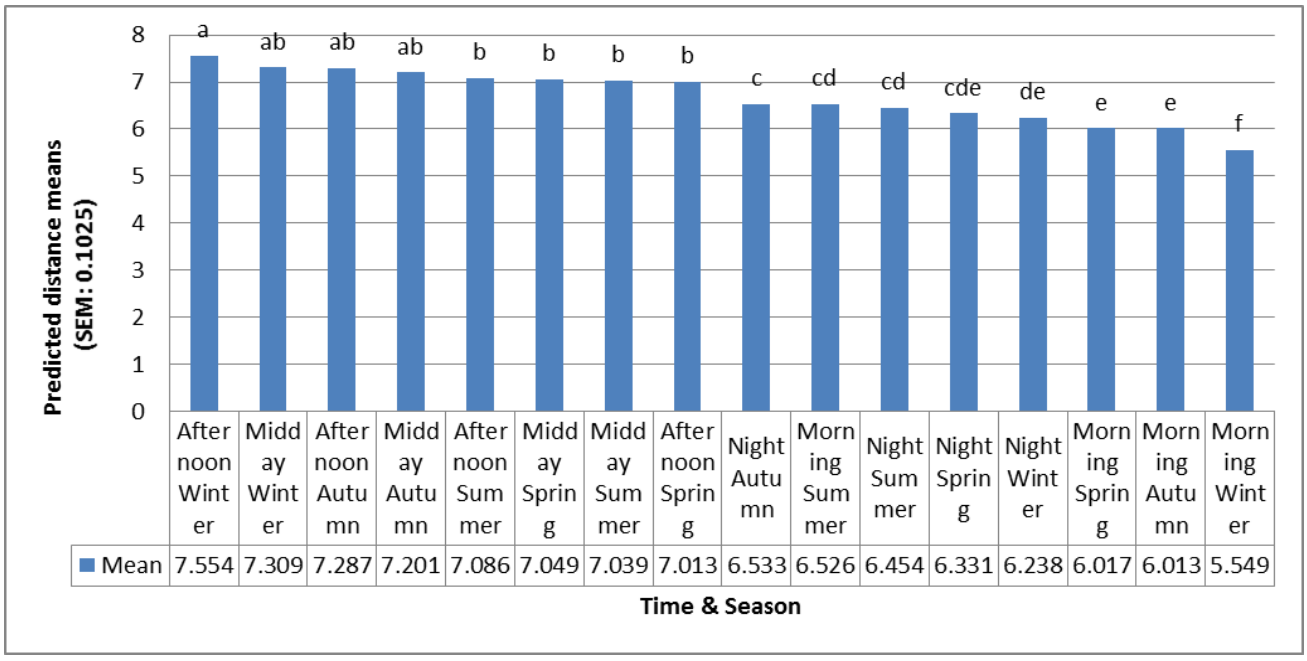


Figure 5.16 Effect of time x season interaction on daily distance travelled for female SAT305Ca (transformed means)

III. Effect of time x season interaction on distance as fixed model (Appendix C)

Distance remained the response variate and the fixed model used was the time x season interaction, analysed with the GLMM biometrika method (Schall, 1991).

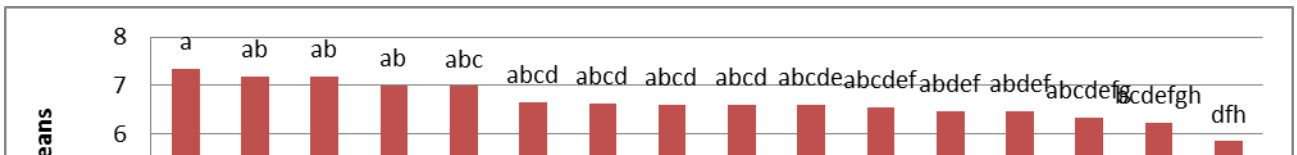


Figure 5.17 Effect of time x season interaction on daily distance travelled for female SAT307Pi (transformed means)

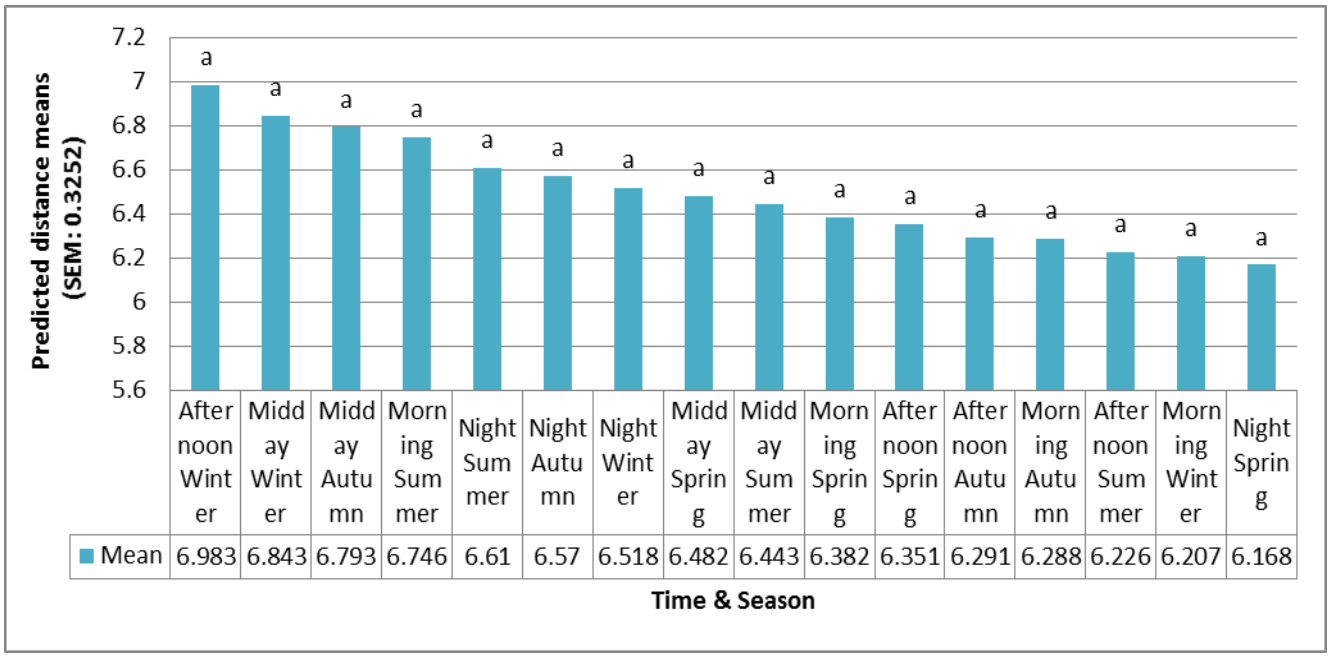


Figure 5.18 Effect of time x season interaction on daily distance travelled for female SAT310He (transformed means)

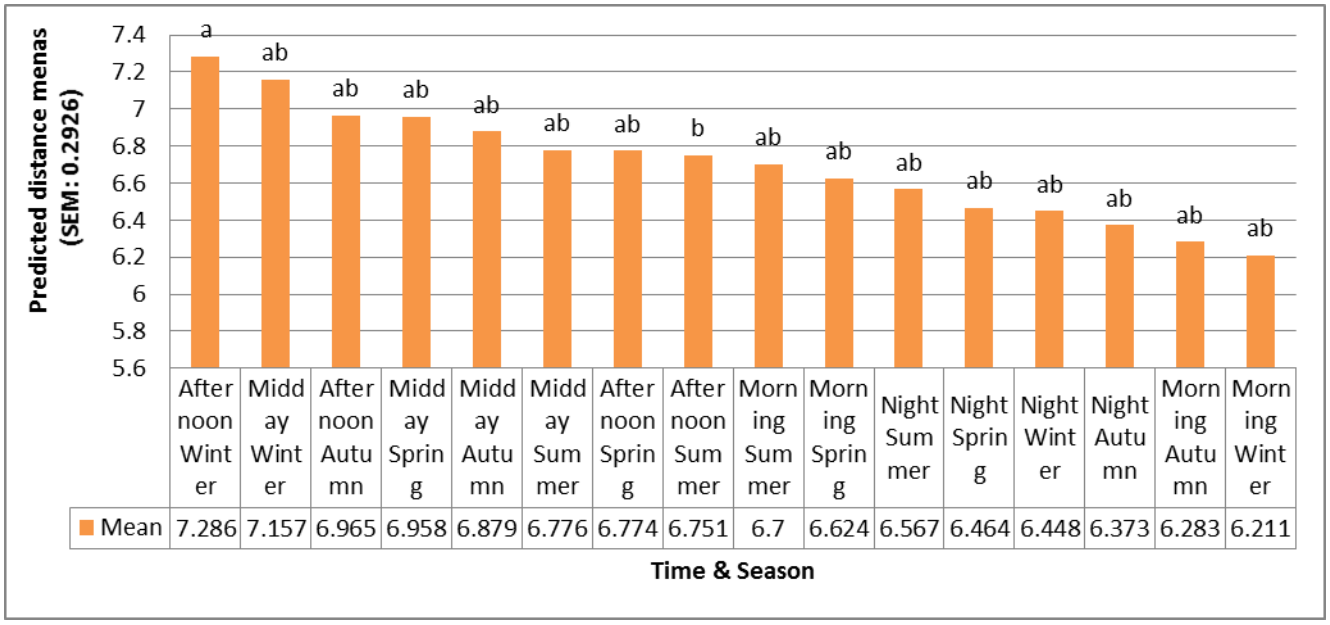


Figure 5.19 Effect of time x season interaction on daily distance travelled for female SAT311Wi (transformed means)

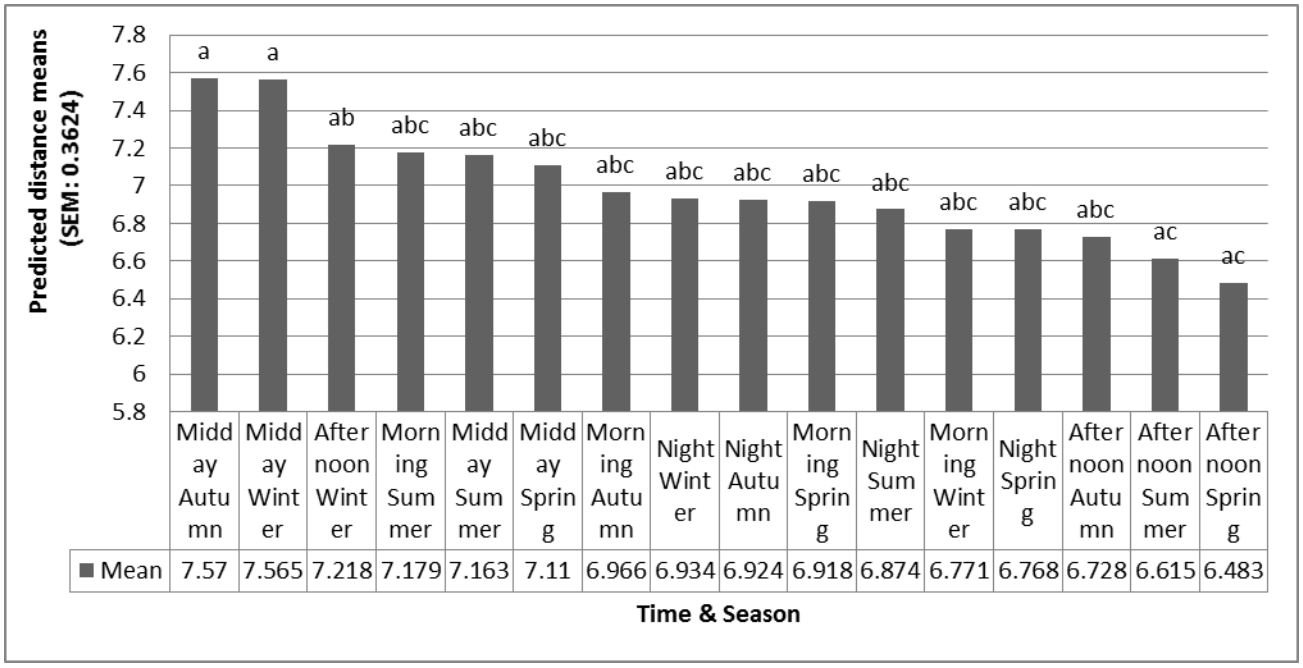


Figure 5.20 Effect of time x season interaction on daily distance travelled for female SAT312Ke (transformed means)

The GLMM analysis for female SAT305Ca showed significant differences in distance travelled due to the time x season effect, where the winter afternoon mean (7.554) was the highest, followed by winter midday (7.309) and winter morning was the lowest (5.549) (Figure 5.16) (untransformed scale). This would mean that the least travelling occurred

during the winter morning hours (256.9 m), but in summer most travelling occurred in the morning (682.8 m) (transformed means). The longest travelling occurred during the winter afternoon (1909.1 m) and midday (1494.4 m) (transformed means). This female travelled 1 237.5 m longer during the winter midday and 1 652.2 m longer during winter afternoons, than during winter morning hours (256.9 m). These figures also indicate that winter afternoon (a), autumn night-time (c), spring morning (e), autumn morning (e) and winter morning (f) were significantly different ($P<0.05$) from the other time x season interactions.

The GLMM analysis for female SAT307Pi showed significant differences in distance travelled due to the time x season effect, where the winter midday mean (7.34) value was the highest, followed by spring midday mean (7.193) and winter morning was the lowest (5.841) (Figure 5.17) (untransformed scale). This would mean that the least travelling occurred during the winter morning hours (344.2 m), and the longest during winter midday (1540.3 m) (transformed means). Therefore, this female travelled on average 1 196.1 m longer during winter midday, than during the winter morning hours. In summer, most travelling took place in the morning (734.1 m) and the least in the afternoon (695.7 m) (transformed means).

The GLMM analysis for female SAT310He showed significant differences in distance travelled due to the time x season effect, where the winter afternoon mean (6.983) value was the highest, followed by winter midday mean (6.843) and spring night-time was the lowest (6.168) (Figure 5.18) (untransformed scale). This would mean that the least travelling occurred during the winter morning (496.3 m), and the longest during the winter afternoon (1540.3 m) (transformed means). Therefore, this female travelled on average 582.1 m longer during the winter afternoon, than during the winter morning hours. In summer, most travelling took place in the morning (850.3 m) and the least in the afternoon (506 m) (transformed means).

The GLMM analysis for female SAT311Wi showed significant differences in distance travelled due to the time x season effect, where the winter afternoon mean (7.286) value was the highest, followed by winter midday mean (7.157) and winter morning was the lowest (6.211) (Figure 5.19) (untransformed scale). This would mean that the least travelling occurred during the winter morning hours (498.3 m) and the longest during the winter afternoon (1459.5 m) (transformed means). Therefore, this female travelled on average 961.2 m longer during the winter afternoon, than during the winter morning hours.

The GLMM analysis for female SAT312Ke showed significant differences in distance travelled due to the time x season effect, where the autumn midday mean (7.57) value was the highest, followed by winter midday mean (7.565) and spring afternoon was the lowest (6.483) (Figure 5.20) (untransformed scale). This would mean that the least travelling occurred during the winter morning hours (872 m), and the longest during the winter midday (1929 m) (transformed means). Therefore, this female travelled on average 1 057 m longer during the winter midday, than during the winter morning hours. In summer, most travelling took place in the morning (1 312 m) and least in the afternoon (746 m) (transformed means).

Analyses of collared giraffe movements at different times and seasons indicated that five of them showed highly significant differences ($P<0.001$) related to interactions between the different times x seasons in which most or least travelling occurred. For each of these differences the morning hours during winter were the times that giraffes travelled the least, whereas in summer the morning was the time when they travelled the longest distances. In

the afternoons the situation was reversed, since the longest distances were covered during the winter midday and afternoon and the least during the summer midday and afternoon hours. This suggests that temperature has an influence on giraffe travelling, such that they avoid moving long distances when it is hot and prefer to travel longer distances during the cooler hours of the day.

5.3.5. Location evaluation recorded by the GPS collars

5.3.5.1. Home ranges (HR) and seasonal variation

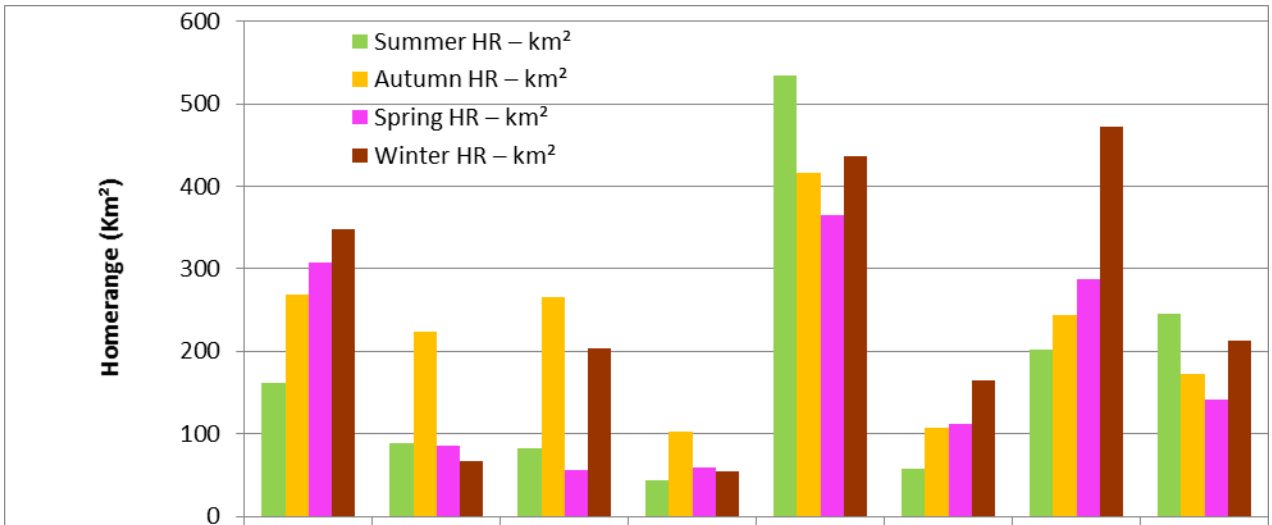
The home ranges of the collared giraffes differed greatly between seasons (Table 5.3). Each female was subject to different circumstances, such as age, social dynamics, physiological stage, etc. Therefore, it would not be possible to make direct conclusions and assumptions that are based on all giraffes. Each female was unique in the way she satisfied her habitat requirements to fit her daily, seasonal and annual needs. The home ranges calculated here are based on giraffes in the Kalahari region within a fenced reserve. Home ranges for seasons are determined with QGIS version 2 AniMove plugin (1991) and ArcView (ESRI, 1996), Minimum Convex Polygons (MCPs) which contained 95% of the giraffe position fixes recorded by the GPS collars and gave the estimated home range for each female giraffe independently.

Table 5.3 Summary of home range (km^2) vs season average for eight collared females (95% MCP method)

	Summer HR – km²	**Autumn HR – km²**	**Winter HR – km²**	**Spring HR – km²**	**Average HR – km²**
SAT305Ca	161.7	268.49	348.35	308.29	**271.71**
SAT308Da	88.37	223.02	67.56	85.43	**116.10**
SAT310He	82.32	266.29	203.64	56.15	**152.10**
SAT306Kem	42.93	103.1	55.18	59.42	**65.16**
SAT312Ke	534.1	416.21	435.78	364.76	**437.71**
SAT309Ni	58.04	107.99	165.19	112.31	**110.88**
SAT307Pi	202.3	244.5	471.52	286.77	**301.27**
SAT311Wi	246.15	172.59	212.61	141.42	**193.19**
Average	**176.99**	**225.27**	**244.98**	**176.82**	**206.02**

The average home range (206.02 km², calculated from the average of the eight females; highest 437.71 km², lowest 65.16 km²) was larger than reported elsewhere – 24.6 km² in the Timbavati Private Nature Reserve in South Africa (Langman, 1973), 68 km² in the South Luangwa Valley in Zambia (Berry, 1978) and 199.51 km² in the northern Namib Desert in Namibia (Fennessy, 2009). Kok & Opperman (1980) found that giraffes increased their home range during colder months. The same can be seen in this study where home range increased in the winter (average 244.98 km²) and autumn seasons (average 225.27 km²)

compared to the summer (average 176.99 km²) and spring seasons (average 176.82 km²) (Table 5.3).



	SAT305Ca	SAT308Da	SAT310He	SAT306Kem	SAT312Ke	SAT309Ni	SAT304Pi	SAT311Wi
Summer HR – km²	161.7	88.37	82.32	42.93	534.1	58.04	202.3	246.15
Autumn HR – km²	268.49	223.02	266.29	103.1	416.21	107.99	244.5	172.59
Spring HR – km²	308.29	85.43	56.15	59.42	364.76	112.31	286.77	141.42
Winter HR – km²	348.35	67.56	203.64	55.18	435.78	165.19	471.52	212.61

Figure 5.21 Summary of home range vs. season for eight collared giraffes determined by QGIS (1991) 95% MCP.

Home range size was the largest for the two females SAT312Ke and SAT307Pi, using the central and western sections of the park. During the entire study period they roamed over an area of 534 km² and 471 km² respectively (Table 5.3 and Figure 5.21). The average home range size of all the collared giraffes over four seasons ranged from 65.16 km² - 437.71 km² (Table 5.3).

It is difficult to identify a preferred vegetation type, as the study area did not vary greatly and was mostly homogeneous. However, vegetation communities as described in chapter two were brought into consideration. The summer home range of SAT312Ke (534.1 km²) was the largest, followed by the winter home ranges of SAT307Pi (471.5 km²) and SAT312Ke (435.8 km²). The three smallest home ranges were those of SAT306Kem (42.9 km²) in the summer, followed by SAT306Kem (55.2 km²) in the winter and SAT310He (56.1 km²) in the spring (Table 5.3). These figures will be helpful for nature conservators and can be applied to determine the minimum size for a game ranch, if intended to keep giraffes. Overall, the average home range calculated from all eight giraffes was the lowest for the spring months (176.8 km²), closely followed by the summer (177.0 km²) and was highest for the winter (245.0 km²), followed by the autumn months (225.3 km²) (Table 5.3). This would indicate to

managers and nature conservation officials that a giraffe in the Kalahari region would need an average of 206.0 Km² (20 602 ha) to roam contentedly in search of foliage (Table 5.3) necessary to support the animal through the leanest season (critical period, see chapter 6).

One advantage of having such large home ranges would be to avoid the build-up of tannins (as sometimes found in condensed/small fenced areas) in trees as a warning mechanism response to over-browsing (chemical defence). These preferred home range areas and avoided areas have been reported in the literature (Kok & Opperman, 1980; Estes, 1997; Frandsen, 1998; Skinner & Chimimba, 2005). Since giraffes are not territorial, these animals moved through a large part of the study area on an annual basis in search of nutritious browse plants located in different areas (Figure 5.22 to Figure 5.29).

KKNR falls within the summer rainfall region with the majority of rain occurring between October and April. The mean annual rainfall is estimated at 333 mm with a high annual coefficient of variation (CV) of 34%. This means that the area is semi-arid with a rainfall pattern that is erratic and unpredictable for any one year or series of years. The consequences of this are that the mean annual rainfall is an unreliable tool for the management of wildlife, especially with respect to calculating herbivore carrying capacities and stocking rates (see chapter 6). KKNR has 111 giraffes which equals 0.87 km²/giraffe, which is a much smaller area per giraffe than the 1.9 km²/giraffe with an average rainfall of 600 mm annually in Kenya (Birkett, 2002) and the 1.47 km²/giraffe with an average rainfall of 811 mm annually, determined by Pellew (1983b) from 6 different Nature Reserves in South Africa.

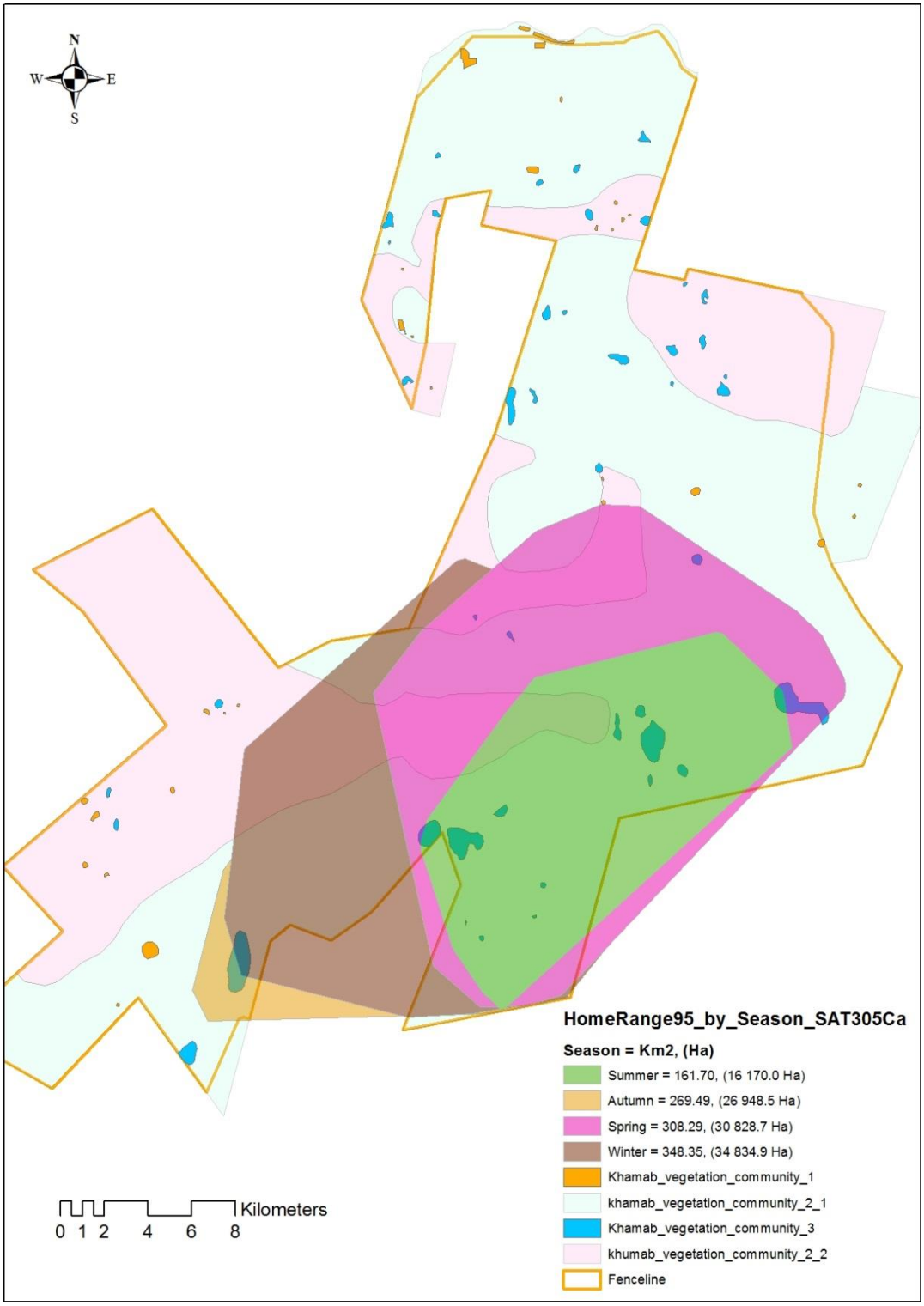


Figure 5.22 Home range variation over seasons for collared female SAT305Ca

Changes were observed in home range size (Figure 5.22) when comparing the wet, hot season (summer, home range size = 161.7 km²), with the dry, cool season (winter, home range size = 348.35 km²). In the summer female SAT305Ca frequented the area surrounding the bigger pans in the southeast area of the reserve. In the winter she concentrated in areas more to the central and south-western parts of the reserve (Figure

5.22). At the end of the dry, hot season (spring) her range moved more to the central eastern areas and with the beginning of the wet, cool season (autumn), she frequented the south-western areas (Figure 5.22). During the critical period (July/August – middle October) when trees are mostly leafless, she relied on a bigger home range to seek vegetation and foliage. This is indicated by the much greater habitat range that this female utilized during the winter (348 km²) and spring (308 km²) compared to the autumn (269 km²) and summer (161 km²) months (Figure 5.22).

A difference in home range size (Figure 5.23) was also observed for female SAT308Da when comparing the summer (home range size = 88.37 km²) with the winter (home range size = 67.56 km²). In the summer she spent more time in the northwest area of the reserve. In the winter she concentrated in areas more to the central and north-eastern parts of the northern part of the reserve (Figure 5.23). At the end of spring her range moved more to the south-western areas into a closed section of the reserve and at the beginning of autumn, she frequented the biggest area of the northern part of the reserve (Figure 5.23). During the critical period (July/August – middle October) when trees are mostly leafless, she relied on a bigger home range to seek vegetation and foliage. This is indicated by the much greater habitat range that this female utilized during autumn (223 km²) than during any of the other months (Figure 5.23). These findings correlate with the findings of chapter six based on the availability of foliage during the critical months (July/August – middle October).

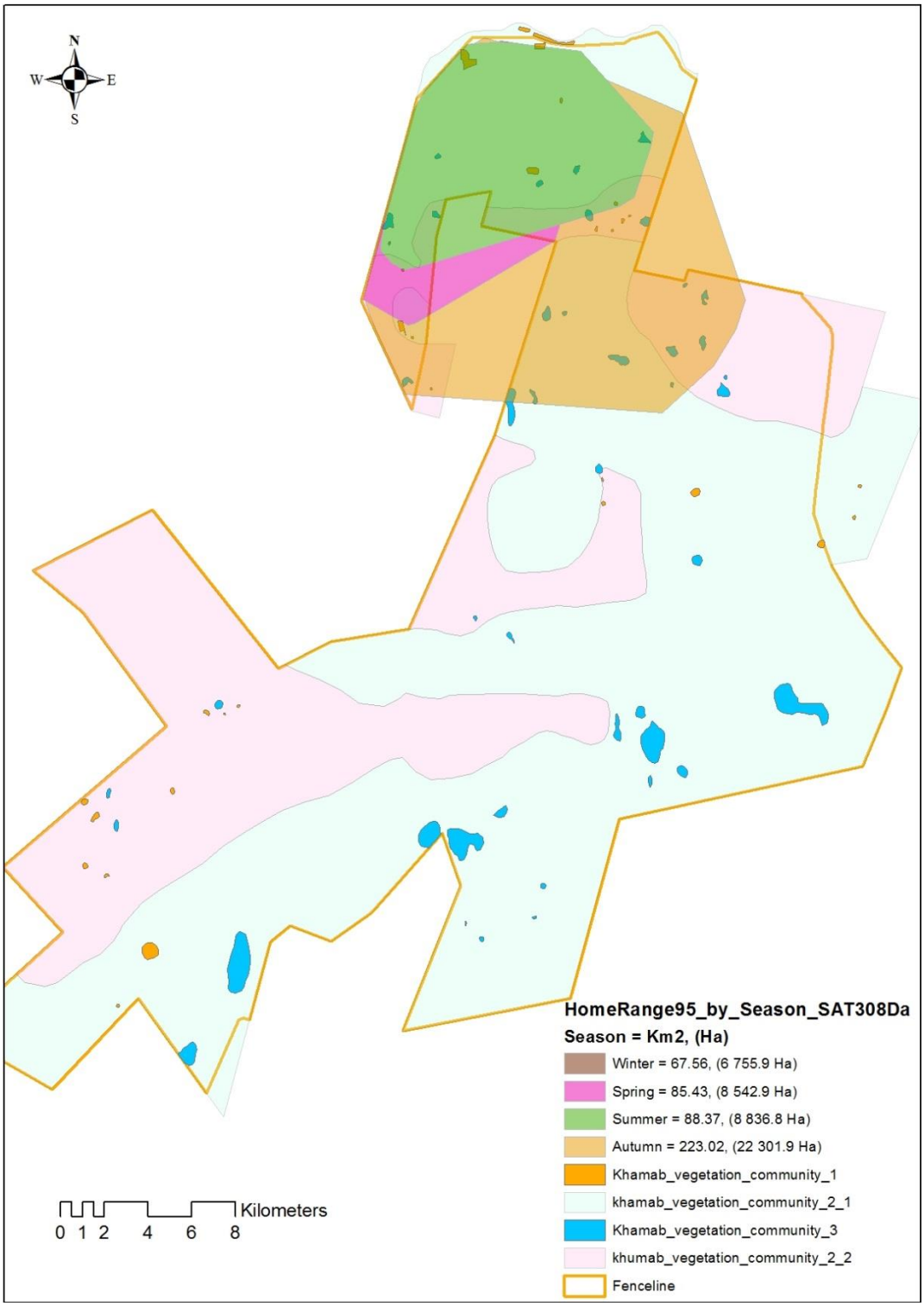


Figure 5.23 Home range variation over seasons of collared female SAT308Da

A difference in home range size was also observed for female SAT310He when comparing the summer (home range size = 82.32 km²), with the winter (home range size = 266.64 km²) (Figure 5.24). In the summer she frequented the area on the eastern side of the reserve and mostly within the vegetation community 2.2 (Figure 5.24). In the winter she concentrated in a much bigger area surrounding the summer area (Figure 5.24). At the end of spring her range

moved a little to the central eastern areas and at the beginning of autumn she frequented the biggest home range surrounding the summer range area (Figure 5.24). During the critical period (July/August – middle October) when trees are mostly leafless, she relied on a bigger home range to seek vegetation and foliage. This is indicated by the much larger habitat range that she utilized during the autumn (266 km²) and winter (203 km²) months compared to the summer (82 km²) and spring (56 km²) (Figure 5.24).

A difference in home range size was also observed for female SAT306Kem when comparing the summer (home range size = 42.93 km²), with the winter (home range size = 55.18 km²) (Figure 5.25). In the summer she spent time in the area northwest of the reserve. In the winter when she occupied the smallest observed home range, she concentrated in areas more to the eastern parts in the northern part of the reserve (Figure 5.25). At the end of spring, her range moved to a slightly bigger area of the reserve and at the beginning of autumn, she frequented the biggest area of the northern part of the reserve (Figure 5.25). During the critical period (July/August – middle October) when trees are mostly leafless, she relied on a larger home range to seek vegetation and foliage. This is indicated by the much larger habitat range that she utilized during autumn (103 km²) compared to any of the other months (Figure 5.25).

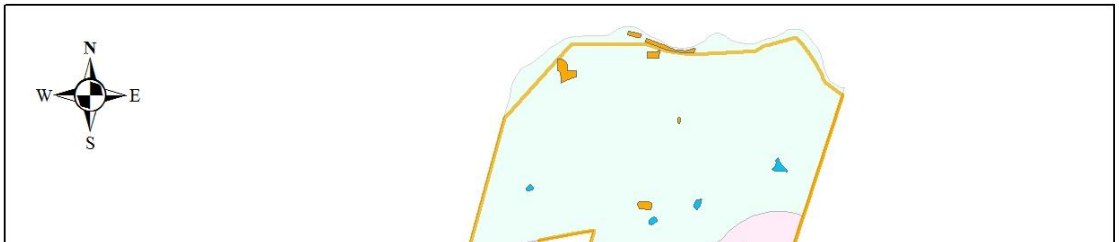


Figure 5.24 Home range variation over seasons for collared female SAT310He

A difference in home range size was also observed for female SAT312Ke when comparing the summer (home range size = 534.10 km²) with the winter (home range size = 435.78 km²) (Figure 5.26). In summer she frequented the area on the central and eastern side of the reserve and mostly within the vegetation community 2.1 (Figure 5.26). In winter she concentrated in an area a little smaller than the summer area, but slightly more to the

western and southern side of the reserve (Figure 5.26). At the end of spring her range moved a little to the south-western areas and at the beginning of autumn she frequented areas much more to the western side of the southern part of the reserve (Figure 5.26). During the critical period (July/August – middle October) when trees are mostly leafless, she relied on a broadened home range to the western side to seek vegetation and foliage that was not utilized during the other months (Figure 5.26). It is unknown why this female's range is so big during the summer months, except that she could have been exploring new ranging areas, as she had been to central and eastern areas within the reserve where no other collared female had ever ventured. Another explanation could be that she explored areas where open water became available during the summer rainy season, and by chance found new utilizable areas.

A difference in home range size was also observed for female SAT309Ni when comparing the summer (home range size = 58.04 km²) with the winter (home range size = 165.19 km²) (Figure 5.27). In the summer she frequented the area on the eastern side of the reserve and almost all her ranging areas were within the vegetation community 2.1 (Figure 5.27). In the winter she concentrated her activities in a much larger area more central and to the west of the summer area (Figure 5.27). At the end of spring her range moved more to the central and southern areas and at the beginning of autumn she frequented a home range a little smaller than the spring area surrounding the summer range area(Figure 5.27). During the critical period (July/August – middle October) when trees are mostly leafless, this female relied on a bigger home range to seek vegetation and foliage. This is shown by the much larger habitat range that she utilized during the winter (165 km²) than during the summer (58 km²) and spring (112 km²) seasons (Figure 5.27). This female remained solitary for most of the time with an occasional excursion outside her habitual area.

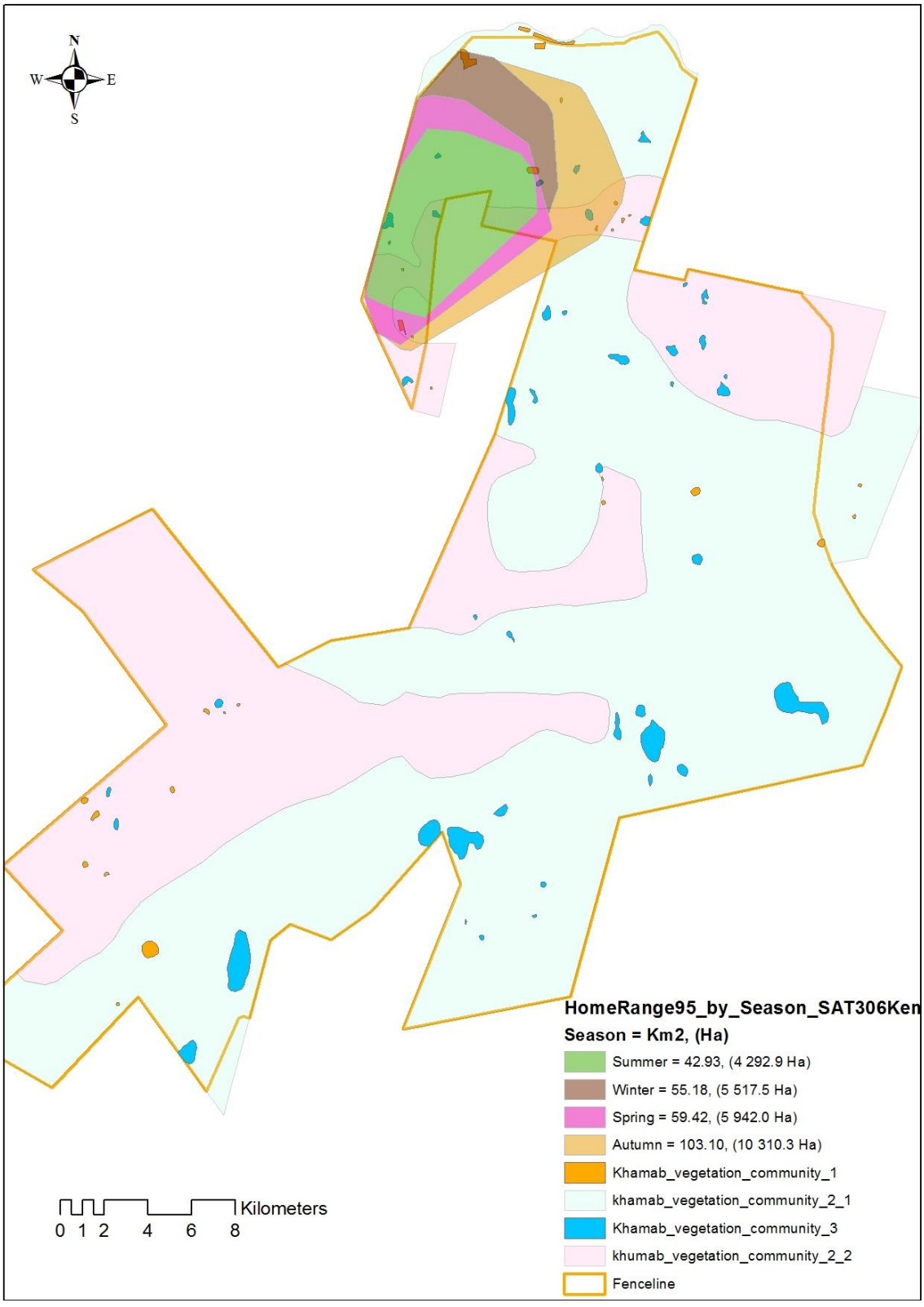


Figure 5.25 Home range variation over seasons of collared female SAT306Kem

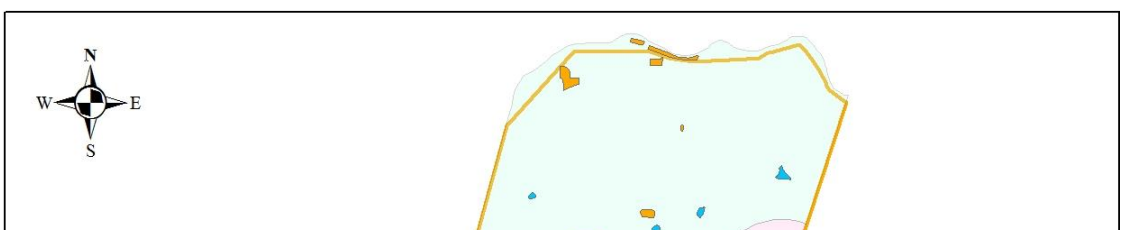


Figure 5.26 Home range variation over seasons of collared female SAT312Ke

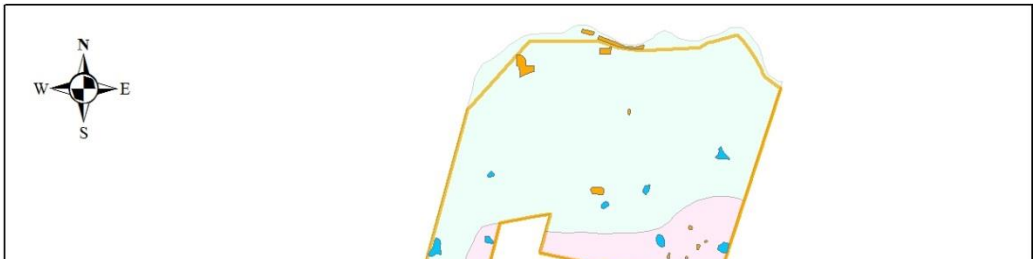


Figure 5.27 Home range variation over seasons of collared female SAT309Ni

A difference in home range size was also observed for female SAT307Pi when comparing the summer (home range size = 202.3 km²) with the winter (home range size = 471.5 km²) (Figure 5.28). In the summer she frequented the area on the eastern side of the reserve (Figure 5.28). In the winter she roamed in a much bigger area in the central and southern areas surrounding the summer range (Figure 5.28). At the end of spring her range moved a little to the north-eastern side of the summer areas and at the beginning of autumn she frequented areas to the south-western side of the southern part of the reserve (Figure 5.28). During the critical period (July/August – middle October) when trees are mostly leafless, she

relied on an extended home range to the western side to seek vegetation and foliage that was not utilized during the other months (Figure 5.28). This is shown by the much larger habitat range that this female utilized during the winter (471 km²) than during the other months (Figure 5.28).

A difference in home range size was also observed for female SAT311Wi when comparing the summer (home range size = 246.1 km²) with the winter (home range size = 212.6 km²) (Figure 5.29). In the summer she frequented the area on the southern and eastern side of the reserve (Figure 5.29). In the winter she concentrated in an area in the central and southern area smaller than the summer area (Figure 5.29). At the end of the spring her range moved slightly to the northern and central side of the summer areas, and at the beginning of autumn she frequented areas to the south-western side of the southern part of the reserve (Figure 5.29). During the critical period (July/August – middle October) when trees are mostly leafless, this female also relied on a little extended home range to the western side to seek vegetation and foliage that was not utilized during the other months (Figure 5.29).

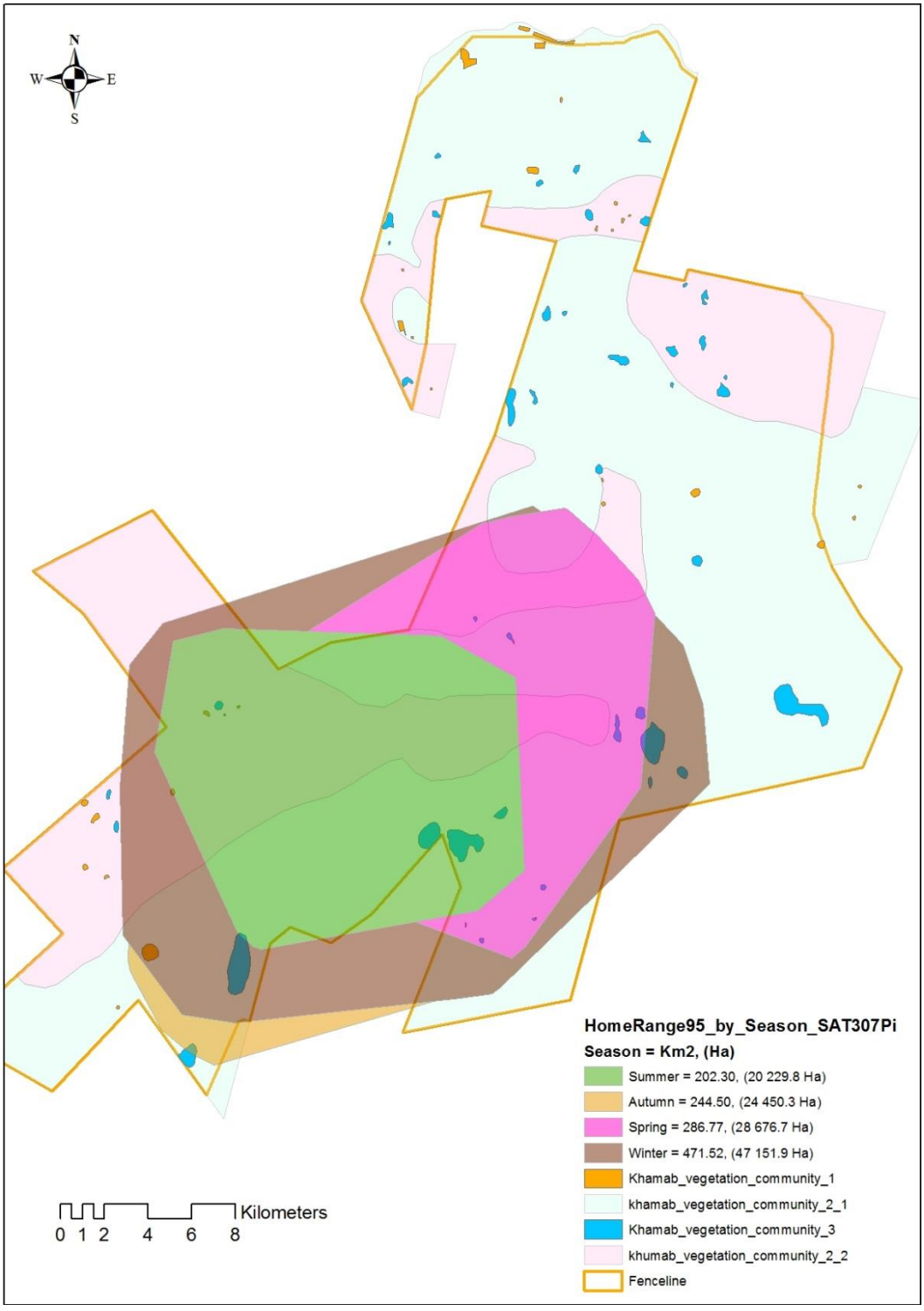


Figure 5.28 Home range variation over seasons of collared female SAT307Pi

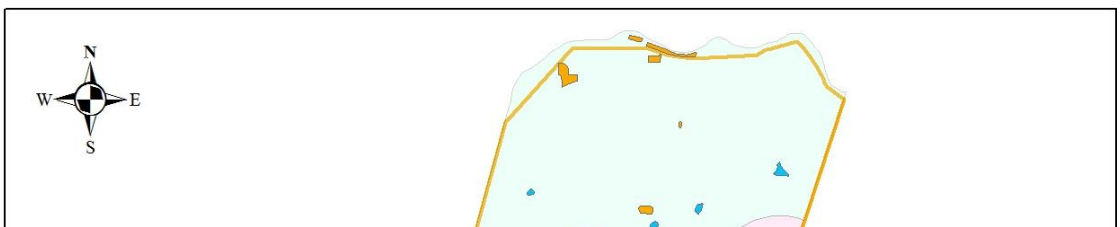


Figure 5.29 Home range variation over seasons of collared female SAT311Wi

From the above analyses, it can be seen that differences were observed within each female's seasonal home range. It was evident that all the females had extended home ranges during the dry periods and critical periods (July/August – middle October). Other studies have found that males usually prefer denser wooded habitats, while females prefer the more open habitats (Du Toit, 1990a; Ginnet & Demment, 1999; Caister *et al.,* 2003). This

was not observed in this study area probably because there were no major differences in the density of the vegetation in their chosen habitat.

In larger areas with a greater choice of vegetation units, such as the Willem Pretorius Game Reserve in the central Free State, Kok & Opperman (1980) reported a definite association between availability of food in different vegetation units and the seasonal movement patterns of giraffes. They reported that giraffes were found on the plains in the wet season for a period of eight months, where winter deciduous species, like *Acacia karroo* having full leaf carriage in the summer, were abundant and moved to the kopjes and rocky hills for four months in the dry season. They made use of other food reserves in the dry season that are usually neglected, such as evergreen species growing mostly on kopjes (Kok & Opperman, 1980). A considerable increase in herd size in the wet season was reported by Kok & Opperman (1980) as well as by Le Pendu *et al.* (2000), probably because more individuals can be sustained by the abundance of leaves present on deciduous plants in the wet summer season. The homogeneity of the KKNR and minimal differences between vegetation communities makes it difficult to reach significant conclusions other than that giraffes roam in larger areas in the dry, cool season in search of sufficient food resources.

These small, seasonal shifts in home range occurring in the study area explain the changes in habitat use by the giraffe. In the wet, hot season (summer) when food was abundant, giraffes frequented the area (average 177 km²) that sustained their daily needs (metabolic rate/food intake), while in the dry, cool season (winter) they roamed more widely to extend their home range (average 245 km²) to fulfil their daily needs (Table 5.3).

Availability of space, resource quality and social structure are possible factors affecting distribution that can play a role in determination of home ranges. Information on home ranges is gained from one individual representing a herd within an area. When leaving it vacant for some time (possibly to avoid tannins), other herds could have moved into that area. This is the reason why home range overlap is considered.

This is the first time that seasonal movements and spatial patterns of giraffes in the arid Kalahari region have been studied. The GPS collars demonstrated their capacity to accurately record movement patterns and locations, and so determine home ranges. Previous studies to determine home range sizes (ranging from 23 – 282 km^2) and spatial patterns (Innes, 1958; Van den Berg, 1999; Le Pendu *et al.,* 2000) have been achieved without GPS collars. Van der Jeugd & Prins (2000) found that mean home ranges for giraffes ranged from 5.2 km² (males) to 8.6 km² (females) in Lake Manyara National Park, Tanzania, but with large variations of 0.1 – 21.5 km² for males and 0.5 – 27.0 km² for females. Berry (1978) found that the average male home range was 82 km² compared with female home range of 68 km² in the Luangwa valley, Zambia, and the largest home range for a male was 145 km².

Fennessy (2009) used a different design GPS collar for a few months (180 days in total) and estimated home range of one of the bulls in the Namib desert in northern Namibia to be 1 950 km² and 1 098 km² for one female. In the same study the female mean annual home ranges varied from 199.5 km², 199.5 km² and 219.7 km² by using the 100% MCP method, but 23.6 km², 100 km² and 119.1 km² by using the 95% MCP method. Ciofolo & Le Pendu (2002) found equally large home ranges for a giraffe bull (1 559 km²) and female (1 379 km²)

tracked in Niger in West Africa. However, these giraffes were not restricted by fences and competition from other browsers such as kudu and eland.

Seasonal home range movements and spatial patterns have not previously been identified for female giraffes in the arid Kalahari region, and there is strong evidence for a relationship between individuals in overlapping home ranges because of habitat, but also possibly because of water, as giraffes are water dependent (Smithers, 1971; Hall-Martin & De Graaff, 1978). However, according to the literature, there are few observations of giraffes drinking water in the northern Namib Desert (less than ten sightings in 70 years), which indicates that surface water is not a factor influencing either seasonal or annual giraffe movements (Hall-Martin & Basson, 1975; Scheepers, 1992; Fennessy, 2009). This would point biologists back to the qualities provided by each habitat and suitability of the vegetation for giraffe needs.

5.3.5.2. Home range overlap

Table 5.4 Summary of all home range overlaps between collared female giraffes within each season

		Percentage (%) overlap between female A & B				
Female A	**Female B**	**Autumn**	**Winter**	**Spring**	**Summer**	**All readings**
SAT305Ca	SAT310He	13.5	17.3	2.7		27.0
SAT305Ca	SAT312Ke	31.4	41.0	38.3	19.4	55.1
SAT305Ca	SAT309Ni	4.9	20.6	21.6	3.2	29.6
SAT305Ca	SAT307Pi	30.1	60.2	33.8	5.5	61.5
SAT305Ca	SAT311Wi	36.2	48.1	31.6	33.1	65.1
SAT308Da	SAT306Kem	31.5	15.3	17.4	10.0	29.6
SAT310He	SAT312Ke	27.3	18.8	5.0	8.3	29.4
SAT310He	SAT307Pi	21.6	36.3	10.3	15.6	46.2
SAT310He	SAT311Wi	13.5	4.3	0.9	2.4	18.3
SAT312Ke	SAT309Ni	8.7	28.4	16.5	11.1	28.4
SAT312Ke	SAT307Pi	29.7	47.8	35.9	17.3	49.2
SAT312Ke	SAT311Wi	24.1	31.7	24.0	39.3	43.9
SAT307Pi	SAT311Wi	22.6	45.7	23.4	12.9	53.8
SAT309Ni	SAT307Pi		20.8	4.2		11.5
SAT309Ni	SAT311Wi		21.0	13.1	11.6	26.3
Average Percentage Overlap		**22.7**	**30.5**	**18.6**	**14.6**	**38.3**

Table 5.4 illustrates that every collared female has a percentage home range (HR) overlap with other females. The two northern females have HR overlap and the six other females in the central and southern sections have HR overlaps. The highest percentage HR overlap between two females is between SAT305Ca and SAT311Wi (65.1%), and the second highest is between SAT305Ca and SAT307Pi (61.5%). It can be seen from Table 5.4 that HR overlap differed from season to season. This table further illustrates that giraffes were

obliged to roam in larger areas during the dryer and critical months when trees were without foliage (winter = 30.5% and autumn = 22.7%) compared to the wet and warmer months (summer = 14.6% and spring = 18.6%). This HR overlap indicates that when the vegetation provided sufficient foliage for the giraffes, there was no need for them to search for browse in the range of other giraffes. The HR overlap further indicates that giraffes were competing for the same resources during the critical periods. This competition for the same resources suggests that browse quantification should be carried out during the critical periods to evaluate habitat suitability and to identify the necessary qualities of a suitable habitat.

In Appendix C Figure C.1 illustrates the summer home range overlap of six females in the central, eastern and southern section of the reserve. The two females in the north remained in the northwest section during the summer months. Figure C.2 illustrates a shift in autumn, when the six southern giraffes moved from the south-eastern section to the south-western section. The two northern females' home ranges also shifted more to the north-eastern side (Figure C.2), with a much larger home range than in the summer months (Appendix D Figure D.1). The winter months showed a greater home range overlap to the central and southern areas of the reserve (Appendix C Figure C.3). During the spring, the giraffe home ranges moved more towards the central and eastern side of the reserve (Appendix C Figure C.4).

In Appendix C the four seasonal illustrations (Figure C.1 - Figure C.4) indicate a definite shift in home range during the annual seasons. This is considered significant, as the vegetation in the study area was very homogeneous. These figures also indicate that the giraffes seek different browse during certain times of the year.

Table 5.5 Table illustrating the number of days certain females spent with other females

	Time spent together: Females A & B	**Days (n)**	**Genetically related**
Northern section	SAT308Da & SAT206Kem	**157**	No
Southern section	SAT312Ke & SAT309Ni	**101**	Yes
	SAT307Pi & SAT311Wi	**88**	No
	SAT312Ke & SAT311Wi	**78**	No
	SAT312Ke & SAT307Pi	**58**	Yes
	SAT310He & SAT307Pi	**45**	No
	SAT305Ca & SAT311Wi	**35**	No
	SAT310He & SAT312Ke	**25**	No
	SAT305Ca & SAT307Pi	**15**	No
	SAT305Ca & SAT309Ni	**10**	No
	SAT305Ca & SAT312Ke	**9**	No
	SAT309Ni & SAT311Wi	**9**	No
	SAT309Ni & SAT307Pi	**4**	Yes
	SAT311Wi & SAT310He	**0**	Yes
	SAT310He & SAT305Ca	**0**	Yes
	SAT310He & SAT309Ni	**0**	No

Analysing the information on the number of days that females spent together it was found that two unrelated females (SAT308Da & SAT206Kem) spent the most amount of time together (157 out of 620 days of observations = 25%) (Table 5.5). The second highest number of days spent together were between two genetically related females SAT312Ke &

SAT309Ni (101 out of 572 days of observations = 17.7%) (Table 5.5). The majority of females spent few days together, and it would seem from the data recorded that most meetings were random, and that they might stay together for a day or two before moving on. This information may be very valuable when *fission fusion* statistics are considered, relating to the exact days and frequencies of meetings. However, it was not considered to be a focus for this chapter.

5.3.5.3. Spatial distribution versus time of day

Appendix D (Figure D.1), using female SAT312Ke as representative, illustrates little variance in spatial distribution over a 24 hour period ranging from morning hours (468.1 km²), night-time (499.5 km²) and afternoon hours (506.9 km²), with the biggest variance during midday (511.6 km²). The Figure shows the occasional roaming at night-time, although to a small extent. Only one example was used for this illustration, as most females did not show a significant (<10 km²) change in movement from day to night-time.

5.3.5.4. Time spent in each vegetation unit

The locations recorded by the GPS collars within each vegetation type were analysed with the Crosstab tool (ESRI, 1996). Giraffes clearly preferred some vegetation types above others as shown in Table 5.6. The number of GPS coordinates within each vegetation type differed between females distributed over the study area. Only SAT310He in the western section spent more time in vegetation type 2.2 (n = 2 194) than in vegetation type 2.1 (n = 1 445). All the other giraffes preferred vegetation type 2.1 above vegetation type 2.2 (Table 5.6).

Table 5.7 gives the same information, but in the form of percentages. Female SAT310He spent 60.2% of her time in vegetation type 2.2, and only 39.6% in type 2.1. The opposite applies to all the other females, who preferred type 2.1 and spent from 60 – 97% of their time there (Table 5.7). In addition, Table 5.8 shows that the eight females spent proportionately 7.3% more time in vegetation type 2.1 than the percentage area available (65.7%) of the total area, and proportionately 7.6% less time in type 2.2 (Table 5.8). This clearly shows that the giraffes preferred vegetation community 2.1 above community 2.2. The qualities of the vegetation as described in chapter three are the main reason why the giraffes prefer this area.

Table 5.6 Giraffe GPS location counts by vegetation type

Vegetation type	SAT305Ca	SAT308Da	SAT310He	SAT306Kem	SAT312Ke	SAT309Ni	SAT307Pi	SAT311Wi	Total
Acacia erioloba - Acacia mellifera Woodland (Vegetation community 2.2)	337	662	2194	1365	1111	53	1081	548	7351
Geigeria ornitiva - Enneapogon desvauxii Forbland (Vegetation community 3)	87	51	3	54	34	41	42	45	357
Grewia retinervis - Acacia erioloba Woodland (Vegetation community 2.1)	3353	2978	1445	2262	2665	3358	2334	2987	21382
Verbesina encelioides - Schmidtia kalahariensis Grassland (Vegetation community 1)	0	123	4	56	11	4	1	0	199
Total	3777	3814	3646	3737	3821	3456	3458	3580	29289

Table 5.7 Giraffe GPS location percentage (%) by vegetation type

Vegetation type	SAT305Ca	SAT308Da	SAT310He	SAT306Kem	SAT312Ke	SAT309Ni	SAT307Pi	SAT311Wi	Total
Acacia erioloba - Acacia mellifera Woodland (Vegetation community 2.2)	8.92%	17.36%	60.18%	36.53%	29.08%	1.53%	31.26%	15.31%	25.10%
Geigeria ornitiva - Enneapogon desvauxii Forbland (Vegetation community 3)	2.30%	1.34%	0.08%	1.45%	0.89%	1.19%	1.21%	1.26%	1.22%
Grewia retinervis - Acacia erioloba Woodland (Vegetation community 2.1)	88.77%	78.08%	39.63%	60.53%	69.75%	97.16%	67.50%	83.44%	73.00%
Verbesina encelioides - Schmidtia kalahariensis Grassland (Vegetation community 1)	0.00%	3.22%	0.11%	1.50%	0.29%	0.12%	0.03%	0.00%	0.68%
Total	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%	100.00%

Table 5.8 Habitat availability (%) versus time spent in each habitat

Vegetation type	Area (n = 95 653ha)	Percentage of total area (%)	Total visits (n =29 289)	Percentage of total visits for that area (%)	Percentage difference (%)
Acacia erioloba - Acacia mellifera Woodland (Vegetation community 2.2)	31291	32.7	7351	25.1	Deducted:7.6
Geigeria ornitiva - Enneapogon desvauxii Forbland (Vegetation community 3)	1278	1.3	357	1.2	Deducted: 0.1
Grewia retinervis - Acacia erioloba Woodland (Vegetation community 2.1)	62861	65.7	21382	73.0	Added: 7.3
Verbesina encelioides - Schmidtia kalahariensis Grassland (Vegetation community 1)	223	0.2	199	0.7	Added: 0.4

5.4. Conclusion

The average daily movement (5.1 km calculated from the average of the eight collared females; highest 6.6 km, lowest 4.2 km) was higher than for cows elsewhere found in Namibia 1.87 km (Fennessy, 2009) and maximum daily distances (2.3 km) for cows in Zambia (Berry, 1978). Most females travelled for longer hours and distances during the winter months compared to other seasons. This study found an increase of average distances moved over the seasons as follows: autumn (5.05 km/day), summer (5.1 km/day), spring (5.2 km/day) and winter (5.75 km/day). Six of the females showed no relationship with temperature with respect to daily distances travelled. Results also indicate that giraffes moved faster on average during the colder periods of the year, and also that they do not travel long distances during the warmer months. The giraffes moved at an average speed of 0.21 km/h.

It is significant that some of the females considerably increased the distance travelled in the second year. Evidence from the females giving birth suggests that they are unlikely to move long distances with a new calf for the first few months.

Results indicate that the time of day giraffe are travelling plays an 87.5% significant role in daily distances, demonstrating they travel only certain times of the day. Time x season interactions demonstrated that giraffes travel the longest distances in summer mornings and least in the afternoons, but the opposite during the winter season. Results also indicate that the fewest travelling occurred during the morning hours in the winter season.

Giraffes in the Kalahari region would need an average home range of 206.0 km² (20 602 ha) to support themselves annually. In the wet, hot season (summer) when food was abundant, giraffe frequented smaller areas (average 177 km²) that sustained their daily needs (metabolic rate/intake), while in the dry, cool season (winter) they needed to extend their home range (average 245 km²) to fulfill their daily needs. From the results there is evidence that giraffes are influenced by environmental factors such as season, rainfall and vegetation.

Summarising the main findings, we can reach the following conclusions:

i. GPS collars fitted on female giraffes generated valuable data to identify daily movement and long term spatial patterns for giraffe herds.

ii. The DNA results showed that both genetically related and unrelated females may share the same habitats.

iii. For six of the collared females, daily temperature did not have an influence on average daily distance travelled.

iv. Seasonal temperatures had an influence on giraffe average seasonal distances travelled, because more travelling occurred during the summer cooler hours than during warmer hours and in winter more travelling occurred during the warmer hours than during the colder hours of the day.

v. Time of day had an influence on giraffe movements - giraffes were more active and moved faster and longer distances during the day than during the night.

vi. Rainfall had an influence on giraffe spatial distribution - average daily distances moved and rate of movement increased if there was an increase in rainfall.

vii. Different seasons had an influence on giraffe movements - in the cool winter months giraffes moved on average faster and farther than during the warm summer.

viii. Different vegetation types had an influence on giraffe home range.

ix. Home range size was influenced by season.

x. Home range overlap was influenced by season and the availability of food. Home range overlap occurred between certain females.

xi. The percentage of time spent in different vegetation types was influenced by the abundance of the principal food species of that plant community.

CHAPTER 6: THE IMPACT OF THE GIRAFFES ON THE VEGETATION OF KHAMAB KALAHARI NATURE RESERVE

6.1. Introduction

The habitat of an animal can be described as the area in which it lives, with both biological and physical features, as well as the presence of other species characterizing it. The habitat quality (opportunities for food and risk of predators) affects the individual's ability to survive and reproduce within the area (Dagg, 2014).

The presence and availability of water and food of necessity plays an important role in habitat preferences, although the physical structure of the habitat is the decisive factor if water and food are available in more than one place (Joubert, 1996). Joubert (1996) further states that components like species composition and structure of vegetation are important in forming a habitat. The animal's spatial separation within an area increases when resources are most limited (warm, dry seasons, etc.).

According to Melton (1987), when studying habitat use, it is important to view the environment from an animal's perspective. What may look like different habitats to a researcher may be equivalent in terms of features of importance to the animal and *vice versa*. When determining habitat selection, it is important to recognize stress and critical periods, in order to obtain a true picture of the significance of the usage of the area (Furstenburg, 1991).

According to Skinner & Smithers (1990), giraffes occur in a wide range of habitats, ranging from forest to savanna woodland and scrub. Giraffes may occur to some extent in open plains and arid areas; however, they prefer areas with shrubs and trees of up to about 5 m in height. Giraffes also prefer well-developed woodlands and thicket areas where they can shelter from various environmental factors.

Kruger (1994) illustrated how giraffes adapted very well in the Kgalagadi Transfrontier Park (KTP) with a habitat similar to the present study area. The key food species in the KTP were *Boscia albitrunca* and *Acacia haematoxylon*, which were identified both as preferred and principal food species for giraffes (Kruger, 1994). These two woody species have the advantage of year round leaf carriage, which is a very important feature for the survival of browsers in a savanna with large seasonal differences. Based on the given information it can be assumed that *A. haematoxylon* will also be an important fodder species within the current study area because it is preferred by giraffes.

As mentioned previously, giraffes are classified as browsing megaherbivores; a herbivorous mammal with males exceeding 1 000 kg (Owen-Smith, 1999) having high absolute energy requirements (Bell, 1971). In order to satisfy these requirements an adult female giraffe must consume approximately 2.2% (~16.60 kg) of her live-weight per day (Pellew, 1984). Thus, if in abundance, giraffes are capable of negatively affecting the vegetation of the area they inhabit (Deacon *et al.,* 2012). More recently, Birkett (2002), using modeling techniques, demonstrated that giraffes in Kenya would have the greatest impact on the three to five metre size class of trees. On the other hand, many woody species, including the African *Acacia* species, are well equipped to defend themselves against over-utilization (e.g. tannins) (Furstenburg, 1991).

Giraffes are not strictly territorial in the sense of defending delimited areas against others of their species, but each adult does tend to remain within a specific home range, which may overlap with the home ranges of other members of the population (Skinner *et al.,* 1990). The size of the home range differs according to sex, age, water points, type of habitat, availability of food and cover, etc. This overlap might result in overexploitation of resources if the number of animals is more than a fenced area can comfortably sustain.

Giraffes are often underrated in terms of the potential influence they might have on their habitat (Parker, 2004; Deacon *et al.,* 2012). In common with many game ranches in the region, some game species were not historically present and it is thus essential to study the adaptation and impact of the introduced species on their new habitat. The species composition, density, height distribution, productivity and condition of woody plants influence the browsing capacity of such areas, and need to be assessed for application in management programs. It is important to understand the factors that might lead to a decline in the giraffe populations, as well as the factors that influence individual needs and physiological balances to ensure that giraffes survive in the new habitat (Shorrocks & Croft, 2009).

The specific objectives of this study were:

i. To identify representative habitats, specifically those preferred and avoided by giraffes;
ii. To assess these habitat preferences by investigating the woody layer and tree phenology;
iii. To calculate the available browse in different height strata;
iv. To determine the number of browsers KKNR can sustain;
v. To determine seasonal variations in the availability of browse.

6.2. Procedure

6.2.1. Selection of survey sites preferred or avoided by giraffes

One year after the eight female giraffes were collared, those areas preferred and avoided by the giraffes were identified according to the spatial distribution of the main herd (the central herd that was followed for daily observations, which contained collared female SAT312Ke) (Figure 6.1). The spatial distribution, using the GPS coordinates, clearly identified those areas the herd preferred or avoided during a one year period. The total area roamed by collared female SAT312Ke (including the herd animals with her) was 55 km² (Chapter 5), the largest area of the eight collared females. This allowed for the classification of areas ranging from high-density areas that were highly preferred to areas that were avoided.

A grid pattern representing areas of 2 000 m x 2 000 m (400 ha) was overlaid on the map of the study area (Figure 6.1). This helped to identify those areas that were preferred and avoided by the giraffes. The grid areas visited more than 40 times during the first year were classified as high preference areas. Those that were visited from 20 to 40 times during the first year were classified as medium preference areas. Those grid areas visited less than 20 times were classified as low preference areas. While those grids that were not visited during the first year, were classified as unutilized areas (Figure 6.1). Ten survey plots in the form of belt transects of 100 m x 2.5 m (250 m²) were randomly selected within each of the four utilization areas (high, medium, low and unutilised). All rooted woody plants in each of those 40 survey plots were measured as described in section 6.2.2 and the data from each of the four utilization areas combined to represent the woody plant characteristics of each of the areas.

Survey sites included the floristic characteristics of the utilized areas, and the diet selection of preferred tree species by giraffes is provided. A full description of how data were collected for diet selection is given in Chapter 7.

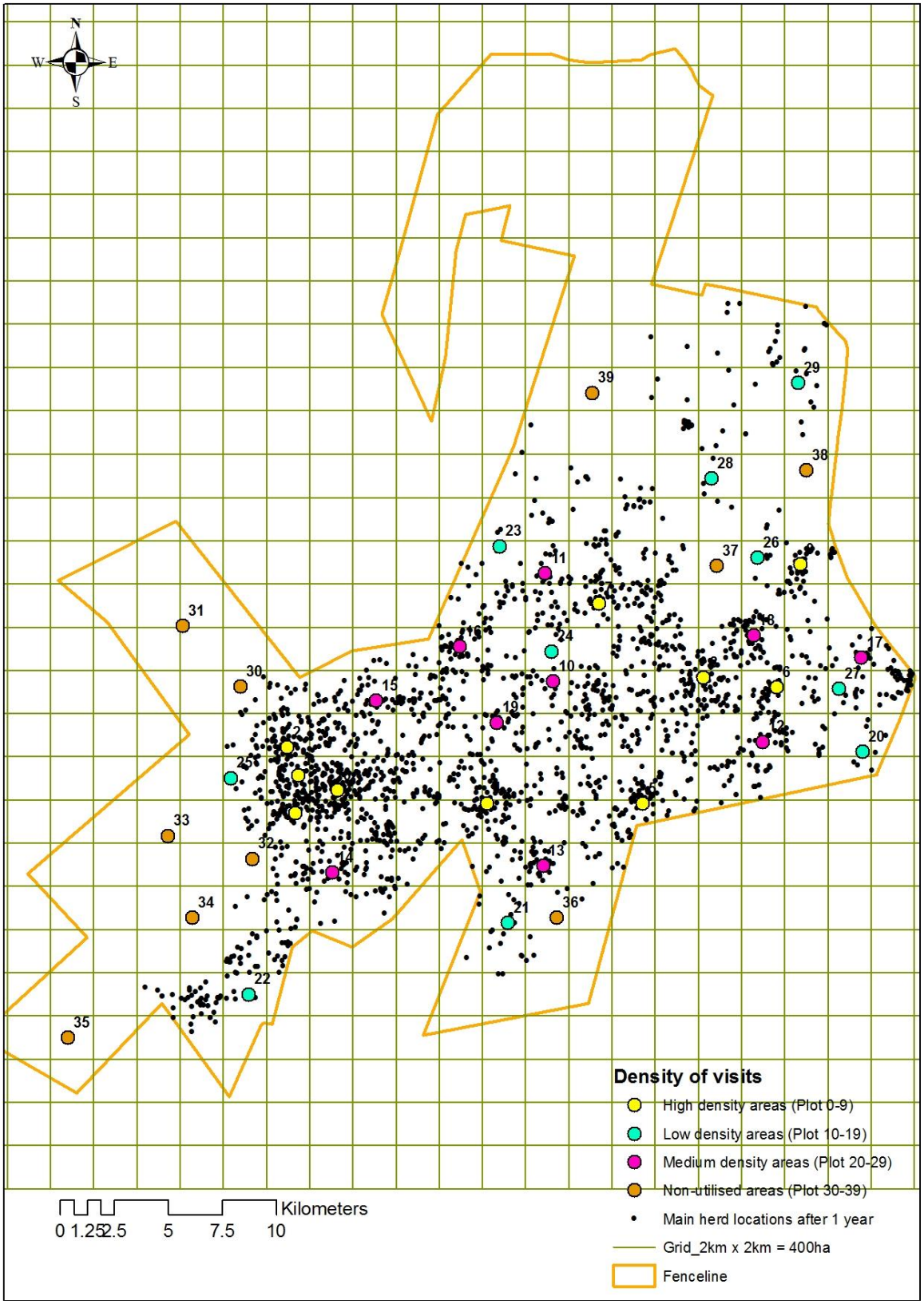


Figure 6.1 Monitored transect-plot classification according to the spatial distribution of the main herd (SAT312Ke) with habitat preferences from highly utilized to unutilized areas.

Shrub and tree densification was deemed undesirable in the context of commercial farming where management objectives were to maximise production of grazing animals and to promote visibility of wildlife to tourists and hunters (Bezuidenhout, *et al*., 2015). Accordingly, previous landowners (discussed in chapter 2) have attempted to eradicate prolific shrubs (particularly *A.mellifera*) by mechanical and chemical means in certain areas in KKNR during the period 1974–2006. Effects of these treatments are still apparent and the effect of herbicide applications and other management practices are furthermore explored to determine the ecological effects it has on giraffe.

Using the location distribution obtained from the GPS collars, it was used to map together with the poison treated or non-treated areas identified. The Collinson (2008) ecology plan for KKNR; EES (2012) ecological report on KKNR and own observations done within KKNR assisted with the procedure in determining how giraffe habitat selection were influenced by management principles. Although the plant community in KKNR is very homogeneous, it is characterized by variations in plant species composition due to previous bush clearing or thinning actions and based on poison recovery after treatment. Confirmed with the KKNR ecologist (Mr. Hanno Killian) the poison used to kill woody species between 1980 and 2006 were 'Molopo 200GG' (with active ingredient Tebuthiuron). It is a non-selective herbicide absorbed by the roots of woody plant species and translocated to the leaves by means of transpiration where it inhibits photosynthesis. Woody plant species may successively loose and regain leaves until death occurs (Bezuidenhout, *et al*., 2015). In KKNR Molopo 200GG' with active ingredient Tebuthiuron mostly in granular form was used, largely targeting the woody plant species. The method of treatment varied among areas being either selective or unselective. Plant-specific application by hand in the form of granules was at a dosage of 6 kg/ha while granule application by aeroplane was used at a dosage of 3 kg/ha in the Mokala National Park in South Africa between 1996 to 2004 (Bezuidenhout, *et al*., 2015).

KKNR treated areas were scored based on experience and evidence and then mapped to determine the percentage arboricedes has influenced each area and how giraffe preferred or avoided these areas. Five categories were identified based on the effect poison had on the plant community. No treatment, selective treatment (>13 years ago), selective treatment (< 13 years ago), unselective treatment or unknown. Selective treatment include bush clearing practices with planning and being selective for plant species, size and the number of plants killed. Unselective treatment include bush clearing practices on a large scale, not concerning species, size or the number of trees.

6.2.2. Survey of the woody layer

The dimensions of all rooted, live woody plants above 0.5 m in height were measured in the permanently marked belt transect of 100 x 2.5 m (250 m²) of each survey plot (Figure 4.6). Plants below 0.5 m were considered seedlings/saplings and were only counted on a species basis and their density calculated as plants ha^{-1}. The measurements of the woody plants above 0.5 m included the following:

i) maximum tree height

ii) height where the maximum canopy diameter occurred

iii) height of first leaves or potential leaf bearing stems

iv) maximum canopy diameter

v) base diameter of the foliage at the height of the first leaves (see Appendix E).

The tree density (plants ha^{-1}), Evapotranspiration Tree Equivalents (ETTE) (Smit, 1989a) and dry mass estimates of the plants were calculated using the BECVOL-model (Biomass Estimates from Canopy Volume) (Smit, 1994; 1996; 2010), which is based on the quantitative description technique proposed by Smit (1989a; 1989b). It includes regression equations, developed from harvested trees, which relate the spatial canopy volume (independent variable) to the actual leaf volume and plant dry mass (dependent variable).

Values that were calculated with the BECVOL model (Smit, 2014) are:

(i) Tree density (plants ha^{-1})

(ii) Evapotranspiration Tree Equivalents (ETTE/ha^{-1}) (An Evapotranspiration Tree Equivalent (ETTE) is defined as the leaf volume equivalent of a 1.5 m single-stemmed tree).

(iii) Total leaf dry mass (DM ha^{-1})

(iv) Leaf biomass below a browsing height of 1.5 m (DM ha^{-1})

(v) Leaf dry mass below a browsing height of 2.0 m (DM ha^{-1})

(vi) Leaf dry mass below a browsing height of 5.0 m (DM ha^{-1})

(vii) Shoot dry mass - shoots <0.5 cm below a browsing height of 1.5 m (DM ha^{-1}),

(viii) Shoot dry mass - shoots <0.5 cm below a browsing height of 2.0 m (DM ha^{-1}),

(ix) Shoot dry mass - shoots <0.5 cm below a browsing height of 5.0 m (DM ha^{-1}),

(x) Stem dry mass - stems >0.5-20 cm in diameter (DM ha^{-1}),

(xi) Wood dry mass - wood >20 cm in diameter (DM ha^{-1}),

(xii) Total wood dry mass (all fractions) (DM ha^{-1}),

(xiii) Total tree dry mass - leaves and wood combined (DM ha^{-1}).

In addition to the total leaf and shoot DM ha-1, stratified estimates of the leaf and shoot DM ha-1 below 1.5 m, 2.0 m and 5.0 m respectively, were also calculated, using the new BECVOL 3-model (Smit, 2014). The height of 1.5 m represents the mean browsing height of the impala (*Aepyceros melampus*) (Dayton, 1978), while 2.0 m and 5.0 m represent the mean browsing heights of the kudu (*Tragelaphus strepciseros*) and the giraffe (*Giraffa camelopardalis*) (Skinner & Smithers, 1990), respectively. These browsing heights are mean heights and not maximum browsing heights. It is known that large individuals are able to reach higher than these mean heights, e.g. 2.5 m and 5.5 m for kudus and giraffes

respectively (Dayton, 1978), while breaking of branches may enable some browsers to feed at even higher strata (Smit, 2014).

Data on the die-back of woody plants were also collected. Woody plants that were completely dead, but still standing were recorded as such and those that showed signs of die-back were recorded as “partially dead”. Partially dead plants were still measured as described above, but only the live parts of the plants were included in the measurements.

6.2.3. Quantifying tree phenology

Phenology (p) can be defined as the presence of the plant during various seasons and is very important when determining browse production. Phenology is the periodic events in the life cycles of plants (such as leaf budding, leaf shedding and flowering), as influenced by the environment, especially seasonal variations in temperature, photoperiodism (day length) and precipitation (Wisiol & Hesketh, 1987; Cleland *et al.,* 2007). Evergreen species are considered as key species, because they keep their leaves and provide food throughout the year. In times of food scarcity (in a controlled environment), additional supplementation should be provided to the animals or they should be moved to an area where enough food is available. Within natural systems, dry matter and leaf phenology play a major part in the plant preferences of browsers; other factors, such as the percentage available for utilization, also influence these preferences and should be considered (Decker & Smith, 1996).

The estimated percentage leaf presence (p = phenology) for the various utilized plant species can theoretically vary from 100% (p = 1.0) in the case of evergreens to 0% (p = 0.0) during winter for the early deciduous tree species. However, there are indications that browsers may utilize the tips of shoots and twigs, even if no leaves are present. This implies that the value of p will always be above zero (Smit, 1989a).

The technique used by Dunham (1991) was modified to monitor the trees for morphological changes in the phenology of the six most prominent tree species. This monitoring included a physical inspection every fortnight for fifteen months in succession. It is important to identify the phenology during the critical winter months. Normally during winter when temperatures drop, day length is shorter and rainfall is limited, most woody species present in the study area are known to be senescing leaves as part of their winter deciduous nature.

Ten plants of each of the six key woody species (the six tree species most utilized by giraffes, see chapter 7) were randomly selected and marked with yellow plastic markers normally used as cattle ear tags. Each marked plant was numbered and its GPS location logged. Marked trees varied in size and age, and were widely dispersed across the study area, with representatives in each vegetation unit.

During every inspection, each tree was allocated a leaf percentage carriage score: 0 = no leaves; 1= 1 – 15% (10%) of full leaf carriage; 2 = 16 – 40% (25%), 3 = 41 – 70% (50%); 4 = 71 – 90% (75%); and 5 = 90 – 100% (100%) (Jenecke & Smit, 2011). Leaves were also classified in different phenological states or phenophases depending on their age and colour, namely budding leaves, immature leaves, mature leaves, yellow leaves and dry and

senescing leaves retained on the tree. A median value for each phenophase of the 10 marked plants per species was determined per date. The sum total of these phenophase median values was calculated per woody species and indicated monthly as class values (1-6), e.g. a total score of 3 may consist of 1 immature leaf plus 2 mature leaves (Janecke & Smit, 2011). The allocated total leaf carriage scores were subdivided into approximate estimates of the phenological composition (phenophase) of the leaves present and were used for descriptive purposes in accordance with Dekker & Smit (1996) and Smit (2001).

6.2.4. Calculation of the browsing capacity

From the leaf and shoot (<0.5 cm diameter) DM per hectare estimations, the browsing capacity of each vegetation unit was calculated according to a similar formula used for the herbaceous layer (Smit, 2010):

$$y = d \div \left[\frac{(DM1 \times f1 \times p1) + (DM2 \times f2 \times p2) + (DM3 \times f3 \times p3) + ...(DMx \times fx \times px)}{r} \right]$$

Where:

y = browsing capacity (ha BU^{-1})

BU = metabolic equivalent of a kudu with an average body mass of 140 kg

d = number of days in a year (365)

DM1 = tree leaf and shoot DM yield ha $^{-1}$ of species 1

DM2 = tree leaf and shoot DM yield ha $^{-1}$ of species 2

DM3 = tree leaf and shoot DM yield ha $^{-1}$ of species 3

•

•

•

f1 = utilization factor for species 1

f2 = utilization factor for species 2

f3 = utilization factor for species 3

•

•

•

p1 = leaf phenology of species 1

p2 = leaf phenology of species 2

p3 = leaf phenology of species 3

•

••r = daily fodder DM required per browser (BU) (2.5% of body mass of 140 kg = 3.5 kg/day)

The utilization factor, expressed as a decimal value, represents that part of the available leaf and shoot material that can be consumed. Actual consumption is limited by browsing preferences of the animals. Limited scientific information currently exists on which to base the utilization factor (f), but indications are that it is very low. In the case of the black rhinoceros (*Diceros bicornis*) it can be as low as 8% (f = 0.08), and up to about 20% or more (f = 0.20) for other browsers.

The substitution values of a few game species in terms of GU (daily fodder DM required per grazer with 2.5% of body mass of 180 kg = 4.5 kg/day) and BU are presented in Table 6.1. These substitution values can be used in the formula when specific species are evaluated for their daily requirements. The descriptive units can be seen in Appendix E.

Table 6.1 Approximate substitution values of a few game species in terms of browser units (BU) (Smit, 1989).

Game species	**Average Mass (kg)**	**Intake (% of mass)**	**% grass**	**% leaves**	**GU**	**BU**
Steenbok (*Raphicerus campestris)*	12[2]	4.1	50	50	0.05	0.07
Springbok (*Antidorcas marsupialis*)	37[2]	3.0	70	30	0.2	0.1
Impala (*Aepyceros melampus melampus*)	52[2]	2.7	70	30	0.2	0.1
Eland (*Tragelaphus oryx*)	460[2]	2.4	30	70	0.7	2.2
Elephant (*Loxodonta africana*)	3 800[2]	0.8	50	50	3.4	4.3
Duiker (*Sylvicapra grimmia*)	21[2]	4.0	0	100	0	0.2
Kudu (*Tragelaphus strepsiceros*)	140[1]	2.5	0	100	0	1.0
Giraffe (*Giraffa camelopardalis*)	**828[2]**	**2.2**	**0**	**100**	**0**	**5.2**
Black Rhinoceros (*Diceros bicornis*)	865[2]	1.5	0	100	0	3.7

[1]Average mass of herd

[2]Average mass of mature female

6.2.5. Determining how many browsers KKNR can sustain

If the browser units exceed the carrying capacity, the animals may have a negative influence on the habitat. The maximum number of browser units that can be supported by the vegetation was calculated per vegetation unit: Surface area of the vegetation unit (ha)/ browsing capacity (ha/BU) of that vegetation unit, as determined by the browsing capacity formula (Smit, 2012). The total number of browser units that can be supported by the vegetation of the study area as a whole was also calculated by dividing the surface area of the study area by the browsing capacity of that area.

The number of browser units that can be maintained on the total area was calculated as follows:

BU = area ÷ BC

Where BU = browser units,

area = 95 653 ha (The total area of KKNR),

BC = browse capacity (ha/BU) from Figure 6.11.

The number of browser units of all the browsers and mixed feeder game species present on KKNR at the time of the study was calculated by using the following equation:

$BU = n \times BU_2$

Where BU = number of browser units,

n = number of animals per species (Table 6.7),

BU_2 = BU value for the relevant species in Table 6.1; each species represents this part of one browser unit

6.2.6. Data analysis

Following the results obtained with the BECVOL-model, it was further tested with the generalized linear mixed models (GLMM) analysis which extends the usual regression analysis to cater for non-Normal distributions (GenStat®, 2012) (Payne *et al.,* 2012). Thus, the same verified data arising from BECVOL were used to determine different sets of distribution of significance.

The GLMM analysis was used to test for differences between different vegetation areas and seasonal effects, and also to test for differences between the qualitative characteristics (plants per hectare, shoot mass, leaf mass etc.) of each vegetation area and tree species effects. Treatment means were separated using Tukey's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran, 1980).

GLMM extends the usual analysis to cater for non-Normal distributions, e.g. the Poisson distribution for counts and the gamma distribution for positively skewed data, such as the browsing capacity as response variate. GLMM also incorporates a link function that defines the transformation required to ensure the linearity of the model. For example, logarithm (base e) is used for counts and for the gamma distribution. GLMM additionally allowed for the inclusion of random effects, such as the season and tree species to account for the variation within the different effects.

A four utilization area x four seasons x three height strata GLMM factorial analysis was done following Schall's (1991) method. The fitting of data from all the distributions, apart from the normal, was complicated by the fact that their variances changed according to their means. These means were further complicated by the way the number of samples per utilization area, height strata (or height) and seasons were influenced by the assemblage of the months.

Ordination helps to identify DM ha^{-1} variables that significantly influence species composition and those species which vary along those gradients. Ordination techniques could also assist in understanding a local environmental classification by "grouping" the same value information together (Verlinden & Dayot, 2005). Following the results obtained after using the BECVOL-model, they were also further tested with the different techniques from the CANOCO 4 (TerBraak & Šmilauer, 1998) package.

The data matrices (utilization area, tree species and height strata) were analysed during the different seasons using the ordination method described by Gauch (1982). This includes multi-dimensional scaling (MDS) to establish whether there were outlier data within each of the separate data matrices that needed to be removed from the rest of the analyses, such as:

- Analysis of similarities (ANOSIM): one-way and two-way crossed to establish whether there were significant differences between the different seasons and/or relative condition groups within and across seasons;

- By means of De-trended correspondence analysis (DCA) for unimodal data that displayed an artificial arch effect, and Principal Component Analysis for linear data;

- Ordination of seasonal compositional data for the different matrices, by employing Canonical Correspondence Analysis (CCA) for unimodal data.

Indirect ordination using De-trended Correspondence Analysis (DCA) (unimodal response) was used to extract ordination axes that described the main special compositional gradient, and to establish which variables were related to the species gradients (Ter Braak & Šmilauer, 1998).

6.3. Results and Discussion

6.3.1. Floristic characteristics of utilized areas (survey sites)

i. Areas of ***high utilization*** (1) Sampling plots 0 - 9 (Figure 6.1 – Yellow locations)
These areas can be described as open woodland with the herbaceous layer described as good with about 60% open areas and with little bare soil (Figure 6.2). Bigger trees are prominent such as *A. erioloba*, *A. luederitzii* and taller than average *A. mellifera*. There is also an abundance of *Z. mucronata* with a good selection of grasses within the open areas. These areas also contain *B. albitrunca* and *G. flava*. These areas are prominently heterogeneous with great diversity of larger size trees and species composition. As little as 10% of these areas were influenced by poor management practices in the past. From own observations (this study) it is the most well-balanced functioning ecosystem within KKNR based on plant and animal diversity.

ii. Areas of ***medium utilization*** (2) Sampling plots 10 - 19 (Figure 6.1 – Turquoise locations)
These areas can be described as open savanna with woody species prominent (Figure 6.3). The herbaceous layer is characterized by the grass species *Stipagrostis uniplumis* and *Schmidtia kalahariensis*. The woody layer is characterized by medium sized *A*. *erioloba and A. luederitzii,* with smaller size *G. flava* and *A. mellifera* also present. It can also be described as a very heterogeneous habitat, with little influence of fire and management practices. More bare ground patches are found where the bush density is higher.

iii. Areas of ***low utilization*** (3) Sampling plots 20 - 29 (Figure 6.1 – Pink locations)

This vegetation area can be described as open shrubland with many bare patches of soil. This area comprises an average herbaceous layer (*Stipagrostis* and *Schmidtia* species) with medium sized trees dominant. The most prominent trees are *G. flava*, *Boscia albitrunca*, *Terminalia sericea*, *A. erioloba* and *A. mellifera* that are sparsely dispersed with many dead trees in-between. Large areas still bear evidence of the influence of chemical arboricide applications in the past. Almost no large trees are visible in areas that are classified as bush encroached areas with *Rhigozum trichononum* and *A. mellifera* present. From own observations it is the poorest functioning ecosystem within KKNR based on plant and animal diversity.

iv. ***Unutilized areas*** (4) Sampling plots 30-39 (Figure 6.1 – Orange locations)

These areas include segments of two separate vegetation units, namely: units 4.1 and 4.2.

Vegetation unit 4.1 (Figure 6.5) has been identified as a clearly damaged area caused by previous poor management. It is evident that chemical arboricides had a negative influence on the larger trees. A large percentages of these areas comprised mainly herbaceous vegetation with many small shrubs of *G. flava* and *B. albitrunca* coppicing still present. The damaged vegetation makes these areas homogeneous with a large amount of open space. Many dead trees are visible and traces of veld fires are present. Amongst the medium to small sized shrubs, *Stipagrostis* is the most prominent grass species. About 60% of all the unutilized areas would consist of damaged veld.

Vegetation unit 4.2 (Figure 6.6) is a well-balanced habitat with beautiful, large trees and a well-established herbaceous layer. It comprises dense habitat with many large *A. erioloba, A. luederitzii, B. albitrunca* and *Z. mucronata* trees present. About 40% of the unutilized areas would comprise these well-balanced, but still non-preferred areas. These areas are particularly heterogeneous with an extensive diversity of plant species. Amongst the herbaceous layer are *Eragrostis plana, Schmidtia* and *Stipagrostis* species.

Figure 6.2 Examples of the highly utilized areas preferred by the main giraffe herd.

Figure 6.3 Examples of areas of medium utilization preferred by the main giraffe herd

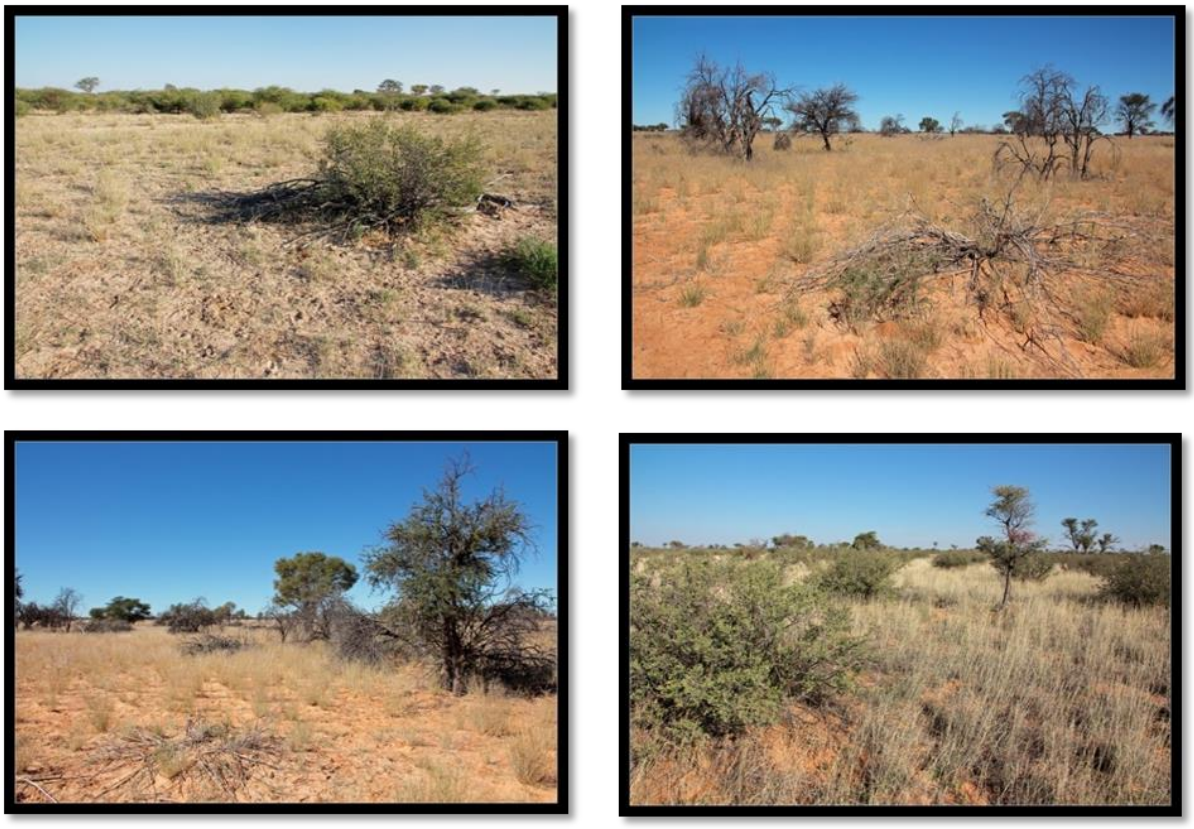


Figure 6.4 Examples of areas of low utilization preferred by the main giraffe herd

Figure 6.5 Examples of unutilized areas, vegetation unit 4.1 (avoided by the main giraffe herd).

Figure 6.6 Examples of unutilized areas, vegetation unit 4.2 (avoided by the main giraffe herd)

6.3.1.1. Effect of poison on the KKNR habitat and giraffe locations

After mapping the treated and non-treated areas in KKNR the percentage (based on the number of giraffe GPS locations) each collared giraffe has spent time are displayed in Figure 6.7 and Table 6.2. Treatment in large areas in the Northern section are unknown, therefore the two females in the northern section GPS locations are excluded from calculations for the moment. Based on the information obtained these five categories clearly demonstrate whether giraffe prefer treated or non-treated areas. Treatment recovery are based on the description of each area in Appendix F.

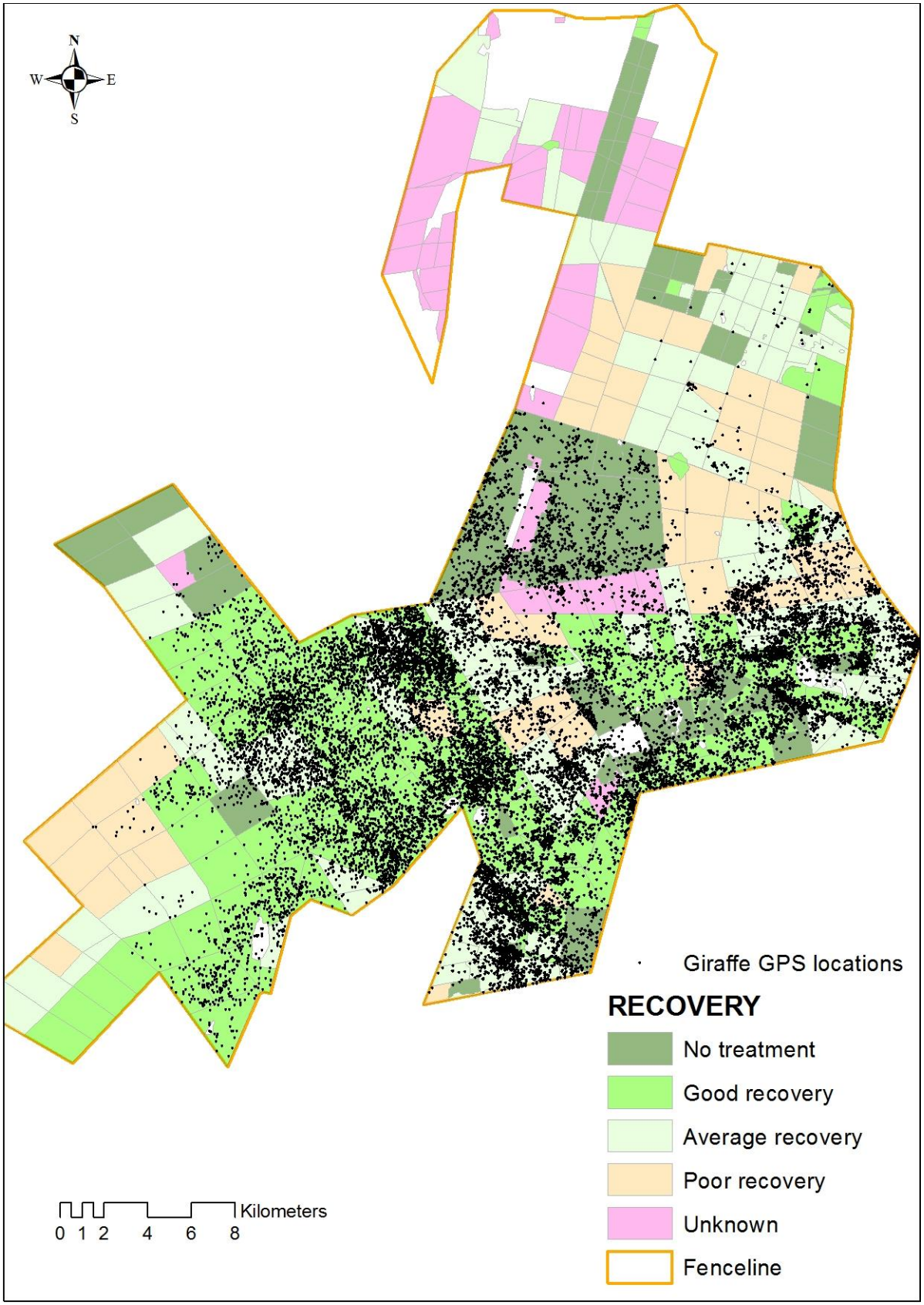


Figure 6.7 Demonstration of poison treated, non-treated and unknown areas in KKNR administered between 1980 and 2006 with the collared females distribution

Table 6.2 Total treated areas and the percentage each collared female has spent in each

Female	No treatment	Selective treatment > 16 years ago	Selective treatment < 16 years ago	Unselective treatment	Unknown
SAT305Ca	1.54%	6.61%	3.64%	0.64%	0.46%
SAT308Da	0.16%	0.20%	3.70%	0.05%	8.90%
SAT310He	1.94%	7.72%	2.40%	0.29%	0.10%
SAT306Kem	0.05%	0.12%	2.48%	0.01%	10.10%
SAT312Ke	1.94%	6.78%	2.85%	1.04%	0.43%
SAT309Ni	1.26%	5.40%	3.51%	1.36%	0.27%
SAT307Pi	0.91%	7.88%	2.26%	0.39%	0.36%
SAT311Wi	1.47%	5.48%	4.10%	0.72%	0.45%
Grand Total	**9.27%**	**40.19%**	**24.95%**	**4.50%**	**21.08%**
Recovery	Not treated	Good	Average	Poor	Unknown
Area (sq m)	135886331	274453176.1	219387447.3	135169523	86894656
Area percentage	15%	30%	24%	15%	10%
Difference between what is available and actual time spent in each area	**5.7**	**10.2**	**0.1**	**10.5**	**11.1**
	61.5% less	25.4% more	0.4% more	233% less	

Table 6.3 Giraffe preference percentage based on poison applications from 1980 -2006

Female	No treatment	Selective treatment > 13 years ago	Selective treatment < 13 years ago	Unselective treatment	Unknown
SAT305Ca	2.07%	8.91%	4.91%	0.86%	0.63%
SAT310He	2.62%	10.40%	3.23%	0.40%	0.13%
SAT312Ke	2.62%	9.13%	3.84%	1.40%	0.58%
SAT309Ni	1.69%	7.28%	4.73%	1.83%	0.36%
SAT307Pi	1.23%	10.62%	3.04%	0.53%	0.48%
SAT311Wi	1.98%	7.38%	5.53%	0.97%	0.61%
Grand Total	**12.21%**	**53.72%**	**25.29%**	**5.98%**	**2.80%**

Information in Table 6.3 is graphically illustrated in Figure 6.7. From available information based on experience and estimations, selective treatment (>13 years ago) represents habitat areas that have recovered well from poison treatment. Selective treatment (<13 years ago) recovered averagely, and unselective treated areas have recovered poorly. The results indicate on average giraffe avoided unselective treated areas by spending less than 6% of time in these poor recovered areas. Giraffe clearly preferred areas that recovered well from treatment with more than 53% of their time in these areas. Non-treated and well recovered areas (>13 years ago) represent 66% of all giraffe locations. In total 91% of GPS locations are within the combination of non-treated and selective treated areas (>13 years or

<13 years) and only 9% of locations are in poorly recovered and unknown areas. Non-treated areas (12.3%) and unselective treated areas (6%) are equally low preferred by giraffe. This could be because untreated areas are too dense for giraffe (see appendix G). This demonstrates giraffe distribution and habitat selection are influenced by human management. Poison treatment can have a long lasting effect on the habitat and will influence the distribution of herbivores many years later (Bezuidenhout, 2015). The unselective treated areas that show poor recovery are avoided by giraffe (233%) from the total area available. This would indicate giraffe definitely have no preference for these areas which make 15% of the total area in KKNR. Giraffe will also avoid un-treated areas with 62%, indicating bush encroached areas are unflavoured and should be selectively treated by management.

6.3.1.2. Tree species list and preferred species

A total of 174 different plant species belonging to 45 plant families were identified on the reserve. A total of 50% of the species belonged to five families, namely: *Poaceae, Fabaceae, Asteraceae, Scrophulariaceae* and *Aizoaceae*. However, only twenty tree species were recorded in the survey plots and used to calculate browse for browsers and specifically for giraffes.

In total, 926 trees from these twenty browsable tree species were measured with the BECVOL method from the 40 identified survey plots (Table 6.4). Only individuals with a height of more than 0.5 m were measured and individuals of less than 0.5 m were only counted as saplings. Seven of the twenty species represented 98.4% of the total diet preference; the other 13 species were classified as “Other” and represented only 1.6% of the diet (Figure 6.8). For this reason, the seven species preferred by the giraffes were classified as key diet species for further investigation. The detailed diet selection is discussed in chapter 7, but it is important here to indicate which of the tree species were analysed for browsing capacity purposes.

Table 6.4 Woody species included in the BECVOL 3 analysis in the 40 sampling plots representing 10 000 m² in size

Nr.	Species
1	*Acacia erioloba*
2	*Acacia luederitzii*
3	*Acacia haematoxylon*
4	*Acacia hebeclada*
5	*Acacia mellifera*
6	*Boscia albitrunca*
7	*Cadaba aphylla*
8	*Dichrostachys cinerea*
9	*Diospyros lycioides*
10	*Ehretia rigida*
11	*Grewia flava*
12	*Grewia flavescens*
13	*Grewia retinervis*
14	*Lycium cinereum*
15	*Rhigozum brevispinosum*
16	*Searsia tenuinervis*
17	*Terminalia sericea*
18	*Ziziphus mucronata*
19	*Phaeoptilum spinosum*
20	*Rhigozum obavatum*

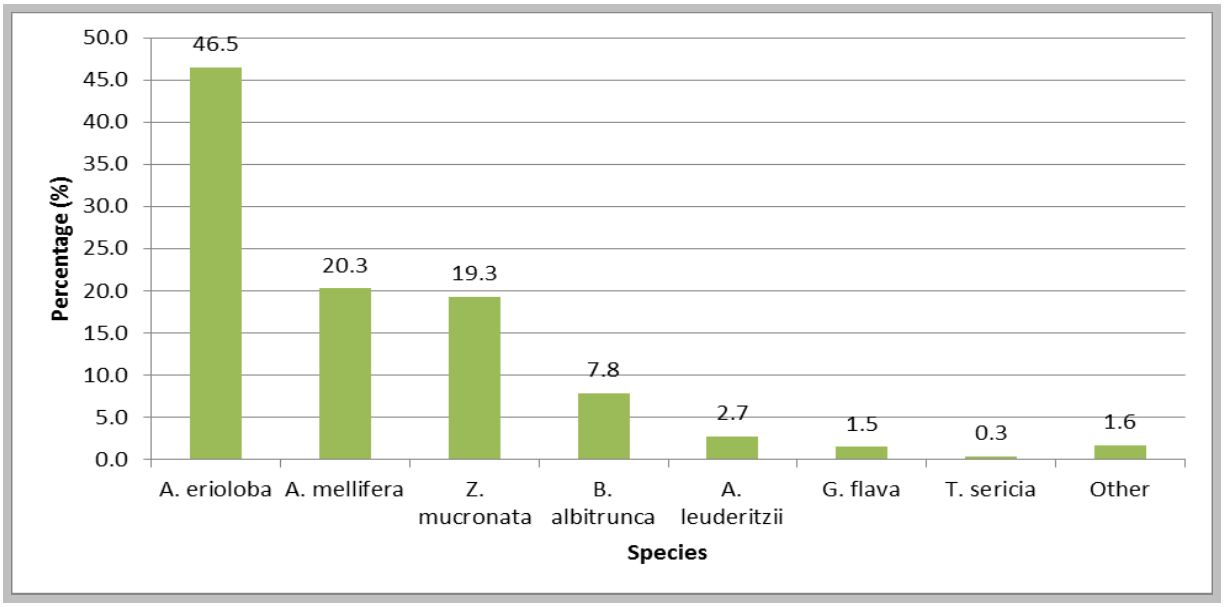


Figure 6.8 Preferred diet selection of giraffes with the utilization percentage for each tree species

6.3.2. Phenology

The estimated dry leaf mass (kg DM ha^{-1}) per tree species is illustrated in Table 6.6. The estimated total per tree species varied as the season progressed, and it is evident that the total percentage was not available throughout the year (Table 6.5). Variations between the tree species can also be seen. The percentage availability of leaves and shoots had a sudden decrease from July until October for all six tree species (*B. albitrunca* was excluded from this survey as it is evergreen). This explains why certain months are considered critical periods, as there were lower percentages of food available.

The estimated percentage leaf presence (p = phenology) for the six tree species theoretically varied from 100% (p = 1.0) to 0% (p = 0.0) during the critical period, except for *A. erioloba,* which had a lowest score of 0.32% during September.

Each tree species was allocated a percentage relating to the utilization factor. The percentage utilization for each tree species was based on years of experience and research and represents that part of the available leaf and shoot material that can be consumed by animals. Actual consumption is limited by browsing preferences of the animals. Table 6.5 lists the utilization factors as used in this study.

Table 6.5 Phenology of six different winter deciduous tree species

SPECIES	**Phenology (%)**											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Acacia erioloba	1.00	1.00	0.94	0.86	0.74	0.60	0.46	0.35	0.32	0.53	0.81	0.97
Ziziphus mucronata	0.88	1.00	1.00	0.90	0.64	0.58	0.34	0.20	0.15	0.00	0.40	0.69
Grewia flava	1.00	1.00	0.93	0.86	0.74	0.55	0.11	0.00	0.00	0.00	0.37	0.71
Terminalia sericea	0.94	1.00	1.00	0.85	0.61	0.39	0.28	0.22	0.14	0.13	0.58	0.75
Acacia luederitzii	1.00	1.00	1.00	0.71	0.69	0.63	0.39	0.29	0.00	0.00	0.75	0.58
Acacia mellifera	1.00	0.87	0.71	0.66	0.65	0.31	0.02	0.00	0.17	0.22	0.86	1.00

Table 6.6 Utilization factors allocated to each tree species

SP_NR	SPECIES	Leaf utilization factor (%)	Shoot (< 2.0 mm) utilization factor (%)
1	*Acacia erioloba*	0.40	0.10
2	*Acacia luederitzii*	0.40	0.10
3	*Acacia haematoxylon*	0.40	0.10
4	*Acacia hebeclada*	0.40	0.10
5	*Acacia mellifera*	0.30	0.05
6	*Boscia albitrunca*	0.50	0.20
7	*Cadaba aphylla*	0.50	0.20
8	*Dichrostachys cinerea*	0.40	0.10
9	*Diospyros lycioides*	0.40	0.10
10	*Ehretia rigida*	0.30	0.05
11	*Grewia flava*	0.40	0.10
12	*Grewia flavescens*	0.40	0.10
13	*Grewia retinervis*	0.10	0.05
14	*Lycium cinereum*	0.30	0.05
15	*Rhigozum brevispinosum*	0.20	0.05
16	*Searsia tenuinervis*	0.30	0.05
17	*Terminalia sericea*	0.40	0.10
18	*Ziziphus mucronata*	0.40	0.15
19	*Phaeoptilum spinosum*	0.40	0.15
20	*Rhigozum obovatum*	0.20	0.05

6.3.3. Available browse in terms of woody species density, Evapotranspiration Tree Equivalents and dry mass

The number of Evapotranspiration Tree Equivalents per hectare (ETTE/ha) is presented in Table 6.7, where 1 ETTE equals the mean leaf volume of a single stemmed tree with a height of 1.5 m = 500 cm^3 leaf volume (Smit 1989a). Tree density data (plants per hectare) of the total woody species in the four vegetation areas utilized are also summarized in Table 6.7.

Table 6.7 illustrates the density and the total dry leaf mass of each species within each utilization area. *G. flava* has the highest density overall (Table 6.8), while *A. erioloba* and *A. mellifera* were also abundant in most of the vegetation areas utilized (Table 6.8). As expected, the total density of woody plants was lower when the grassland and other open areas of the study area were included (Table 6.8). Although *A. hebeclada, Dichrostachys*

cinerea, Diospyros lycioides, Ehretia rigida and *Rhigozum brevispinosum* species were present, they did not contribute substantially to the browse production. This may be due to their low numbers and because they were intensively browsed, thus listed as zero DM ha^{-1}. Table 6.8 also shpws the total edible material available to herbivores by adding the total leaf mass up to 5.0 m (LM_50) and the shoot diameter < 2.0 mm (WM_5_50).

Table 6.7 Summary of the Tree Density (plants ha^{-1}), Evapotranspiration Tree Equivalents, dry mass (total leaf mass - kg DM ha^{-1}) and shoot mass of woody plants for the total range of 55.4 km^2 of the main herd within the four vegetation areas utilized.

Preferred area	Total plants per ha (plants ha^{-1})	Evaoptranspiration Tree Equivalents (kg DM ha^{-1})	Total leaf mass up to 5.0m (km DM ha^{-1})	Leaf mass up to 5.0m (km DM ha^{-1})	Shoot mass up to 5.0m (km DM ha^{-1})	Total (kg DM ha^{-1}) (Leaf + shoot)
Highly utilized	744	5696	1302	1083	1545	**2 847**
Medium utilized	1084	5040	1132	1076	1363	**2495**
Low utilized	956	3646	798	790	873	**1671**
Non-utilized	912	3942	858	826	906	**1764**

Table 6.8 Summary of the Tree Density, Evapotranspiration Tree Equivalents and dry mass of woody plants for each key tree species for each vegetation area utilized.

		UTILIZED AREA				**PL_HA**	UTILIZED AREA				**ETTE**	UTILIZED AREA				**TOTAL LEAF MASS**	UTILIZED AREA				**LEAF MASS UP TO 5M**	UTILIZED AREA				**SHOOT DIAMETER (< 2.0 MM)**
		High	Medium	Low	Non	**Total**	High	Medium	Low	Non	**Total**	High	Medium	Low	Non	**Total**	High	Medium	Low	Non	**Total**	High	Medium	Low	Non	**Total**
SP_NR	SPECIES																									
1	*Acacia erioloba*	136	260	132	64	**592**	2282	1226	777	495	**4780**	544	288	183	116	**1131**	384	273	181	103	**941**	654	378	255	139	**1426**
2	*Acacia luederitzii*	36	36	56	28	**156**	638	944	383	499	**2464**	152	226	90	118	**586**	143	200	90	107	**540**	263	367	118	174	**922**
5	*Acacia mellifera*	120	168	192	56	**536**	902	1090	855	497	**3344**	213	255	199	117	**784**	213	255	199	117	**784**	335	332	238	166	**1071**
6	*Boscia albitrunca*	36	40	16	36	**128**	422	222	300	333	**1277**	93	49	66	74	**282**	43	34	60	66	**203**	41	31	55	59	**186**
11	*Grewia flava*	272	372	368	484	**1496**	559	809	1030	1042	**3440**	102	149	195	193	**639**	102	149	195	193	**639**	75	111	154	147	**487**
16	*Searsia tenuinervis*	44	76	24	36	**180**	52	42	7	14	**115**	12	9	2	3	**26**	12	9	2	3	**26**	9	7	1	2	**19**
17	*Terminalia sericea*	8	20	12	36	**76**	61	365	89	548	**1063**	14	81	20	121	**236**	14	81	20	121	**236**	12	73	17	110	**212**
18	*Ziziphus mucronata*	36	20	8	16	**80**	719	269	42	268	**1298**	159	59	9	59	**286**	159	59	9	59	**286**	146	54	*8*	*54*	***262***

By using the phenology values (Table 6.5), the browsing capacities were calculated for the total area (55.4 km² for the main herd) utilized for each month of the year. During August and September, the months following winter, it was clear that the ha per BU were higher than in the months after the growing season (April or May) (Figure 6.10 & 6.9). This can be explained by the condition of the vegetation being not as good as after the growing season when new plants have grown and the nutritional value of the trees has increased. If the browsers were only relying on browse below 1.5 m height, then 126.7 ha would be needed to sustain one BU for one year. Similarly, 85.3 ha are needed to sustain one BU for one year if the browser was relying on browse below 2.0 m, but only 27.7 ha are needed if the browser can feed up to 5.0 m.

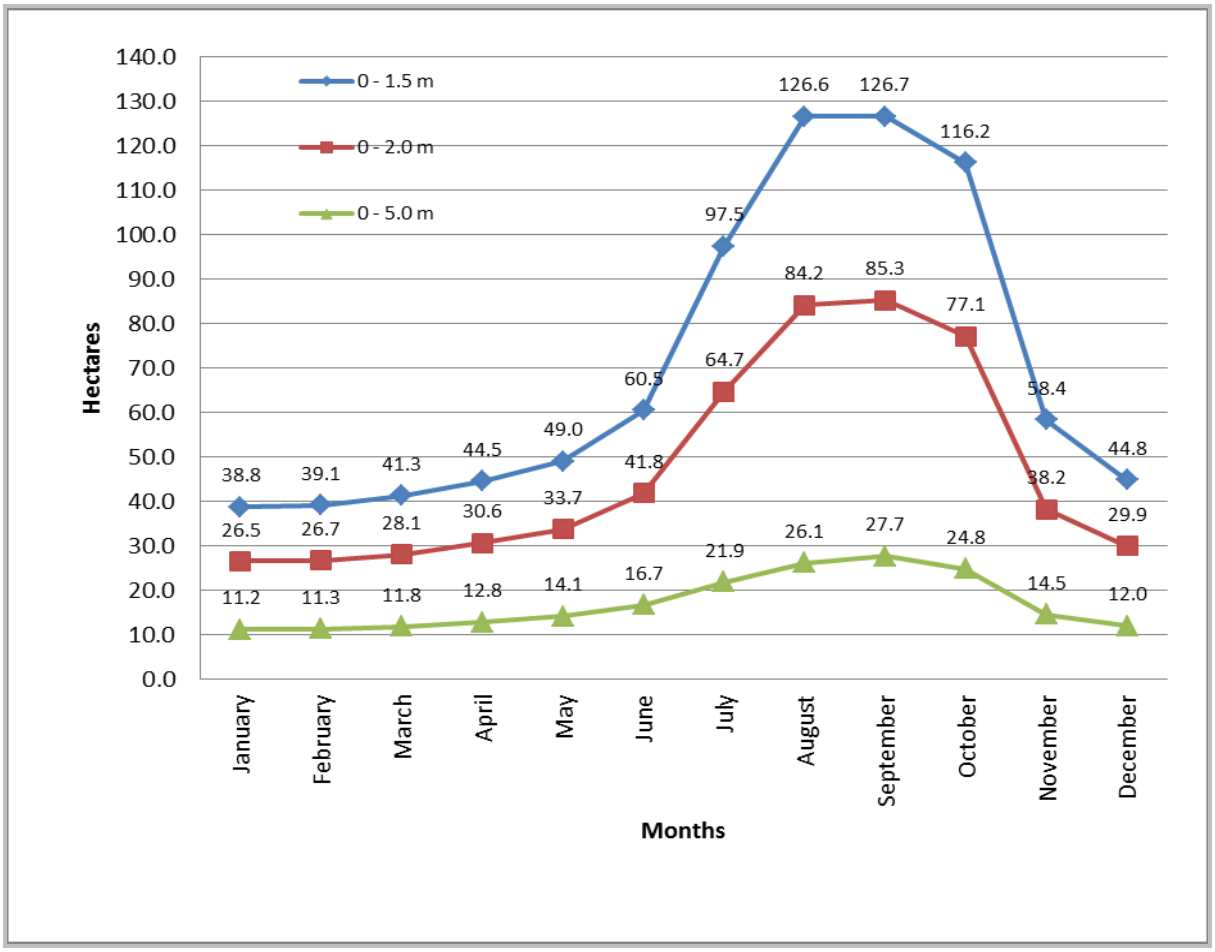


Figure 6.9 Total hectares needed to sustain one browser unit (BU) for one year on height strata 1.5 m, 2.0 m and 5.0 m

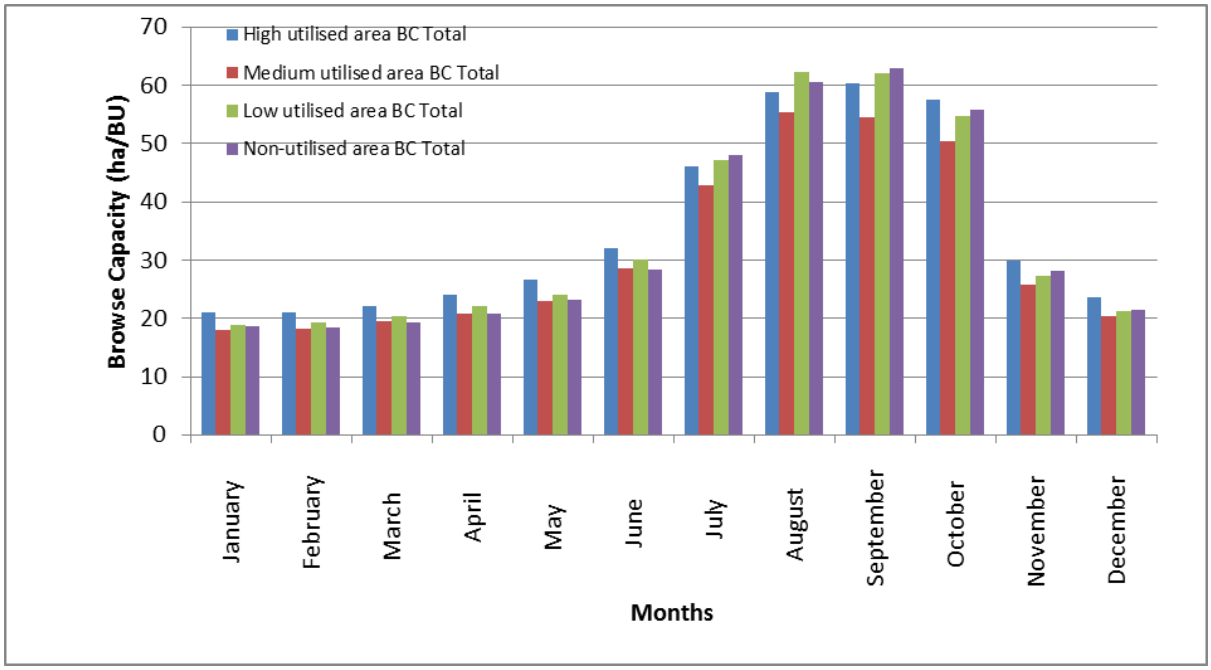


Figure 6.10 Total browsing capacity of KKNR for each vegetation area by month of the year

The total browse or total dry matter per hectare (DM ha^{-1}) of KKNR (Figure 6.11) shows the same tendency as Figure 6.13 for the same reasons. When comparing the dry matter per hectare between the different utilized areas, it is clear that the dry matter showed a definite decline from the highly utilized areas to areas of low utilization. It is evident which key species contributed the most to the total dry matter per hectare in Figure 6.11.

The recorded tree species include protected species such as *A. erioloba* and *B. albitrunca*. Although bush encroachment and thickening is seen as a common problem in many savanna areas of Southern Africa, including the Molopo Bushveld, Kalahari Plains and Thorny Bushveld, it is a relatively slow process and what is visible today is mainly the result of the previous management history of the farms. The data from the surveys indicated that bush thickening in some areas might be a problem in KKNR, but is fortunately restricted to a few small areas, notably where *A. mellifera* is the dominant species, such as in the areas of low utilization (Figure 6.13 and Table 6.8).

At browsing heights of 0 – 2.0 m where most animals browse, with the exception of giraffes that can reach up to 5.0 m, the highly utilized areas (Figure 6.10 and 6.11) produced the highest browse quantities. Low utilized areas contributed the least amount of available browse (Figure 6.10 and 6.11) and these are also the most disturbed areas.

Characteristics of the highly utilized areas included an abundance of key woody species (Figure 6.13) and the soil comprised deep Kalahari sand. The species variety of the herbaceous layer of the ten survey plots differed, but unlike the rest of the vegetation units, non-grasses were almost absent. The species composition did not vary substantially among the ten survey plots. The highest dry matter DM yield was recorded in this vegetation area (Figure 6.11 and Table 6.7). A high yield (shoot diameter < 2.0 mm = 1 545 kg DM ha^{-1} plus the total leaf mass = 1 302 kg DM ha^{-1}) of 2 847 kg DM ha^{-1} in total was recorded for the

highly utilized areas (Table 6.7). This would make these areas favourable for giraffes and if mismanaged, the giraffes may have a negative impact on this type of habitat with resulting decrease in overall production.

A notable factor in this high production was the presence of large *A. erioloba* trees. It is known that trees create islands of elevated soil nutrients under their canopies, which is especially important on nutrient poor soil such as the Kalahari sands (Hagos & Smit, 2005). Typical of the deep Kalahari sands, the characteristic species of the woody layer was *A. erioloba*, and some exceptionally large individuals were present. *A. mellifera* and *G. flava* were also abundant (Figure 6.13), but due to their smaller size, they were not as distinctive as the large *A. erioloba* trees. Tables 6.6 and 6.7 show that number of plants/ha does not necessarily imply that they contribute the highest DM ha^{-1}, but the Evapotranspiration Tree Equivalent (ETTE/ha) is the most important factor giving 5 696 kg DM ha^{-1}. The browse value of *A. erioloba* in the highly utilized areas was the highest at 2 282 ETTE ha^{-1} and therefore contributes most to the high percentage preference by giraffes. Giraffe preference for such areas could lead to over-utilization in the long term, if giraffe numbers are above the carrying capacity.

Characteristics of the vegetation within the medium utilized areas in terms of plants ha^{-1} included tree species dominated by *G. flava, A. erioloba* and *A. mellifera* (Table 6.8). Tree densities were low and the ETTE/ha-values of all ten survey plots were half of those from the highly utilized areas for *A. erioloba,* (1 226 out of the total 5 040 kg DM ha^{-1}) (Table 6.7 & 6.7). Vegetation within the medium utilized area, however, had the highest plants/ha score, at 1 084 plants/ha (Table 6.7 and Figure 6.13). This could influence the impact giraffes might have, as they avoid very dense habitats.

Distinctive of the vegetation within the areas of low utilization was the near absence of woody plants in large areas of this vegetation unit. In contrast to the other vegetation areas, the few woody plants present were almost exclusively *G. flava* and *A. mellifera* (Table 6.8). This is the direct result of using arboricides and shows the effect of chemicals on vegetation. *G. flava* in particular is not as severely affected by arboricides as *A. erioloba, A. luederitzii* and *Z. mucronata.* Tree densities were low and the ETTE/ha-values of all ten survey plots were 3 646 ETTE/ha, which is the lowest for all the vegetation areas utilized. Table 6.7 indicates that, as expected, the leaf mass and shoot mass were the lowest recorded. These low utilized areas had the fewest *B. albitrunca* and *Z. mucronata* of all the utilized areas (Table 6.8 and Figure 6.13). The *A. erioloba* in this area were dead (remnants of the arboricides), and therefore did not contribute to the biomass available for browse. This suggests that giraffes prefer areas with *B. albitrunca* and *Z. mucronata.*

The vegetation from the unutilized areas was divided into two units, 4.1 and 4.2, which were very distinct from each other. Unit 4.1 had the typical small, low woody plants that add little in browse production to the small to medium plants in the study area. Unit 4.2 is generally one of the most balanced vegetation types within the whole of KKNR from own observations. The unutilized vegetation areas had almost the same tree density (plants/ha^{-1}) as the low utilized areas, but had far lower ETTEs (Table 6.8) and differed in tree species. In these areas, however, no water was provided by KKNR management, which could possibly be a reason why these areas were under-utilized and not used to their full potential. This could also indicate that browsers such as giraffes might negatively influence preferred vegetation close to water, but less so farther away from water.

The impact of giraffes is further influenced by the characteristics of the plant growth. Not all the vegetation areas contributed to the full production for browsers, as some areas were influenced by mismanagement. There was a high production of biomass in the 0-2.0 m strata (Figure 6.13). Stuart-Hill & Tainton (1988) discussed similar results for the Eastern Cape where high (> 2.0 m tall) and medium trees (1.4 – 1.8 m tall) produced significantly similar quantities of browse, but still much higher yields than those in the low stratum (0.8 – 1.2 m). Dekker & Smit (1996) determined that the highest browse production was present in the 1.5 m – 2 m height stratum in seven of the eight plant communities on the Messina Experimental Farm, Limpopo Province.

Abule *et al.* (2007) reported that browse production in the Awash valley of Ethiopia was the highest in the 1.5 m – 2.0 m height stratum, followed by the height stratum of <1.5 m. These production results in the 2 m height stratum from the savanna areas agree with findings in the current study. Abule *et al.* (2007) stated that there are limited published results of browse production for comparison.

The biggest differences between seasons in terms of number of ha needed per browser unit were observed from July to October (Figure 6.10). Depending on the rainfall, September and October are normally the months when deciduous woody species sprout new leaves after the winter (Table 6.6) Abule *et al.* (2007) indicated differences in ranges between dry (17 – 25 ha/BU) and wet months (7 – 13 ha/BU) in diverse areas of their study terrain in Ethiopia. The seasonal pattern in browsing capacity in the current study area corresponded with the seasons and followed the inverse pattern of leaf phenology. For practical and management reasons this also illustrates that a large area (ha) is needed per browser unit (lower browsing capacity) when leaf carriage is low in July, August, September and October.

Results from Janecke & Smit (2011) in the central Free State in South Africa demonstrate that new-season leaves appeared with regularity during the second part of September and that active growth ended in March. Yellow leaves appeared in April and dry leaves ocurred until June for both *A. karroo* and *Diospyros lycioides*. *Z. mucronata* had leaf flush in the second part of October, budding leaves appeared at the end of September and active growth was October to March. Leaves turned yellow in May and *Z. mucronata* was leafless from the end of September to mid-October in the central Free State region, South Africa. In KKNR, *Z. mucronata* shows leaf senescence in early May, which lasts until mid-November, with active growth only starting at the end of November. Unfortunately this region in the Free State does not have *A. erioloba, A. luederitzii* or *A. mellifera* to compare with results from KKNR.

The number of browser units (BU) that can be maintained by the study area, as adjusted to the leaf carriage percentages per month in each season, are presented in Figure 6.9. Barnes (1976) stated that it is necessary to define the height to which animals can browse and to relate dimensions to the production of edible material below the height strata where leaves occur above the reach of browsing animals. This is the case with the 0 – 5.0 m and >5.0 m height strata, where most of the browse is out of reach of animals smaller than an adult giraffe bull.

Based on the browsing capacity calculations presented in Figure 6.10 and the areas covered by each of the vegetation units, the total number of BUs that KKNR can support was calculated and presented in Table 6.10. It is demonstrated that the number of browser units

currently utilizing the material at height strata 1.5 m – 2.0 m within KKNR is too high and puts extra pressure on juvenile giraffes. From other studies (Kok & Opperman, 1980; Theron, 2005) it was recorded that giraffes occasionally feed on herbs and grasses. The added pressure is also seen in the fact that the giraffe numbers are not increasing. The reason for this could be the increasing competition between juvenile giraffes and other herbivore species, especially elands, since the eland is a very robust and tough animal with respect to feeding resources.

The tree layer of KKNR is characterized by a high abundance of *A. mellifera* and *Grewia spp*. From a browser's point of view, these species are either winter deciduous or unpalatable for some reason. One of the key browse species for giraffes during the dry period (August – October) was *Boscia albitrunca*. Therefore, this woody species can be considered a key resource for browsers and giraffes during the critical period from August to October when the winter deciduous species had lost their leaves. As seen in Table 6.8 they occurred in low numbers and they can be considered an indicator species (i.e. when their numbers are declining, or if they are over-utilized, then management should take notice and modify the management plan accordingly).

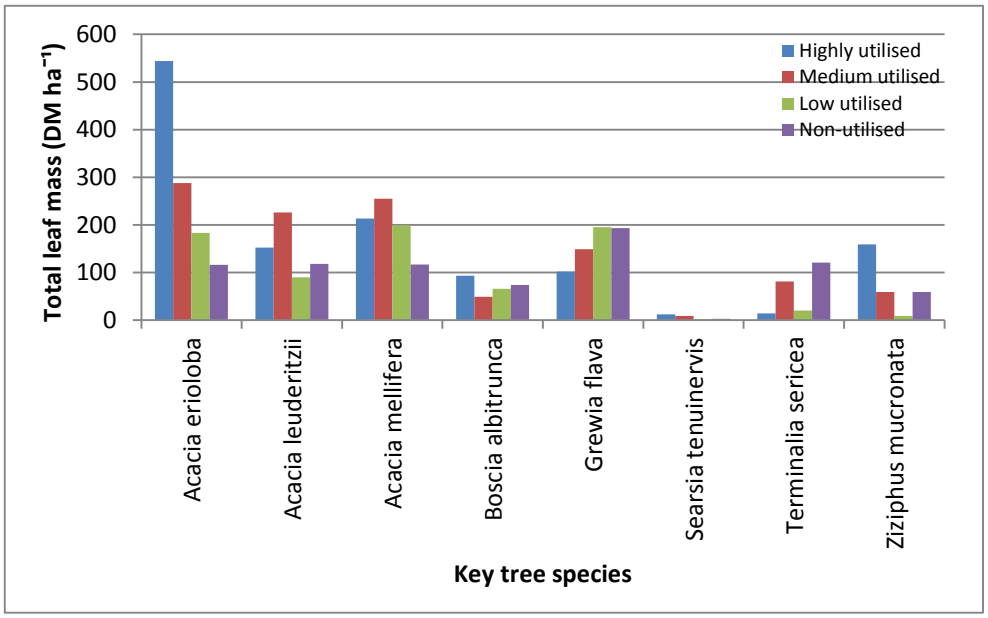


Figure 6.11 Dry leaf mass per ha (DM ha⁻¹) for each of the key tree species and dry matter per ha for each of the utilized areas

The calculation of the ETTE and BTE are based on the relations between the spatial volume of a tree and its true leaf dry mass and true leaf volume respectively. The number of Evapotranspiration Tree Equivalents per ha (ETTE ha⁻¹) is presented in Figure 6.12, with the key plant species and the different utilized areas. When evaluating and interpreting results of any plant-based study, four important factors should be taken into consideration. These four factors can be divided into two main effects:

- A negative effect on plants as the result of the decrease of either plants or plant material. This can either occur due to mortality of plants or over-utilization of plants.

- A positive effect on plants as the result of an increase of plants or plant material. This can occur due to the growth of new saplings or resettlement, as well as the growth of established plants. This should, however, not exceed the threshold and cause bush thickening.

The negative and positive effects work against each other, influencing each other continuously. The available plant material in an area depends on the effects that have the greatest influence on the plants during that given time, or in the long-term. This competition effect (positive vs negative) can be seen in Figure 6.12 where a positive threshold appears for *A. erioloba* in the highly utilized areas and a negative effect in unutilised areas, with *G. flava* indicating the negative effect. Here, the total ETTE ha^{-1} for each key species within each utilized area can be seen, with *A. erioloba* having the highest value.

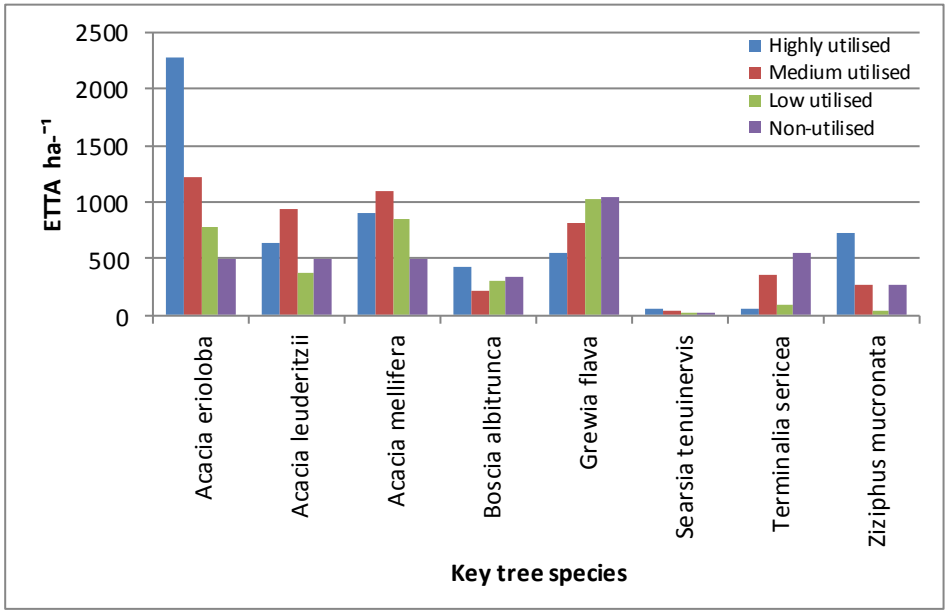


Figure 6.12 Total Evapotranspiration Tree Equivalents (ETTE ha^{-1}) for each of the key species within the utilized areas.

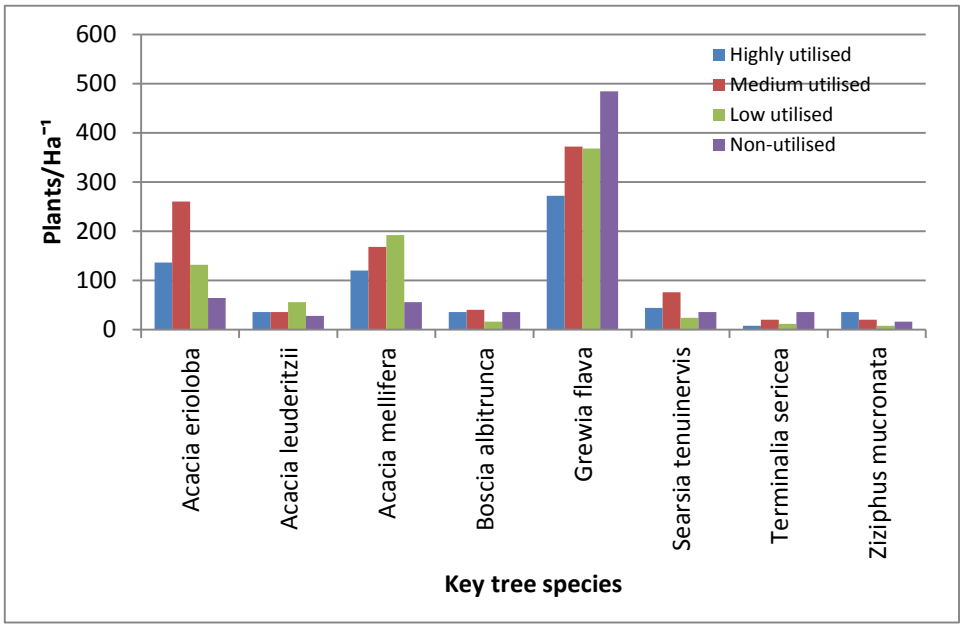


Figure 6.13 Total plants per ha for each of the key species within the utilized areas.

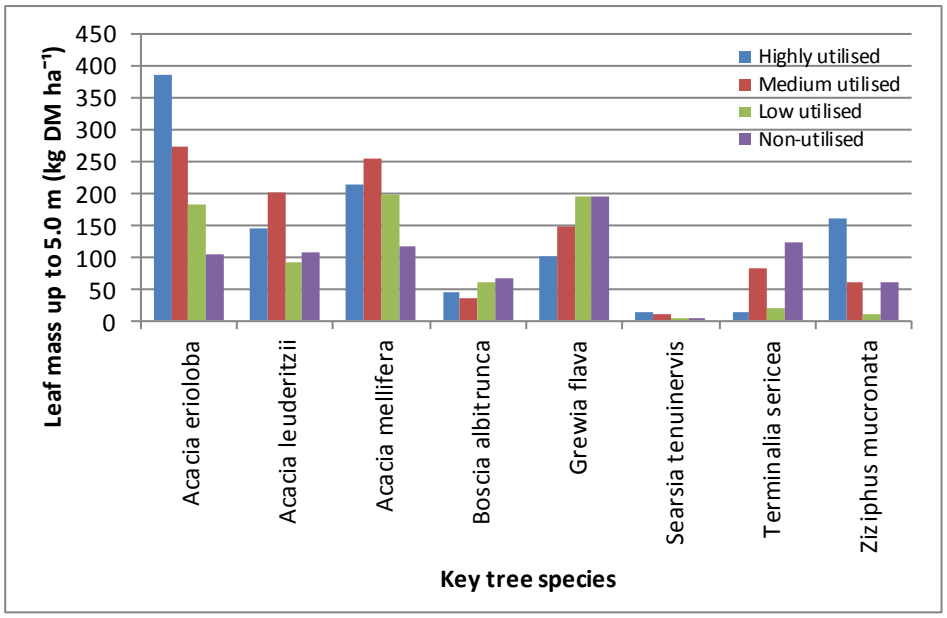


Figure 6.14 Total leaf dry mass up to 5.0 m (kg DM ha⁻¹) for each of the key species within the utilized areas

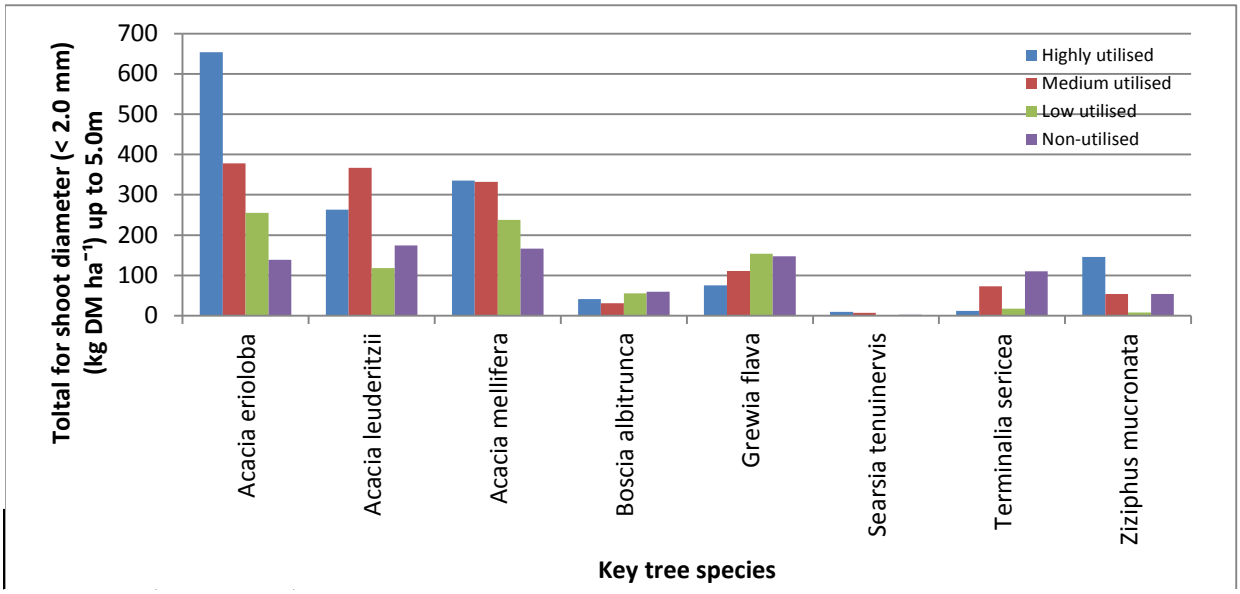


Figure 6.15 Total shoot mass (< 2.0 mm in diameter) (kg DM ha⁻¹) for each of the key species within the utilized areas

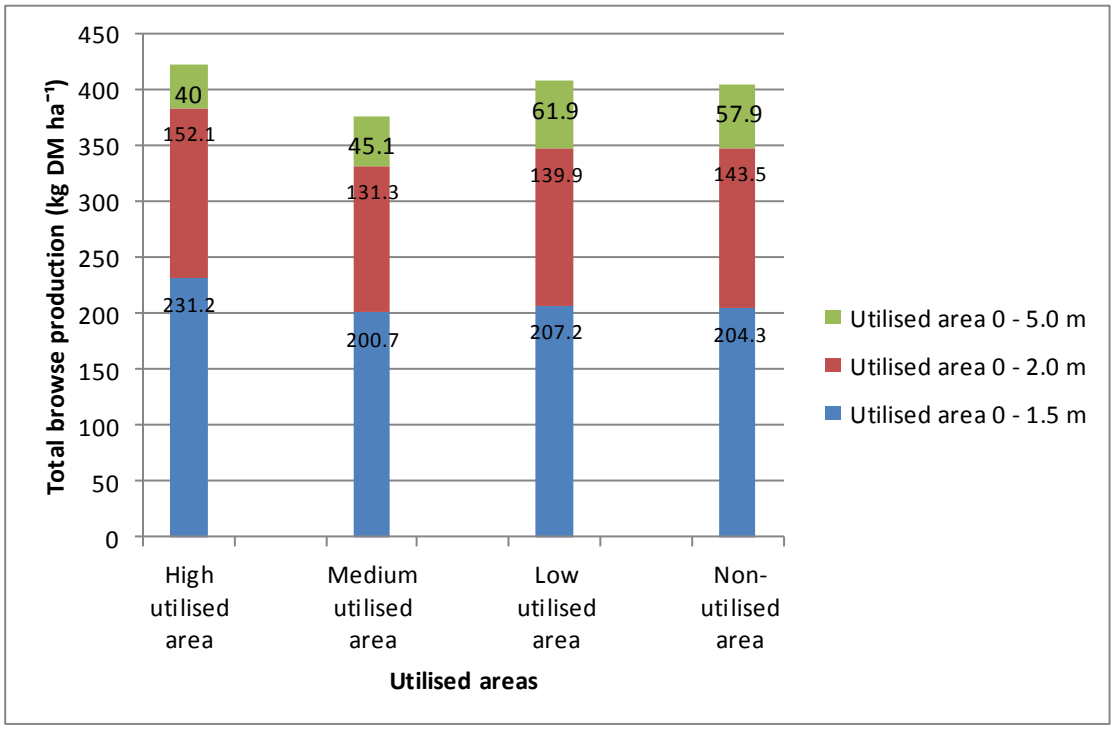


Figure 6.16 Browse production totals between different vegetation areas utilized for each height stratum. Total kilogram per hectare (kg DM ha⁻¹) for highly utilized areas n = 423, medium utilization areas n = 377, low utilization areas n = 409 and unutilized areas n = 405

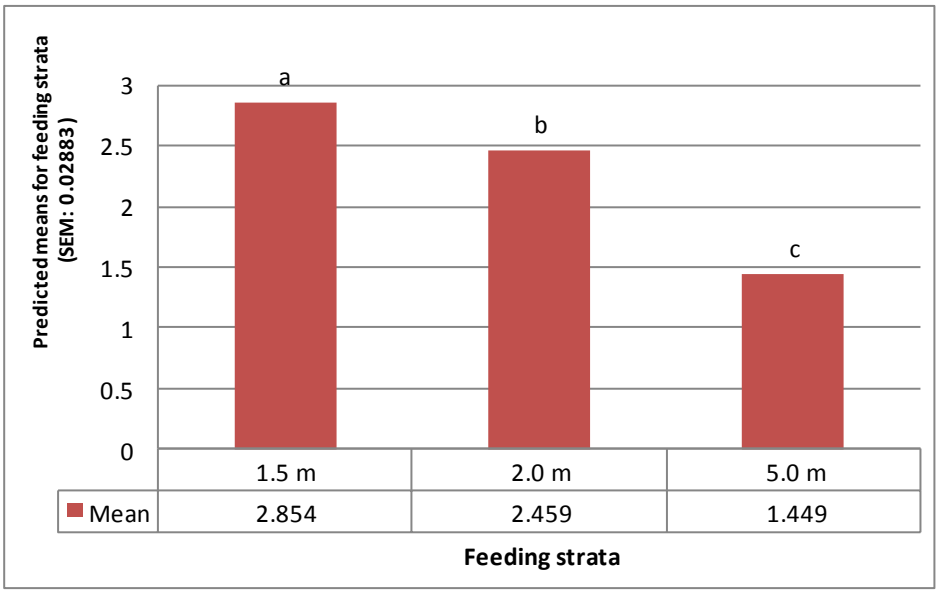


Figure 6.17 Feeding strata effect on the browsing capacity

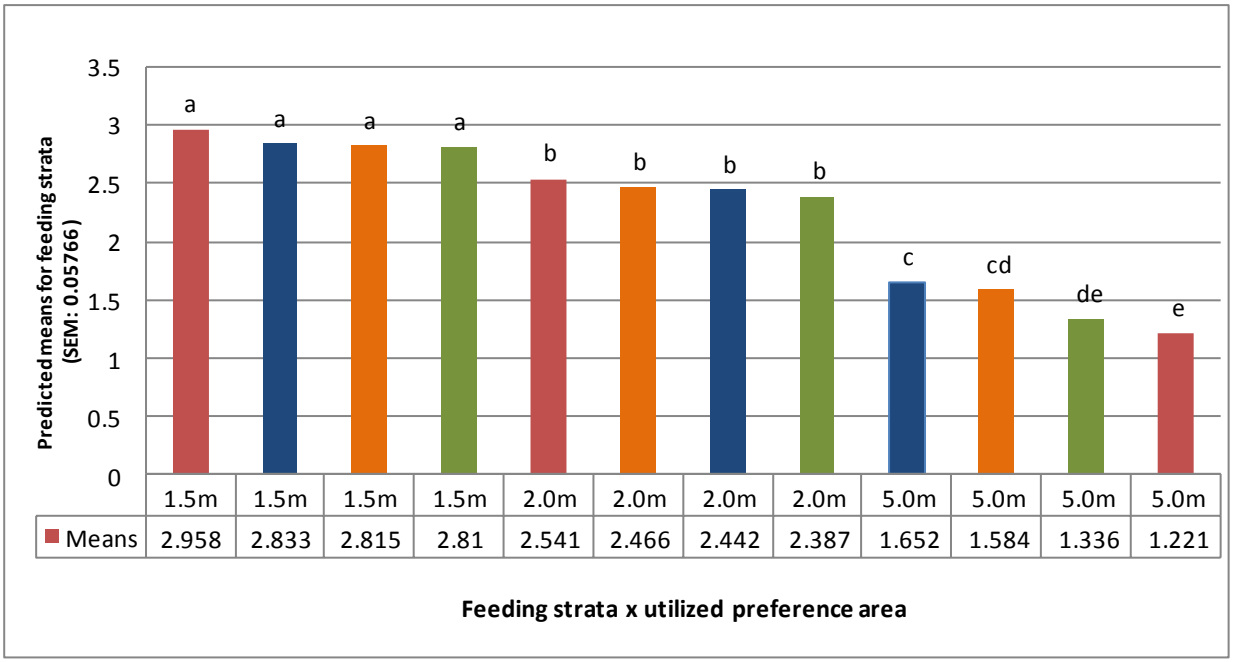


Figure 6.18 Predicted means for the different feeding strata within each utilized area (red = highly utilized areas, green = medium utilization areas, blue = low utilization areas, orange = unutilized areas)

A summary of the highly significant (P<0.001) predicted means for different height strata on the browsing capacity can be seen in Figure 6.16 (untransformed scale). On the transformed scale (Appendix F) this would mean that plant material below 1.5 m (17.4) followed by plant material below 2.0 m (11.7) had the biggest effect on the browsing capacity between utilized areas. Browsing capacity is the least influenced by the plant material from 2.0 m to 5.0 m. Plant material above 2.0 m shows the most variation between the utilized areas, with highly utilized areas having some similarities with medium utilized areas, which have some

similarities with low utilized areas, which have some similarities with unutilized areas. Highly utilized areas differ substantially from low- and unutilized areas. This indicates that more hectares are needed to sustain one browser unit on plant material below 1.5 m compared to plant material up to 5.0 m in the low- and unutilized areas than in the highly utilized areas.

Figure 6.17 shows the highly significant (P<0.001) interaction between different height strata within the different utilized areas on the browsing capacity (untransformed scale). On the transformed scale (Appendix F) this would mean in utilized area 1 that the plant material below 1.5 m (19.3) has the least effect on the browsing capacity (as BC is a direct function of the plant material quantity), but the biggest effect on plant material up to 5.0 m (3.4). Browsing capacity is the least stable between 2.0 m and 5.0 m, indicating that smaller trees <1.5 m provide more stable and sufficient plant material, by adding to the browsing capacity in the low- to unutilized areas, than trees >2.0 m (they are absent because of previous misuse of arboricides in these areas). Thus the areas preferred by giraffes (such as highly utilized areas without human disturbance) are the areas with the highest number of taller trees (≥2.0 m – 5.0 m), and the lowest number of smaller trees (<1.5m).

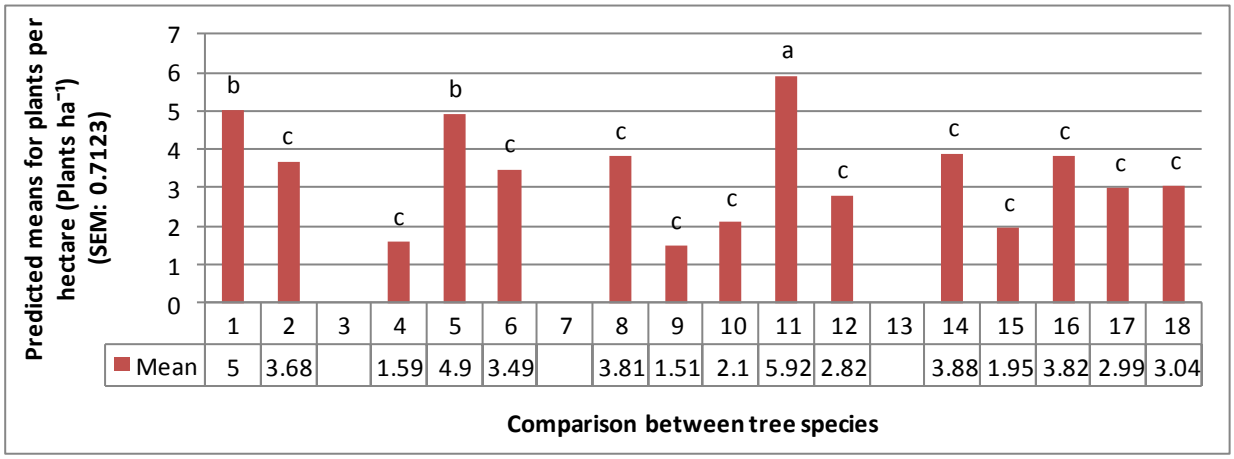


Figure 6.19 Tree species density per hectare

Comparisons from the predicted means for plants per ha are shown in Figure 6.19. Species no. 11 (*G. flava*) had the highest mean (5.92) and had the highest density in plants per ha ("a" value, Figure 6.18), followed by species no. 1 (*A. erioloba*) (5) with a "b" value and species no. 5 (*A. mellifera*) (4.9) also with a "b" value. All the other species showed the same "c" value in density (untransformed scale). On the transformed scale (Appendix F) this would mean plant species 11 (372.0), species 1 (147.8) and species 5 (133.9) represent the highest density of plants per ha. These three tree species constitute almost 70% (68.98%) of all trees represented in KKNR. The implication of this would mean that if *A. erioloba* were removed, damaged or negatively influenced on a large scale – it would have a direct effect on the giraffe population within KKNR (see chapter 7, tree species preference).

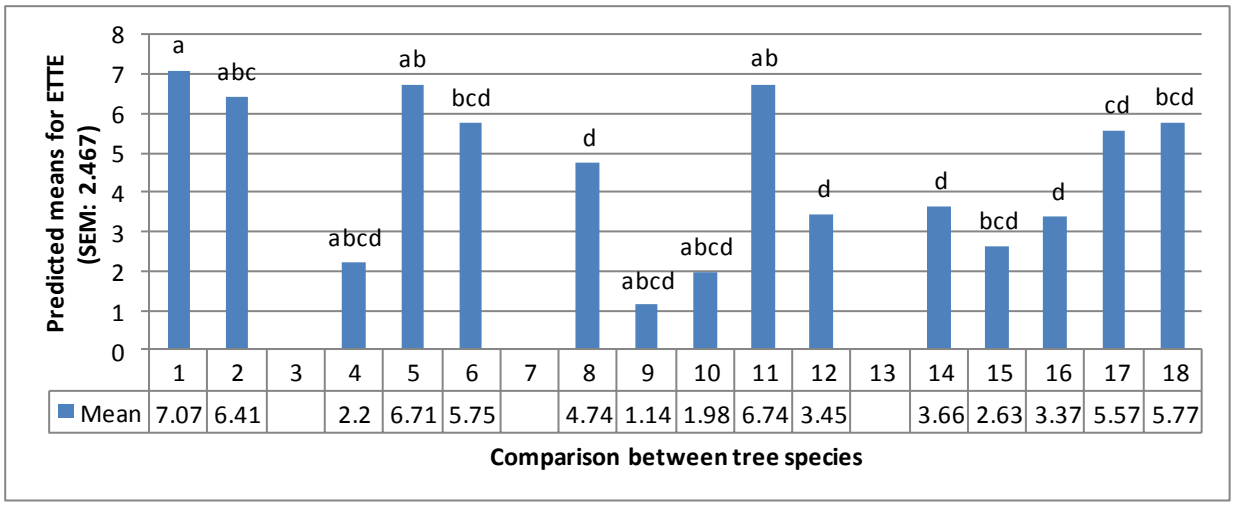


Figure 6.20 Evapotranspiration Tree Equivalent value for each tree species (ETTE)

Species no. 1 (*A. erioloba*) was highly significantly different (P<0.001) from the other tree species and provided the highest value in terms of the Evapotranspiration Tree Equivalents (ETTE) (Figure 6.20) (untransformed scale). On the transformed scale (Appendix F) this would mean plant species 1 (1 173.8), plant species 11 (845) and plant species 5 (821.5) represent the highest number of ETTEs. Unfortunately, these three trees are deciduous and season has an effect on them (Figure 6.16 and 6.20). The ETTE also differed significantly (P=0.042) between the utilized areas.

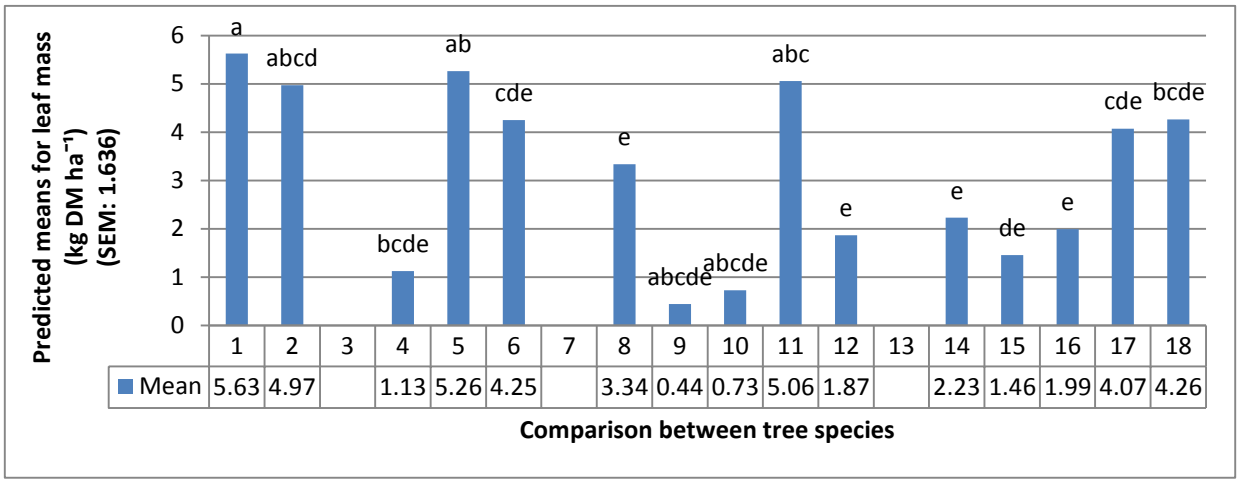


Figure 6.21 Total dry leaf mass value for each tree species

Species no. 1 (*A. erioloba*) was highly significantly different (P<0.001) from the other tree species and provided the highest value (per plant) in terms of the total leaf mass (Figure 6.21) (untransformed scale). On the transformed scale (Appendix F) this would mean plant species 1 (277.5), plant species 11 (157.2), plant species 5 (192.7) and plant species 2 (*A. luederitzii,* 144.3) were producing the highest proportion of the total leaf mass in KKNR,

implying that, if *A. erioloba* were to be removed, giraffes would be negatively affected. The Wald statistic also demonstrated that the total dry leaf mass per tree species (kg DM^{-1}) differed significantly (P=0.02) between the utilized areas (Appendix F).

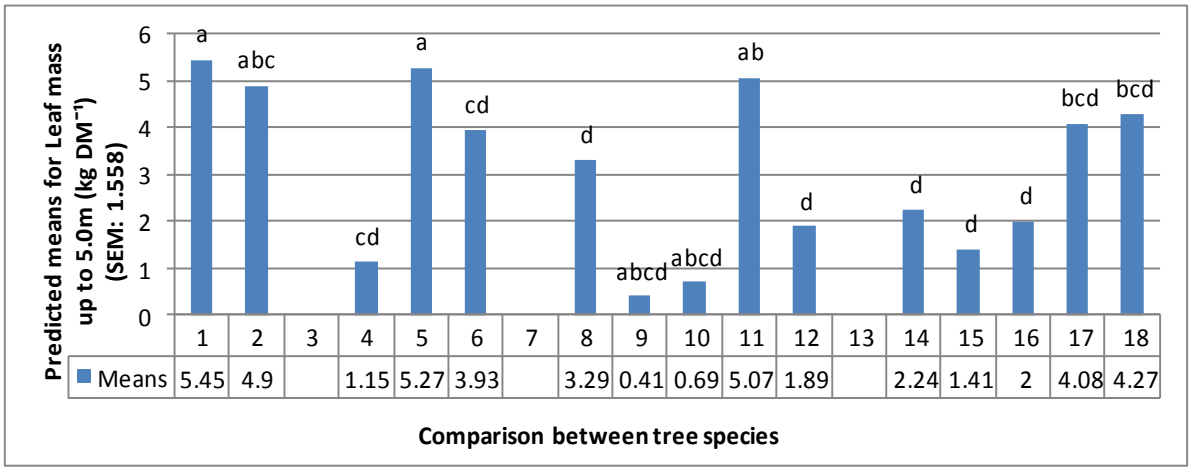


Figure 6.22 Leaf mass value for each tree species for height strata up to 5.0 m (kg DM^{-1})

Figure 6.22 illustrate how much *A. erioloba* contributed in significance, differing from all the other species and how much value it added to the feeding habitat (untransformed scale). On the transformed scale (Appendix F) this would mean plant species 1 (*A. erioloba*) contributed 233.3 units to the total leaf mass up to 5.0 m.

6.3.4. Actual and available browser units

The total browser units for each month were calculated from the numbers of the different browser species currently present in KKNR.

Table 6.9 List of current browsers within KKNR following the most recent aerial census (2013)

Species	Plant material	Plant material	Plant material	Animals counted	BU representation
	< 1.5 m	**< 2.0 m**	**< 5.0 m**	**(N)**	
Giraffes	Yes (♀ & sub-adult ♂)	Yes (♀ & sub-adult ♂)	Yes (only adult ♂)	111	577
Kudus	Yes	Yes	No	803	803
Elands	Yes	Yes	No	2 086	4 589
Impalas	Yes	No	No	141	14
Springboks	Yes	No	No	1 397	140
Duikers	Yes	No	No	74	15
Steenboks	Yes	No	No	296	21
Total				**4 908**	**6 159**

Table 6.10 Summary of the total browser units (BU) the KKNR can sustain on each height stratum <1.5 m, <2.0 m and <5.0 m

MONTH	Browsing Capacity 1.5 m	Total BU (up to 1.5 m) that can be sustained for the month	Number of giraffes that can be sustained on 95 653 ha each month (1 giraffe = 5.2 BU)	Number of giraffes that can be sustained on 55 400 ha roamed by the main herd
January	9.6	9963.9	1916.1	1109.8
February	9.7	9861.1	1896.4	1098.4
March	10.2	9377.7	1803.4	1044.5
April	11	8695.7	1672.3	968.6
May	12.1	7905.2	1520.2	880.5
June	15	6376.9	1226.3	710.3
July	24.4	3920.2	753.9	436.7
August	31.7	3017.4	580.3	336.1
September	31.6	3027.0	582.1	337.2
October	28.9	3309.8	636.5	368.7
November	14.5	6596.8	1268.6	734.8
December	11.1	8617.4	1657.2	959.8

MONTH	Browsing Capacity 2.0 m	Total BU (up to 2.0 m) that can be sustained for the month	Number of giraffes that can be sustained on 95 653 ha each month	Number of giraffes that can be sustained on 55 400 ha roamed by the main herd
January	6.6	14492.9	2787.1	1614.3
February	6.6	14492.9	2787.1	1614.3
March	7	13664.7	2627.8	1522.0
April	7.6	12585.9	2420.4	1401.9
May	8.4	11387.3	2189.9	1268.4
June	10.4	9197.4	1768.7	1024.4
July	16.1	**5941.2**	1142.5	661.8
August	21	**4554.9**	875.9	507.3
September	21.2	**4511.9**	867.7	502.6
October	19.1	**5008.0**	963.1	557.8
November	9.5	10068.7	1936.3	1121.5
December	7.4	12926.1	2485.8	1439.8

MONTH	Browsing Capacity 5.0 m	Total BU (up to 5.0 m) that can be sustained for the month	Number of giraffes that can be sustained on 95 653 ha each month	Number of giraffes that can be sustained on 55 400 ha roamed by the main herd
January	2.7	35427.0	6812.9	3946.0
February	2.7	35427.0	6812.9	3946.0
March	2.9	32983.8	6343.0	3673.9
April	3.1	30855.8	5933.8	3436.9
May	3.4	28133.2	5410.2	3133.6
June	4	23913.3	4598.7	2663.6
July	5.3	18047.7	3470.7	2010.2
August	6.3	15183.0	2919.8	1691.2
September	6.7	14276.6	2745.5	1590.2
October	6	15942.2	3065.8	1775.7
November	3.5	27329.4	5255.7	3044.1
December	2.9	32983.8	6343.0	3673.9

The number of browser units (Table 6.10) that can be maintained by the total area for the different height strata of the plant material was determined to be:

- **3 027 BU** for plant material ≤1.5 m
- **4 512 BU** for the plant material ≤2.0 m; thus 4 512 BU – 3 027 BU = 1 485 BU for the plant material between 1.5 m and 2.0 m
- **14 277 BU** for the plant material ≤5.0 m; thus 14 277 BU – 4 512 BU = 9 765 BU for the plant material between 2.0 m and 5.0 m

A total of 4 512 browser units can thus be maintained by the calculated biomass available in the KKNR below 2.0 m. The number of browser units presently utilizing the plant material in KKNR was calculated from the number of browsers or mixed feeders currently present in the KKNR feeding up to 2.0 m, as well as the substitution values in Table 6.8 & 6.9. This would mean that 9 765 BUs are available only for giraffes between the 2.0 m and 5.0 m strata.

According to the BECVOL-3 calculations, the total BUs currently present in the KKNR = 6 159 BUs, which does not exceed the maintenance potential and carrying capacity of KKNR of 14 277 BU up to 5.0 m level. However, if the feeding of giraffes is excluded above 2.0 m (6 159 BU – 577 BU = 5 582 BU), then KKNR is overstocked by 1 070 BUs (5 582 BU – 4 512 BU). The giraffes contribute 577 BU of the total of 14 277 BU currently within KKNR, kudus contribute 809 BU and elands 4 589 BU (Table 6.7). This highlights key information for the critical period (July - October) when KKNR would be almost 20% overstocked. During these four months the BUs currently within KKNR exceed the carrying capacity calculated for plant material ≤2.0 m. This would further mean that if giraffes are feeding below 2.0 m during these four months, they would directly compete with kudus and elands for the same resources. Juvenile giraffes would, therefore, be affected the most and this could be one of the main reasons why giraffe mortalities are the highest for giraffes younger than one year, and why giraffe numbers are not increasing within KKNR. Kudus and elands also feed on herbs and grasses, and do not rely completely on woody tree species for their survival.

6.3.5. Seasonal effect on browsing capacity

Ordinations using the browsing capacity (ha/BU^{-1}) data obtained from the BECVOL 3 technique from the CANOCO 4 (TerBraak & Šmilauer, 1998) showed clear differences in browsing capacity (ha/BU^{-1}) for each month and for each season within each of the utilized areas. Figure 6.23 illustrates the ordination of data over a twelve month period, showing clear differences between the utilized areas. When data are grouped together, Figure 6.23 shows the ordination of data between the four seasons and verifies the same differences between the four utilized areas. Medium and low utilization areas had some similarities, but highly utilized and unutilized areas were very different from each other. These figures also show, with reference to either the months or the seasons, that the utilized areas differed from each other in terms of the browsing capacity (ha BU $^{-1}$).

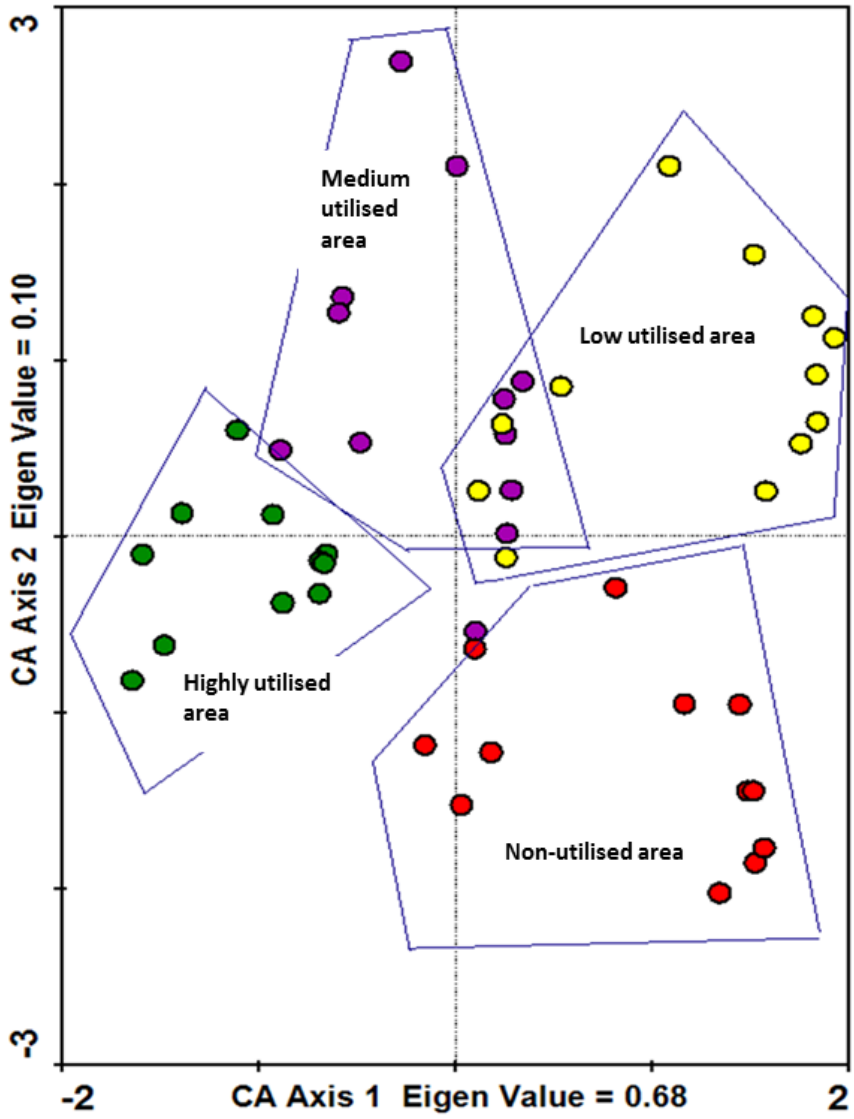


Figure 6.23 Ordination of utilized areas during the months.

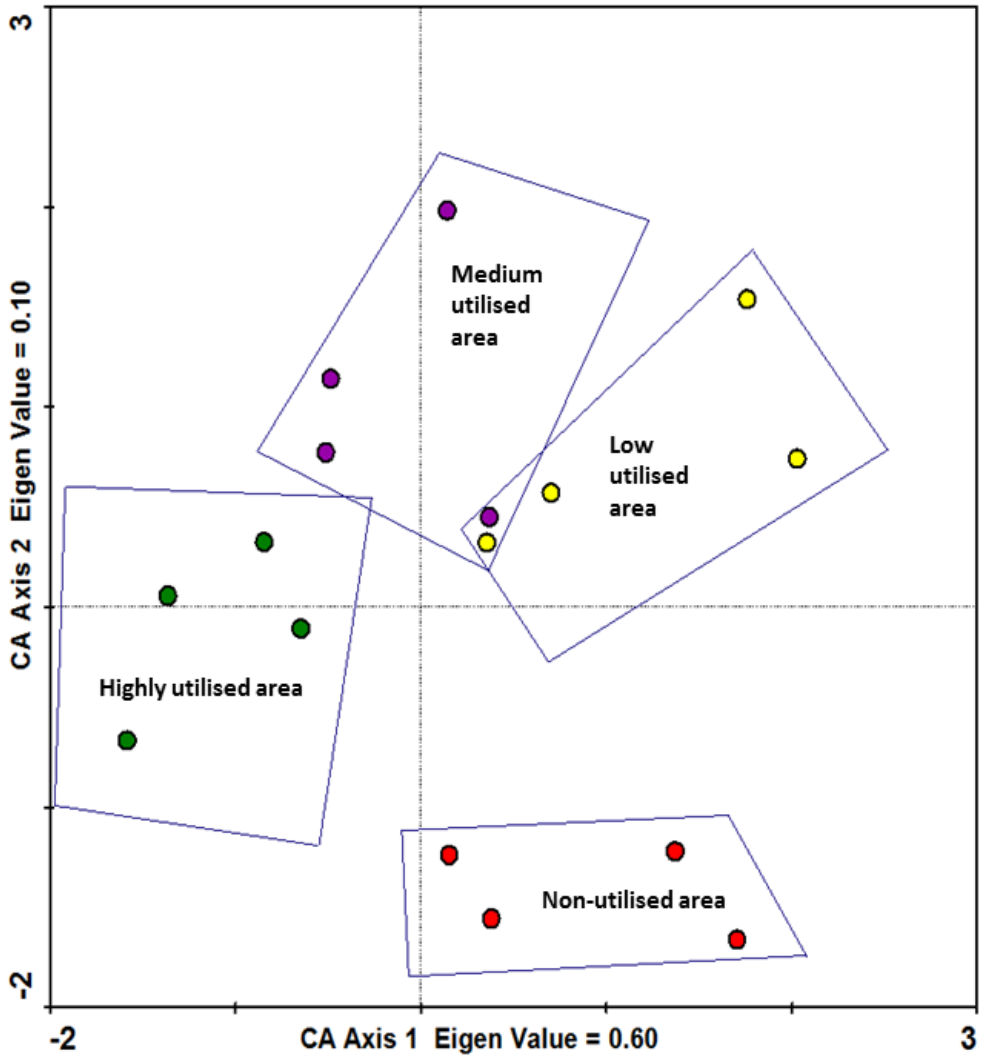


Figure 6.24 Ordination of utilized areas during the four seasons.

The Wald statistic was used to determine high statistical significance ($P<0.001$) regarding the effect of the seasons on the utilized areas (Schall, 1991). The analysis provided sufficient evidence that the different seasons and feeding strata had a significant influence on the browsing capacity (Appendix F Table F.2) of each of the areas.

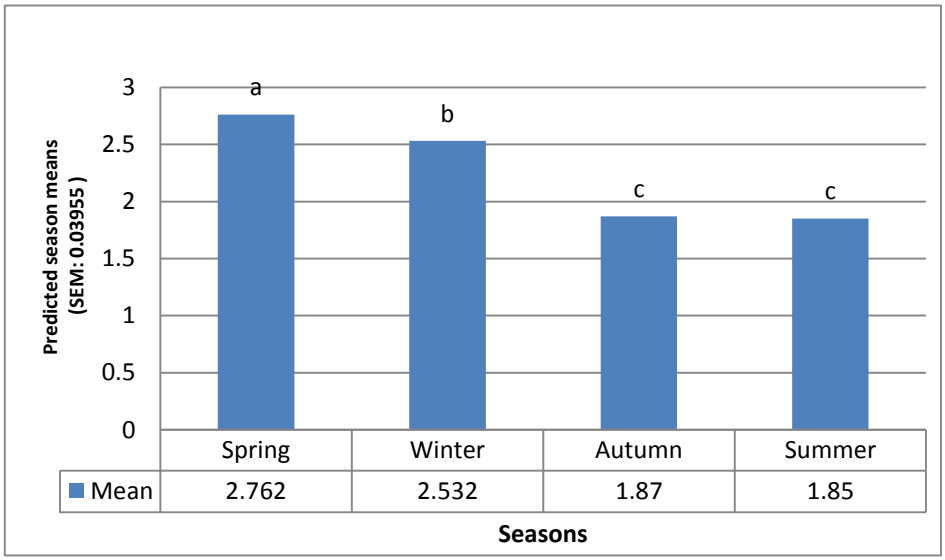


Figure 6.25 Seasonal effect on browsing capacity

The Wald statistic indicated that feeding strata accounted for most of the variation in seasonal differences, followed by utilized areas x feeding strata interaction. The Wald statistic for utilized areas was very low. A summary of the highly significant (P<0.001) predicted means for seasonal effects on browsing capacity can be seen in Figure 6.25 (untransformed scale). On the transformed scale (Appendix F Table F.2) this would mean that the spring (15.8) and winter (12.6) seasons had the biggest effect on the browsing capacity. Browsing capacity was least influenced by summer (6.4) and autumn (6.5) seasons. Spring and winter seasons are the times when most deciduous trees do not have sufficient leaves. These are the critical seasons with insufficient plant material for browsers.

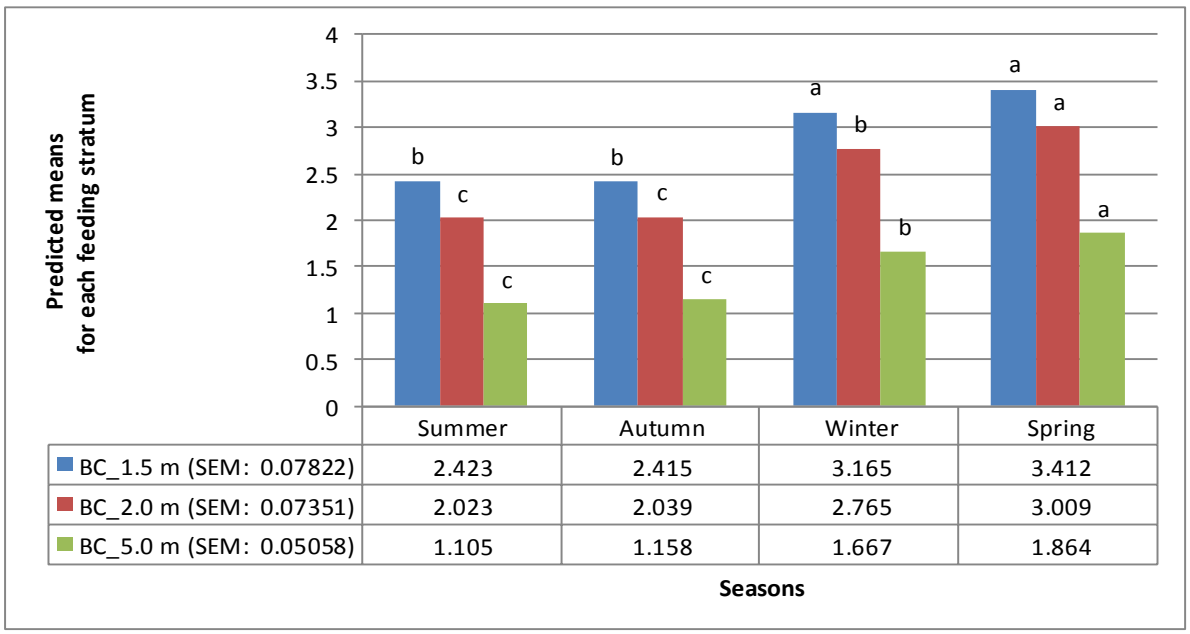
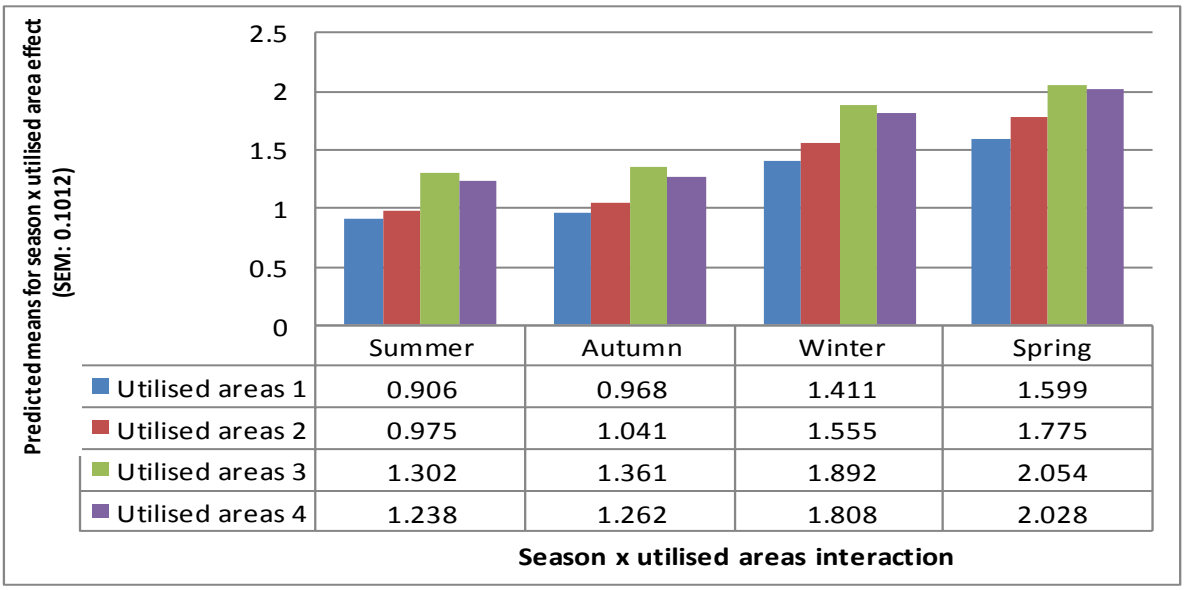


Figure 6.26 Seasonal effects on height strata

Figure 6.26 shows the highly significant (P<0.001) influences each season had on the different height strata (1.5 m, 2.0 m and 5.0 m) (untransformed scale). On the transformed

scale (Appendix F) this would mean that the plant material below 1.5 m in spring (30.3) had three times more effect on the browsing capacity than during summer (11.3) or autumn (11.2). Even for height strata below 5.0 m spring season (6.5) was double that for the summer (3.0). For one browser to survive during spring (eating only plant material up to 1.5 m) a total of 30.3 ha are needed compared to only 6.5 ha needed for plant material up to 5.0 m.



	Summer	Autumn	Winter	Spring
Utilised areas 1	0.906	0.968	1.411	1.599
Utilised areas 2	0.975	1.041	1.555	1.775
Utilised areas 3	1.302	1.361	1.892	2.054
Utilised areas 4	1.238	1.262	1.808	2.028

Figure 6.27 Seasonal effect on utilized areas

Figure 6.27 shows the highly significant ($P<0.001$) influences each season had on the different utilized areas (untransformed scale). On the transformed scale (Appendix F) this would mean the plant material within utilized area 1 (highly utilized areas) during spring (5.0) had twice the effect on the browsing capacity compared to summer (2.5). This can be directly related to the tree phenology (Table 6.4), because in spring most winter-deciduous trees were without leaves (0% - 20%), compared to 80% - 100% with leaves during summer. Even in areas 3 and 4 spring season (7.8 & 7.6 respectively) had almost double the effect compared to area 1. This indicates why giraffes prefer area 1 above the other areas, because the least fluctuation occurred in the browsing capacity between 2.0 m and 5.0 m.

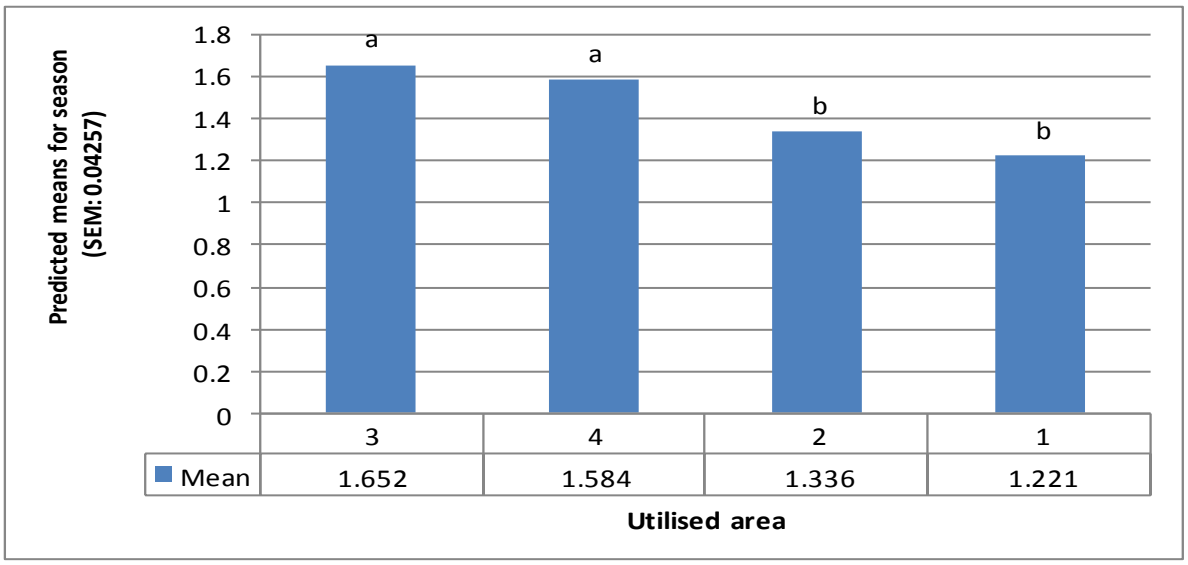


Figure 6.28 Utilized area x season interactions on feeding strata up to 5.0 m

Figure 6.28 illustrates each utilized area's significance up to 5.0 m height and the influence of season (untransformed scale). On the transformed scale (Appendix F) this would mean the plant material within utilized areas 3 (5.2) and 4 (4.9) was more influenced by season than areas 1 (3.4) and 2 (3.8). Spring (6.5) and winter (5.3) had more influence on the browsing capacity up to 5.0 m than summer (3.0) and autumn (3.2) seasons.

6.4. Conclusion

From the results the following can be concluded:

i. This is the first study to make use of the spatial distribution of giraffes to identify preferred areas of utilization where vegetation could be monitored. The GPS collars assisted in identifying utilization areas preferred and areas avoided by giraffes and limited any effect of human subjectivity.

ii. Giraffe clearly favoured areas that were not treated, or have been treated more than 13 years ago and have recovered well. Well recovered areas (>13 years ago) represent 53% of all giraffe locations, indicating giraffe can select for or avoid certain habitat qualities. From a giraffe preference point of view, untreated areas are equally low preferred than poorly recovered areas.

iii. From analysis of the utilized areas it was clear that giraffes favour a very specific habitat type and are influenced by tree density and the availability of dry mass (kg DM^{-1}) of leaves and shoots. In the study area they prefered a tree density of between 744 - 1 084 plants ha^{-1}, but also avoided areas that were too dense. More importantly, giraffes preferred areas with a medium (5 040) to high (5 696) Total Evapotranspiration Tree Equivalents (ETTE ha^{-1}) compared to the low (3 646) and unutilized (3 942) areas. Giraffes also favour areas with high shoot availability (<2.0 mm) within the high preference areas (1 545 kg DM ha^{-1}), which is almost two times more than in the low preference areas (873), indicating that this is one of the main attractions influencing habitat selection other than tree species.

iv. Giraffes rely on key plant species for their main diet. The results demonstrate that giraffes prefer areas with *B. albitrunca* and *Z. mucronata*, but are mostly influenced by the browsing capacity of an area with an abundance of *A. erioloba*. What influences the calculation of browsing capacity for giraffes is the acceptability of the available plant species, the habitat type, the height distribution of the browse material, the phenology of the plant species and seasonal variations in availability of browse. The lack of tree species diversity can result in lower dry matter (kg DM $^{-1}$) preferred by giraffes, which may directly influence their survival and production.

v. The results indicate browsers will experience difficulty finding foliage material during the critical period from July – October below 2.0 m, because the reserve is 20% overtsocked. From the results, there are 1 070 more browsers than the KKNR fenced area can sustain. Giraffes, however, do not rely only on plant foliage up to 2.0 m and can maintain daily requirements feeding on strata above 2.0 m.

vi. Giraffe survival is influenced by the browsing capacity within a fenced off area due to the competition with other browsers for the same resources. The results indicate that browsing capacity should be determined by the quantity of food available during the dry months just before the onset of the new season (August to October), as the phenology and deciduous nature of tree species results in the lack of available foliage. During this time areas that can be described as “critical

resource areas", such as *B. albitrunca* areas, may play an important role in the survival of browsers during this critical pre-season dry period.

vii. The results indicate that low- and unutilized areas still bear evidence of the influence of chemical arboricide applications in the past and that giraffes avoid these areas. These treated areas further indicate that giraffes can distinguish between affected and unaffected habitats and which ones they prefer. These influenced areas are one of the reasons why giraffes need to increase their habitat to maintain their daily requirements during the critical period.

viii. One of the main concerns for the wellbeing of giraffes is the small variety of preferred tree species available for browsing within KKNR, but a bigger concern is the small variety of tree species available during critical periods, adding to the possibility of nutritional stress.

CHAPTER 7: GIRAFFE DIET SELECTION AND FEEDING PREFERENCES

7.1. Introduction

The diet assessment of herbivores is crucial, not only in understanding trophic relationships, but also in providing insight into potential competition with other herbivore species and the influences that herbivores may have on an ecosystem (Bookhout, 1996; Parker 2005). In addition, studies of herbivore diets are useful as they provide the initial step towards understanding the resources and habitat required on which management decisions must be based (see chapter 10) (Bookhout, 1996; Parker, 2005). The diet of giraffes has been the focus of numerous research projects in Africa. Only one study, however, emanates from the arid Kalahari region in the Northern Cape Province and was done within the Kgalagadi Transfrontier Park (Kruger, 1994).

Giraffes are browsers, although it has been reported that they feed on small forbs and occasionally graze on certain grasses (Dagg, 1960; Leuthold & Leuthold, 1972; Hall-Martin, 1974; Langman, 1978; Kok & Opperman, 1980; Pellew, 1984; Kok & Opperman, 1985; Parker, 2000; Parker *et al*., 2003; Blomqvist & Renberg, 2007), especially during the wet season. According to Goddard (1968, 1970), Hofmann & Steward (1972) and Hofmann (1973) the giraffe is a selective feeder and generally rejects dry plant material. During browsing, they manoeuvre food into their mouths with the aid of the prehensile tongue, stripping leaves and biting off shoots with the premolar teeth, which are then ground up by the molar teeth (Lahkar *et al*., 1989; 1992).

Giraffes have certain daily requirements in order to survive and maintain physical condition. The behavioural factors that giraffes can manipulate to achieve certain requirements include: (1) the choice of feeding habitat; (2) the selection criteria for choosing food items; (3) the relative proportion of time allocated to feeding and non-feeding activities.

Giraffes mainly feed at heights that have certain food qualities and they seek growth to obtain edible parts (Kok & Opperman, 1980). Different parts of plants, such as shoots, twigs, leaves, thorns, etc. are included in the diet of giraffes (Sauer *et al*., 1977; Caister *et al*., 2003). From previous studies (Ciofolo & Le Pendu, 2002; Parker, 2000) conducted on the diet selection of giraffes, it is evident that they feed on an unusually large variety of plant species (depending on the environment and availability) and they are flexible, shifting their preferences according to availability of specific plant species. In the study done by Parker *et al.* (2003) in the Eastern Cape Province, giraffe diet comprised 14 plant species. According to many authors, the number of plant species selected by giraffes is usually more than 20 (Leuthold & Leuthold, 1972; Hall-Martin, 1974; Van Aarde & Skinner, 1975; Sauer *et al.,* 1977; Langman, 1978; Kok & Opperman, 1980; Sauer *et al.,* 1982; Pellew, 1984; Kok & Opperman, 1985; Parker, 2000; Parker *et al*., 2003; Blomqvist & Renberg, 2007). This could be because they are able to travel long distances to find a greater variety of vegetation types (see chapter 5). They are also able to utilize plants unavailable to other herbivores due to their height (chapter 8), and ability to overcome chemical and morphological defences.

Food preferences can only be determined if the plants selected by giraffes are compared to their food availability in the environment. A “preferred food species” is that which is proportionately more frequent in the diet than is available in the immediate environment, and a “principal food” is simply that which is consumed in the greatest quantities irrespective of

its availability or proportional abundance (Petrides, 1975). However, Oates (1972) illustrated that food selection by giraffes was not always related to plant species availability in the mopane woodland in South Africa.

Although the southern giraffe, *G. c. giraffa*, occurs in fairly large numbers on wildlife ranches and in private and national game reserves across southern Africa (WRSA, 2013), specific information on the diet selection, feeding and social behaviour of these animals is limited for arid regions. Information on giraffe activity budgets and diet preference will assist wildlife managers to manage them in such a way as to prevent mortalities and unnecessary losses of genetic variability and ultimately a further decline in giraffe populations, as well as prevent environmental degradation. A deeper look into the social or non-feeding related behaviour of giraffes (see chapter 9) might show that giraffes devote significant time to various non-feeding activities that add to their health and comfort, and we might understand why giraffe social structures are considered to be complex (Bercovitch & Berry, 2009).

Shorrocks & Croft (2009) illustrate how little is known about diet changes of giraffes over annual seasons. One way of comparing diet over seasons is by performing physical observations on plant species preferred by giraffes, and by determining how they allocate time throughout the day to feeding activities and diet selection.

The specific objectives of the study were to determine:

i. the percentage of daily activities spent in feeding;
ii. tree species preferences;
iii. how diet preferences change over seasons;
iv. how diet preferences change during the day.

7.2. Procedure

7.2.1. Data collection

Field observations were performed using the scan sampling method modified from Altmann (1974) and were used to determine the feeding behaviour of the giraffes. Each giraffe activity was recorded on a voice recorder (Kok, 1980; Theron, 2005). Scan sampling is the recording of an individual's current activity or state at predetermined intervals in time and, in this case, every five minutes from sunrise until sunset. Scan sampling is used to determine the percentage of time spent on various activities of animals simultaneously by observing each individual (Kok, 1980).

Observations of different activities included: (1) Standing, (2) Walking, (3) Feeding/Browsing, (4) Lying down, (5) Standing & ruminating (S/R), (6) Walking & ruminating (W/R), (7) Lying & ruminating (L/R), (8) Galloping, (9) Looking around, (10) Feeding on bones (Osteophagia) and soil (Geophagia), (11) "Other activities"/alternative activities (recorded as a short description of the activity). When processing the data, the activities occurring most in the "other activities" category were made into separate categories. These included defecating, urinating, grooming, rubbing/scratching, suckling (calves), flehmen (males) and sniffing cows (males). These different activities are discussed in detail in chapter 9, but within this chapter the focus is specifically on feeding/browsing.

A "feeding/browsing record" is defined as an individual foraging on one plant (2 individuals utilizing the same plant is 2 feeding records, etc.) The frequency of utilization of each species was determined by expressing the number of feeding records per plant as a percentage of the total number of feeding records.

Furthermore, if the current activity of an individual was recorded as "feeding/browsing", the plant species that was/were being utilized, as well as the height level of browsing were also recorded. These levels of browsing range from ground level (Level 1) to above the head of the giraffe (Level 6). This will be discussed in further detail in chapter 8. The sex and age class of the individual was included with each activity record.

Activities were recorded every five minutes with a SANYO ICR-FP600D digital voice recorder from sunrise until sunset each day, depending on how soon the main herd was located. Recordings were done each month for ten consecutive days for a total of fifteen months from June 2012 to August 2013. Within these 15 months seasonal changes were also investigated to determine the effect they might have on giraffe diet. Four seasons were identified for the arid Kalahari and are grouped into summer (wet hot, November – February), autumn (wet cool, March – May), winter (dry cool, June – August) and spring (dry hot, September & October).

The same herd was followed throughout the 15 months observation period by using the collared female (SAT312Ke) as the focus animal. This permitted consecutive data collection on the same individuals that were in the main herd at any time. All observations were made by tracking the giraffes by vehicle (Figure 7.1). Observations were made with binoculars at distances ranging between 20 and 100 m. Periods when the giraffes could not be found were excluded from the calculations. Sometimes they had to be located with the VHF antennae when the vegetation was very dense (Figure 7.1).

Figure 7.1 Field observations with binoculars and the use of the yagi antennae

The same herd was monitored for an entire day, and data were grouped within morning (06:00-10:00), midday (10:00-14:00), afternoon (14:00-19:00) and night (19:00-06:00) hours, to determine if diet changes occurred during certain times of day. The quantity of data varied throughout the day and from day to day, because the group size and composition changed regularly, which resulted in a different number of entries for every day and was the main reason for grouping hours together and working with the average for each group.

7.2.2. Data analysis

7.2.2.1. Determining the feeding percentage

After each day the data were entered into a worksheet in Excel (Microsoft, 2010). Feeding records were modified from Parker & Bernard (2005) and each feeding record was defined as 1 plant species consumed by 1 animal during 1 scan (same as above). Feeding records for each species consumed/hour were totalled and expressed as a percentage of all feeding records for that hour.

7.2.2.2. Determining the tree species preference

The key tree species and diet preferences were identified by observations made on the giraffes while feeding. Only the key tree species were further analysed using the data analyst toolbox (Excel, 2010), and the rest of the plant species were grouped together and

are referred to as “other species” (Table 7.1). Correlation analysis was used to compare which of the tree species were correlated in terms of utilization, by calculating the correlation coefficient between their percentage utilization. The correlation analysis tool was particularly used when there were more than two measurement variables. Tree species were compared with each other, and correlations indicated whether certain species were utilized at the same time, and which of them were utilized at different time periods. It provides a correlation matrix that shows the value applied to each possible pair of measurement variables (Raubenheimer, 2012). The value of any correlation coefficient must be between -1 and +1 inclusive (Raubenheimer, 2012). The correlation analysis tool was used to examine each pair of tree species to determine whether the two species were similarly utilized.

For practical reasons only part of the scientific name was used in some of the figures, for example; Aer = *Acacia erioloba*, Bal = *Boscia albitrunca,* Ame = *A. mellifera*, Tse = *Terminalia sericea*, Gfl = *Grewia flava* and Zmuc = *Ziziphus. mucronata*. The least prominent tree species are combined under *“*other species*”*.

7.2.2.3. Determining how giraffe diet changes over seasons

Data were statistically analysed with GenStat® (Payne *et al*., 2012) for each dataset recorded by the GPS collars for each female giraffe. Generalized Linear Mixed Models (GLMM) extends the usual analysis to cater for non-Normal distributions. The GLMM analysis was used to test for differences between the utilization of tree species and season effects, as well as the time x season interaction (Fixed effects). The random effect was specified as hour. Treatment means were separated using Tukey's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran, 1980).

The GLMM analysis was used with the Poisson distribution and logarithmic link to test for differences between feedings (Schall’s, 1991). The numbers of samples for untransformed means per season per time of day are shown in Appendix H.

Data were further tested with the different techniques from the CANOCO 4 (TerBraak & Šmilauer, 1998) package. Ordination techniques assisted in understanding a local environmental classification by “grouping” the same seasonal information together (Verlinden & Dayot, 2005). Each data matrix (tree species and season) was analysed during the different seasons using the Analysis of similarities (ANOSIM): one-way and two-way crossed to establish whether there were significant differences ($P<0.05$) between the different feedings during seasons.

7.2.2.4. Determining how giraffe diet changes during the time of day

A constant + time + season + (time x season) GLMM factorial analysis was done following Schall’s (1991) method. The GLMM analysis was used with the Poisson distribution and logarithmic link to test for differences between time spent feeding and time of day effects, as well as the time x season interaction as fixed effects (Schall’s, 1991). The time of feeding during the day was grouped into the same hours described in section 7.2.1.

7.3. Results and Discussion

7.3.1. Feeding percentages observed from daily activities

A total of 41 511 observation records were made (Figure 7.2). Observations were made on each individual that showed visible distinguishing markings. Of the total observations, a total of 18 999 recordings were of giraffes browsing (Figure 7.2).

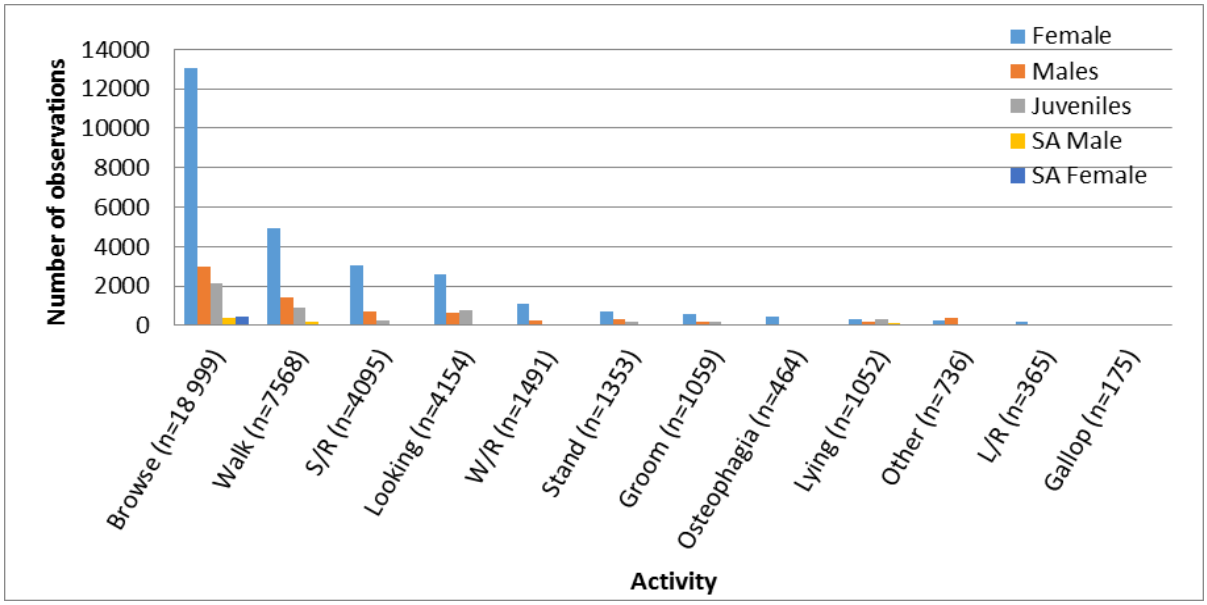


Figure 7.2 Total observations divided according to specific activities

Browsing was by far the most common activity of the giraffes (Figure 7.2 and 7.3). Browsing was very prominent for females (48%) and somewhat lower for males (41%). This could be because males spent comparatively more time on walking and standing (2% more than females), “other” activities (flehmen, necking etc., 4% more than females) and lying down (2% more than females). Possible explanations as to why males spend less time than females on feeding may be because they utilize nutritious feeding strata above 5.0 m, containing higher protein material such as seedpods and flowers, with no competition from other herbivores (see chapter 8) or because testosterone levels played a significant role causing males to seek female attention. It is also significant that sub-adult males only spent 38% of their time on feeding, which is 3% less than adult males, 10% less than adult females and 19% less than sub-adult females (Figure 7.3). Sub-adult males groomed 7%, but sub-adult females spent 57% of their time feeding and 11% lying down, indicating they are more relaxed than adult females, but also they are still growing and require more proteins and minerals for physical development.

Blomqvist & Renberg (2007) found in the Mokolodi Reserve in Botswana that giraffes spent only 36% of their time on browsing, which is 10% less than what was found in the current study.

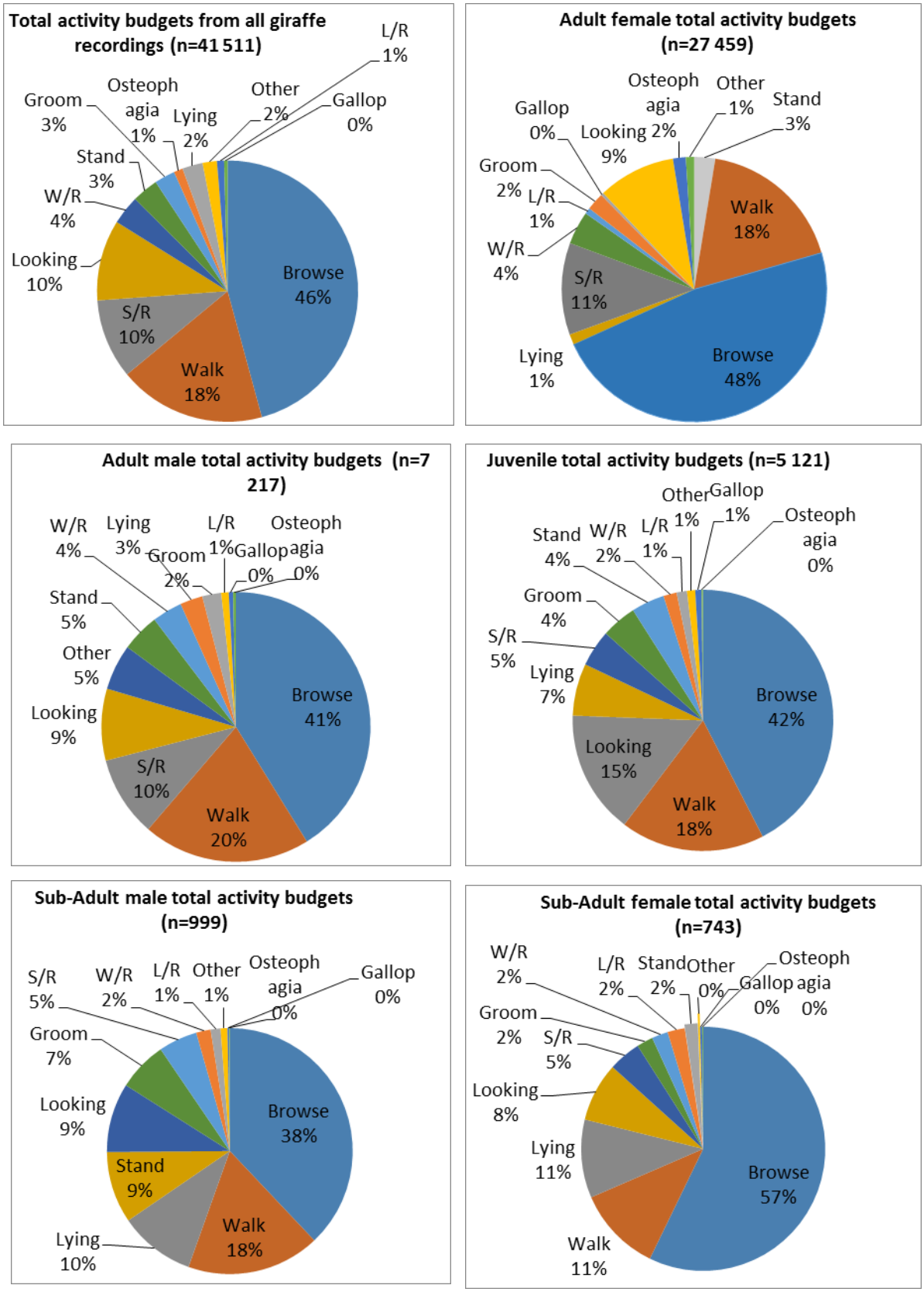


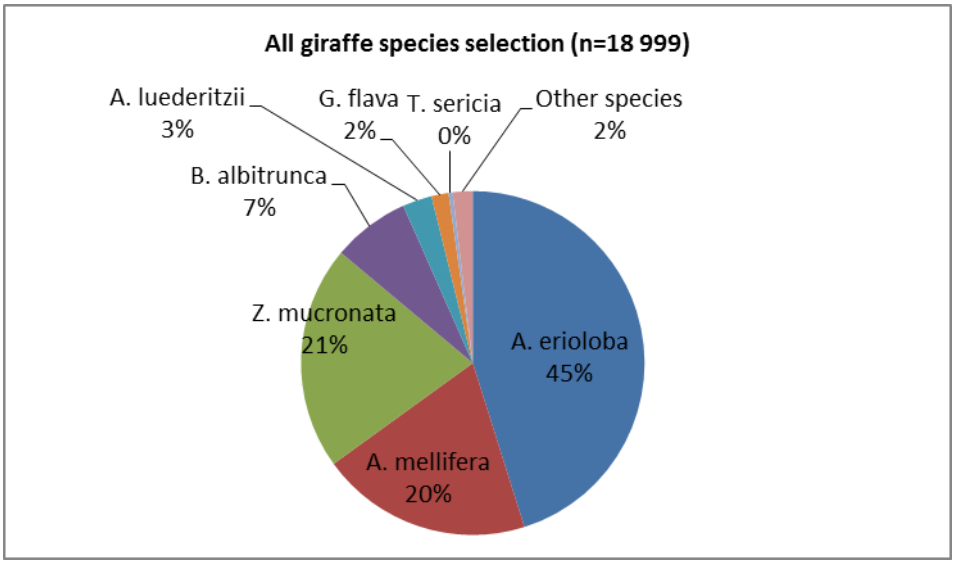
Figure 7.3 Illustration of the activities of each giraffe sex and age group for a period of fifteen months (June 2012 to August 2013) (S/R = standing & ruminating, L/R = lying & ruminating and W/R = walking & ruminating)

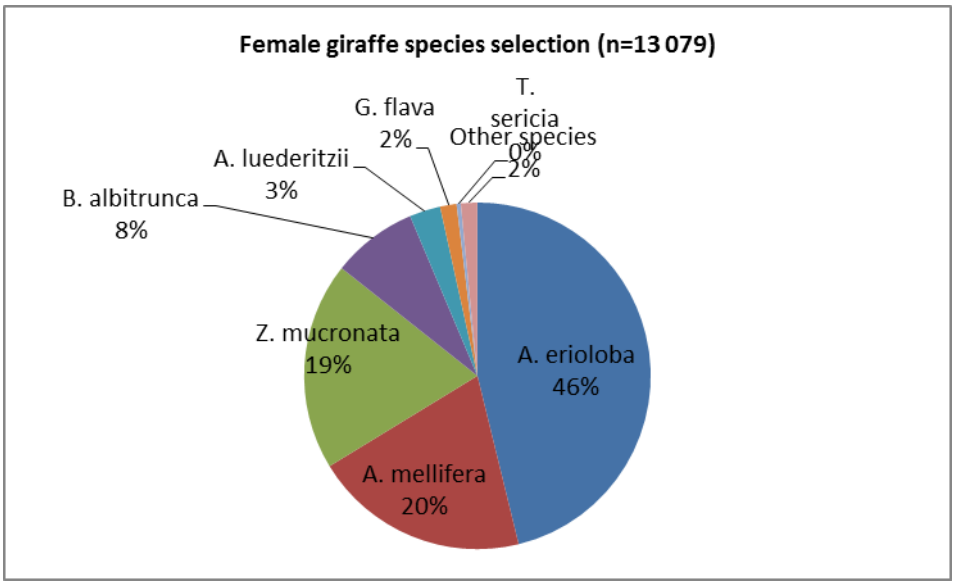
7.3.2. Tree species preferred by giraffes

Table 7.1 lists all the plant species utilized by giraffes. In terms of mean frequency of occurrence, the most important species recorded in the diet of giraffes in KKNR were *A. erioloba, Z. mucronata, B. albitrunca* and *A. mellifera.* These four species are therefore considered to be critical resource species in the diet of giraffes. This, however, is not a big variety of plant species and a greater concern is that only one tree is evergreen (*B. albitrunca),* the rest being winter deciduous. In chapter 6 the BECVOL 3 analysis provided valuable information regarding the number of trees available per ha and also how much they contribute with evapotranspiration tree equivalents (ETTE's). This information will determine the percentage of foliage provided by each woody species vs diet preferences of giraffes in KKNR.

Table 7.1 List of all the woody tree species utilized by giraffes with the percentage ETTE and plants per hectare (plants ha^{-1}) composition

Species number	Species	Utilized by giraffe	> 5 % of diet	Critical resource species	Percentage ETTE's represented (%)	Percentage plants per hectare represented (%)
1	*Acacia erioloba*	Yes	**Yes**	**Yes**	**26.1**	**16.0**
2	*A. luederitzii*	Yes	**Yes**	No	**13.4**	**4.2**
3	*A. haematoxylon*	Yes	No	No	**0.2**	**0.8**
4	*A. hebeclada*	Yes	No	No	**0.1**	**0.3**
5	*A. mellifera*	Yes	**Yes**	**Yes**	**18.2**	**14.5**
6	*Boscia albitrunca*	Yes	**Yes**	**Yes**	**7.0**	**3.5**
7	*Cadaba aphylla*	Yes	No	No	**0.0**	**0.1**
8	*Dichrostachys cinerea*	Yes	No	No	**1.0**	**2.4**
9	*Diospyros lycioides*	Yes	No	No	**0.0**	**0.2**
10	*Ehretia rigida*	Yes	No	No	**0.1**	**0.4**
11	*Grewia flava*	Yes	No	No	**18.8**	**40.5**
12	*G. flavescens*	Yes	No	No	**0.5**	**1.3**
13	*G. retinervis*	Yes	No	No	**0.0**	**0.6**
14	*Lycium cinereum*	Yes	No	No	**0.8**	**5.2**
15	*Rhigozum brevispinosum*	Yes	No	No	**0.1**	**0.3**
16	*Searsia tenuinervis*	Yes	No	No	**0.6**	**4.9**
17	*Terminalia sericea*	Yes	No	No	**5.8**	**2.1**
18	*Ziziphus mucronata*	Yes	**Yes**	**Yes**	**7.1**	**2.2**





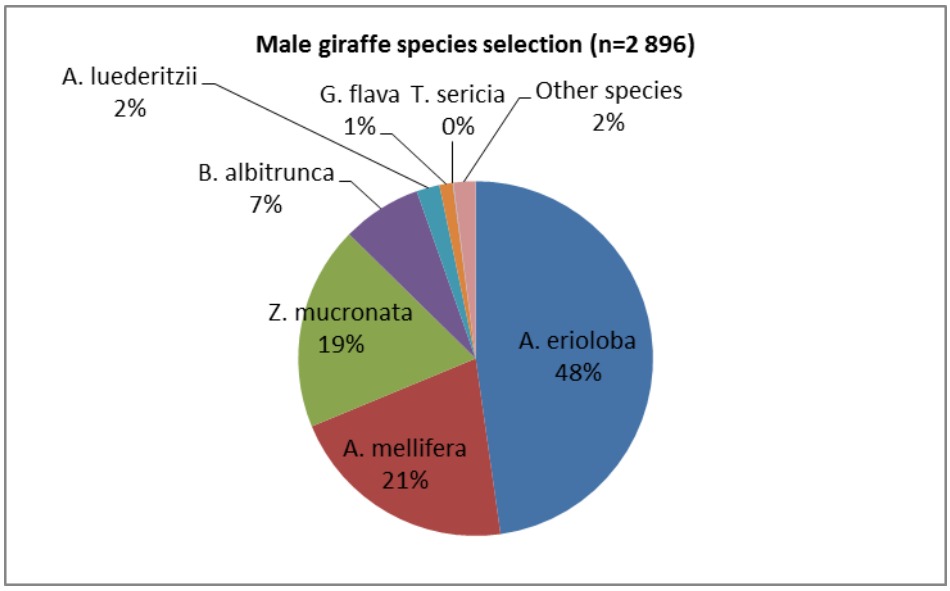


Figure 7.4 Browsing preferences of giraffes (by gender) for the most important woody species

Of 18 999 observations of giraffe feeding, 45% of observations consisted of *A. erioloba*, 20% of *A. mellifera*, 21% of *Z. mucronata* and 7% of *B. albitrunca* (Figure 7.4). These four woody species combined represent 93% of the total giraffe diet in KKNR. This suggests that giraffe are preferentially searching for these woody species, although they are not the most abundant species available (Table 7.1). These four species combined represent 36.2% of all woody species per ha (*A. erioloba* (16%), *A. mellifera* (14.5%), *Z. mucronata* (2.2%) and *B. albitrunca* (3.5%)) (Table 7.1). The most abundant woody species is *G. flava* (40.5% of plants per ha), but only 2% favoured in their diet and therefore not considered critical resource species. However, using the evapotranspiration tree equivalents (ETTE's), these four species combined represent 58.4% of food provided (*A. erioloba* (26.1%), *A. mellifera* (18.2%), *Z. mucronata* (7.1%) and *B. albitrunca* (7%). This illustrates the value of these four woody species, which are considered critical resource species.

Combining the feeding percentages on just the three key deciduous species, *A. erioloba, Z. mucronata* and *A. mellifera, showed that* over 85% of giraffe diet came from these three trees. Figure 7.5 to 7.7 show how giraffe diet preferences changed over the course of 15 months. *A. erioloba* was very prominent for most months, but less so during November and December, *A. mellifera* showed a decrease in the winter months, *B. albitrunca* increased in the winter and spring and *Z. mucronata* decreased in the spring.

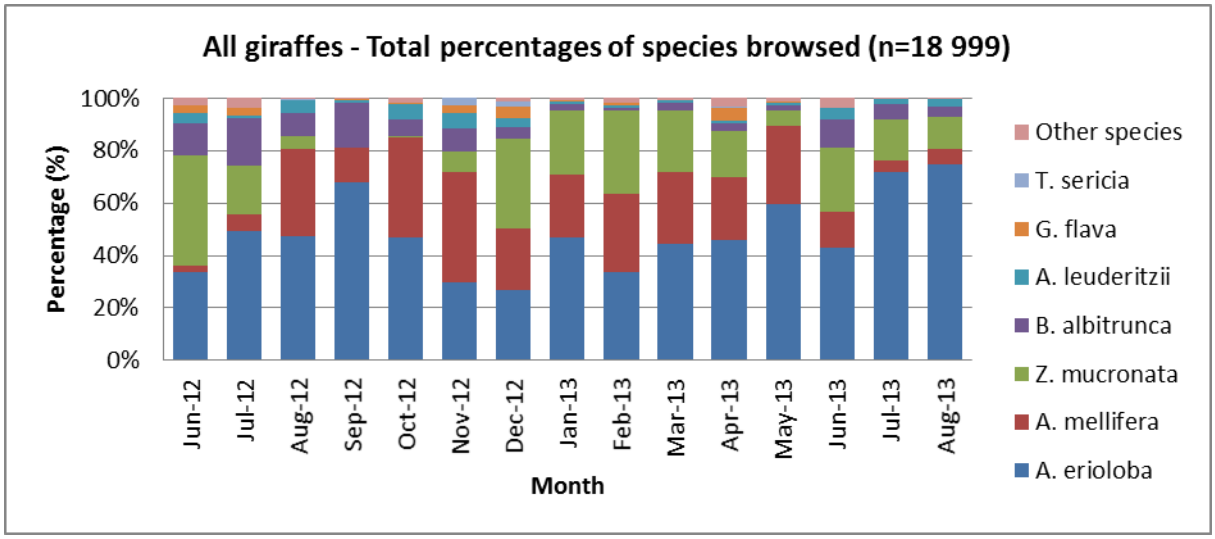


Figure 7.5 Total percentages of trees browsed by all giraffes over 15 months (June 2012 – August 2013)

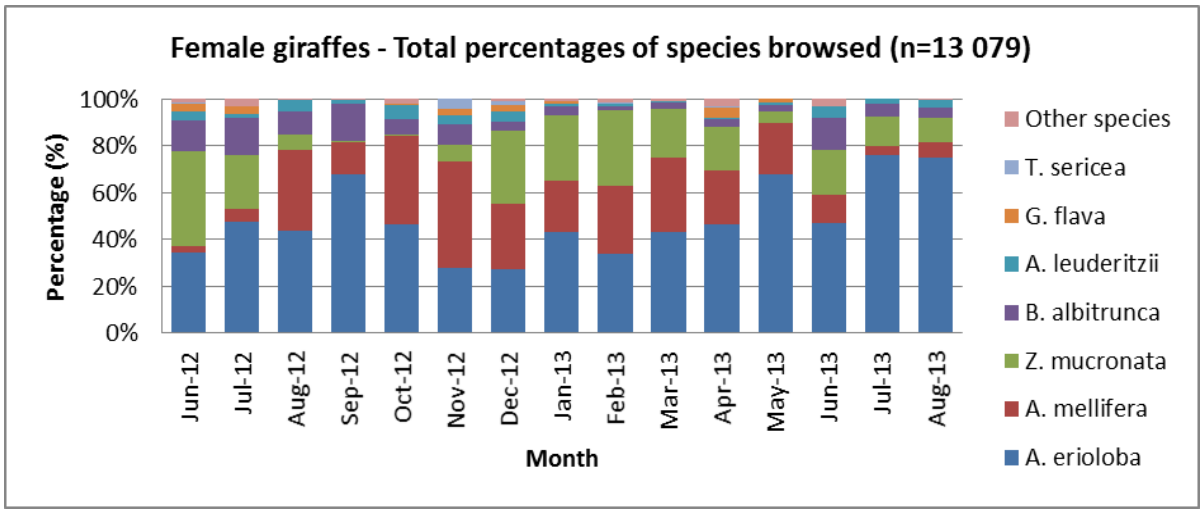


Figure 7.6 Total percentages of trees browsed by female giraffes over fifteen months (June 2012 – August 2013)

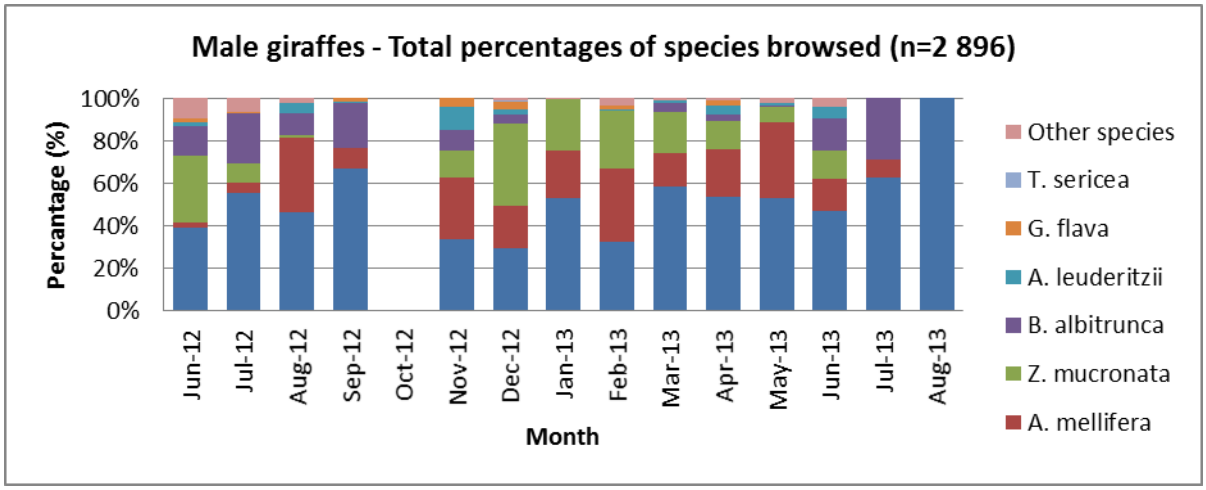


Figure 7.7 Total percentages of trees browsed by male giraffes over fifteen months (June 2012 – August 2013)

The way the diet varied over the months is clearly demonstrated when male and female diets are separated (Figure 7.5 to 7.7). Males utilized more of the "other species" (Figure 7.7) from June 2012 to August 2012 compared to the females (Figure 7.6). Deciduous *Z. mucronata* was less utilized from August to November and the deciduous *A. mellifera* was less utilized in June and July. *B. albitrunca* was not utilized by males during January and February (Figure 7.7), but was utilized to a lesser extent by females (Figure 7.6).

Correlation analysis demonstrates how most woody species were positively correlated ($P<0.05$) in terms of utilization (green coloured values), but some species were negatively correlated (red coloured values) (Figure 7.2 to 7.4). Correlations help to explain when certain tree species are utilized at the same time, but also when avoided. For instance, *T. sericea* was not browsed at the same time as *A. erioloba, B. albitrunca* or *"other species"*. It is the same for females, except that *G. flava* were not browsed during the same period as *B. albitrunca* or *A. luederitzii.* For males, *B. albitrunca* was negatively correlated with

A. mellifera and *Z. mucronata*, and *A. erioloba was* negatively correlated with *A. luederitzii* and *G. flava. "Other species"* were negatively correlated with *A. mellifera*, *T. sericea* and *A. luederitzii.* One should note here that it is not the tree species that are correlated with each other, but which ones are utilized or avoided during the same period.

In the correlation, the female utilization showed strong correlation of *B. albitrunca* with *A. erioloba* (r = 0.774), *B. albitrunca* with *A. luederitzii* (r = 0.758) and *A. erioloba* with *"other species"* (r = 0.801) (Table 7.3). Male giraffe diet showed strong correlation of *A. mellifera* with *A. erioloba* (r = 0.841), *Z. mucronata* with *A. erioloba* (r = 0.743) and *A. mellifera* (r = 0.748) and *"other species"* with *G. flava* (r = 0.847) (Table 7.4). In future studies the plant qualities and nutrient compounds of each tree should be investigated to identify the reasons why some species are utilized together, whereas other combinations of species are avoided.

Table 7.2 Statistical correlations between the utilization of tree species by all giraffes

	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	Other species
A. erioloba	1							
A. mellifera	0.540	1						
Z. mucronata	0.689	0.584	1					
B. albitrunca	0.713	0.168	0.545	1				
A. luederitzii	0.624	0.520	0.698	0.752	1			
G. flava	0.091	0.387	0.488	0.000	0.141	1		
T. sericea	-0.104	0.440	0.362	-0.072	0.301	0.720	1	
Other species	0.775	0.418	0.709	0.816	0.774	0.209	-0.022	1

Table 7.3 Statistical correlations between the utilization of tree species by females

	A. erioloba	*A. mellifera*	*Z. mucronata*	*B. albitrunca*	*A. luederitzii*	*G. flava*	*T. sericea*	*"Other species"*
A. erioloba	1							
A. mellifera	0.282	1						
Z. mucronata	0.460	0.359	1					
B. albitrunca	0.774	0.062	0.425	1				
A. luederitzii	0.611	0.395	0.478	0.758	1			
G. flava	0.095	0.315	0.530	-0.031	-0.066	1		
T. sericea	-0.232	0.481	0.181	-0.170	0.081	0.477	1	
"Other species"	0.801	0.401	0.601	0.720	0.654	0.339	-0.088	1

Table 7.4 Statistical correlations between the utilization of tree species by males

	A. erioloba	*A. mellifera*	*Z. mucronata*	*B. albitrunca*	*A. luederitzii*	*G. flava*	*T. sericea*	*Other species*
A. erioloba	1							
A. mellifera	0.841	1						
Z. mucronata	0.743	0.748	1					
B. albitrunca	0.034	-0.313	-0.135	1				
A. luederitzii	-0.133	0.153	0.102	0.036	1			
G. flava	-0.008	0.150	0.485	0.218	0.614	1		
T. sericea	0.066	0.228	0.585	0.051	0.356	0.847	1	
Other species	0.199	-0.018	0.110	0.580	-0.178	0.055	-0.048	1

7.3.3. Diet change of giraffes over seasons

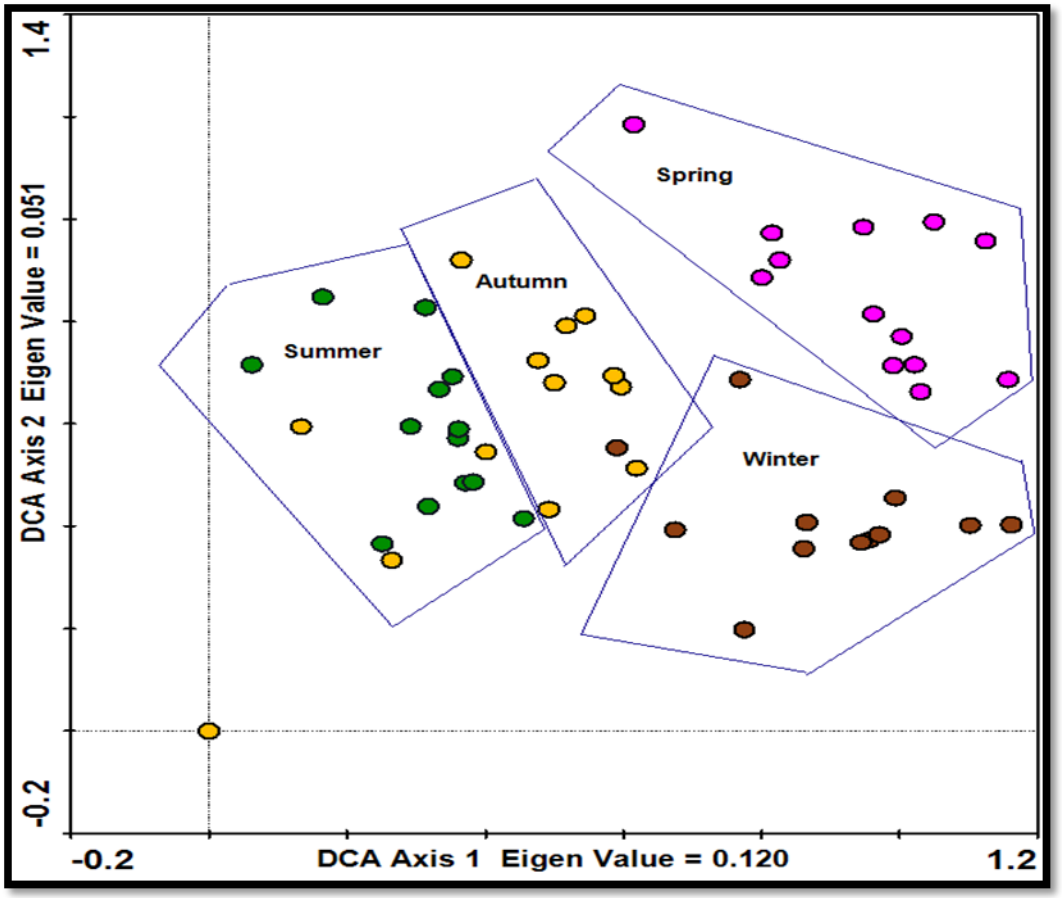


Figure 7.8 Ordination of female giraffe diet over seasons

Table 7.5 Percentage utilization of tree species per season by female giraffes

	Summer	Autumn	Winter	Spring
A. erioloba	33.8	48.0	56.7	57.5
A. mellifera	28.7	25.0	9.8	25.7
Z. mucronata	27.2	17.8	16.7	0.5
B. albitrunca	4.0	3.0	10.5	11.4
A. luederitzii	2.3	0.4	4.3	3.6
G. flava	1.9	3.2	0.0	0.2
T. sericea	1.1	0.4	0.0	0.0
“Other species”	0.8	2.3	2.0	1.2

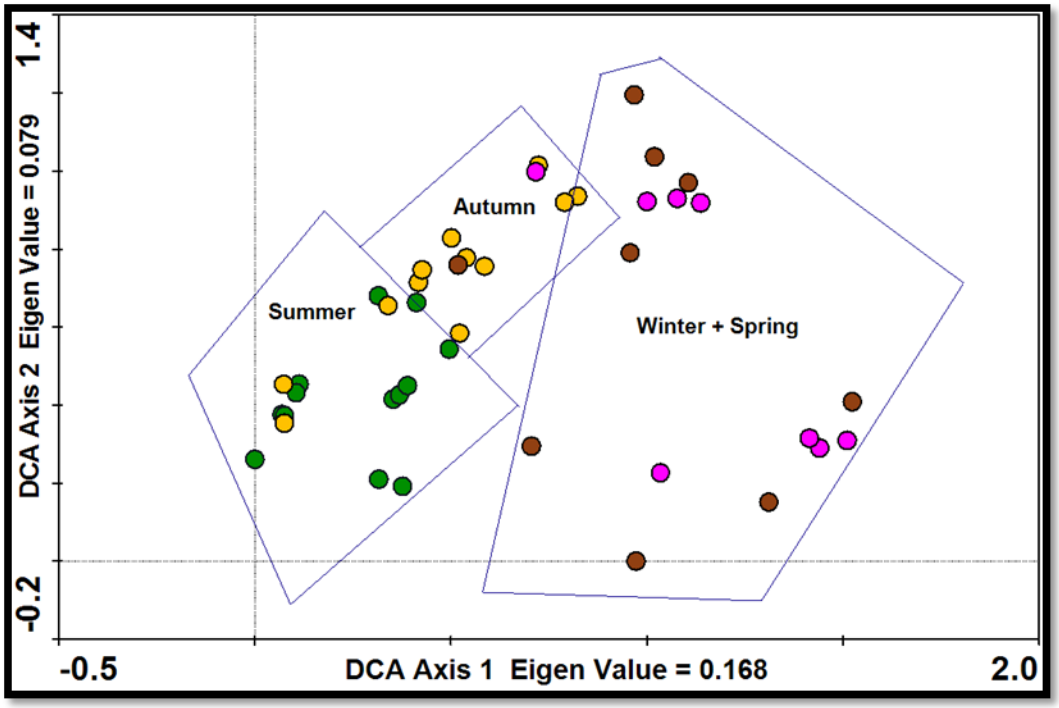


Figure 7.9 Ordination of male giraffe diet over seasons

Table 7.6 Percentage utilization of tree species per season by male giraffes

	Summer	Autumn	Winter	Spring
A. erioloba	39.7	55.1	54.2	66.7
A. mellifera	22.6	27.5	12.5	10.0
Z. mucronata	26.4	10.9	8.3	0.0
B. albitrunca	4.8	2.2	18.8	21.7
A. luederitzii	3.1	2.2	4.2	0.0
G. flava	2.7	0.7	0.0	1.7
T. sericea	0.0	0.0	0.0	0.0
"Other species"	0.7	1.4	2.1	0.0

The ordinations (Conoco 4) showed the same seasonal tendency, having a small overlap between summer and autumn and distinctive groupings based on diet preferences for winter and spring (Figure 7.8). This helps to identify variations in giraffe diet over seasons. Figure 7.8 and 7.9 show how male and female diets changed over the seasons. The diet of males during spring and winter months was more constant (the same woody species) (Figure 7.10) than for females. Females still showed distinctive preference groupings for each season (Figure 7.9).

In summer, the order of preference for females was *A. erioloba, A. mellifera, Z. mucronata, B. albitrunca, A. luederitzii, G. flava, T. sericea* and *"Other species"* (Table 7.5). For males the order of preference was *A. erioloba, Z. mucronata, A. mellifera, B. albitrunca, A. luederitzii, G. flava, "Other species"* and *T. sericea* (Table 7.6). In summer, there was little overlap in woody species preferences between males and females (Appendix H). This indicates that there was enough species variety for the giraffes to select their diet in the summer months.

In autumn, the order of preference for females was *A. erioloba, A. mellifera, Z. mucronata, G. flava, B. albitrunca, "Other species", A. luederitzii* and *T. sericea* (Table 7.5). For males, the order of preference was *A. erioloba, A. mellifera, Z. mucronata, B. albitrunca, A. luederitzii, "Other species" G. flava,* and *T. sericea* (Table 7.6). In autumn, there was also little overlap in woody species preference between males and females (Appendix H).

In winter, the order of preference for females was *A. erioloba, Z. mucronata, B. albitrunca, A. mellifera, A. luederitzii, "Other species"* and no *G. flava* or *T. sericea* (Table 7.5). For males the order of preference was *A. erioloba, B. albitrunca, A. mellifera, Z. mucronata, A. luederitzii, "Other species"* and no *G. flava* or *T. sericea* (Table 7.6). Thus, there was a large overlap in woody species preferences of males and females. This indicates that there was a limited variety of foliage available for selection in winter. *B. albitrunca* was prominent in the diet of both males and females.

In spring, the order of preference for females was *A. erioloba, A. mellifera, B. albitrunca, A. luederitzii, "Other species", Z. mucronata, G. flava* and no *T. sericea* (Table 7.5). For males the order of preference was *A. erioloba, B. albitrunca, A. mellifera, G. flava* and no *Z. mucronata, A. luederitzii, "Other species"* or *T. sericea* (Table 7.6). Thus, in spring, there was a large percentage overlap in species preference between male and female giraffe. This could indicate that when the season starts changing and the deciduous trees start re-sprouting (see phenology in chapter 6), male and female diet preferences also start to differ.

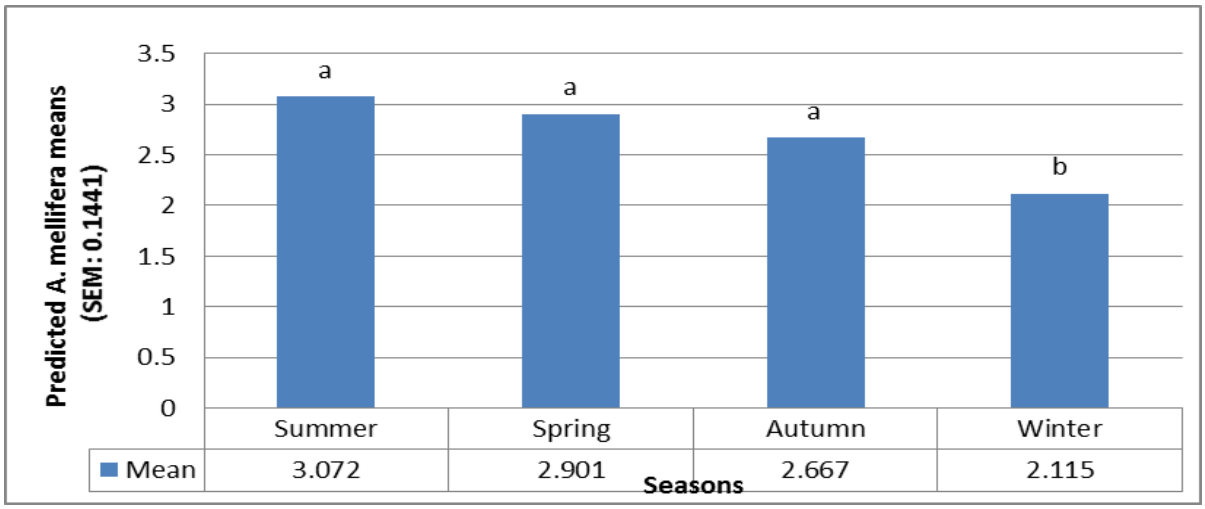


Figure 7.10 Seasonal effects on female giraffes feeding on *A. mellifera*

With the GLMM the Wald statistic (Tukey's LSD test) demonstrates which of the woody species had a significant effect (P<0.05) on the diet of females. *A. mellifera* (Figure 7.10) was less utilized during the winter months. Over the seasons, the summer mean (3.072) values were the highest followed by spring (2.901), autumn (2.667) with the lowest in winter (2.115) (untransformed scale). On the transformed scale (Appendix H Table H.5) this would mean that summer (21.6), spring (18.2) and autumn (14.4) were highly significantly different (P<0.001) from the winter months (8.3). The reason for females avoiding *A. mellifera* during winter season was because it is leafless during this period (see chapter 6). *A. mellifera,* however, can be considered a key tree species, because of the foliage it provides during autumn and because it starts re-sprouting earlier than the other *Acacia* tree species in spring.

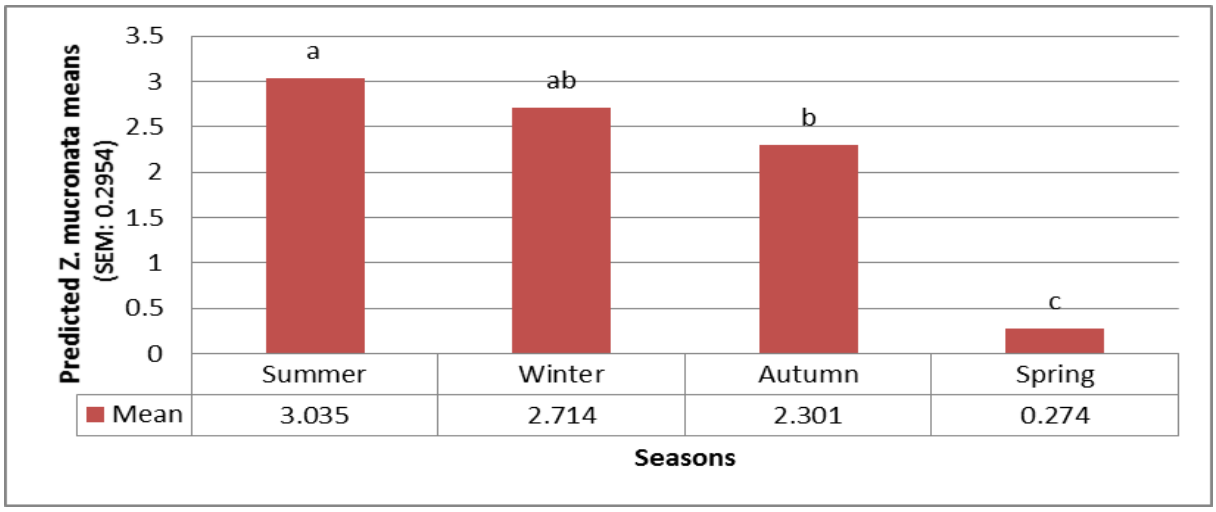


Figure 7.11 Seasonal effects on female giraffes feeding on *Z. mucronata*

Figure 7.11 illustrates the seasonal utilization of *Z. mucronata* by females, which was very low during spring (mean 0.274), and highest during summer (3.035) followed by winter (2.714) and autumn (2.301) (untransformed scale). On the transformed scale (Appendix H Table H.5), this would mean that summer (20.8), winter (15.1) and autumn (10.0) were highly significantly different (P<0.001) from the spring months (1.3). The reason why females avoided *Z. mucronata* during spring was due to the phenology cycle, as the tree had no leaves at that season (see chapter 6). *Z. mucronata,* however, can be considered a key tree species, because of the foliage it provides during winter and autumn.

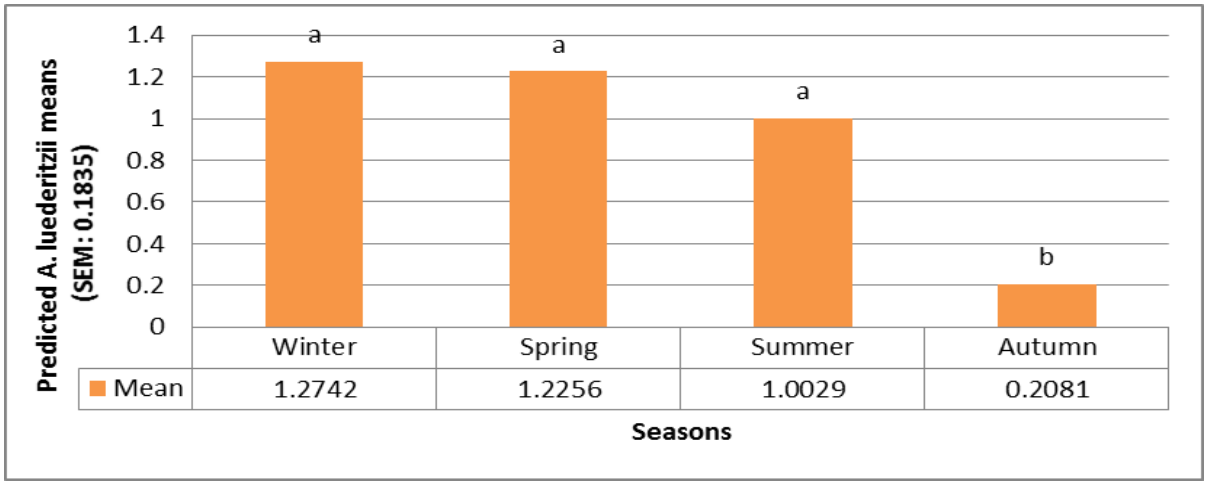


Figure 7.12 Seasonal effects on female giraffes feeding on *A. luederitzii*

Figure 7.12 illustrates the seasonal utilization of *A. luederitzii* by females, which was very low during autumn (mean 0.2081) and highest during winter (1.2742) followed by spring (1.2256) and summer (1.0029), (untransformed scale). On the transformed scale (Appendix H Table H.5) this would mean that winter (3.6), spring (3.4) and summer (2.7) were highly significantly different (P<0.001) from the autumn months (1.2). Tree phenology is the reason for female avoidiing *A. luederitzii* during the autumn season.

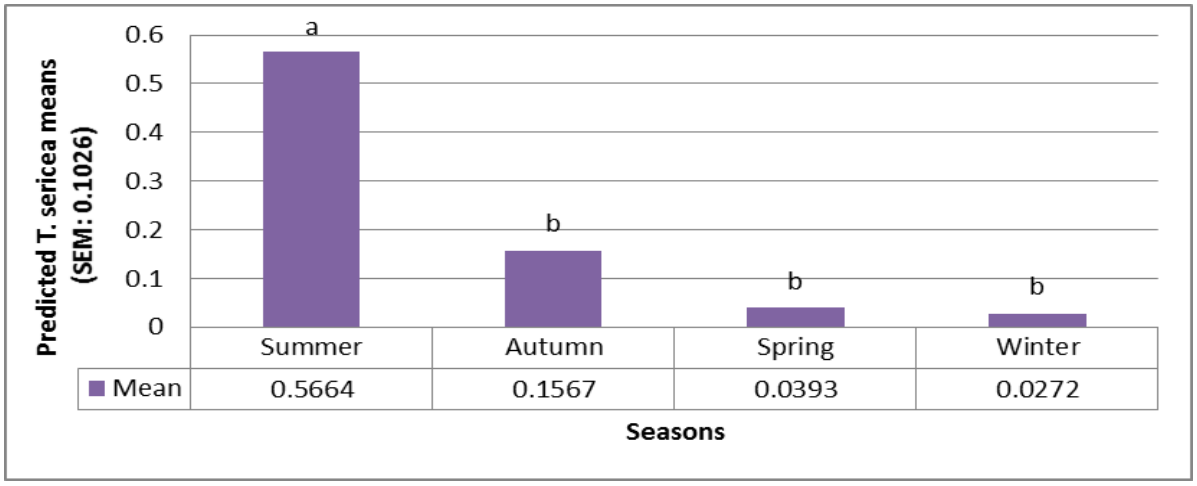


Figure 7.13 Seasonal effects on female giraffes feeding on *T. sericea*

Figure 7.13 illustrates the seasonal utilization of *T. sericea* by females, which was very low in spring (mean 0.0393) and winter (0.0272), and highest in summer (0.5664) followed by autumn (0.1567), (untransformed scale). On the transformed scale (Appendix H Table H.5) this would mean that summer (1.8) was highly significantly different (P<0.001) from winter (1.0), spring (1.0) and autumn months (1.2). Overall, *T. sericea* contributed very little to the diet of females and cannot be considered as a key resource species.

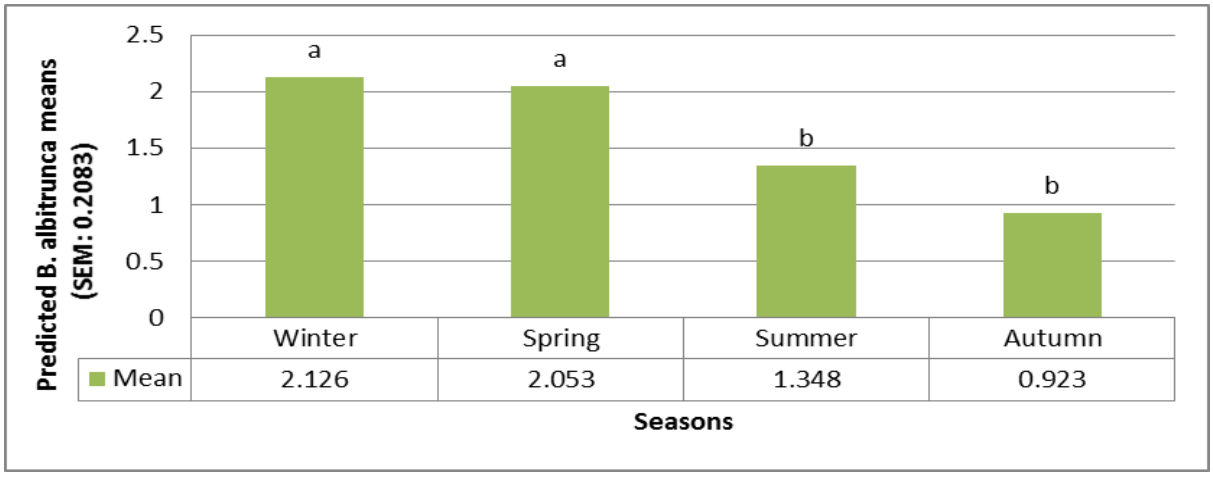


Figure 7.14 Seasonal effects on female giraffes feeding on *B. albitrunca*

Figure 7.14 illustrates the seasonal utilization of *B. albitrunca* by females, which was similar for winter (mean 2.126) and spring (2.053) and lowest in summer (1.348) and autumn (0.923) (untransformed scale). On the transformed scale (Appendix H Table H.5) this would mean that winter (8.4) and spring (7.8) were highly significantly different (P<0.001) from summer (3.9) and autumn seasons (2.5). *B. albitrunca* can be considered as a key resource tree species, because of the foliage it provides during the winter and spring seasons.

During the test for fixed effects, the Wald statistic (Tukey's LSD test) showed season had a significant effect (P<0.05) on female feeding on *A. erioloba* and *G. flava*, but not for "*other species*". *A. erioloba* (P=0.04) on the transformed scale showed that spring (39.3) and winter (35.6) were significantly different from autumn (26.3) and summer (25.4). Because *A. erioloba* constitutes almost half female diet (46%, Figure 7.6) and was utilized throughout the year, it can be considered as a key resource species.

G. flava (P=0.02) on the transformed scale showed that autumn (2.7) and summer (2.4) were significantly different from winter (1.7) and spring (1.1) seasons. These tests demonstrated that all the prominent tree species utilized by females were influenced by seasonal effects.

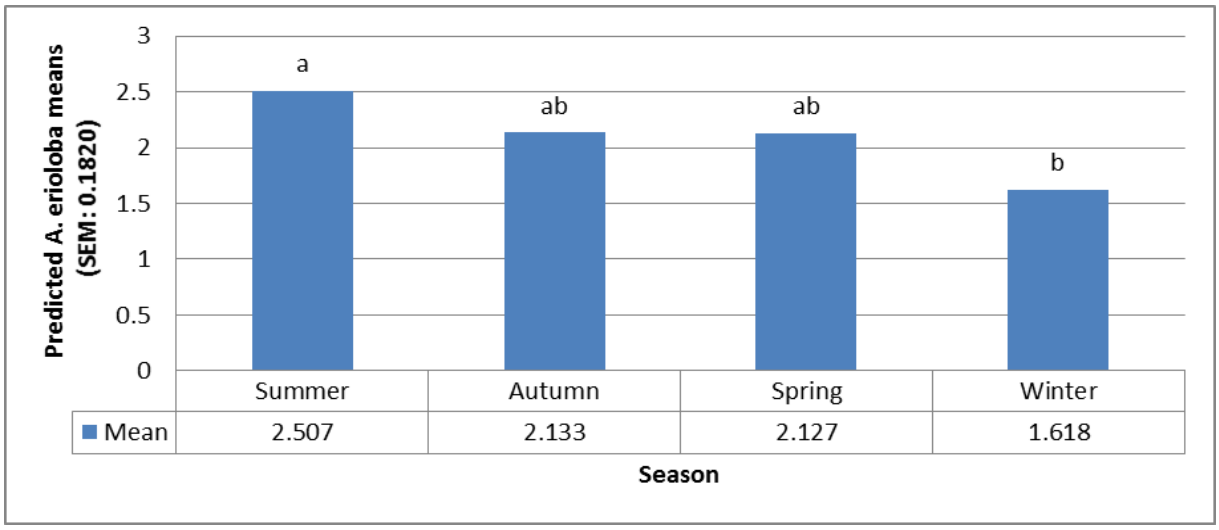


Figure 7.15 Seasonal effects on male giraffes feeding on *A. erioloba*

With the GLMM the Wald statistic (Tukey's LSD test) demonstrates which of the woody species had a significant effect (P<0.05) on the diet of male giraffes. Figure 7.15 illustrates the seasonal utilization of *A. erioloba*, which was highest in summer (mean 2.507) followed by autumn (2.133) and spring (2.127), with the lowest value in winter (1.618) (untransformed scale). On the transformed scale (Appendix H Table H.8) this would mean that summer months (12.3) were highly significantly different (P<0.001) from autumn (8.4), spring (8.4) and winter (5.0).

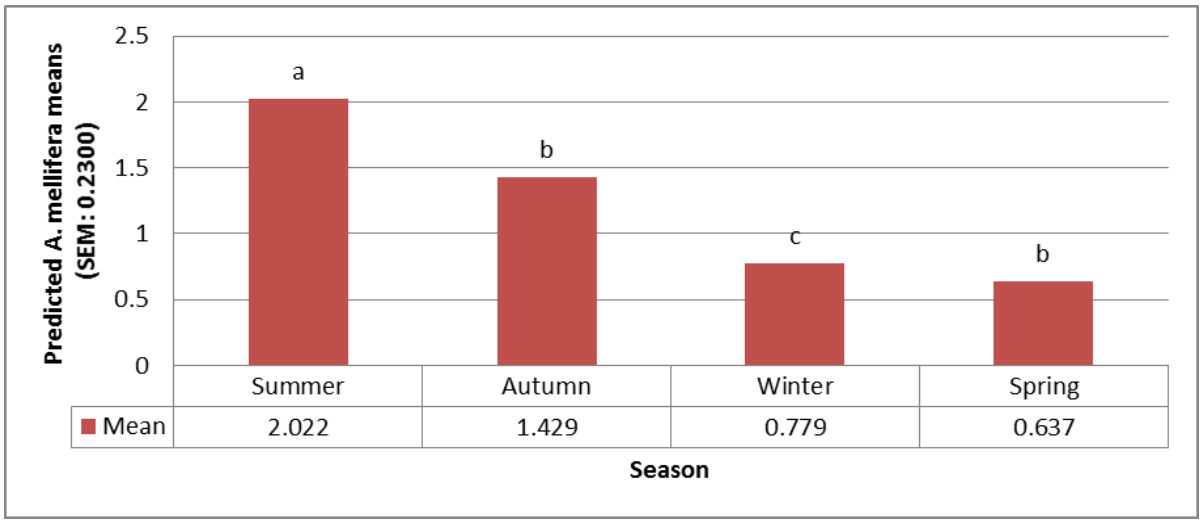


Figure 7.16 Seasonal effects on male giraffes feeding on *A. mellifera*

Figure 7.16 illustrates the seasonal utilization of *A. mellifera by males,* which was highest during the summer (2.022), followed by autumn (1.429), winter (0.779) and lowest in spring (0.637) (Figure 7.16) (untransformed scale). On the transformed scale (Appendix H Table H.8) this would mean that males preferred to utilize *A. mellifera* during the summer (7.6) rather than during the autumn (4.2), winter (2.2) and spring (1.2) months.

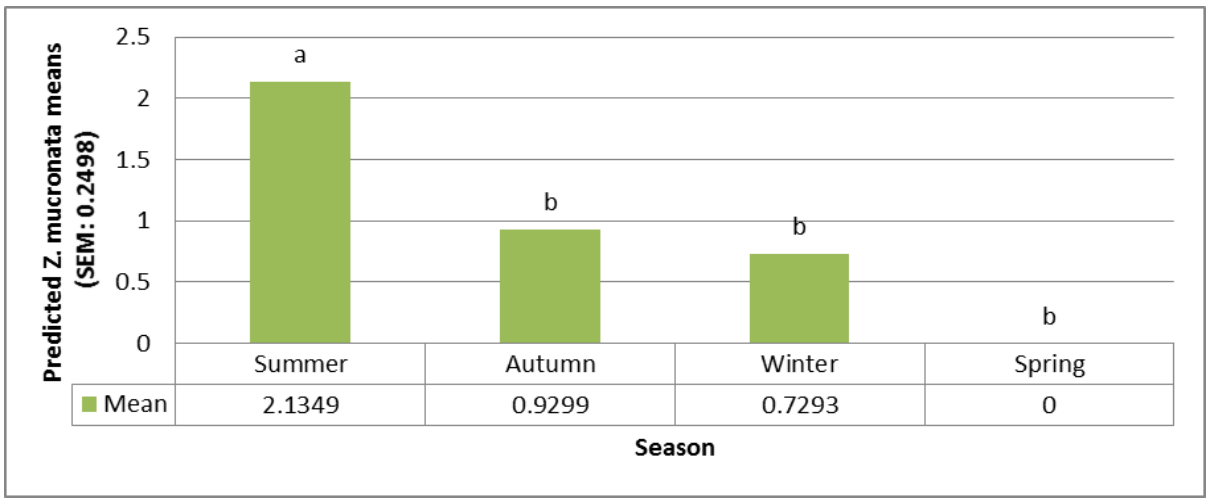


Figure 7.17 Seasonal effects on male giraffes feeding on *Z. mucronata*

Figure 7.17 illustrates the seasonal utilization of *Z. mucronata,* which was highest during summer (2.1349), followed by autumn (0.9299), winter (0.7293) and lowest0 in spring (0) (untransformed scale). On the transformed scale (Appendix H Table H.8) this would mean that males preferred to utilize *Z. mucronata* during summer (8.5) rather than in autumn (2.5), winter (2.1) and spring (1.0) months.

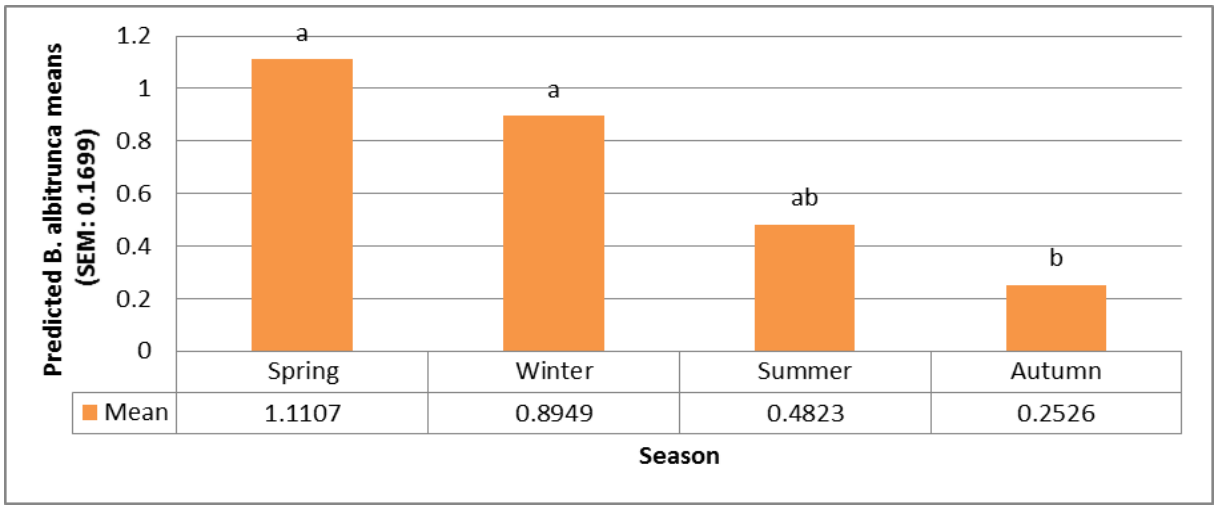


Figure 7.18 Seasonal effects on male giraffes feeding on *B. albitrunca*

Figure 7.18 illustrates the seasonal utilization of *B. albitrunca*, which was highest in spring (mean 1.1107), followed by winter (0.8949), summer (0.4823) and lowest in autumn (0.2526) (untransformed scale). On the transformed scale (Appendix H Table H.8) this would mean that males preferred to utilize *B. albitrunca* during spring (3.0) and winter (2.4), rather than during the summer (1.6) and autumn (1.3) months.

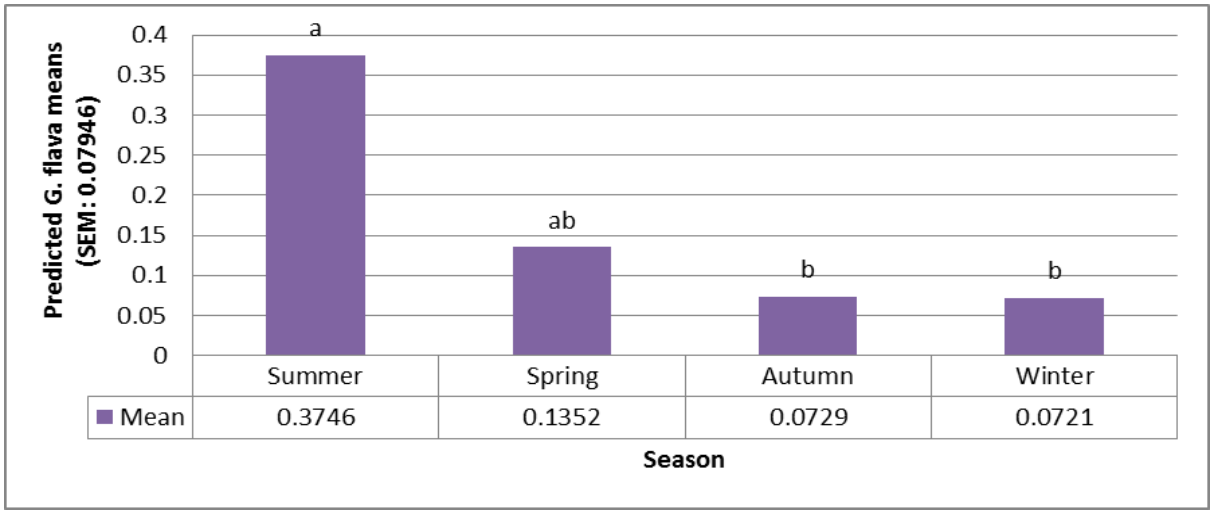


Figure 7.19 Seasonal effects on male giraffes feeding on *G. flava*

Figure 7.19 illustrates the seasonal utilization of *G. flava,* which was highest during the summer (0.3746), followed by spring (0.1352), autumn (0.0729) and lowest in,winter (0.0721) (untransformed scale). On the transformed scale (Appendix H Table H.8) this would mean that males preferred to utilize *G. flava* during the summer (1.5) and spring (1.1) rather than during the autumn (1.1) and winter (1.1) months.

The test for fixed effects, the Wald statistic (Tukey's LSD test) showed that season had a significant effect (P<0.05) on the utilization of *A. luederitzii* (P=0.02), but not for *T. sericea* or "*other species*". On the transformed scale (Appendix H Table H.8) this would mean that males would utilize *A. luederitzii* during the summer (1.6) rather than during the autumn (1.3), winter (1.2) and spring (1.1) months. This demonstrates that the majority of tree species fed on by giraffes experienced seasonal effects.

There was also a difference in species preference and diet between males and females. In the case of males, it was evident that there were significant differences (P<0.001) for *A. erioloba, A. mellifera, Z. mucronata, B. albitrunca* and *G. flava* (Appendix H). *A. erioloba* preference was the same during autumn and spring, but it differed significantly (P<0.001) from summer to winter (Figure 7.15). *A. Mellifera* diet preference for autumn and spring was the same, but different for summer and winter (Figure 7.16). *Z. mucronata* was not utilized during spring months, and summer differed from autumn and winter, (Figure 7.17). *G. flava* was mostly utilized during the summer months; however, the preference for spring, autumn and winter months was similar (Figure 7.19).

7.3.4. Predicted preference trend over seasons

From the results it is clear the diet of the giraffes change seasonally. This change was not necessarily due to preferences, but rather to what was available. If *A. erioloba* were available, it would probably be their main food source throughout the year, but the results show that tree species availability was not constant in different seasons.

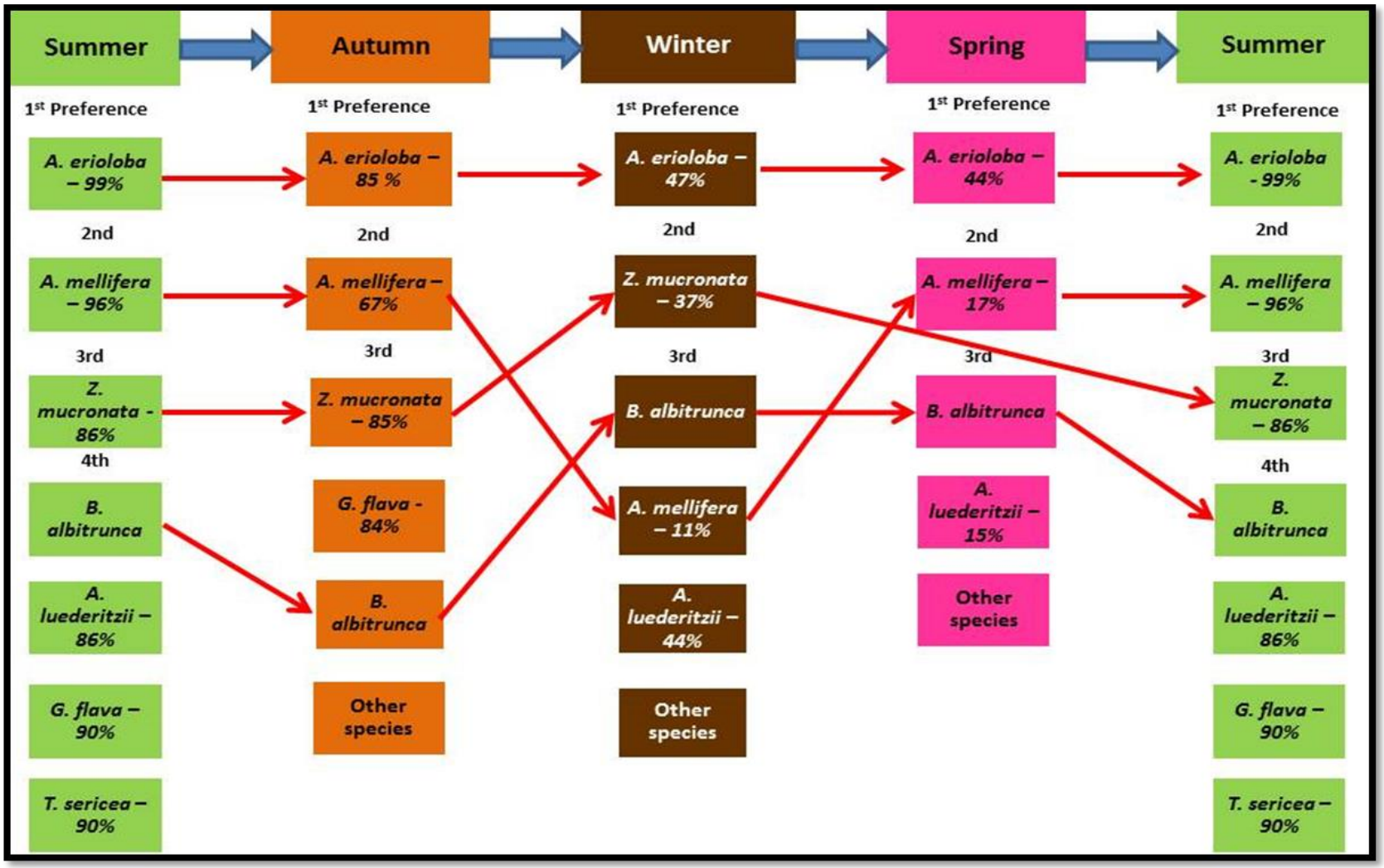


Figure 7.20 Diagram illustrating the change in giraffe diet preferences over seasons and the percentage of woody species (% of leaves available) in each season (red arrows indicate the trend for each key resource species)

Figure 7.20 shows how diet changed from what giraffes preferred, to what was available for that season. Figures 7.11 – 7.20 show the seasonal effect of changing availability of each species ($P<0.05$) on giraffe diet. The phenology of each woody species illustrates the percentage availability of leaves for browse (phenology described in chapter 6). *B. albitrunca* (evergreen) was utilised as a key resource during the most critical period from mid-winter (July) to the end of spring (October). Spring had only four woody species available for utilization, with *A. erioloba* (44%) and *A. mellifera* (17%) at their lowest percentage of leaves available and "other species" becoming important during the critical period. Although the phenology percentage of *A. luederitzii* (86%), *G. flava* (90%) and *T. sericea* (90%) was high, these species were less preferred by giraffes overall and *Z. mucronata* was not available during spring.

7.3.5. Preferred times of day for browsing

Over the fifteen months study period the preferred times of day for feeding were identified (Figures 7.21 to 7.24). To account for seasonal changes in day length and temperature, the GLMM was used with the Wald statistic (Tukey's LSD test) to determine the significance of time of day vs season effects. The test showed no significance ($P>0.05$) for any of the time of day vs season effects (Appendix H Table H.5).

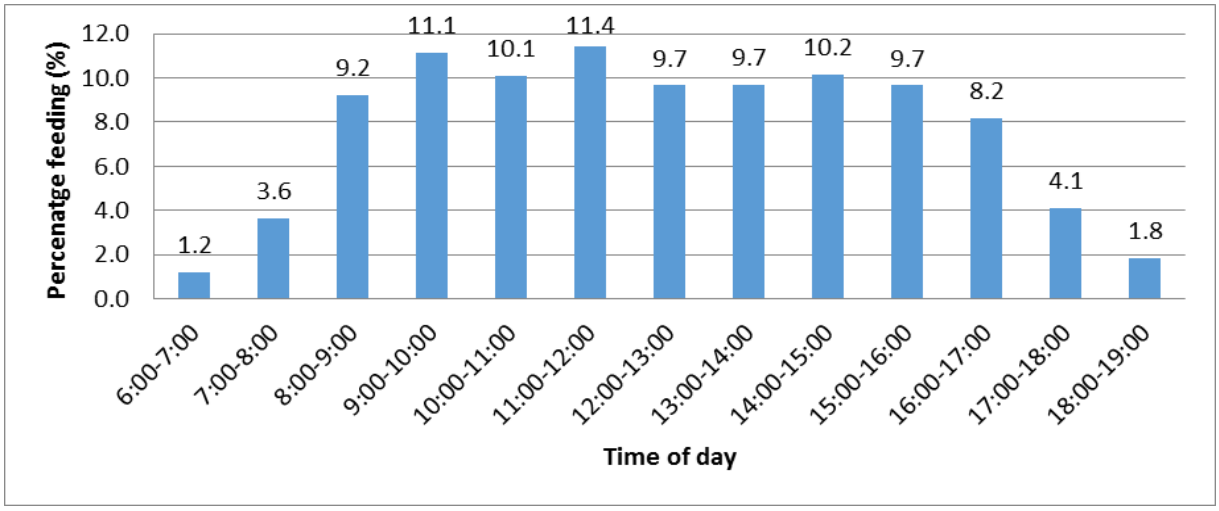


Figure 7.21 Total giraffe feeding percentage for each hour of the day

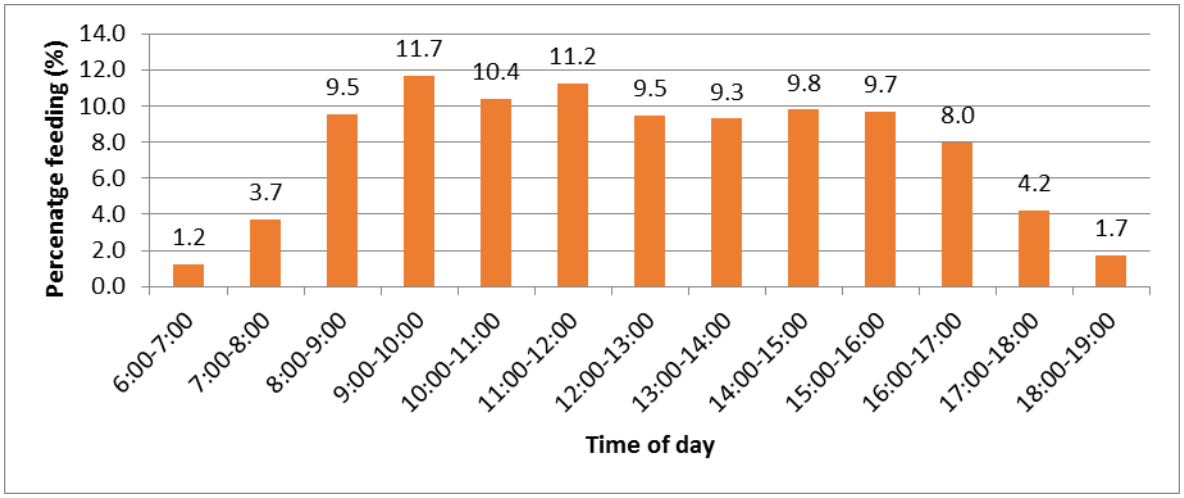


Figure 7.22 Female giraffe feeding percentage for each hour of the day

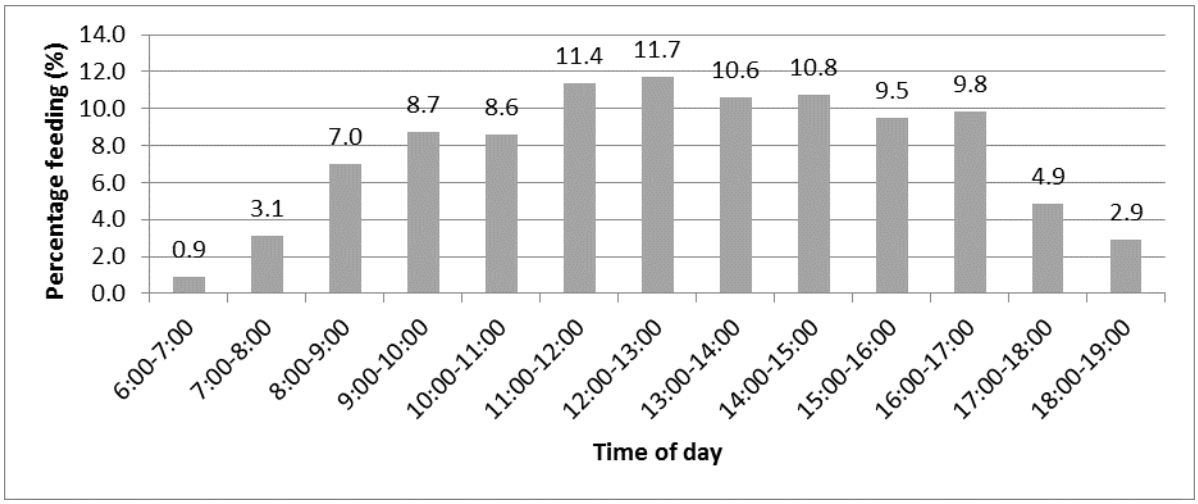


Figure 7.23 Male giraffe feeding percentage for each hour of the day

Overall the preferred times of day for feeding activities (both sexes) were from 09:00 – 10:00 (11.1%) and from 11:00 – 12:00 (11.4%) (Figure 7.21) over all seasons. Feeding by females was very similar: 09:00 – 10:00 (11.7%) and second highest from 11:00 – 12:00 (11.2%) over all seasons (Figure 7.22). For males the most preferred times were from 11:00 – 12:00 (11.4%) and from 12:00 – 13:00 (11.7%) over all seasons (Figure 7.23). When female feeding times were compared with males, whereas for females the preferred time was between 09:00 – 10:00 (11.7%), for the same hour for males it was only 8.7%. For males the highest feeding hour was from 12:00 – 13:00 (11.7%), but for females at that time only 9.5%, much less than the males. The Anova (Kruskal-Wallis ANOVA; $P< 0.05$) showed a significant difference ($P<0.05$) for time of day feeding (Table 7.5).

Table 7.7 Anova statistical variance for giraffe feeding for each hour

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	1110572	12	92547.66667	2.412011276	**0.0155**	1.96012106
Error	1841736	48	38369.5			
Total	11658308.4	64				

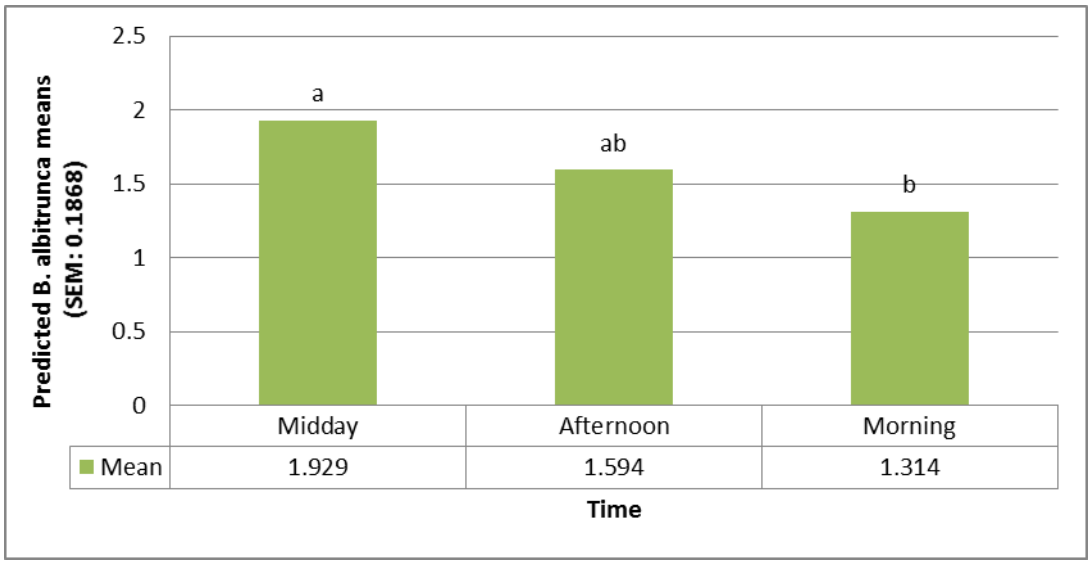


Figure 7.24 Time of day effect on female giraffes feeding on *B. albitrunca*

B. albitrunca was utilized by females during certain times of day with midday (1.929) having the highest value, followed by afternoon (1.594) and the lowest value during the morning hours (1.314). Midday (a) was significantly different (P<0.001) from morning (b),which was significantly different (P<0.001) from afternoon (ab) (Figure 7.24) (untransformed scale). On the transformed scale (Appendix H Table H.5) this would mean that females utilized *B. albitrunca* during the midday hours (6.9) rather than during the afternoon (5.0) or morning (3.7) hours.

During the test for fixed effects for females the Wald statistic showed that time of day had a significant effect (P<0.05) on *A. erioloba* (P=0.002) and *A. luederitzii* (P=0.037). On the transformed scale (Appendix H Table H.5) this would mean that females utilized *A. erioloba* during midday (41.1) rather than during the afternoon (26.3) or morning (27.8) hours. On the transformed scale (Appendix H Table H.5) this would mean that females utilized *A. luederitzii* during midday (3.0) rather than during the morning (2.5) or afternoon (2.2) hours.

This analysis shows that only three tree species fed on by females were influenced by time of day effects.

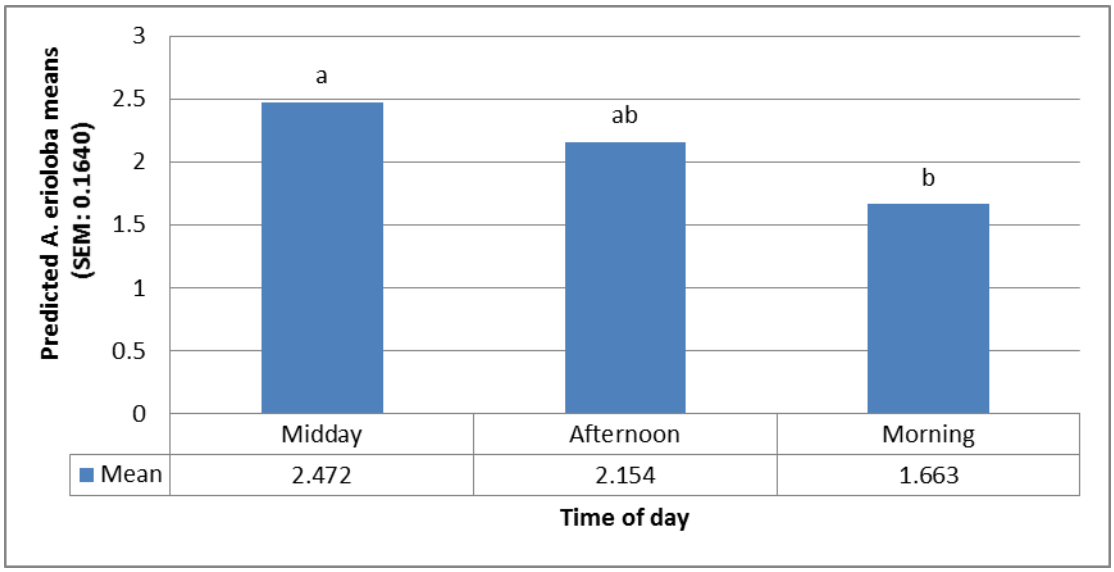


Figure 7.25 Time of day effect on male giraffes feeding on *A. erioloba*

Figure 7.25 illustrates that males utilized *A. erioloba* more during certain times, with midday (2.472) having the highest value, followed by afternoon (2.154) and the least during the morning (1.663) (untransformed scale). On the transformed scale (Appendix H Table H.8) this would mean that males utilized *A. erioloba* during the midday hours (11.8) rather than during the afternoon (8.6) or morning (5.3) hours.

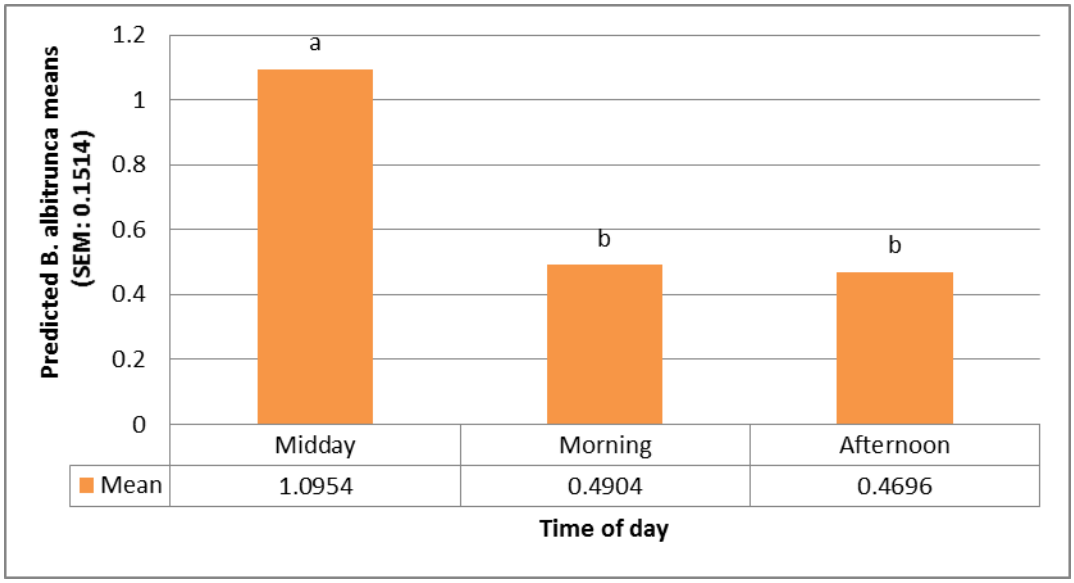


Figure 7.26 Time of day effect on males feeding on *B. albitrunca*

Figure 7.26 illustrates that males utilized *B. albitrunca* more during certain times, with midday (1.0954) having the highest value, followed by morning (0.4904) and the least during the afternoon (0.4696) (untransformed scale). On the transformed scale (Appendix H Table H.8) this would mean that males utilized *B. albitrunca* during the midday hours (3.0) rather than during the afternoon (1.6) or morning (1.6).

During the test for fixed effects for males, the Wald statistic showed that time of day had a significant effect ($P<0.05$) on *A. mellifera* ($P=0.012$) and *A. luederitzii* ($P=0.274$). On the transformed scale (Appendix H Table H.8) this would mean that males utilized *A. mellifera* and *A. luederitzii* during midday (4.8, 1.4 respectively) rather than during the morning (2.2, 1.2 respectively) or afternoon (3.6, 1.2 respectively)

This demonstrates that of the prominent tree species fed on by males, only *A. luederitzii, B. albitrunca* and *A. mellifera were* influenced by time of day effects.

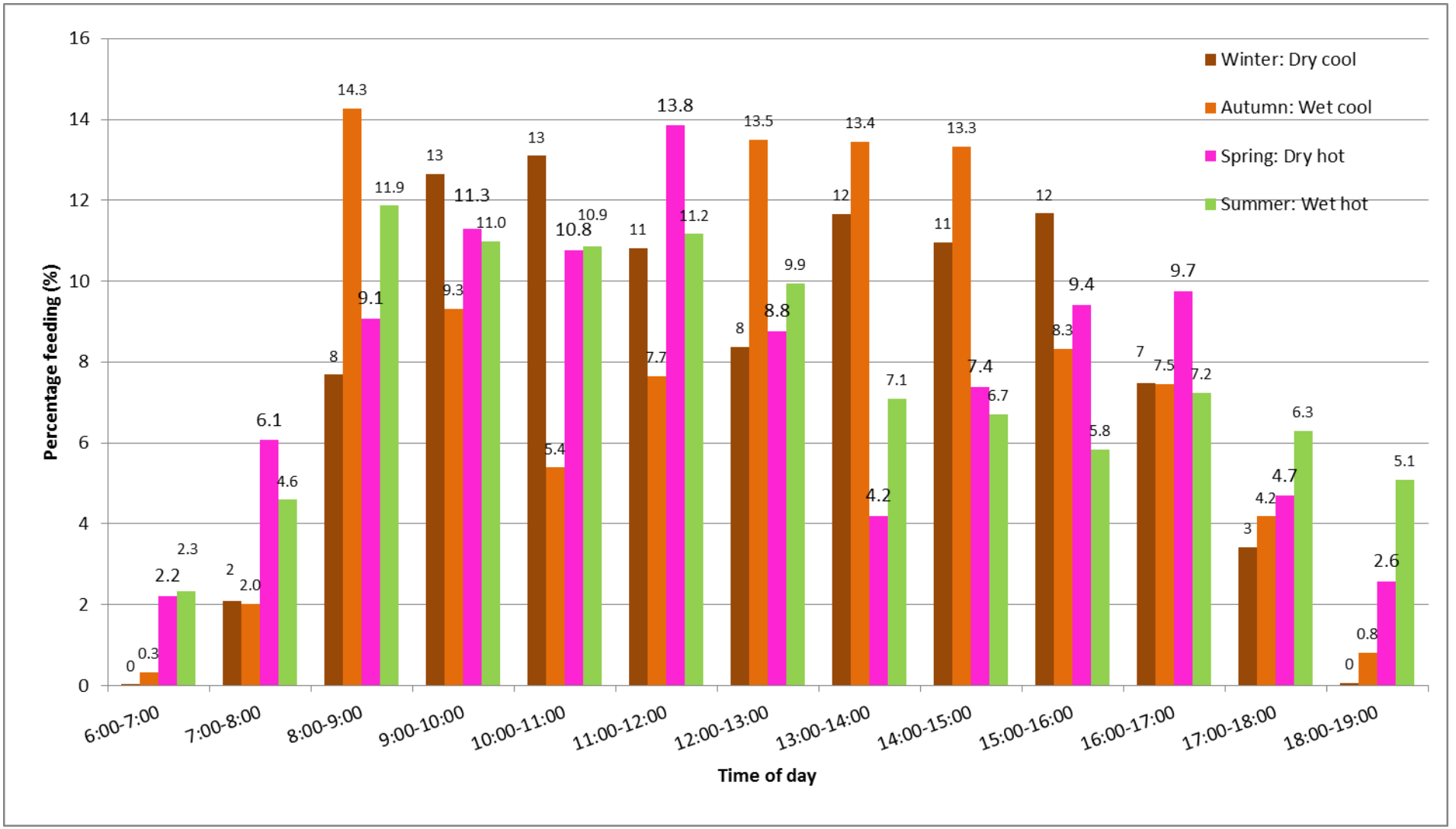


Figure 7.27 All giraffe feeding percentages (%) during time of day for each season

Figure 7.27 shows the seasonal influence on daily feeding times. Due to extended day length in summer the giraffes start feeding earlier and also feed for longer hours than during the winter months. In addition to day length, temperature is another factor which might influence thermoregulation and the activities of giraffes (see chapter 9). No night time observations were possible, and it can only be assumed giraffes were also feeding at night. However, giraffes were less active during the night than during the day and they did not travel long distances (see chapter 5).

Appendix H further shows how giraffe diet preferences changed over seasons and how time x season interactions influenced giraffe feeding. During the summer, *A. erioloba* (14:00-15:00), *A. mellifera* (11:00-14:00), *Z. mucronata* (15:00-16:00) and *B. albitrunca* (08:00-09:00) had different time preferences for feeding. During the autumn, *A. erioloba* (13:00-14:00), *A. mellifera* (14:00-15:00), *Z. mucronata* (07:00-08:00) and *B. albitrunca* (07:00-08:00) had different time preferences. During the winter, *A. erioloba* (12:00-13:00), *A. mellifera* (16:00-17:00), *Z. mucronata* (09:00-10:00) and *B. albitrunca* (14:00-15:00) had different time preferences. During the spring *A. erioloba* (10:00-11:00 and 15:00-16:00), *A. mellifera* (12:00-15:00), *Z. mucronata* (17:00-18:00) and *B. albitrunca* (11:00-12:00) had different time preferences (Appendix H).

This finding, however, needs to be investigated in more detail in relation to the availability of food and the principal food species. The specific area and habitat will identify the principal food species for that specific hour. Combining these 15 months of observations of feeding does not provide sufficient evidence of significant differences. However, there was a change in diet and times of preference for males (Appendix H), where only four species were prominently used during the winter months. *A. erioloba* was very prominent throughout the day during the spring. For females (Appendix H), certain species like *B. albitrunca* were strong during the winter and *Z. mucronata* was avoided during the spring.

7.4. Conclusion

From the results, the following can be concluded:

i) Browsing/feeding is by far the most important activity performed by giraffes. It takes most time per day and changes from season to season. Browsing (including all activities related to browsing, such as ruminating and osteophagia) constituted 46% of the total observations. For females 48% and males 41% of all activities were spent on browsing. However, juveniles (42%), sub-adult males (38%) and sub-adult females (57%) differed significantly in the time they spent on browsing.

ii) *Acacia erioloba, Z. mucronata, B. albitrunca* and *A. mellifera* were the four species mostly preferred and made up the majority of giraffe diet. 45% of all feeding consisted of *A. erioloba*, 20% of *A. mellifera*, 21% of *Z. mucronata* and 7% of *B. albitrunca*. When combined, these four woody species represent 93% of the total giraffe diet in KKNR. These four species are not the most abundant in KKNR and, therefore, they are considered to be key preference species and should be managed as critical resource species.

iii) Giraffe diet varied over the months and seasons, and each season had a significant effect on the preferred tree species. Seasons in particular had the most significant effect on giraffe diet, because of the phenology cycle for each woody species. During the critical months (July – October) most changes in giraffe diet occurred and the greatest differences were between the four critical resource species.

iv) The utilization of most tree species was positively correlated in terms of their utilization in the diet of the giraffes. However, a few were negatively correlated, which will require further investigation regarding the reasons for this.

v) Ordinations helped to identify tendencies regarding how giraffe diet varied over seasons by grouping similar utilization values together. From the ordinations it was clear there was a seasonal effect on diet preferences of giraffes. Season will determine what was available and most abundant and how deciduous trees influenced giraffe diet.

vi) Certain preferred tree species, like *Z. mucronata,* were almost completely avoided during critical periods because of the season and phenology. With respect to season and time of day, the time of day effects had little influence on most species. Only *B. albitrunca* and *A. erioloba* were influenced by the time of day when giraffes were feeding.

CHAPTER 8: FEEDING HEIGHT PREFERENCES OF GIRAFFES IN RELATION TO INTERSPECIFIC COMPETITION INTERACTIONS

8.1. Introduction

Adult giraffe cows are on average at least a full metre shorter than adult bulls (Lönnig, 2007). The tallest female giraffe measured in Kenya was 5.88 metres; the tallest female measured in the northern Kalahari was 5.17 metres (Dagg & Foster, 1982).

Du Toit (1990) compared preferred feeding heights of giraffes to those of a potential competitor, such as the kudu (*Tragelaphus strepsiceros*). He found in the Kruger National Park (KNP) that giraffes tend to feed at heights of 1.7 to 3.7 m with a preferred neck angle of 90 - 135° (with respect to the forelegs). Giraffe bulls generally fed at higher levels than cows (Du Toit, 1990). Kudus on the other hand, had a height preference of about a metre, but a range of up to 2.0 m, and a preferred neck angle of 45 - 90°. According to Breebaart (2000), kudus are in direct competition with female and juvenile giraffes. (Woolnough & du Toit (2001) found in KNP that kudus frequently browsed at a 1.5 m level, the same height at which juvenile giraffes feed.

Young & Isbell (1991) in East Africa found that the preferred feeding height of giraffes is shoulder height i.e. 60% of maximum height and far below maximum feeding height. Feeding height varied according to the gender composition of groups. Females in female groups fed mainly at 1.5 m, females in male groups mainly at 2.5 m, and males in male groups mainly at 3.0 m. Therefore, at best, a long neck may confer intermittent advantage (Lönnig, 2007).

In another study, Leuthold & Leuthold (1972) found that in a different habitat (Tsavo National Park, Kenya), giraffes spent about half their feeding time browsing below a height of 2.0 m. In the Serengeti, giraffes spent almost all their feeding time browsing low *Grewia* bushes (Pellew, 1984). This raises the question that if a height of 3.0 m is adequate to avoid nutrient competition, why do giraffes grow to heights of 5.0 m? Dagg & Foster (1976) suggested that when giraffes were evolving there were a number of high-level browsers, including Sivatheres, competing for browse. This hypothesis, however, is weak, because for many millions of years small giraffes were coexistent with Sivatheres and larger giraffes, and would not have been able to compete with them for nutrients (Lönnig, 2007).

Environmental factors also influence giraffe diet throughout the year (Stuart-Hill & Tainton, 1988). Simmons & Scheepers (1996) found that giraffes generally feed on lower shrubs and not tall trees during the dry season. Ginnett & Demment (1999), however, said there is no evidence for competition between male and female giraffes and that resources are well shared. Stuart-Hill & Tainton (1988) found in the Eastern Cape Province (South Africa), that tall (>2.0 m) and medium trees (1.4 – 1.8 m) produced similar quantities of browse, but had higher yields than those in the low category (0.8 – 1.2 m). Tall trees were also defoliated less intensely than medium trees. Sauer *et al*. (1977) found that 67.4% of browsing took place above 2.0 m in the western Limpopo Province, South Africa. Dekker and Smit (1996) determined that the highest browse production was present in the 1.5 – 2.0 m height stratum from seven of the eight plant communities in the Messina Experimental Farm, Limpopo

Province. Abule *et al.* (2007) reported that browse production in the Awash valley of Ethiopia was highest in the 1.5 m – 5.0 m height stratum, followed by the height stratum of <1.5 m.

Shorrocks & Croft (2009) found in Kenya that (Reticulated giraffes) giraffes frequently fed at shoulder level (2.0 m) during winter and dry seasons. Ginnett & Demment (1997) found in east Africa (Masai giraffes) demonstrated that giraffes' longer necks should assist them in gaining a feeding height advantage. Young & Isbell (1991), found in East Africa that giraffes fed faster at shoulder level (2.5 m for females and 3.0 m for males), as this is the most comfortable feeding level. Giraffes are considerably taller than other browsers and have been for more than a million years (Mitchell & Skinner, 2003). The latter, therefore, suggested there must be other selection pressures at work to explain why giraffes have such long necks, other than avoiding competition.

However, South African giraffes were found to browse more above shoulder level (du Toit, 1990), partly because more browse was available at higher strata (Woolnough & du Toit, 2001), and partly due to their move into dry river beds in winter where leaves remained on tall trees (du Toit, 1995). Further experimental support was found in a field study in the KNP of feeding competition, indicating that more forage was available above 2.5 m in *A. nigrescens* trees protected by exclosures at levels used by giraffes (relative to unprotected trees), because of the competition with shorter browsers (Cameron & du Toit, 2007). The latter concluded that giraffes preferentially browse at higher levels in the canopy to avoid competition with other browsers. Although Lönnig (2007) does not agree with the experiment done by Cameron & du Toit (2007), Simmons & Altwegg (2010) found it useful as an indicator of how browsers compete for resources.

According to Abule *et al.* (2007), there are limited published results of browse production to compare results of interactions of giraffes competing with other browsers. No such results exist for giraffes in the arid Kalahari region and most studies have been done in the Lowveld, which is located in the higher rainfall eastern savannah areas of South Africa.

The specific objectives for this study were to determine:

i) The preferred feeding levels (height strata) of male and female giraffes,
ii) Whether there are seasonal variations in feeding levels,
iii) Whether the time of day influences the preferred feeding levels,
iv) Whether the preferred feeding levels of giraffes are in direct competition with other browser species.

8.2. Procedure

8.2.1. Determining the preferred feeding levels for male and female giraffes

A scan sampling method, slightly modified from the approach described by Blomqvist & Rensburg (2007), was used to record the feeding levels (height strata) of the giraffes. For example: if the current activity of an individual was recorded as "browsing", the plant species that was being utilised, as well as the height level (in relation to the body posture of the

specific individual) of browsing, was recorded on a voice recorder. The general browsing heights of giraffes were determined by differentiating between six levels of browsing ranging from ground to above the head (levels 1 to 6) (Figure 8.1). Level 1 = Ground level, head lower than knee, including knee bent positions (<1.0 m, Figure 8.2). Level 2 = Knee height; head lower than the underside of the belly, except for knees bent associated with grazing at ground level (1.0 m, Figure 8.2). Level 3 = Chest height; neck horizontal or lower, but still above the underside of the belly (2.0 m, Figure 8.2). Level 4 = Neck height; neck bowing less than 45° to the horizontal level, but not lower than the hump (3.0 m, Figure 8.2). Level 5 = Head height; normal upright posture with the neck position at an angle of at least 45° above the horizontal (3.5 m, Figure 8.2). Level 6 = Stretch height; mouth lifted higher than horn bases (>4.0 m, Figure 8.2).

When a giraffe browsed a specific plant, it was noted as a feeding record for that plant species. The browsing of the same plant by more than one individual was also noted as such and then assigned to each sex. An utilisation frequency for the various plant species was calculated as the total number of feeding records per plant, expressed as a percentage of all observations.

The voice recorder data were captured into a Microsoft Excel worksheet. Male and female data were entered into separate worksheets. The data for each feeding level for each tree species were analysed for each season and time of day with the analyse data tool (Excel, 2010) and include Mean values, Standard Deviations, Standard Error of the Mean, Percentages and Totals. Figures and Tables were created and used to compare different feeding levels for males and females and were then tested for differences in significance (ANOVA, $P<0.05$) using GenStat® (Payne, *et al.,* 2012). The number of samples used for females is shown in Appendix I Table I.2 and for males in Appendix I Table I.5.

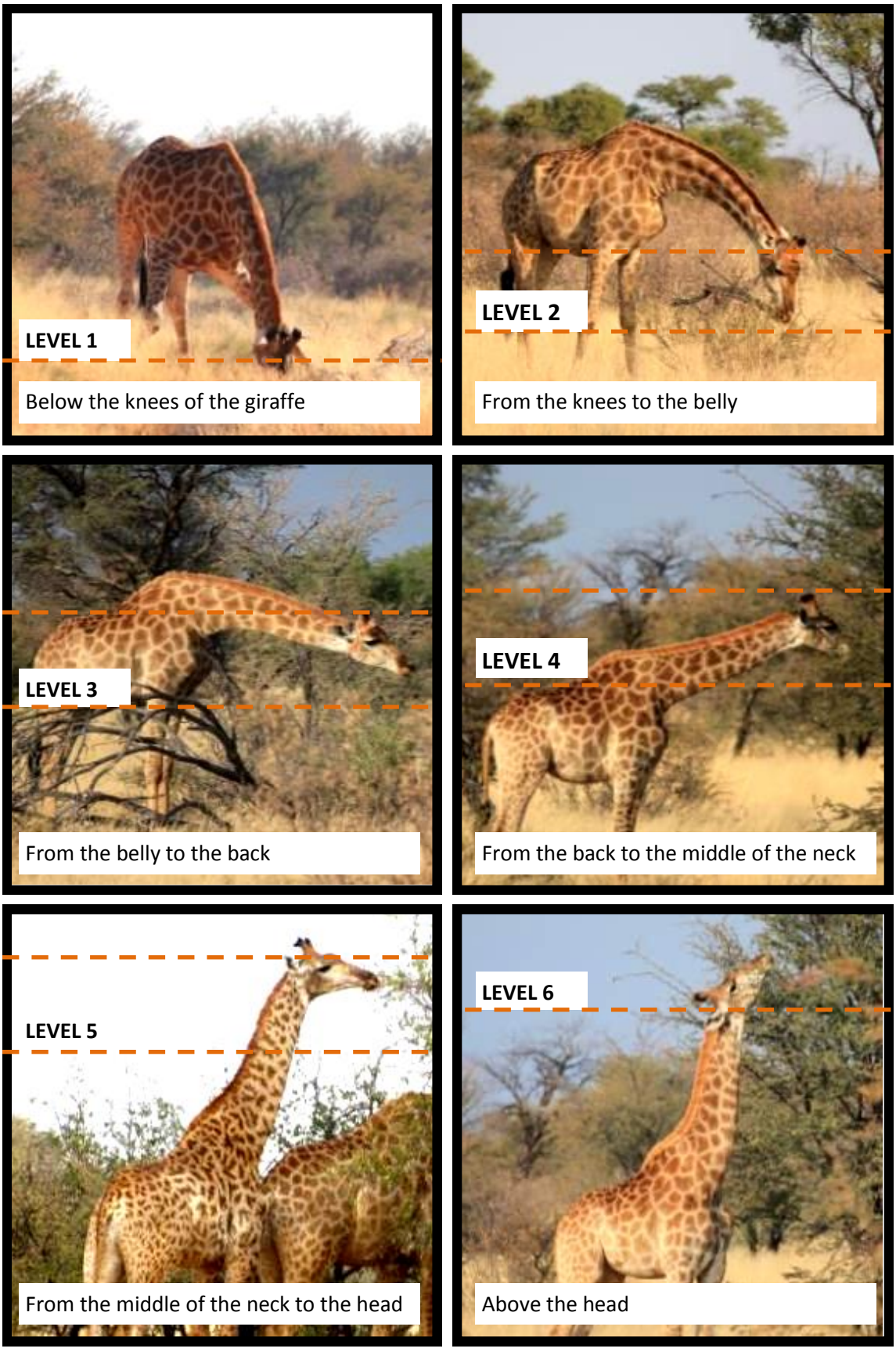


Figure 8.1 Browsing levels according to the body posture of giraffes while feeding, modified from Blomqvist & Renberg (2007)

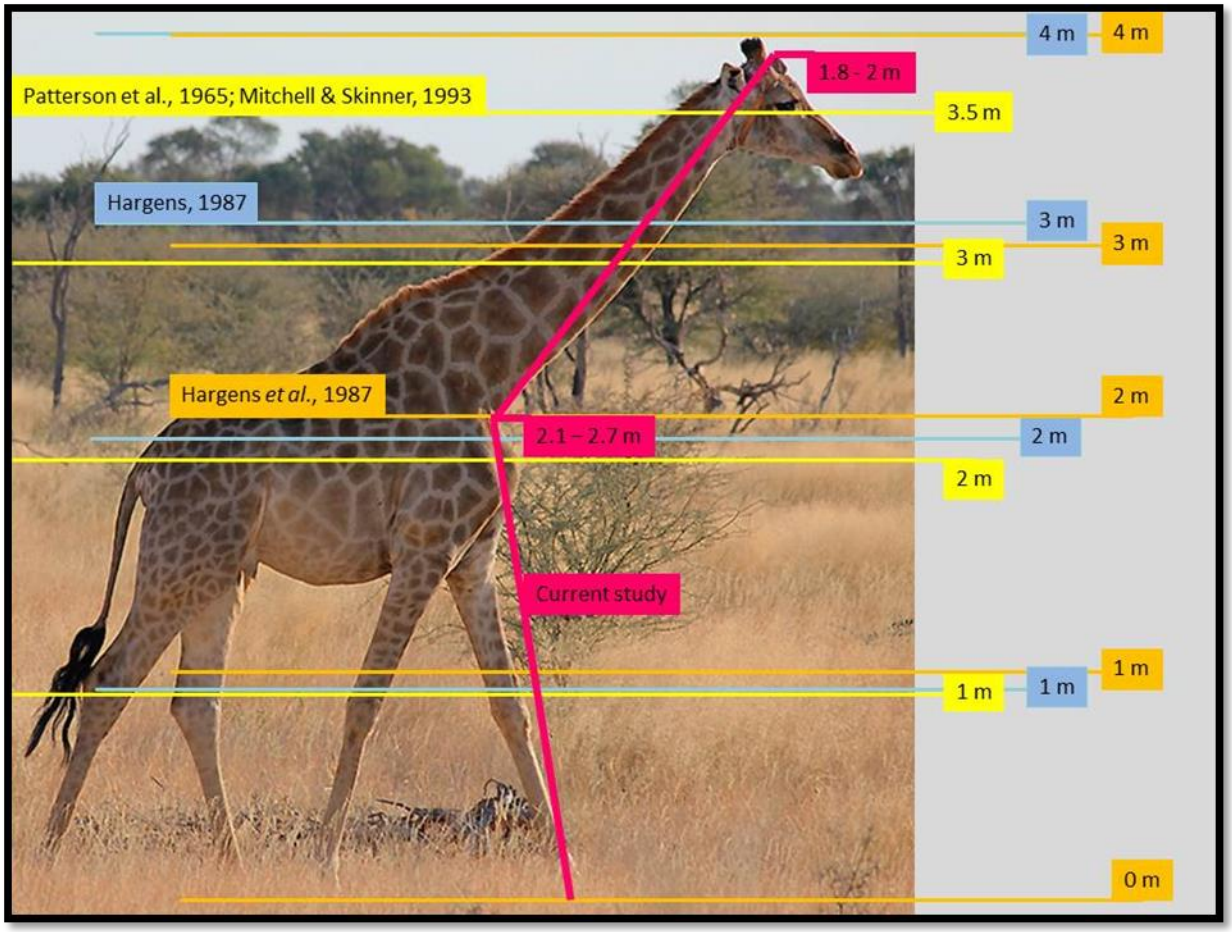


Figure 8.2 Giraffe height measurements as reported in the literature

8.2.2. Seasonal variation in feeding levels

To determine if the preferred feeding levels of giraffes changed over seasons, Genstat (Payne, *et al.,* 2012) was used to analyse the recorded data for each of the four seasons: winter (June, July, August), spring (September, October), summer (November, December, January, February) and autumn (March, April, May). Generalized Linear Mixed Models (GLMM) were used to cater for non-Normal distributions for the Poisson distributions.

The GLMM analysis was used to test for differences between feeding level and season effects, feeding level and time effects, as well as the time x season interactions (fixed effects). The random effect was specified as hour. Treatment means were separated using Tukey's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran, 1980). All observations recorded within each of the seasons were grouped together and used to compare tree species and giraffe feeding levels for each sex during each season.

Each feeding level from each tree species was used as the response variate, and season, time and also the interaction between season and time of day (season x time) were used as fixed models to identify highly significant differences ($P<0.001$) using the Wald and F statistic (Schall, 1991).

The data obtained from the recordings were further tested with the different techniques from the CANOCO 4 (TerBraak & Šmilauer, 1998) package by “grouping” the same value information together (Verlinden & Dayot, 2005). The data matrices were analysed during the different seasons using the Correspondence Analysis, and the De-trended Correspondence Analysis (DCA) was used for ordination of seasonal variation for each feeding preference (Gauch, 1982; TerBraak, 1986, 1987). This included multidimensional scaling (MDS) to establish whether there were outlier data within each of the separate data matrices that needed to be removed from the rest of the analyses. Indirect ordination using DCA (unimodal response) was used to extract ordination axes that described the main special compositional gradient, and to establish which levels were related to male and which to female gradients (Ter Braak & Šmilauer, 1998).

8.2.3. Influence of the time of day on feeding levels

To determine whether giraffes preferred to change feeding levels during a particular time of day, Genstat (Payne, *et al.,* 2012) was used to analyse the recorded data for each time of day: morning (06:00 - 10:00), midday (10:00 – 14:00), afternoon (14:00 – 19:00). All observations recorded within each of the three time slots were grouped together Tukey's least significant difference test was used to compare tree species feeding levels for each of the two sex groups during each time of day. The method of Schall (1991) was also used to analyse the GLMM for both the Wald statistic and F statistic with a 5% level of significance (Snedecor & Cochran, 1980).

8.2.4. Interspecific competition

Results from this study are compared with the feeding levels of other species, as reported in the literature. This chapter discusses aspects concerning feeding competition with kudus and elands by asking whether giraffes are involuntarily competing with other browsers because of the height distribution of available browse. Information on available browse (chapter 6) and preferred browse (chapter 7) is included in the discussion.

8.3. Results and Discussion

8.3.1. Descriptive statistics for the preferred feeding levels

The highest number of feeding records (n = 13 082), regardless of the plant species or height level, are from adult female giraffes. When combining all the recorded feeding levels, it is clear that levels three (22%), four (33%) and five (32%) were the preferred feeding levels. Combining these three levels shows that 87% of all female feeding occurred between 2.0 and 3.5 m (Figure 8.3). When level six is also included, then 93% of all female feeding occurred at 2.0 m or above. Only 7% of female feeding occurred below 2.0 m, (levels one and two). And combining levels four (33%) and five (32%) shows that 65% of all feeding occurred at a height of 3.0 - 3.5 m (Figure 8.3).

Combining all the recorded feeding levels for male giraffes (n = 2 968), shows that levels four (31%) and five (40%) are the preferred feeding levels. Combining these two shows that 71% of all male feeding occurred at a height of 4.0 - 4.5 m (Figure 8.3). According to Lönnig (2007) and Dagg & Foster (1982), male giraffes are on average 1.0 – 1.5 m taller than females. When level six is also included, 81% of all male giraffe feeding occurred above 4.0 m, which is on average a metre higher than females (Figure 8.3) Only 19% of male feeding occurred below 4.0 m, which includes levels one to three (Figure 8.3). The 71% of feeding time at levels four and five by males compares to 65% at those levels by females (Figure 8.3).

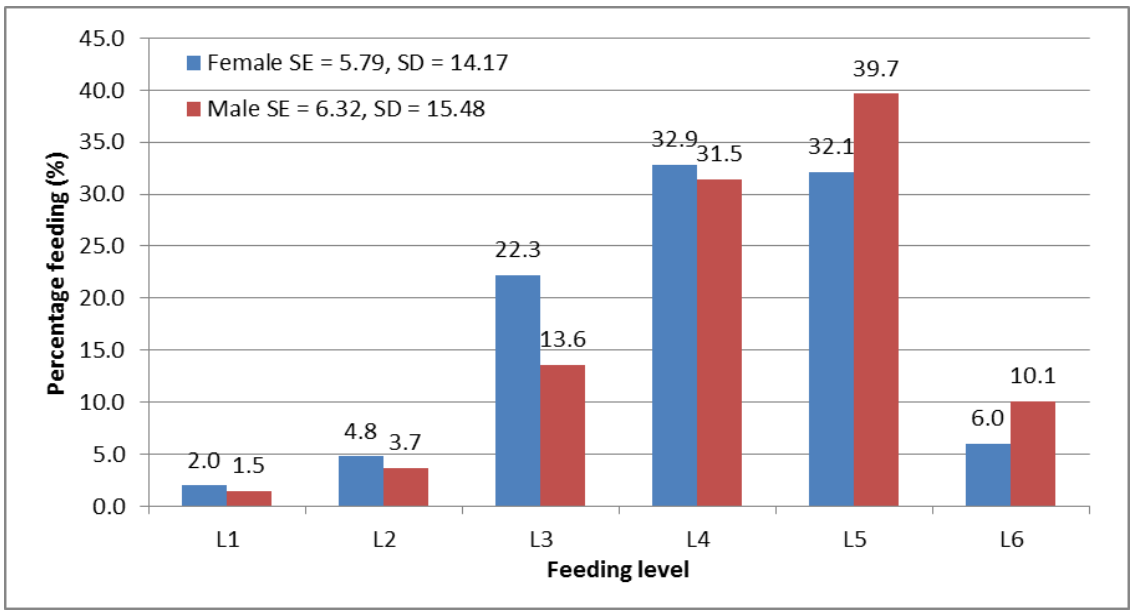


Figure 8.3 Preferred feeding levels of male (n = 2 968) and female (n = 13 082) giraffes by height class.

8.3.1.1. Female giraffes

Each tree species has different growth structures and height distributions (Table 8.1). The way different plant species were utilised at different height levels demonstrated the preference of females for the higher levels four and five (Figure 8.4). This preference, however, changes according to the shape and size of the tree species. The average height of the tree and the average height above ground where the first leaves occurred was a measure of the availability of foliage at different heights. Table 8.1 demonstrates why giraffes may involuntarily compete or not compete with other browsers because of the average height distribution of available browse.

Chapter 6 discusses how the tree height (A) and height of first leaves (C) were measured during the performance of the BECVOL technique (Appendix E).

Table 8.1 Mean tree height with mean height of first leaves measured within KKNR (n = 924)

Tree species	Height of tree (m)	Height of first leaves (m)

	Mean	SE	SD	Range	*Min*	*Max*	Mean	SE	SD	Range	*Min*	*Max*
Acacia erioloba	2.91	0.17	2.03	8.6	*0.4*	*9*	1.12	0.07	0.87	5.6	*0*	*5.6*
Acacia luederitzii	3.14	0.3	1.88	6.5	*0.5*	*7*	0.76	0.08	0.49	1.9	*0*	*1.9*
Acacia mellifera	1.99	0.09	1.08	4.6	*0.5*	*5.1*	0.6	0.04	0.45	2	*0*	*2*
Boscia albitrunca	3.5	0.44	2.49	8.1	*0.5*	*8.6*	1.67	0.25	1.42	5.5	*0*	*5.5*
Grewia flava	1.41	0.03	0.49	2.5	*0.3*	*2.8*	0.31	0.01	0.27	1.2	*0*	*1.2*
Terminalia sericea	3.36	0.26	1.14	3.9	*0.6*	*4.5*	0.88	0.09	0.41	1.4	*0.1*	*1.5*
Ziziphus mucronata	3.34	0.22	0.99	3	*2.1*	*5.1*	0.38	0.05	0.24	0.9	*0*	*0.9*
Other species	1.01	0.04	0.52	2.5	*0.5*	*3*	0.23	0.02	0.19	0.8	*0*	*0.8*

When *A. erioloba* was utilised, 99% of feeeding occurred at 3.0 m or above and only 1% occurred on level two. The preferred levels for feeding on *A. erioloba* were levels four (34%) and five (41%), (combined = 75%). The average height of *A. erioloba* trees was 2.91 m, indicating that females browsed on trees taller than the average measured (Table 8.1).

When *A. mellifera* was utilised, 89% of feeding occurred at 3.0 m or above and 11% occurred at below 2.0 m. The preferred levels for feeding on *A. mellifera* were levels three (34%) and four (34%), (combined = 68%). The average height of *A. mellifera* trees was 1.99 m, indicating that females browsed on trees taller than the average measured (Table 8.1).

When *Z. mucronata* was utilised, 91% of feeding occurred at 3.0 m or above and 9% at below 2.0 m. The preferred levels for feeding on *Z. mucronata* were levels three (37%) and four (33%), (combined = 70%) (Figure 8.4). This is interesting as the foliage of *Z. mucronata* is mostly available from ground level and thus available for other smaller browsers. This may indicate how giraffes avoid competing with other browsers by feeding on levels unavailable to them, as *Z. mucronata* is a preferred species by most browsers. Table 8.1 shows the average height of *Z. mucronata* to be 3.34 m, indicating that giraffes browsed on average size trees, but mostly avoided trees lower than about 2.0 m.

When *B. albitrunca* was utilised, 90% of feeding occurred above 3.0 m and only 10% below 2.0 m. The preferred feeding levels for *B. albitrunca* were levels four (31%) and five (52%), (combined = 83%) (Figure 8.4). This may be because of the average higher tree canopy of *B. albitrunca.* Table 8.1 shows the average height of *B. albitrunca* to be 3.5 m, indicating that giraffes browsed on average size trees, but mostly avoided trees lower than about 2.0 m.

When G. flava was utilised 95% of feeding took place at or below 2.0 m (levels one to three) and only 5% above 2.0 m at levels four to six (Female giraffe). Table 8.1 shows the average height of *G. flava* to be 1.41 m, indicating that giraffes browsed on average size trees, and occasionally on trees over 2.0 m.

When *A. luederitzii* was utilised, 85% of feeding occurred above 3.0 m and 15% below 2.0 m. The preferred feeding levels were four (34%) and five (42%), (combined = 76%) (Female giraffe). Table 8.1 shows the average height of *A. luederitzii* to be 3.14 m, indicating that giraffes browsed on average size trees.

When *T. sericea* was utilised, 84% of feeding occurred above 3.0 m and 16% below 2.0 m. The preferred feeding levels were four (30%) and five (54%), (combined = 84%) (Figure 8.4). Table 8.1 shiows the average height of *T. sericea* to be 3.36 m, indicating that giraffes browsed on average size trees.

When "*other species*" were utilised, 69% of feeding took place at or below 1.0 m (levels one and two) (Figure 8.4), suggesting that giraffes were browsing at lower levels than the preferred levels (Figure 8.3). The average height of *"other species"* was 1.01 m, so 69% of browsing was on average size trees and 31% above average height (Table 8.1)

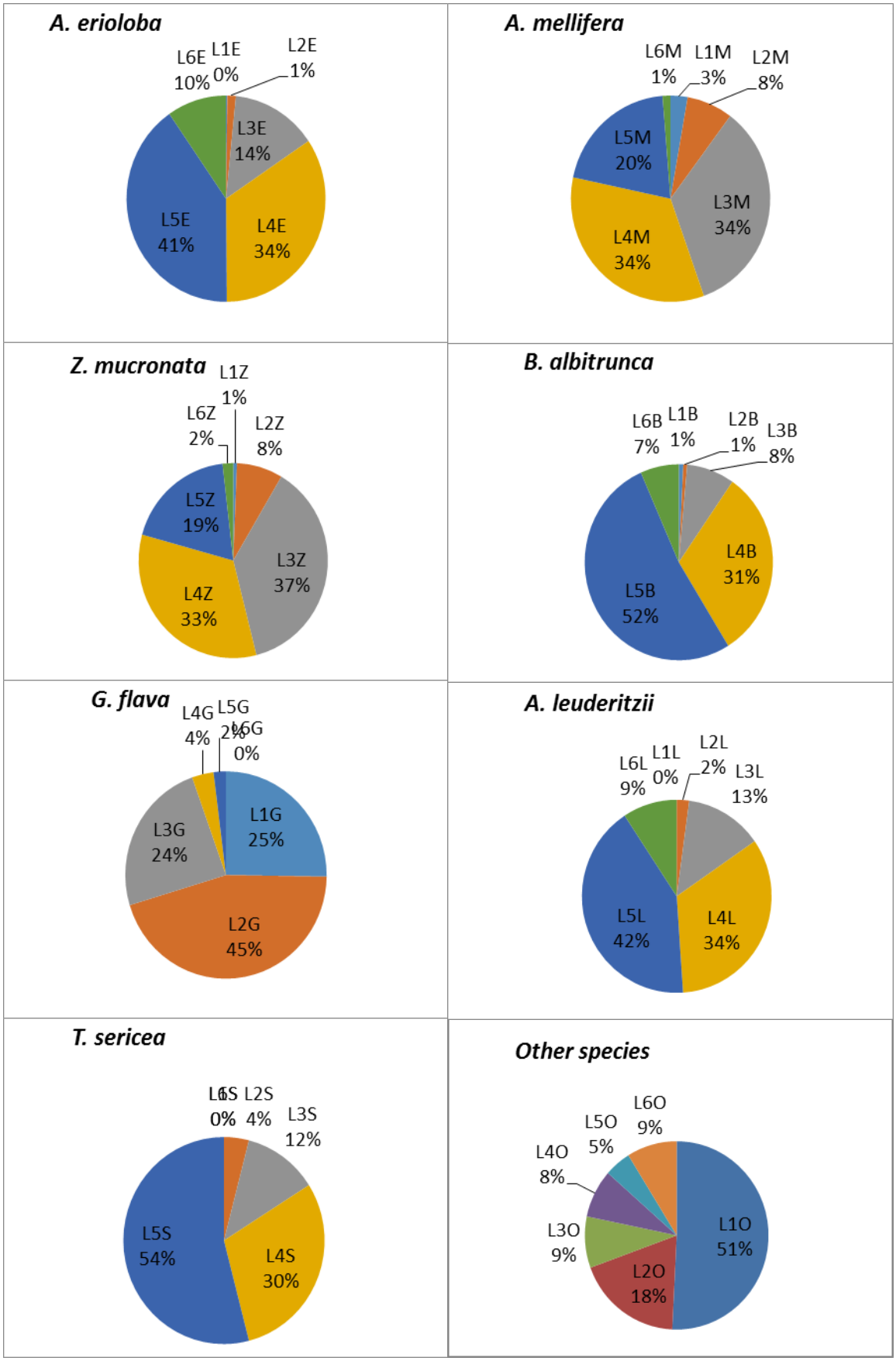


Figure 8.4 Preferred feeding levels of female giraffes by height class of different tree species

8.3.1.2. Male giraffes

Male giraffes showed a preference for feeding at level five (4.5 m) (Figure 8.5). The tree species shape and size must be taken into consideration, as the structure of each species influences the availability of foliage (Table 8.1).

When *A. erioloba* was utilised, 94% of feeding occurred at or above 4.0 m and only 6% below that. The preferred feeding levels were levels four (29%) and five (50%), (combined = 79%) (Figure 8.5). The average height of *A. erioloba* was 2.91 m, so males browsed on trees taller than average (Table 8.1).

When *A. mellifera* was utilised, 90% of feeding occurred at or above 3.0 m and only 10% below that. The preferred feeding level was level four (39%) (Figure 8.5). The average height of *A. mellifera* was 1.99 m, so males browsed on trees taller than average (Table 8.1).

When *Z. mucronata* was utilised, 92% of feeding occurred at or above 3.0 m and only 8% below that. The preferred feeding levels were levels four (36%) and five (28%), (combined = 64%) (Figure 8.5). The average height of *Z. mucronata* was 3.34 m, so males browsed on average size trees (Table 8.1).

When *B. albitrunca* was utilised, 95% of feeding occurred above 4.0 m and only 5% below that. The preferred feeding levels were levels four (26%) and five (55%) (combined = 81%) (Figure 8.5). The average height of *B. albitrunca* was 3.5 m, so males browsed on trees taller than average.

When G. flava was utilised, 75% of feeding occurred on levels one to three at a height below 3.0 m and only 25% above that (levels four to six), because of the lower growing level and size of *G. flava*. (Figure 8.5). The average height of *G. flava* was 1.41 m, so males spent about 15 % browsing time on trees taller than average (Table 8.1).

When *A. luederitzii* was utilised, 90% of feeding occurred above 4 m and only 10% below that. The preferred feeding levels were levels four (37%) and five (46%) (combined = 83%) (Figure 8.5). The average height of *A. luederitzii* was 3.14 m, so males browsed on trees taller than average (Table 8.1)

When "*other species*" were utilised, the preferred feeding levels were levels five and six and 73% of all feeding occurred at above 3.5 m (for females it was below 1.0 m). In addition, about 19% of feeding took place at below 1.5 m (levels one and two) (Figure 8.5), which showed that at times there was more browse available at lower levels than the preferred levels. Thus, these results show that 19% of browsing was on average size trees, since the average height of *"other species"* was 1.01 m, whereas 73% of browsing was on above average size trees (Table 8.1). No observations for feeding on *T. sericea* were recorded for male giraffes.

Feeding level preferences show that bulls preferred foraging at a higher level than cows. These differences were statistically significant when they were tested between males and females (ANOVA, $P<0.05$) (Figure 8.2). In general, bulls preferred levels 4 and 5, compared to levels 3 and 4 for cows. These differences could be due to sex-related size dimorphism, availability of food at different heights, positioning for maximum visibility for predator

vigilance (as suggested by Cameron & Du Toit, 2005) or more effective browsing and utilization of resources by males.

Table 8.2 ANOVA test illustrating the feeding height preference between male and female giraffes

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	0	1	0	0	1	6.607891
Columns	2127.304	5	425.4609	27.98826	**<0.001**	5.050329
Error	76.00703	5	15.20141			
Total	2203.311	11				

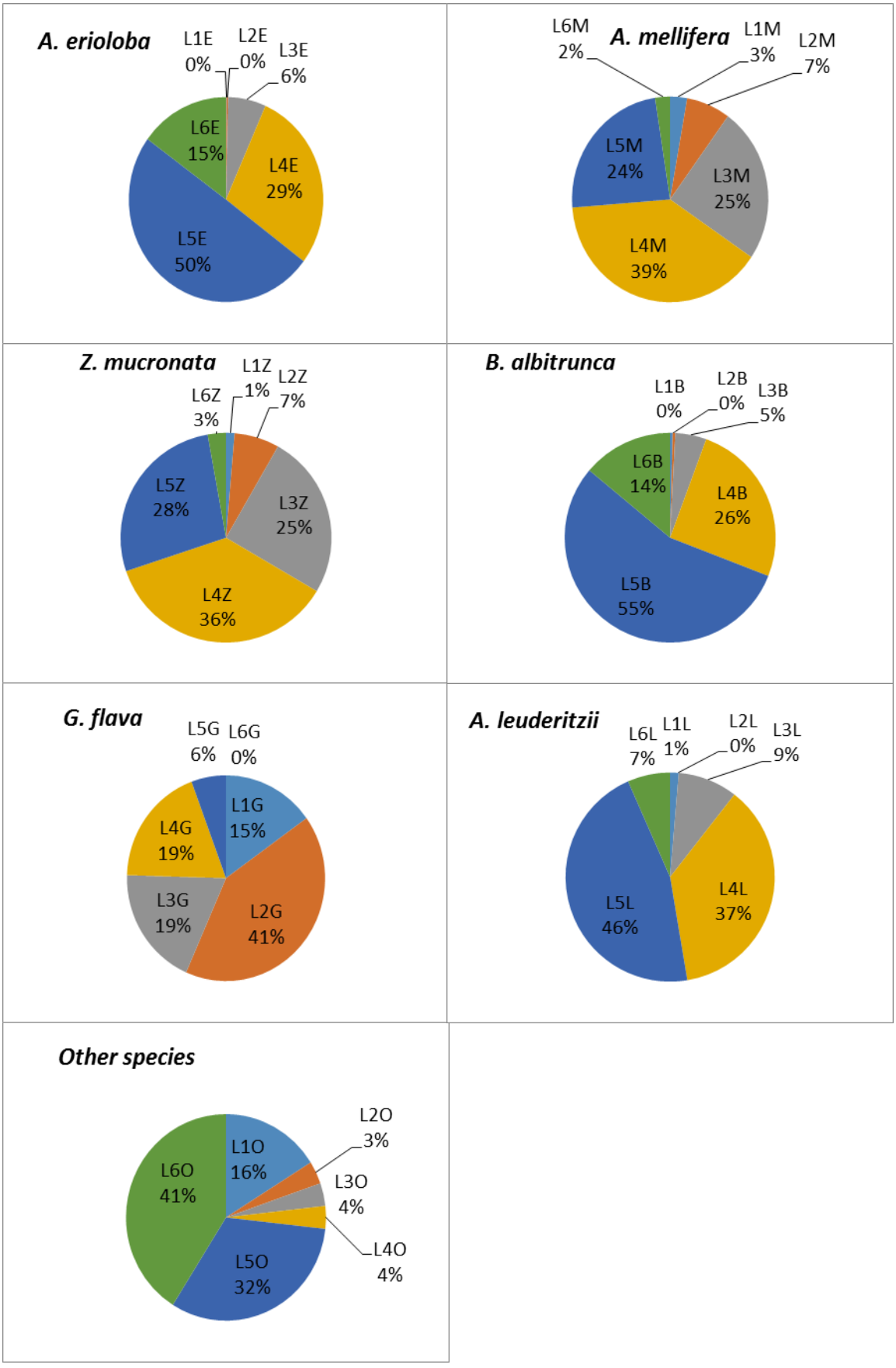


Figure 8.5 Preferred feeding levels of male giraffes by height class of different tree species

8.3.2. Seasonal variation in preferred feeding levels

8.3.2.1. Female giraffes

Seasonal changes in preferred feeding levels between wet and dry seasons can be seen in Figure 8.6 for female giraffes. Levels one to three were utilised more during the wet season (10%) compared to the dry season (4%), and levels four and five more in the dry season (67%) compared to the wet season (62%) (Figure 8.6). These differences were, however, not statistically significant (ANOVA, P>0.05) (Table 8.3).

Looking at the four climatic seasons we can see that feeding level one becomes more prominent during the autumn (wet and cool) season and less so during the spring (dry and hot) season. Level two is more prominent during the summer (wet and hot) and autumn seasons than during the spring (Figure 8.7). This may indicate that females are selecting foliage at lower levels more often during the critical period (autumn) than during the less critical periods (summer and spring). Alternatively, they might be selecting a greater variety of food.

Female giraffes demonstrates how preferred feeding levels changed over the seasons, indicating the largest differences were between spring and autumn. These differences were, however, not statistically significant (ANOVA, P>0.05) (Table 8.3).

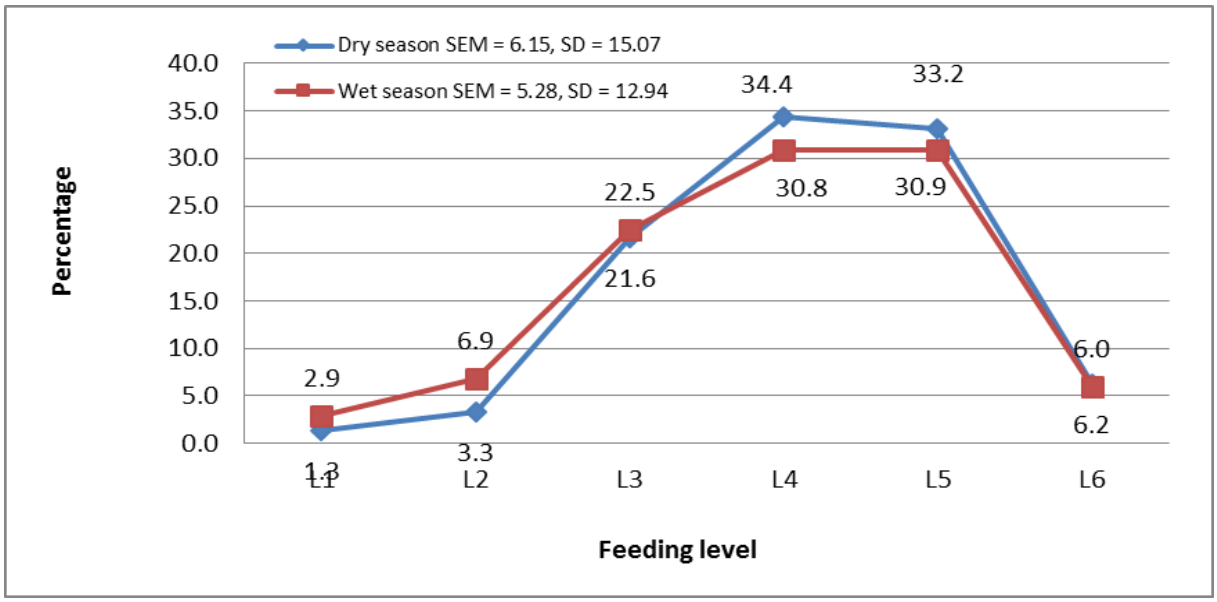


Figure 8.6 Wet and dry season feeding levels of female giraffes

Table 8.3 ANOVA test illustrating the wet and dry season feeding levels of female giraffes

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.243489	1	0.243489	0.001332	**0.971**	5.317655
Within Groups	1462.65	8	182.8312			
Total	1462.893	9				

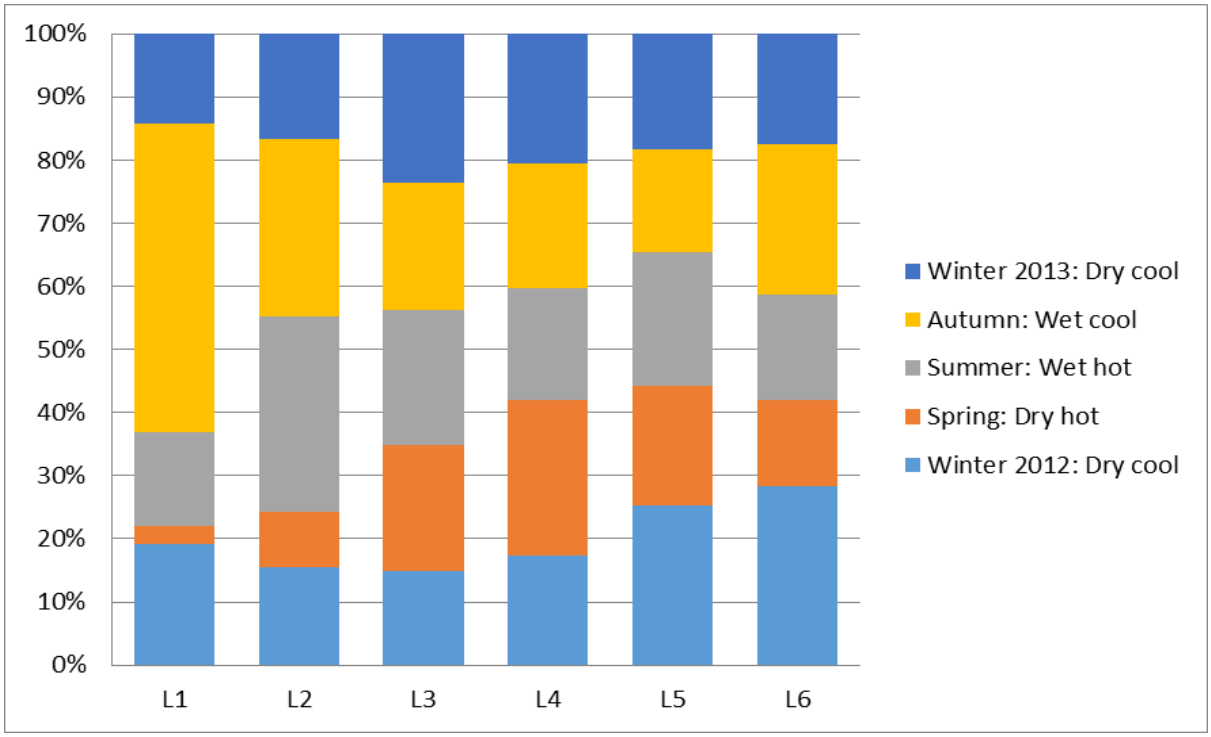


Figure 8.7 Percentage of the preferred feeding levels of female giraffes by height class during different seasons

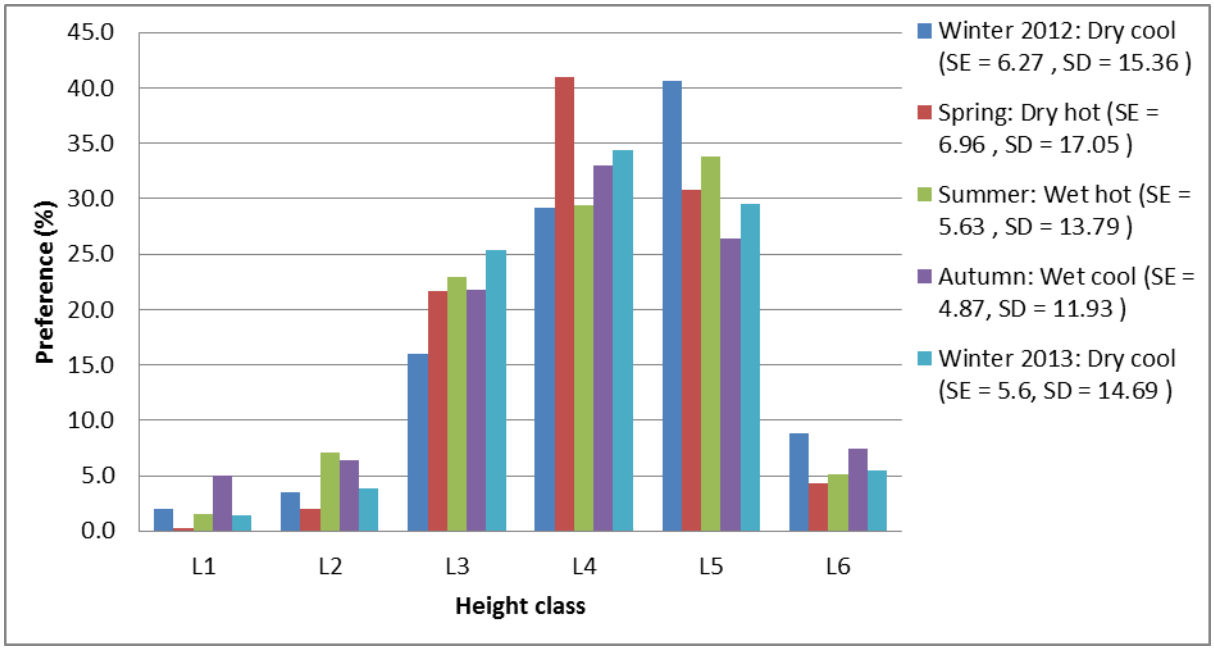


Figure 8.8 Preferred feeding levels of female giraffes by height class during different seasons

8.3.2.2. Statistical results for female giraffes

i. Seasonal effects on feeding levels

Appendix I shows the values for females and Appendix 8B for male giraffes by sequentially adding terms to the fixed model, using both the Wald and F statistic as indicators for high values and significance (Schall, 1991). The true value of each observation is presented as back-transformed means from the untransformed means in Appendix I, by summarising the female feeding preferences per time of day and season interactions on the original scale (Appendix I). During the tests for fixed effects (Appendix I) there were significant differences (P<0.05) between the feeding level, tree species, season and time x season interactions (P<0.05) Tukey's LSD test.

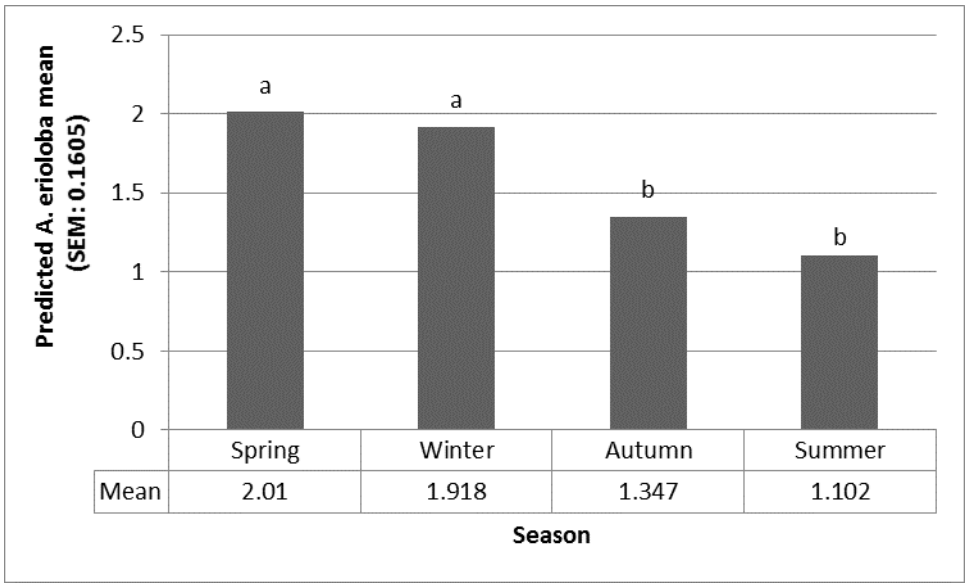


Figure 8.9 Seasonal effect on female giraffes feeding on *A. erioloba* level three

Using A. erioloba as response variate demonstrates that there was a significant difference (P<0.001) in the feeding preference at level three of females during spring and winter compared to autumn and summer seasons (Figure 8.9) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean females fed on *A. erioloba* at level three during the spring (7.5) and winter (6.8) seasons rather than during summer (3.0) and autumn (3.8).

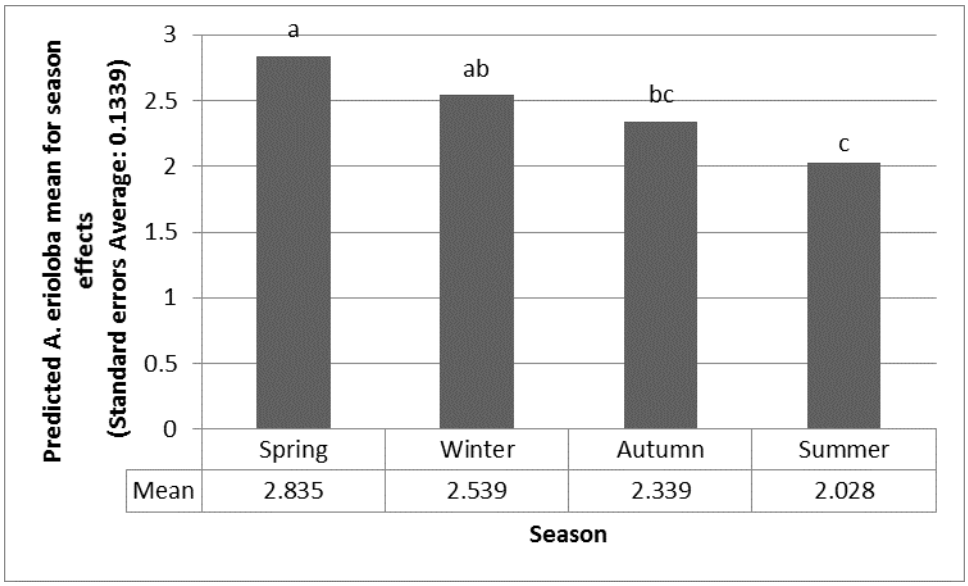


Figure 8.10 Seasonal effect on female giraffes feeding on *A. erioloba* level four

There was also a significant difference (P<0.001) in the feeding preference of females at level four on *A. erioloba* during the spring and winter seasons (Figure 8.10) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *A. erioloba* at level four during the spring (17.0) and winter (12.7) seasons rather than during the summer (7.6) and autumn (10.4).

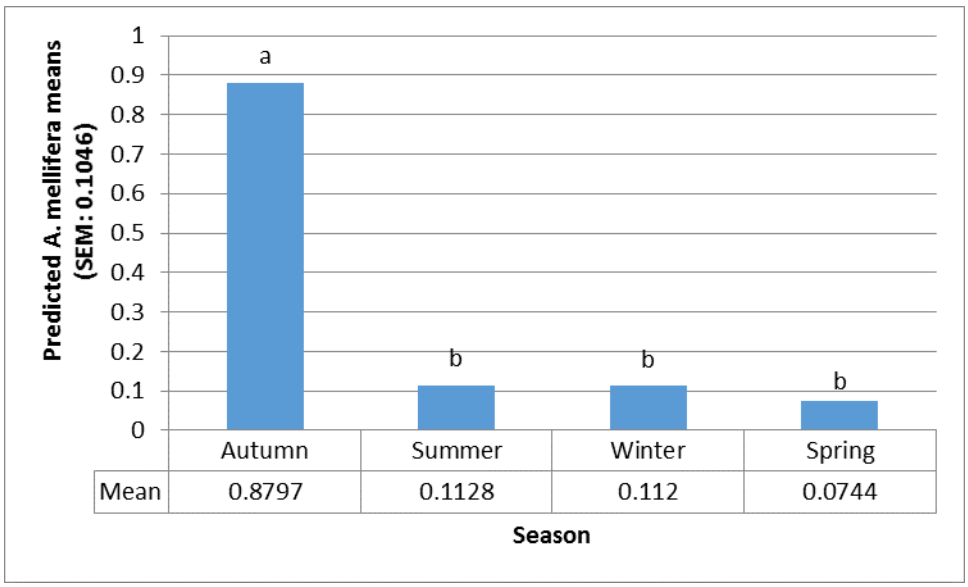


Figure 8.11 Seasonal effect on female giraffes feeding on *A. mellifera* level one

Using *A. mellifera* level one as response variate, there was a significant difference in the feeding preference of females (P<0.001) during autumn compared to the other three seasons (Figure 8.11) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *A. mellifera* level one mainly during the autumn (2.4) and less so during the spring (1.1), summer (1.1) and winter (1.1) seasons. When considering the phenology of *A. mellifera* (Table 6.4) it was expected that this change in diet might occur during the critical period July to October rather than during the autumn.

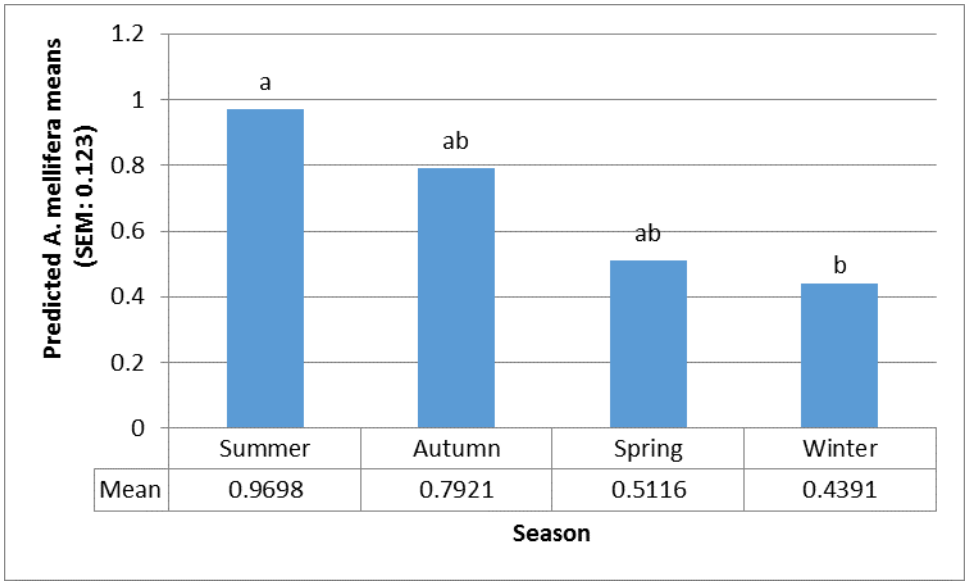


Figure 8.12 Seasonal effect on female giraffes feeding on *A. mellifera* level two

There was also a significant difference in the feeding preference of females (P<0.001) when feeding on *A. mellifera* level two during summer compared to winter months (Figure 8.12) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *A. mellifera* level two during the summer (2.6) and autumn (2.2) seasons rather than during spring (1.7) and winter (1.6).

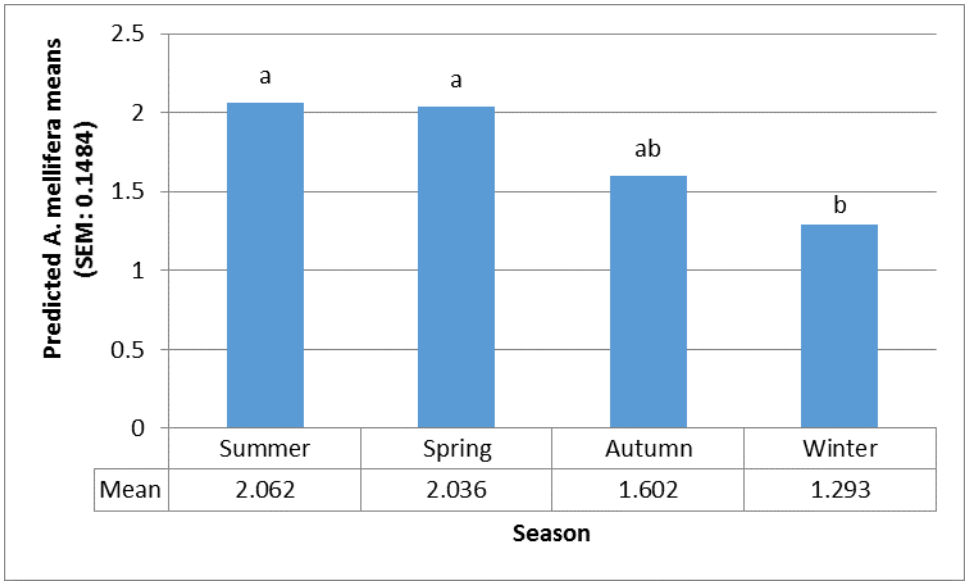


Figure 8.13 Seasonal effect on female giraffes feeding on *A. mellifera* level three

There was also a significant difference in the feeding preference of females (P<0.001) when feeding on *A. mellifera* level three during summer and spring months compared to winter (Figure 8.13) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *A. mellifera* level three during the summer (7.9) and spring seasons (7.7) rather than during the autumn (5.0) and winter (3.6).

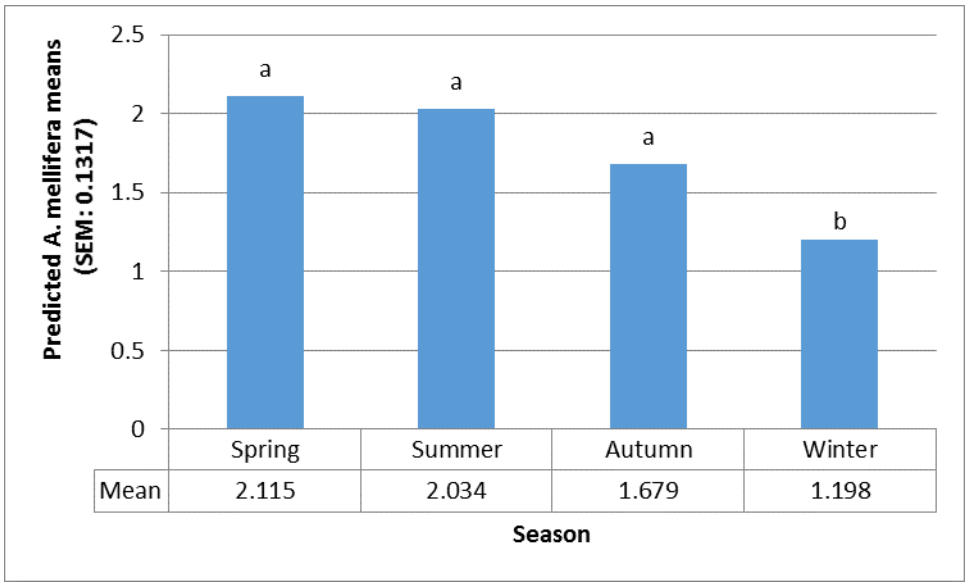


Figure 8.14 Seasonal effect on female giraffes feeding on *A. mellifera* level four

There was also a significant difference in the feeding preference of females (P<0.001) when feeding on *A. mellifera* level four during summer and spring compared to the other months (Figure 8.14) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *A. mellifera* level four during the summer (7.6) and spring seasons (8.3) rather than during the autumn (5.3) and winter (3.3). When referring back to Table 6.4, regarding the phenology of trees, it would seem the winter

months have the least amount of foliage available, which would explain the significant difference from the other months.

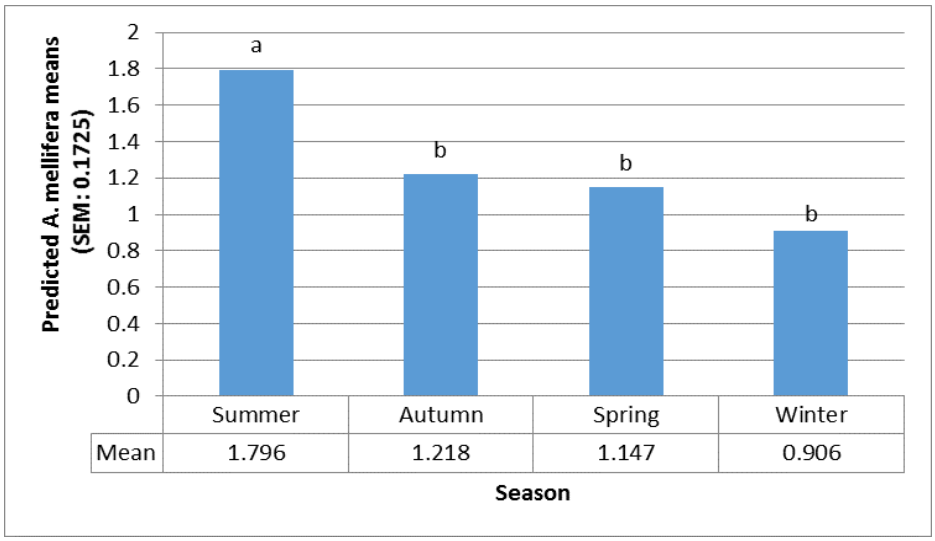


Figure 8.15 Seasonal effect on female giraffes feeding on *A. mellifera* level five

There was also a significant difference in the feeding preference of females ($P<0.001$) when feeding on *A. mellifera* level five during summer compared to the other months (Figure 8.15) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *A. mellifera* level five during summer (6.0) rather than during the spring (3.2) autumn (3.4) and winter (2.5) seasons. Considering the phenology of trees (Table 6.4), it would seem that during the summer months the foliage is most abundant, which could explain the significant difference from the other months.

When *A mellifera was* used as response variate for feeding level six, there was no significance ($P>0.001$) for seasonal effects. The reason could possibly be the growth structure and shape of *A. mellifera.*

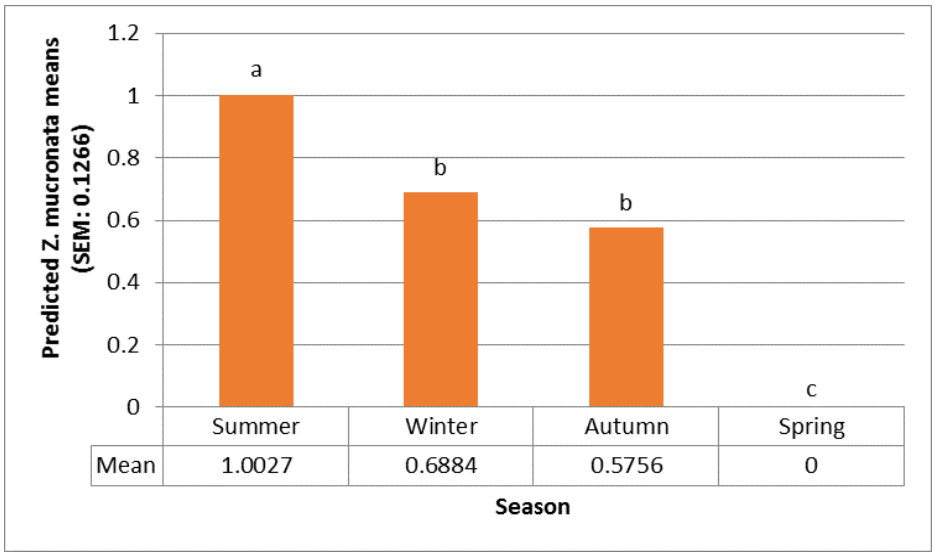


Figure 8.16 Seasonal effect on female giraffes feeding on *Z. mucronata* level two

When Z. mucronata was used as response variate there was a significant difference in the feeding preference of females (P<0.001) when feeding on level two during summer compared to the winter and autumn months (Figure 8.16) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean females fed on *Z. mucronata* level two during the summer (2.7) rather than during the spring (1.0), autumn (1.8) and winter (2.0) seasons. From Table 6.4 one can see that in spring *Z. mucronata* has almost no leaves, therefore value = 0.

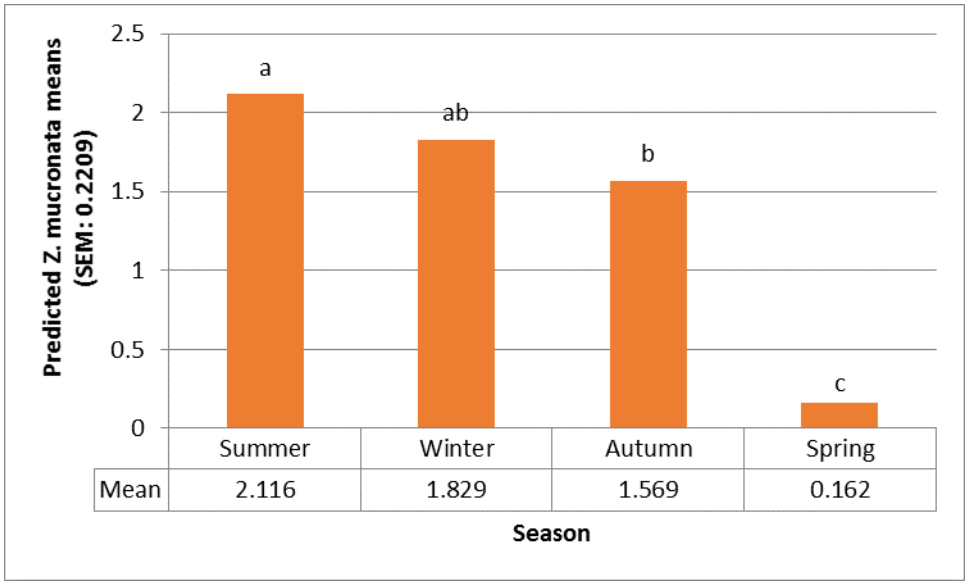


Figure 8.17 Seasonal effect on female giraffes feeding on *Z. mucronata* level three

The same applies to females when feeding on *Z. mucronata* at level three during summer, autumn and winter months compared to the spring (Figure 8.17) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *Z. mucronata at* level three during the summer (8.3), autumn (4.8) and winter (6.2) seasons rather than during spring (1.2).

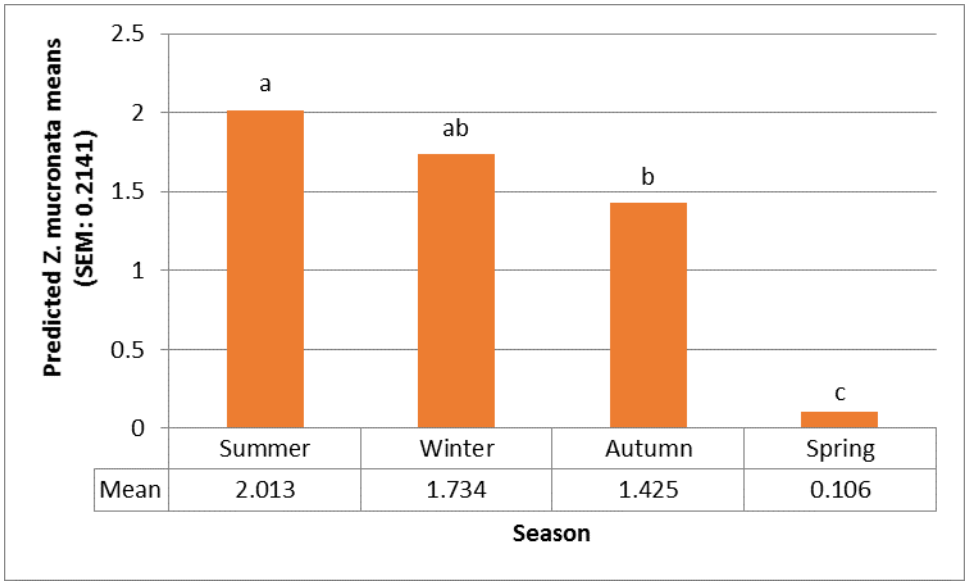


Figure 8.18 Seasonal effect on female giraffes feeding on *Z. mucronata* level four

The same applies to females when feeding on *Z. mucronata* at level four. The seasons are significantly different (P<0.001) (Figure 8.18) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *Z. mucronata* level four during the summer (7.5), winter (5.7) and autumn (4.2) seasons rather than during spring (1.1).

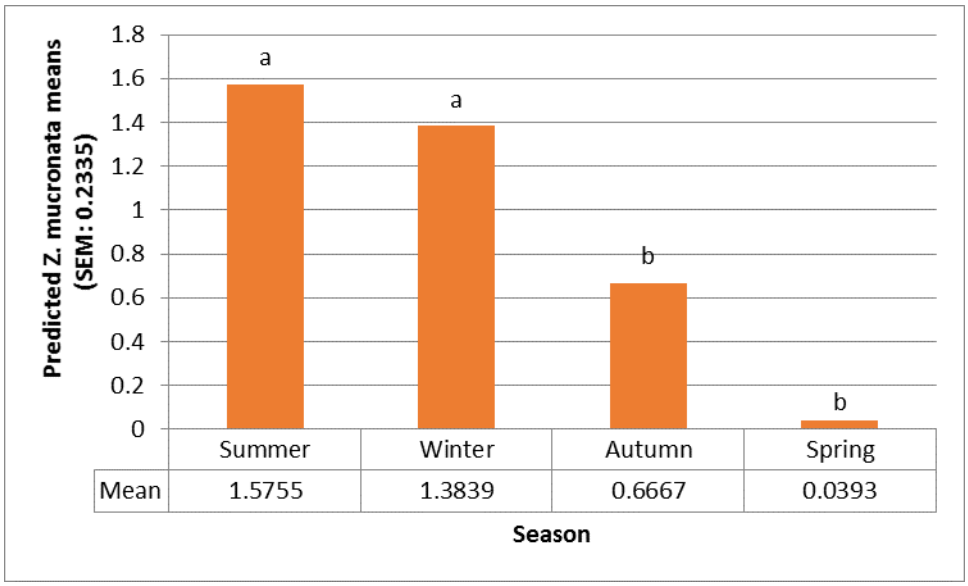


Figure 8.19 Seasonal effect on female giraffes feeding on *Z. mucronata* level five

The same applies to females when feeding on *Z. mucronata* at level five. Summer and winter seasons are significantly different (P<0.001) from autumn and spring (Figure 8.19) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table

I.3) this would mean that females fed on *Z. mucronata at* level five during the summer (4.8) and winter (4.0) seasons rather than during autumn (1.9) and spring (1.0).

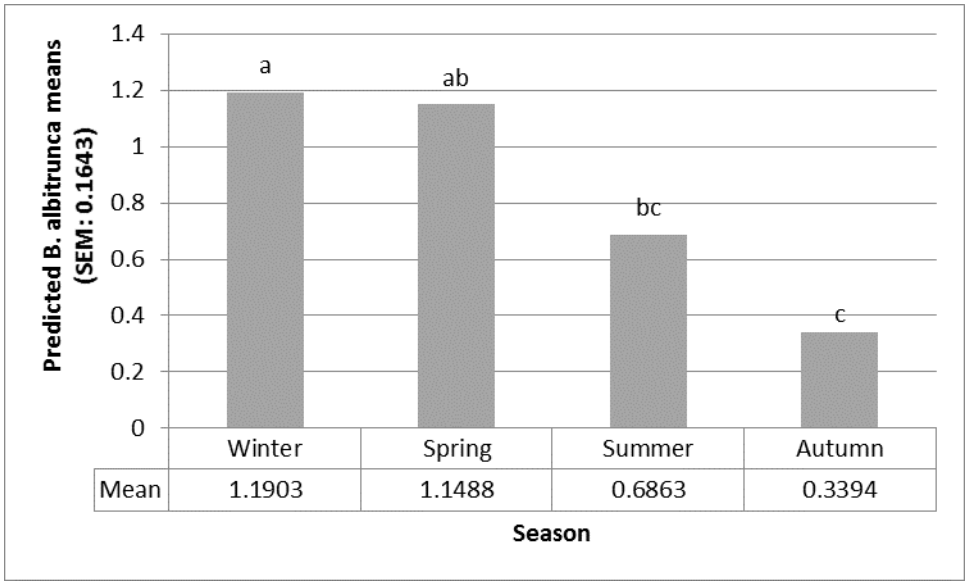


Figure 8.20 Seasonal effect on female giraffes feeding on *B. albitrunca* level four

When females were feeding on *B. albitrunca* at level four, there was a significant difference (P<0.001) during the winter when compared with the autumn season (Figure 8.20) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *B. albitrunca* at level four during the winter (3.3) and spring (3.2) seasons rather than during autumn (1.4) and summer (2.0).

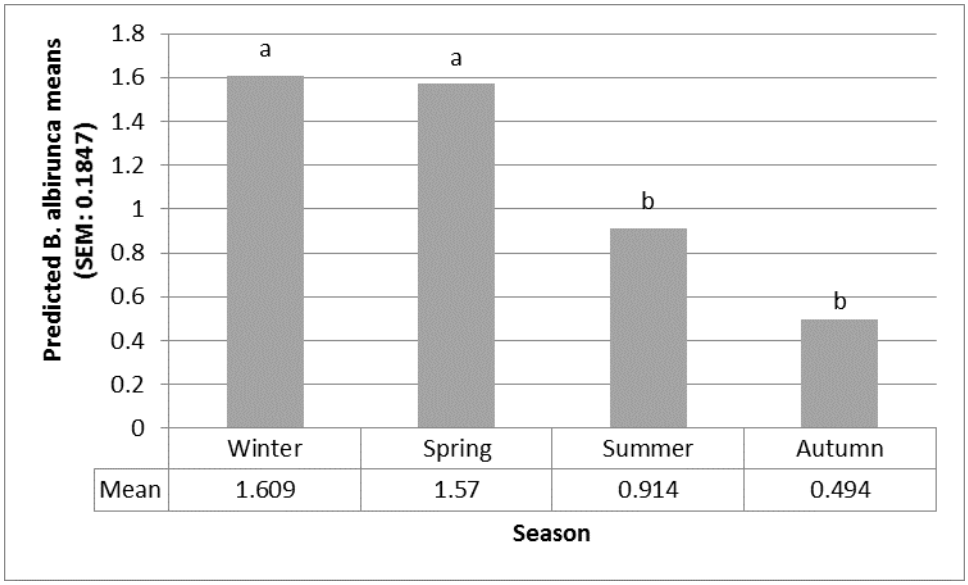


Figure 8.21 Seasonal effect on female giraffes feeding on *B. albitrunca* level five

When females were feeding on *B. albitrunca* at level five, there was a significant difference (P<0.001) during the winter and spring when compared with the autumn and summer seasons (Figure 8.21) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *B. albitrunca* at level five during the winter (5.0) and spring (4.8) rather than during autumn (1.6) and summer (2.5) seasons.

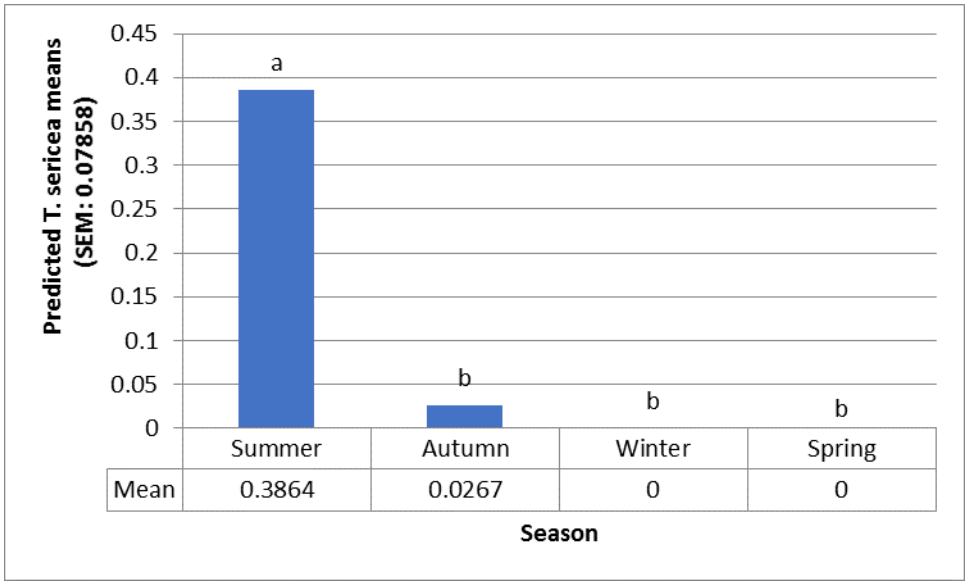


Figure 8.22 Seasonal effect on female giraffes feeding on *T. sericea* level five

When T. sericea was used as response variate there was a significant difference in the feeding preference of females (P<0.001) when feeding on level five during summer when compared with the other seasons (Figure 8.22) (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *T. sericea* level five during the summer (1.5) rather than during the autumn (1.0) spring (1.0) and winter (1.0) seasons.

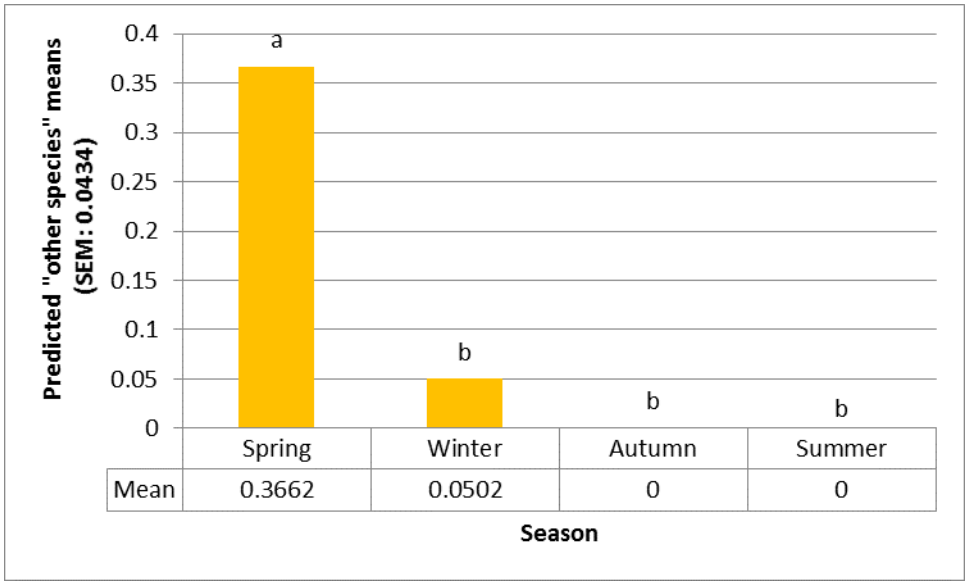


Figure 8.23 Seasonal effect on female giraffes feeding on *"other species"* level four

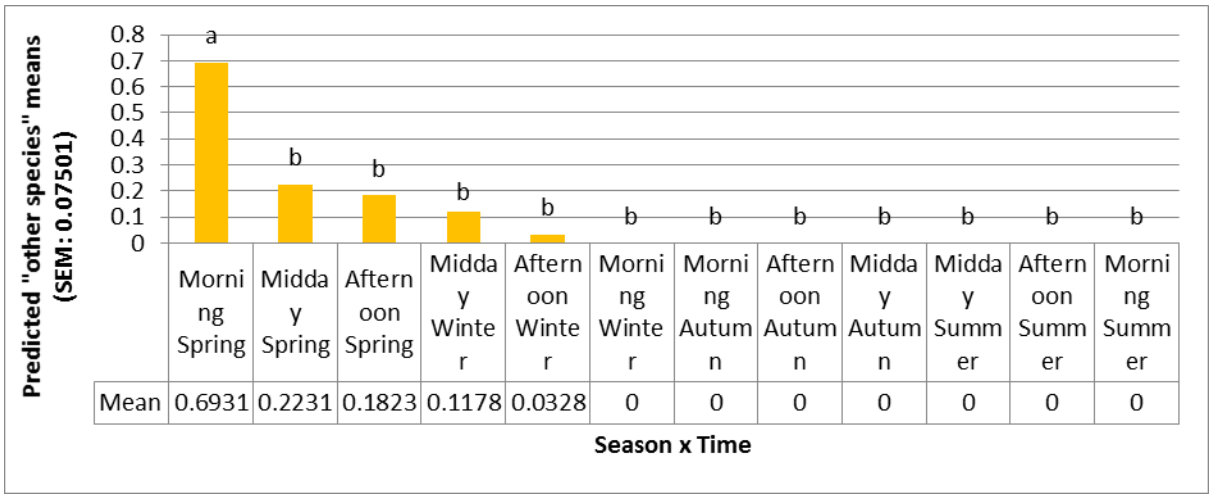


Figure 8.24 Season x time of day effect on female giraffes feeding on "*other species"* level four

When *"other species"* was used as response variate there was a significant difference in the feeding preference of females (P<0.001) when feeding on level four during spring, when compared with the other seasons (Figure 8.23). Figure 8.24 further shows that the morning feeding during spring is significantly different (P<0.001) from any of the other time x season means (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean females fed on *"other species"* at level four during the spring morning (2.0), spring midday (1.3), spring afternoon (1.2), and winter midday (1.1) rather than the other seasons, with equally low season x time interactions (1.0). "*Other species*" are only utilised during the time of regrowth when some plant species may look attractive, but females also utilised "other species" during the dry winter months.

When *"other species"* were used as response variate for feeding levels 1, 2, 3, 5 and 6 there was no significance (P>0.05) for season effects. There was only one significant time x season interaction effect observed on level four and no significance observed for any time of day effects.

All tree species utilised with season having a significant (P<0.05) effect are shown in Appendix I Table I.1. For instance, for *A. erioloba* level one (p = 0.04), it is shown (transformed scale) that females utilised it during the summer (1.2) rather than during autumn (1.0), winter (1.0) or spring (1.0) months. For *A. erioloba* level five (p = 0.04), it is shown (transformed scale) that females utilised it during winter midday (20.4) rather than during autumn afternoon (8.7) due to the time x season interaction. For *B. albitrunca* level three (p = 0.02), it is shown (transformed scale) that females utilised it during the winter (1.6) and spring (1.7) rather than during the autumn (1.1) and summer (1.2) seasons. For *B. albitrunca* level six (p = 0.01), it is shown (transformed scale) that females utilised it during the winter (1.6), autumn (1.3) and spring (1.3) months and the least during the summer (1.2) season. This indicates that females do not like feeding on this evergreen tree during the wet, warm season.

For *G. flava* level two (p = 0.003), it is shown (transformed scale) that females utilised it during the autumn (1.9), summer (1.6) and winter (1.3) rather than during the spring (1.0) season. The same applies for *G. flava* level three (p = 0.01), where it is shown (transformed scale) that females utilised it during the autumn (1.3), summer (1.4) and winter (1.3) rather than during the spring (1.0) season.

For *A. luederitzii* level four (p = 0.003), it is shown (transformed scale) that females utilised it during the winter (2.0), spring (1.7) and summer (1.5) rather than during the autumn (1.0) season. For *A. luederitzii* level five (p = 0.005), it is shown (transformed scale) that females utilised it during the winter (1.9), spring (2.2) and summer (1.9) rather than during the autumn (1.1) season. For *A. luederitzii* level six (p = 0.02), it is shown (transformed scale) that females utilised it during winter (1.2), spring (1.4) and summer (1.1) rather than during the autumn (1.0) season.

For *T. sericea* level three (p = 0.008), it is shown (transformed scale) that females utilised it during the summer (1.1) rather than during the autumn (1.0) winter (1.0) and spring (1.0) months.

What this significance demonstrates is that the season affects all the prominent tree species preferred by female giraffes. Some tree species are preferred during certain times of the year, but also because of availability of the tree species for browsing.

ii. Time of day effect on feeding level

During the tests for fixed effects (Appendix I) there were significant differences (P<0.05) between the feeding level, tree species, time of day and time x season interactions (P<0.05) Tukey's LSD test.

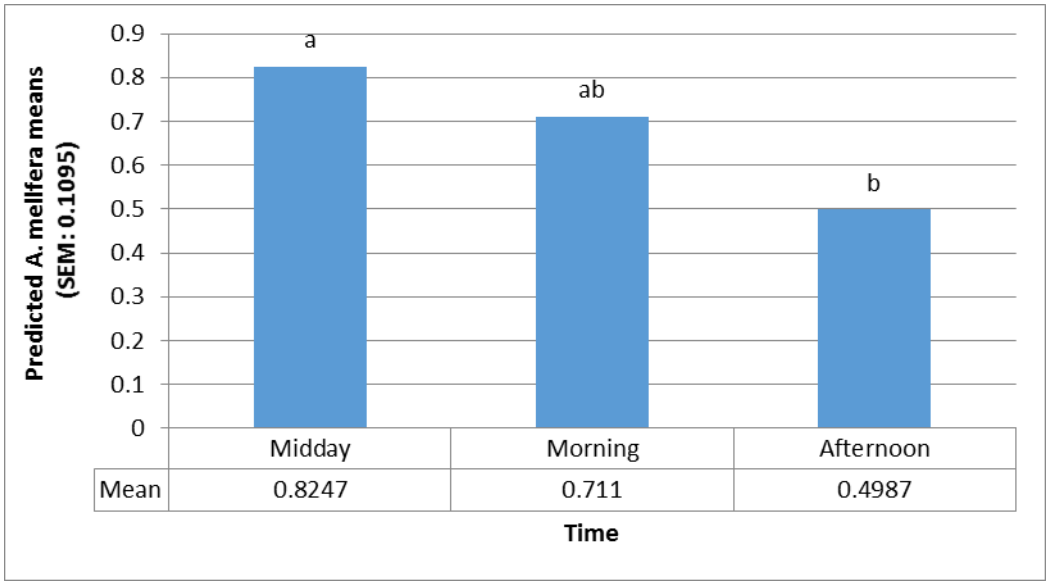


Figure 8.25 Time of day effect on female giraffes feeding on *A. mellifera* level two

Figure 8.25 shows that there was a significant difference (P<0.001) in the feeding of females on *A. mellifera* level two during midday compared to the afternoon (untransformed scale) (Appendix I Table I.1). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *A. mellifera* level two during the midday (2.2) and morning hours (2.0) rather than during the afternoon (1.6). This means that females would bend down to level two to get preferred browse during the morning more often than during the afternoon.

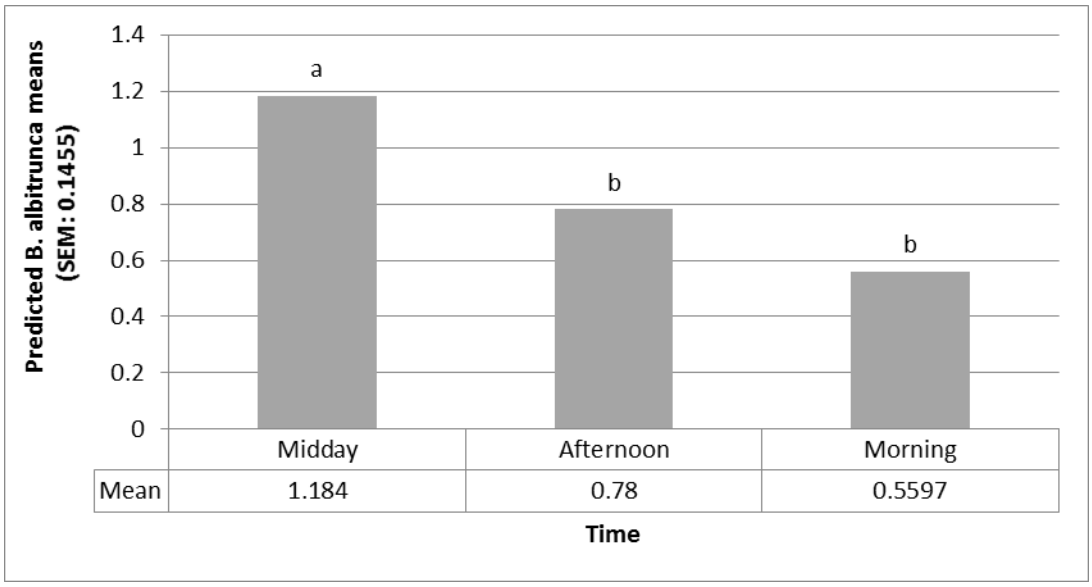


Figure 8.26 Time of day effect on female giraffes feeding on *B. albitrunca* level four

Using *B. albitrunca* as response variate shows that there was a significant difference in the feeding of females (P<0.001) on *B. albitrunca* level four during midday than during other times of day (Figure 8.26) (untransformed scale). On the transformed scale (Appendix I Table I.3) this would mean that females fed on *B. albitrunca* level four during the midday hours (3.3) rather than during the afternoon (2.2) and morning (1.8).

All tree species which were utilised where time of day had a significant (P<0.05) effect are listed in Appendix I Table I.1. For instance, for *A. erioloba* level four (p=0.002), it is shown (transformed scale) that females utilised it during midday (14.9) rather than during the morning (10.5) or afternoon (9.6) hours. For *A. mellifera* level one (p=0.003), it is shown (transformed scale) that females utilised it during the morning (1.5) and midday (1.4) rather than during the afternoon (1.1) hours. For *Z. mucronata* level five (p=0.04), it is shown (transformed scale) that females utilised it during midday (3.0) rather than during the afternoon (2.3) and morning (2.3) hours. For *B. albitrunca* level five (p=0.004), it is shown (transformed scale) that females utilised it during midday (4.0) rather than during the afternoon (3.0) and morning (2.6) hours. For *"Other species"* level four (p=0.05), it is shown (transformed scale) that females utilised it during the morning (1.2) rather than during the midday (1.1) or afternoon (1.1) hours.

For *A. erioloba,* feeding by females on levels two and six is significantly influenced by time of day (p=0.02, p=0.004 respectively) (transformed scale) and it is shown that midday hours (1.6, 4.9 respectively) are preferred rather than morning (1.4, 3.4 respectively) and afternoon (1.3, 3.2 respectively). For *B. albitrunca,* feeding by females on level three was significantly influenced by time of day (p=0.032), (transformed scale). It is shown that females utilised it during the midday (1.5) rather than during the afternoon (1.4) and morning (1.3) hours. For *G. flava* level one (p=0.017), (transformed scale), it is shown that females utilised it during the midday (1.4) rather than during the afternoon (1.1) and morning (1.3) hours. For *A. luederitzii* levels three and five (p=0.006, p=0.017 respectively), (transformed scale) it is shown that females utilised it during the midday (1.4, 2.0 respectively) rather than during the afternoon (1.2, 1.5 respectively) and morning (1.1, 1.7 respectively) hours.

What this significance demonstrates is that the time of day affects feeding on all the prominent tree species preferred by female giraffes. Some tree species are preferred during certain times of day and this could lead to further investigation regarding the possible reasons for this behaviour. It may be to do with the peak transpiration, photosynthesis, chemical defence or taste aspects.

8.3.2.3. Male giraffes

Seasonal changes in preferred feeding levels of male giraffes between wet and dry seasons are presented in Figure 8.27. This graph illustrates that levels one to four are utilised more during the wet season (56%) compared to the dry season (36%), and levels five and six are utilised more in the dry season (64%) than the wet season (45%) (Figure 8.27). These differences between wet and dry seasons for male feeding levels were statistically significant (ANOVA, P>0.05) (Table 8.4).

Dividing the year into the four climatic seasons, illustrated in Figure 8.28, shows that feeding level two became more prominent during the summer (wet and hot) and less so during the

spring (dry and hot) season. Feeding at level five was equally divided between all seasons (Figure 8.28). This could indicate that males find most of their foliage on higher levels (>4.0 m) out of reach for other browsers, including females. Figure 8.29 illustrates that preferred feeding levels changed over the seasons, showing that levels four (4.0 m) and five (4.5 m) were the preferred feeding levels for males. This may provide evidence that most (81%, Figure 8.2) of male feeding is without competition, thus creating the opportunity to feed on only the highest nutrient material (Breebaart, 2000).

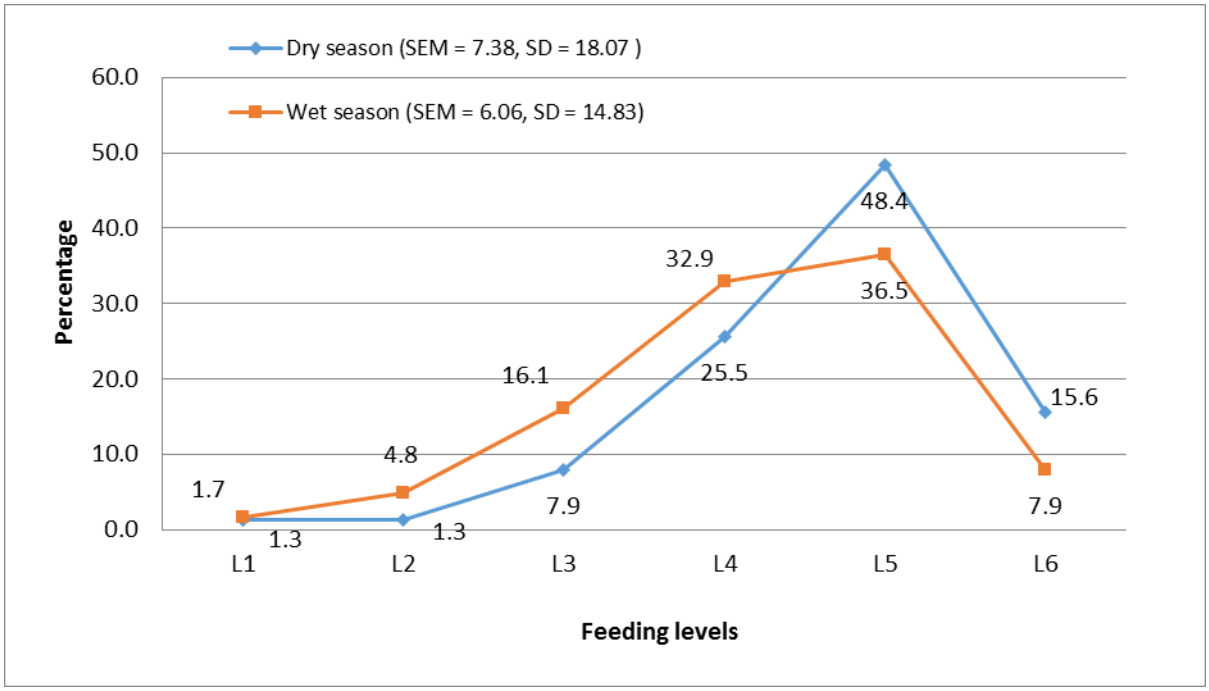


Figure 8.27 Wet and dry season feeding levels of male giraffes

Table 8.4 ANOVA test illustrating the wet and dry season feeding levels of male giraffes

ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2566.612	5	513.3223	18.56996	**<0.001**	4.387374
Within Groups	165.8557	6	27.64262			
Total	2732.467	11				

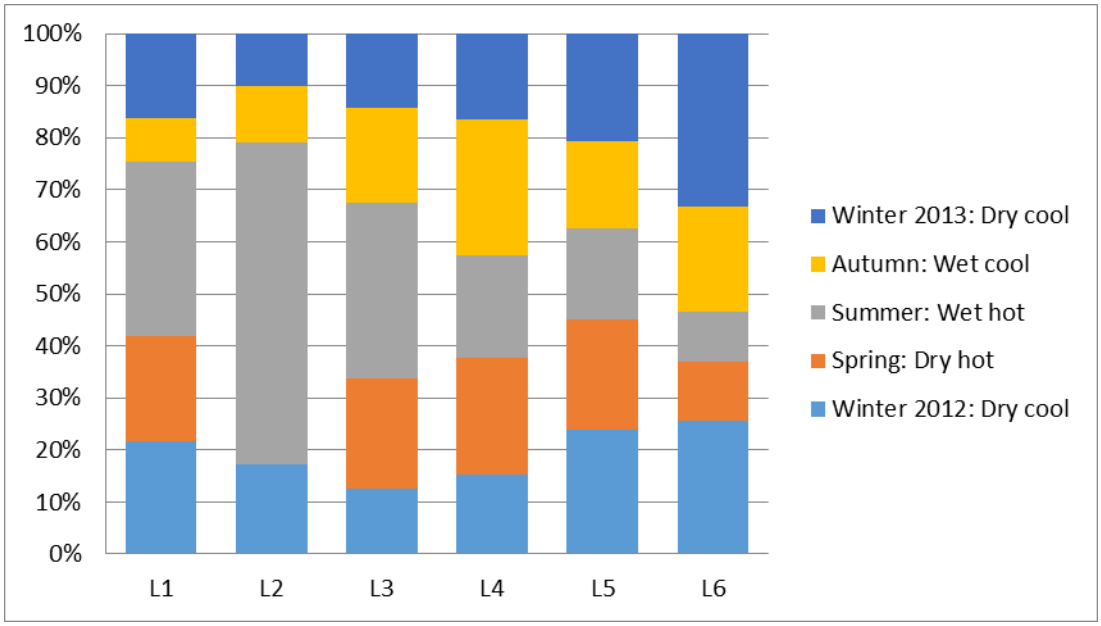


Figure 8.28 Percentage of feeding level changes during each season for male giraffes

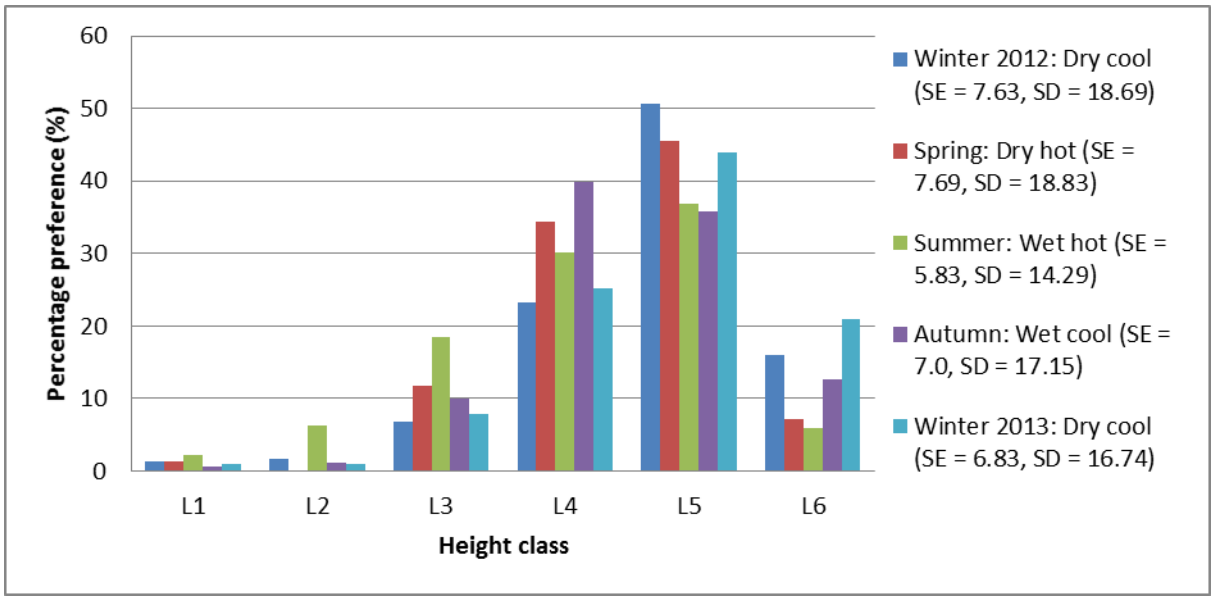


Figure 8.29 Feeding level differences during each season for male giraffes

8.3.2.4. Statistical results for male giraffes

i. Seasonal effect on feeding levels

During the tests for fixed effects (Appendix I) there were significant (P<0.001) differences between the feeding level, seasonal effect and the season x time interactions (P<0.001) (Tukey's LSD test). Only tree species that were highly significantly (P<0.001) utilised per height class are illustrated in Figures 8.30 – 8.42.

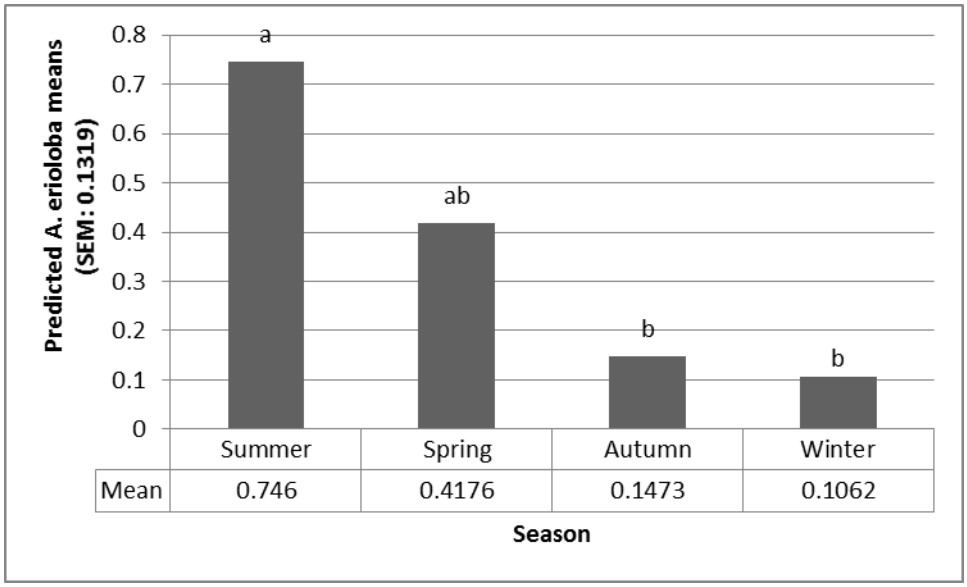


Figure 8.30 Seasonal effects on male giraffes feeding on *A. erioloba* level three

When males were feeding on *A. erioloba* level three there was a significant difference in feeding preference (P<0.001) during summer compared to winter and autumn seasons (Figure 8.30) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *A. erioloba* level three during the summer (2.1) and spring (1.5) rather than during autumn (1.2) and winter (1.1) months. Being deciduous, it is understandable that the winter months were not the preferred months for *A. erioloba* feeding.

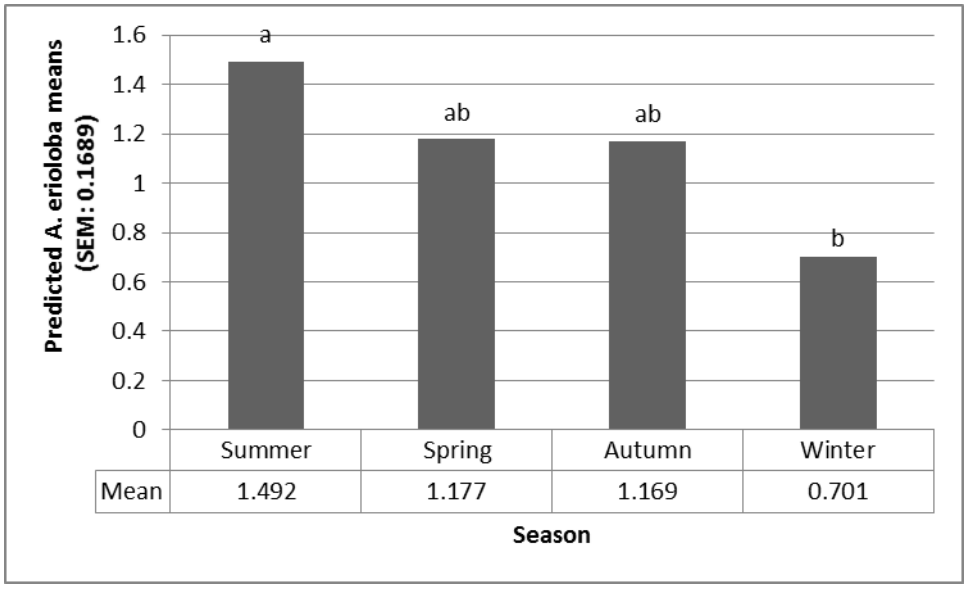


Figure 8.31 Seasonal effects on male giraffes feeding on *A. erioloba* level four

When males were feeding on *A. erioloba* level four there was a significant difference in feeding preference during summer compared to winter (Figure 8.31) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean males fed on *A. erioloba*

level four during the summer (4.4), spring (3.2) and autumn (3.2) rather than during the winter (2.0) months.

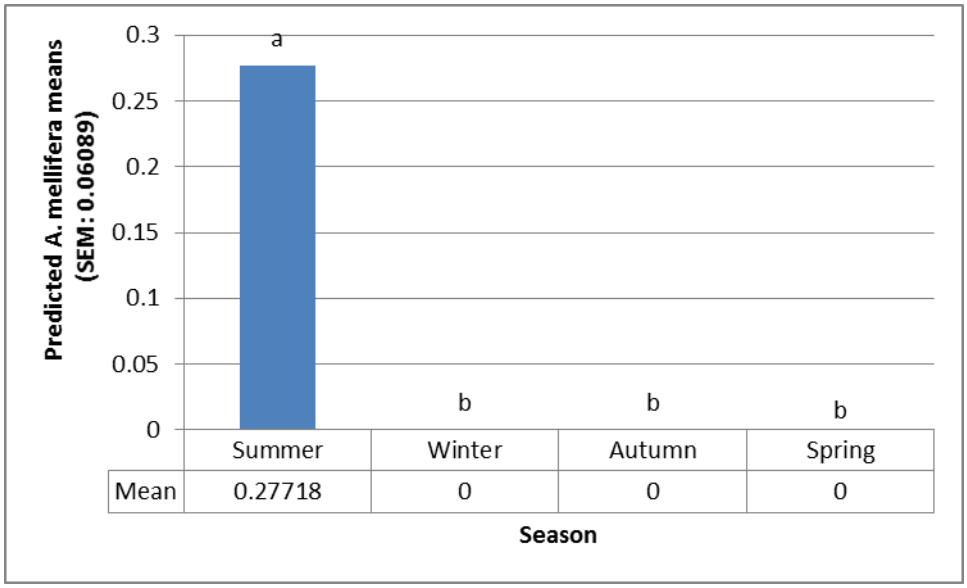


Figure 8.32 Seasonal effects on male giraffes feeding on *A. mellifera* level one

When *A. mellifera* was used as response variate, there was a significant difference in male feeding (P<0.001) when feeding on level one during summer compared to the other seasons (Figure 8.32) (untransformed scale). On the transformed scale (Appendix 6 Table I.6) this would mean that males fed on *A. mellifera* level one during summer (1.3) rather than during autumn (1.0), winter (1.0) and spring (1.0) months. When looking at the phenology (Table 6.4), one might rather have expected to see this change in diet in the critical period July to October.

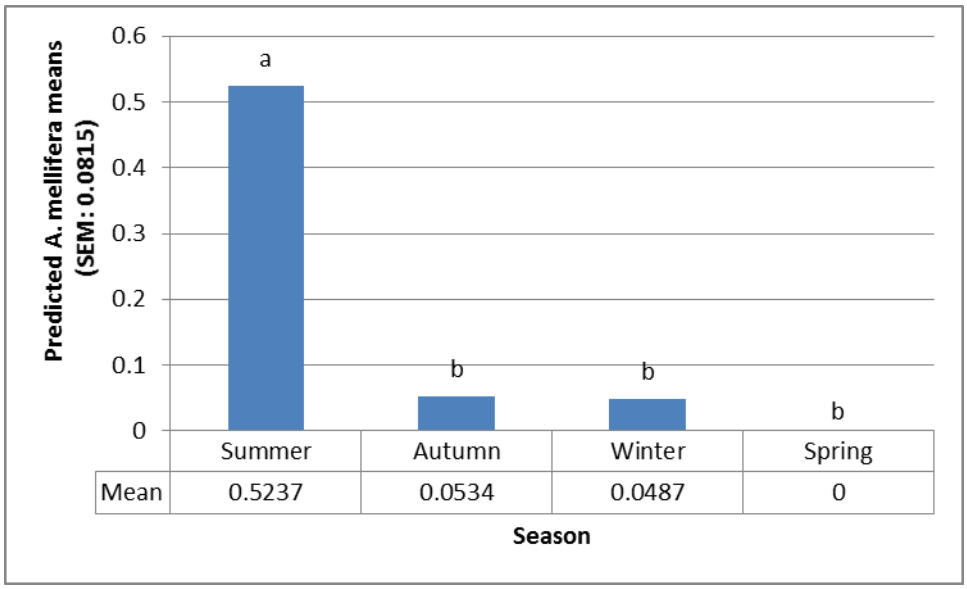


Figure 8.33 Seasonal effects on male giraffes feeding on *A. mellifera* level two

There was a significant difference in male feeding (P<0.001) when feeding on *A. mellifera* level two during summer compared to the other seasons (Figure 8.33) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *A. mellifera* level two during the summer (1.7) rather than during autumn (1.1), winter (1.0) and spring (1.0) months.

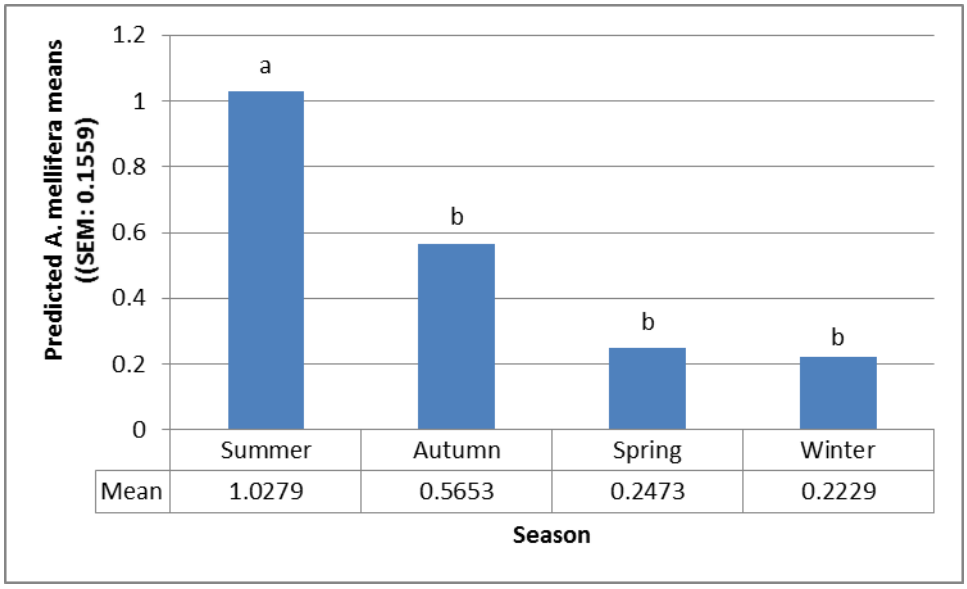


Figure 8.34 Seasonal effects on male giraffes feeding on *A. mellifera* level three

There was also a significant difference in male feeding (P<0.001) when feeding on *A. mellifera* level three during the summer, compared to the other seasons (Figure 8.34) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *A. mellifera* level three during the summer (2.8) rather than during the autumn (1.8), winter (1.3) and spring (1.3) months.

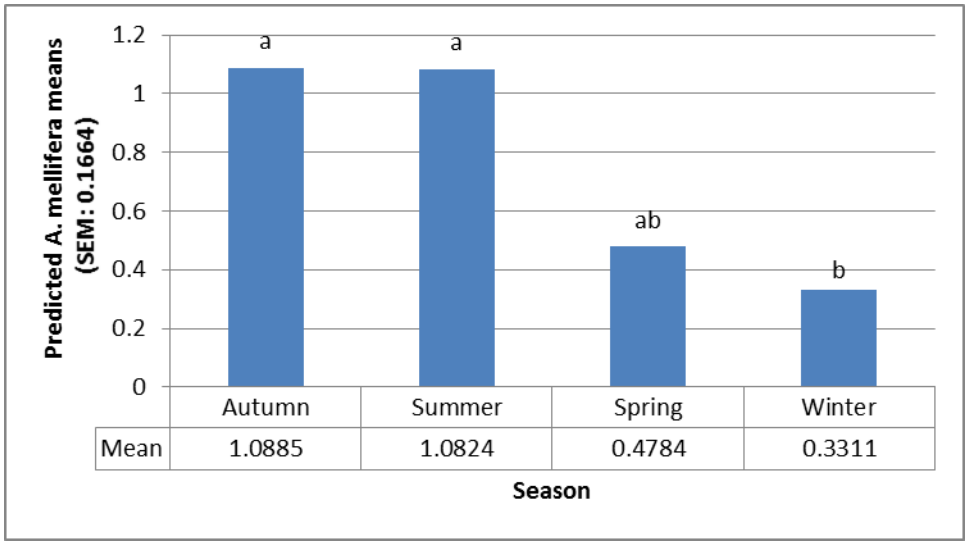


Figure 8.35 Seasonal effects on male giraffes feeding on *A. mellifera* level four

There was also a significant difference in male feeding on *A. mellifera* level four, (P<0.001) during autumn, summer and spring compared to the winter months (Figure 8.35) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean males fed on *A. mellifera* level four during the summer (3.0) and autumn (3.0), rather than during winter (1.4) and spring (1.6) months.

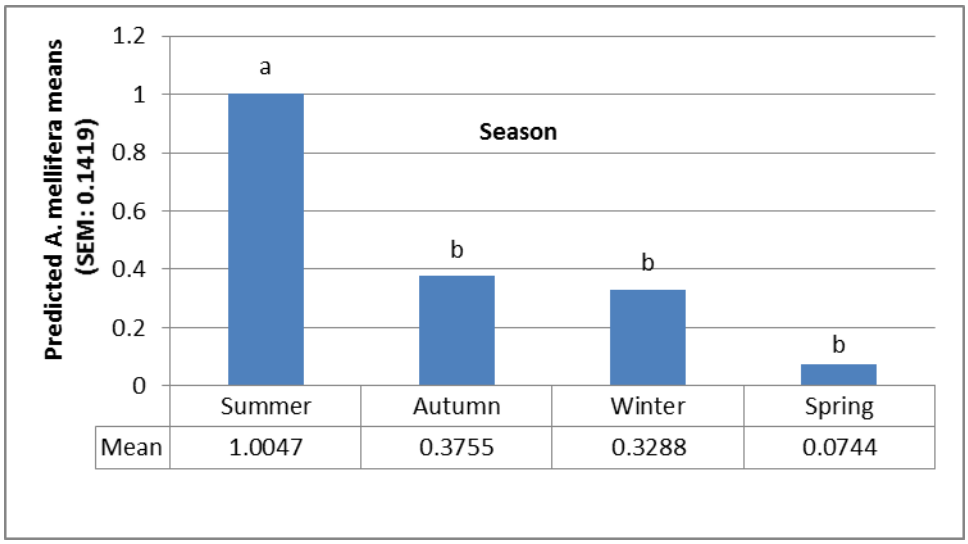


Figure 8.36 Seasonal effects on male giraffes feeding on *A. mellifera* level five

There was also a significant difference in male feeding on *A. mellifera* level five, (P<0.001) during summer compared to the other months, (Figure 8.36) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean males fed on *A. mellifera* level five during the summer (2.7) rather than during autumn (1.5), winter (1.4) and spring (1.1) months. When referring to the phenology of trees (Table 6.4), the greatest quantity of foliage

is available in the summer months which would therefore explain the significantly greater utilisation compared to other months. When *A. mellifera was* used as response variate for feeding level 6 it showed no significance (P>0.001) for seasonal effects.

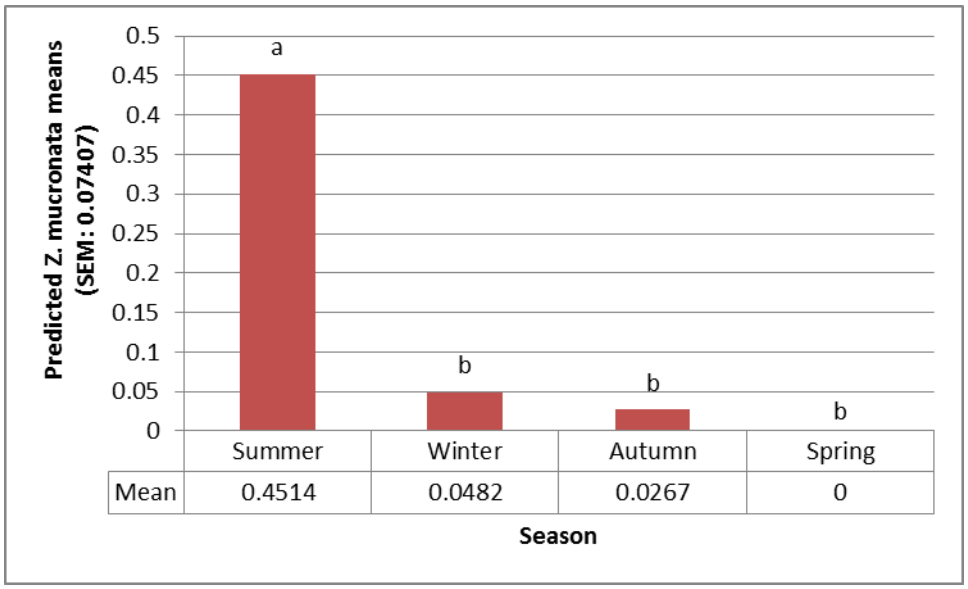


Figure 8.37 Seasonal effects on male giraffes feeding on *Z. mucronata* level two

When *Z. mucronata* was used as response variate, the feeding of males was significantly different (P<0.001) on level two during summer compared to winter and autumn months (Figure 8.37) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *Z. mucronata* level two during the summer (1.6) rather than during autumn (1.0), winter (1.0) and spring (1.0) months. From Table 6.4 we can see that in spring *Z. mucronata* has almost no leaves, therefore zero value.

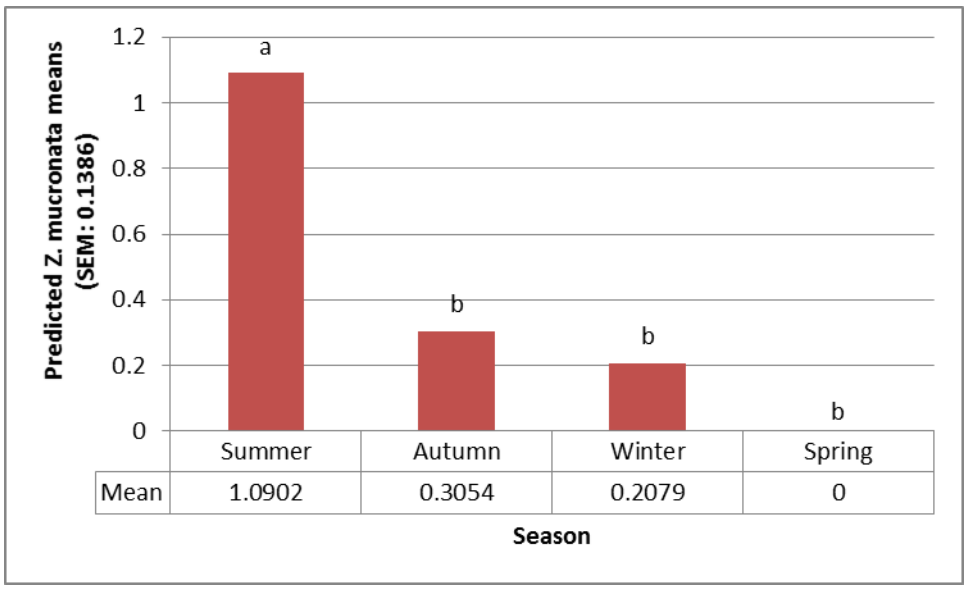


Figure 8.38 Seasonal effects on male giraffes feeding on *Z. mucronata* level three

The feeding of males was also significantly different (P<0.001) on *Z. mucronata* level three during summer compared to autumn and winter months (Figure 8.38) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *Z. mucronata* level three during the summer (3.0) rather than during autumn (1.4), winter (1.2) and spring (1.0) months.

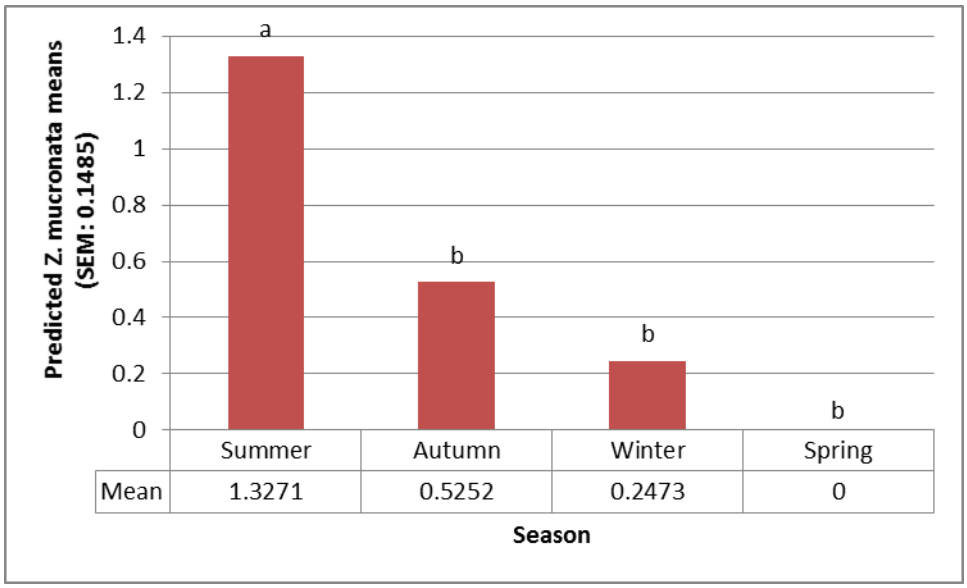


Figure 8.39 Seasonal effects on male giraffes feeding on *Z. mucronata* level four

The feeding of males was also significantly different on *Z. mucronata* level four (P<0.001) during summer (Figure 8.39) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *Z. mucronata* level four during the summer (3.8) rather than during the autumn (1.7), winter (1.3) and spring (1.0) months.

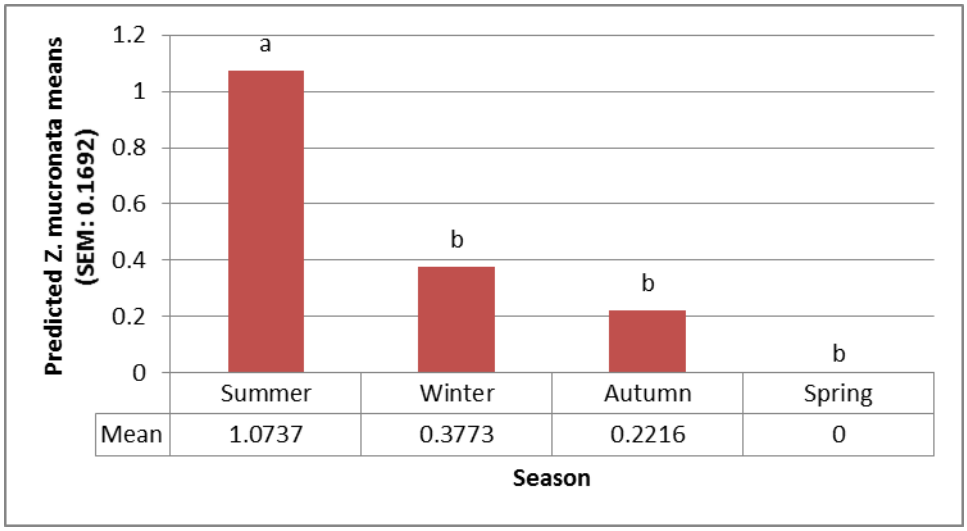


Figure 8.40 Seasonal effects on male giraffes feeding on *Z. mucronata* level five

The feeding of males on *Z. mucronata* level five was also significantly different (P<0.001) during summer compared to winter, autumn and spring seasons (Figure 8.40) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *Z. mucronata* level five during the summer (2.9) rather than during autumn (1.2), winter (1.6) and spring (1.0) months. When *Z. mucronata* was used as response variate for feeding levels 1 and 6 there was no significance (P>0.001) for seasonal effects, nor was any significance observed for any time of day or time x season interaction effects.

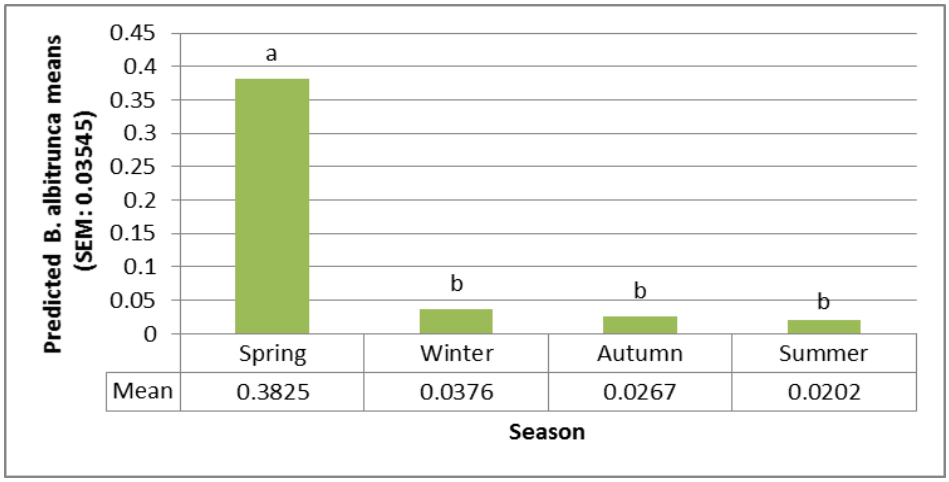


Figure 8.41 Seasonal effects on male giraffes feeding on *B. albitrunca* level three

When *B. albitrunca* was used as response variate there was a significant difference in males feeding on *B. albitrunca* level three (P<0.001) during spring (Figure 8.41) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *B. albitrunca* level three during spring (1.5) rather than during the autumn (1.0), winter (1.0) and summer (1.0) months.

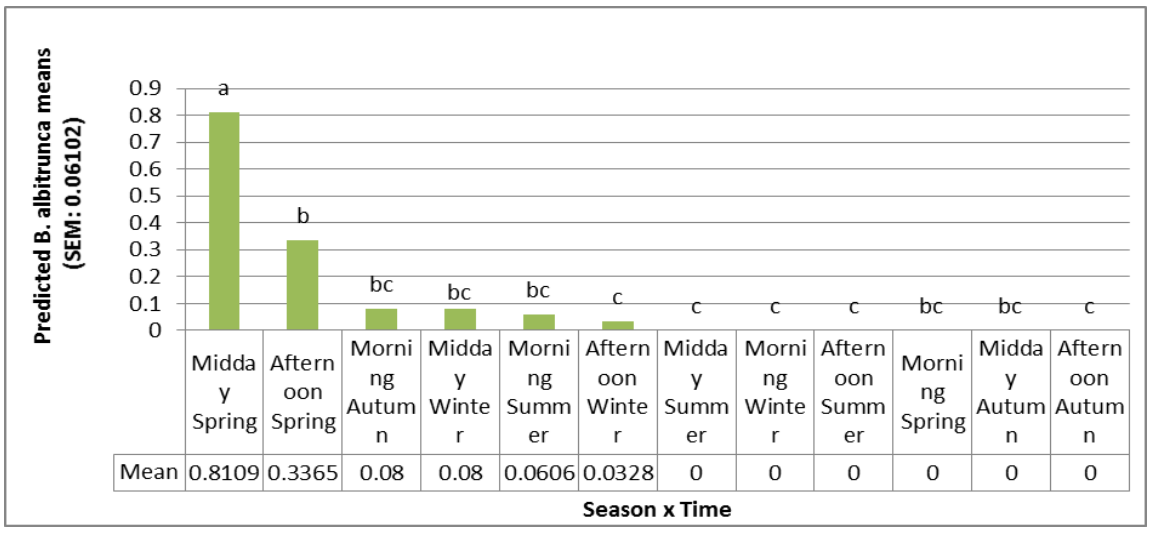


Figure 8.42 Season x Time of day effects on male giraffes feeding on *B. albitrunca* level three

There was also a significant effect on male feeding on *B. albitrunca* level three of season x time of day interaction. The midday spring season was significantly different (P<0.001) from the other interactions (Figure 8.42) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *B. albitrunca* level three during spring midday (2.3) and afternoon (1.4) rather than during any other season or time of day (1.0). When *B. albitrunca was* used as response variate for feeding levels 1, 2 and 6 they showed no significance (P>0.001) for season effects. Also, no significance was observed for any time of day or time x season interaction effects.

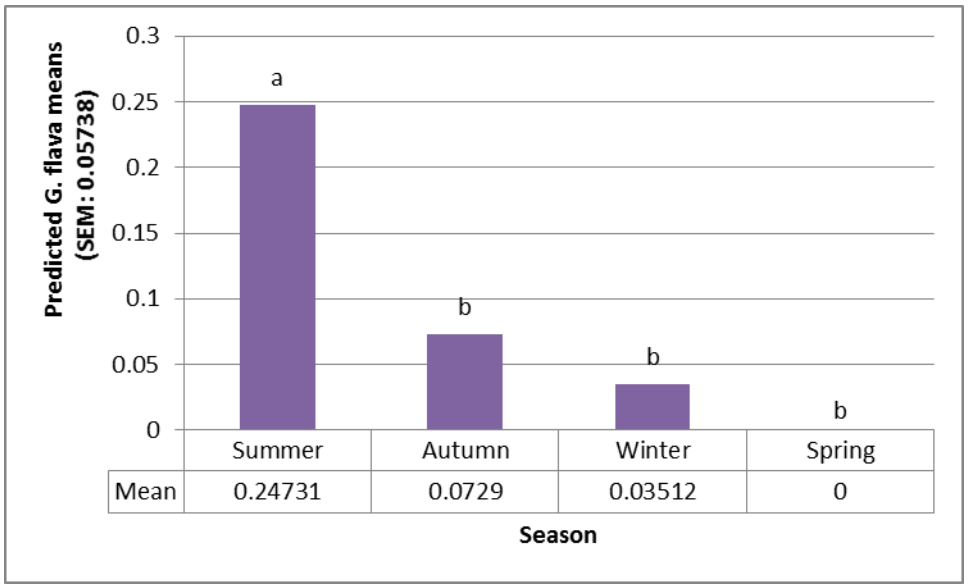


Figure 8.43 Seasonal effects on male giraffes feeding on *G. flava* level two

When *G. flava* was used as response variate there was a significant difference in males feeding (P<0.001) on *G. flava* level two during the summer compared to the winter and autumn months (Figure 8.43) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *G. flava* level two during the summer (1.3) rather than during the autumn (1.1), winter (1.0) and spring (1.0) months.

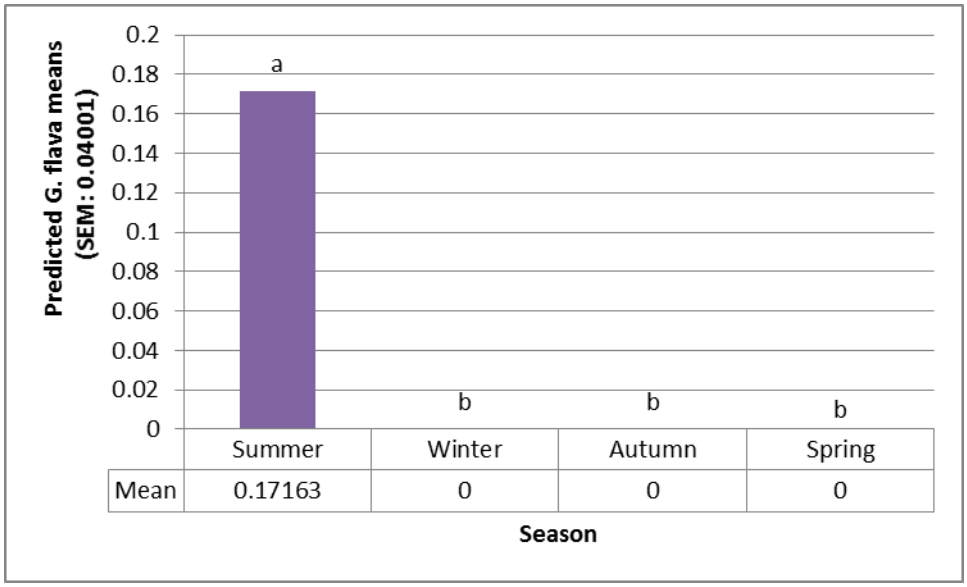


Figure 8.44 Seasonal effects on male giraffes feeding on *G. flava* level four

When males fed on *G. flava* level four, there was a significant difference (P<0.001) during the summer (Figure 8.44) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *G. flava* level four during the summer (1.2) rather than during the autumn (1.0), winter (1.0) and spring (1.0) months. When *G. flava was* used as response variate for feeding levels 5 and 6 they showed no significance (P>0.001) for season effects, which could be due to the size and growth shape of *G. flava*. Also, no significance was observed for any time of day or time x season interaction effects.

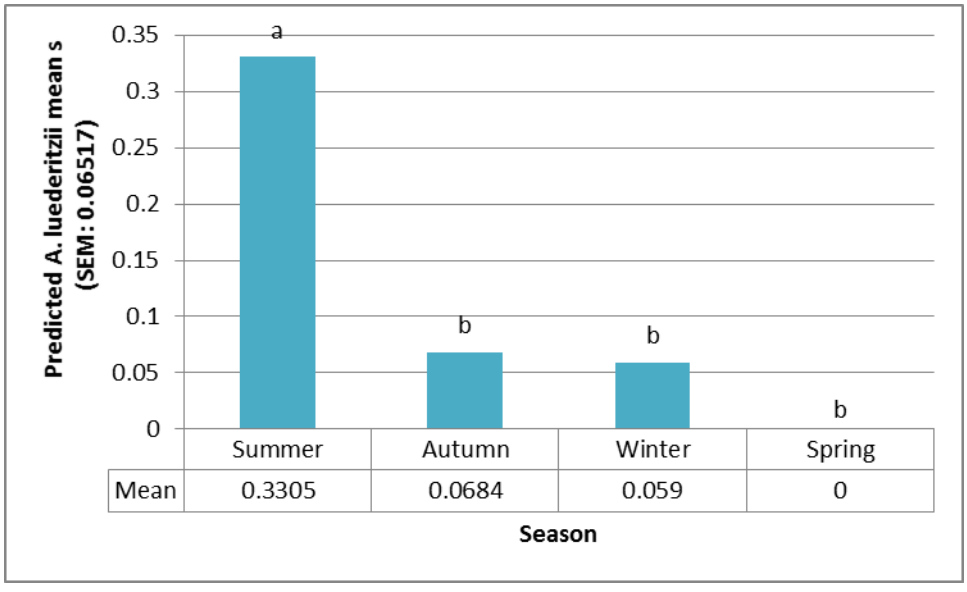


Figure 8.45 Seasonal effects on male giraffes feeding on *A. luederitzii* level four

When *A. luederitzii* was used as response variate there was a significant difference in males feeding on *A. luederitzii* level four (P<0.001) during the summer (Figure 8.45)

(untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *A. luederitzii* level four during the summer (1.4) rather than during the autumn (1.1), winter (1.1) and spring (1.0) months. When *A. luederitzii* was used as response variate for feeding levels 1, 2 and 6 they showed no significance (P>0.001) for season effects. Also, no significance was observed for any time of day or time x season interaction effects.

All tree species utilised for which season had a significant (P<0.05) effect are shown in Appendix I Table I.4. For *A. erioloba* level two (p=0.09), it is shown that (transformed scale) males utilised it during the summer (1.1) rather than during the autumn (1.0), winter (1.0) or spring (1.0) months. For *A. erioloba* level five (p=0.007), it is shown that (transformed scale) males utilised it during the summer (6.4) rather than during the autumn (4.7), winter (3.3) and spring (5.0) seasons.

For *B. albitrunca* level four (p=0.013), it is shown that (transformed scale) males utilised it during the spring (1.6) rather than during the autumn (1.1), summer (1.4) or winter (1.4) seasons. For *B. albitrunca* level five (p=0.01), it is shown that (transformed scale) males utilised it during the winter (1.9), spring (1.8) and summer months (1.8), but not during the autumn (1.2) season. This indicates that males avoid this evergreen tree during the wet, warm season.

For *G. flava* level one (p=0.048), it is shown that (transformed scale) males utilised it during the spring (1.1) and summer months (1.1) rather than during winter (1.0) and autumn (1.0) seasons. The same applies for *G. flava* level three (p=0.005), for which it is shown that (transformed scale) males utilised it during the summer (1.2), rather than during the autumn (1.0), winter (1.0) and spring (1.0) seasons.

For *"Other species"* level five (p=0.047), it is shown that (transformed scale) males utilised it during the winter (1.2), rather than during the spring (1.0), summer (1.1) and autumn (1.0) seasons.

For *A. luederitzii* level three (p=0.002), it is shown that (transformed scale) males utilised it during the summer (1.9), rather than during the spring (1.0), winter (1.0) and autumn (1.0) seasons.

What this significance shows is that the season affects all the prominent tree species preferred by males. Some tree species are preferred during certain times of the year, but also because of availability of the tree species for browsing.

ii. Time of day effect on feeding levels of males

During the tests for fixed effects (Appendix I) there were significant (P<0.001) differences between the feeding level, time of day effect and the season x time interactions (P<0.001) for male feeding (Tukey's LSD test).

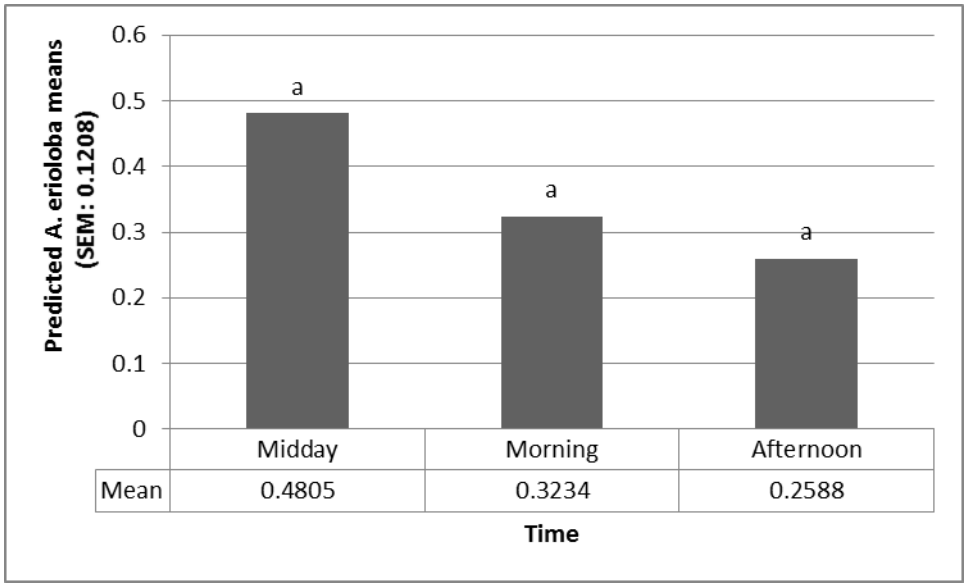


Figure 8.46 Time of day effects on male giraffes feeding on *A. erioloba* level three

When *A. erioloba* was used as response variate, there was a significant difference (P<0.001) when males fed on level three during midday compared to the other hours of the day (Figure 8.46) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *A. erioloba* level three during the midday (1.6) rather than during the morning (1.4) or afternoon (1.3) hours.

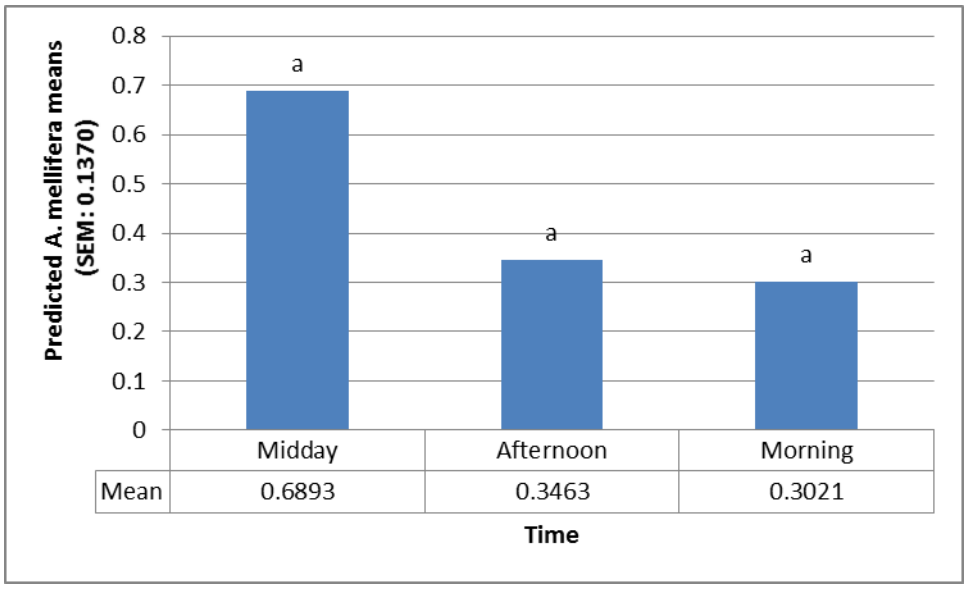


Figure 8.47 Time of day effects on male giraffes feeding on *A. mellifera* level five

When *A. mellifera was* used as response variate, there was a significant difference (P<0.001) when males fed on level five during midday compared to the other hours of the day (Figure 8.47) (untransformed scale). On the transformed scale (Appendix I Table I.6) this would mean that males fed on *A. mellifera* level five during the midday (2.0) rather than during the morning (1.4) or afternoon (1.4) hours.

All tree species utilised for which feeding time of day had a significant (P<0.05) effect are listed in Appendix I Table I.1. For instance, the time x season interaction for *A. erioloba* level three (p=0.037), showed (transformed scale) that males utilised it during the summer midday hours (3.8) rather than during the other seasons and hours (p<1.7). The time x season interaction for *A. erioloba* level four (p=0.003), showed (transformed scale) that males utilised it during the midday hours (4.3) rather than during the afternoon (3.2) or morning (2.2) hours.

A. mellifera level four (p=0.002), showed (transformed scale) that males utilised it during the midday (2.9) and afternoon hours (2.2) rather than during the morning (1.5) hours.

Z. mucronata level two (p=0.007), showed (transformed scale) that males utilised it during the midday (1.2) and afternoon (1.2) rather than during the morning (1.0) hours.

B. albitrunca level three (p=0.007), showed (transformed scale) that males utilised it during the midday (1.2) rather than during the afternoon (1.1) and morning (1.0) hours.

G. flava level two (p=0.05), showed (transformed scale) that males utilised it during the midday (1.1) and afternoon hours (1.1) rather than during the morning (1.0)

Feeding on *A. erioloba* was significantly influenced by time of day when males were feeding on levels five and six (p=0.02, p=0.003 respectively) (transformed scale) and shows that midday (6.3, 2.6 respectively) and afternoon (5.0, 2.0 respectively) hours are preferred rather than morning (1.5, 1.5 respectively).

Feeding on *B. albitrunca was* significantly influenced by time of day when males were feeding on levels four and five (p=0.002, p=0.011 respectively), (transformed scale) and shows that males utilised it during midday (1.8, 2.0 respectively) rather than during the afternoon (1.1, 1.4 respectively) and morning (1.3, 1.5 respectively) hours.
The time x season interaction for *B. albitrunca* level four (p=0.027), showed that (transformed scale) males utilised it during the spring midday (3.5) rather than during other seasons and times (<1.6).

A. luederitzii level five (p=0.021), showed that (transformed scale) males utilised it during the midday (1.3) rather than during the afternoon (1.1) and morning (1.1) hours.

What these significant results demonstrate is that the time of day affects all the prominent tree species preferred by male giraffes. Some tree species are preferred during certain times of the day and this was the same for females. Further investigation should be done to determine the influences of peak transpiration, photosynthesis, chemical defence or taste/smell of each tree species on male giraffes.

Figure 8.48 shows that the feeding levels of females changed between seasons for all recorded tree species. For example, they showed a preference for *B. albitrunca* (levels 2 – 6) and *A. luederitzii* (levels 3 – 6) during the winter 2013 season. The ability to switch feeding to different tree species at different levels at different seasons enables females to achieve adequate variation in their diet.

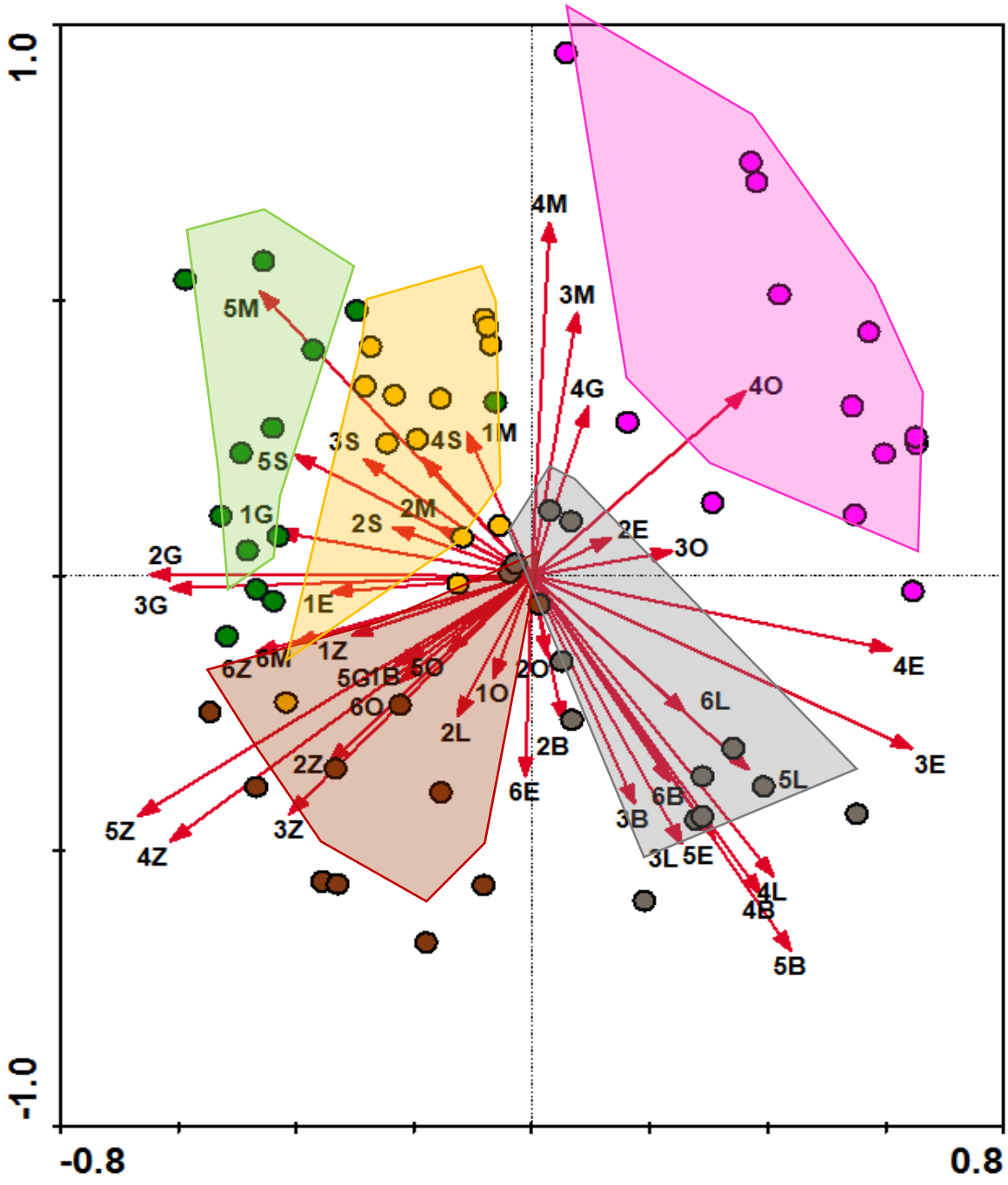


Figure 8.48 Ordination result of the feeding level preferences of female giraffes during different seasons and for different tree species (green = summer; yellow = autumn; brown = winter 2012; grey = winter 2013; pink = spring) (explanation of the acronyms below).

Table 8.5 List of acronyms

Legend for ordination figures							
1E	*A. erioloba* level 1	1L	*A. luederitzii* level 1	1B	*B. albitrunca* level 1	1O	*Other species* level 1
2E	*A. erioloba* level 2	2L	*A. luederitzii* level 2	2B	*B. albitrunca* level 2	2O	*Other species* level 2
3E	*A. erioloba* level 3	3L	*A. luederitzii* level 3	3B	*B. albitrunca* level 3	3O	*Other species* level 3
4E	*A. erioloba* level 4	4L	*A. luederitzii* level 4	4B	*B. albitrunca* level 4	4O	*Other species* level 4
5E	*A. erioloba* level 5	5L	*A. luederitzii* level 5	5B	*B. albitrunca* level 5	5O	*Other species* level 5
6E	*A. erioloba* level 6	6L	*A. luederitzii* level 6	6B	*B. albitrunca* level 6	6O	*Other species* level 6
1M	*A. mellifera* level 1	1S	*T. sericea* level 1	1G	*G. flava* level 1		
2M	*A. mellifera* level 2	2S	*T. sericea* level 2	2G	*G. flava* level 2		
3M	*A. mellifera* level 3	3S	*T. sericea* level 3	3G	*G. flava* level 3		
4M	*A. mellifera* level 4	4S	*T. sericea* level 4	4G	*G. flava* level 4		
5M	*A. mellifera* level 5	5S	*T. sericea* level 5	5G	*G. flava* level 5		
6M	*A. mellifera* level 6	6S	*T. sericea* level 6	6G	*G. flava* level 6		
Legend for back-transformed mean tables							
Level1E	*A. erioloba* level 1	Level 1L	*A. luederitzii* level 1	Level 1B	*B. albitrunca* level 1	Level 1O	*Other species* level 1
Level 2E	*A. erioloba* level 2	Level 2L	*A. luederitzii* level 2	Level 2B	*B. albitrunca* level 2	Level 2O	*Other species* level 2
Level 3E	*A. erioloba* level 3	Level 3L	*A. luederitzii* level 3	Level 3B	*B. albitrunca* level 3	Level 3O	*Other species* level 3
Level 4E	*A. erioloba* level 4	Level 4L	*A. luederitzii* level 4	Level 4B	*B. albitrunca* level 4	Level 4O	*Other species* level 4

Level 5E	*A. erioloba* level 5	Level 5L	*A. luederitzii* level 5	Level 5B	*B. albitrunca* level 5	Level 5O	*Other species* level 5
Level 6E	*A. erioloba* level 6	Level 6L	*A. luederitzii* level 6	Level 6B	*B. albitrunca* level 6	Level 6O	*Other species* level 6
Level 1M	*A. mellifera* level 1	Level 1S	*T. sericea* level 1	Level 1G	*G. flava* level 1		
Level 2M	*A. mellifera* level 2	Level 2S	*T. sericea* level 2	Level 2G	*G. flava* level 2		
Level 3M	*A. mellifera* level 3	Level 3S	*T. sericea* level 3	Level 3G	*G. flava* level 3		
Level 4M	*A. mellifera* level 4	Level 4S	*T. sericea* level 4	Level 4G	*G. flava* level 4		
Level 5M	*A. mellifera* level 5	Level 5S	*T. sericea* level 5	Level 5G	*G. flava* level 5		
Level 6M	*A. mellifera* level 6	Level 6S	*T. sericea* level 6	Level 6G	*G. flava* level 6		

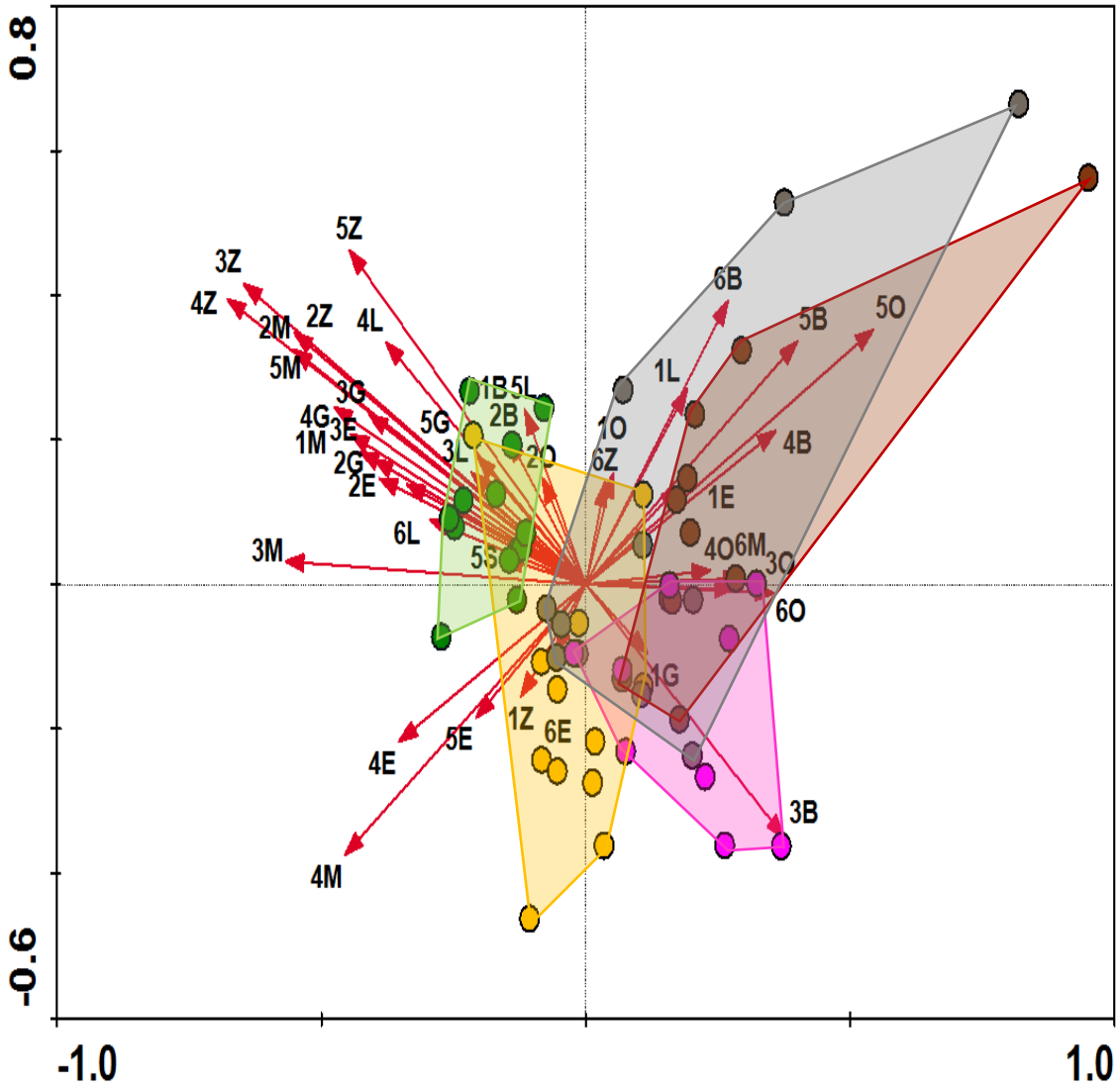


Figure 8.49 Ordination result of the feeding level preferences of male giraffes during different seasons and for different tree species (green = summer; yellow = autumn; brown = winter 2012; grey = winter 2013; pink = spring).

Figure 8.49 ordination result of the feeding level preferences of male giraffes during different seasons and for different tree species (green = summer; yellow = autumn; brown = winter 2012; grey = winter 2013; pink = spring).

The same changes in feeding patterns during each season can be seen for males (Figure 8.49). However, there is more overlap between seasons, with the winter 2012 and 2013 seasons distinctly different from the other seasons, but overlapping each other. *B .albitrunca* levels 4, 5 and 6 and "*other species*" level 5 were prominent for both the winter seasons. This may indicate that males do not vary their feeding levels and diet during different seasons as much as females do.

8.3.3. Interspecific competition

It is speculated in the literature that the evolution of the giraffe's long neck is to avoid feeding competition with other herbivore species (Cameron & Du Toit, 2007). However, this study found a large percentage of giraffe feeding occurring below 2.0 m, which is directly in competition with other browsers also present in large numbers in KKNR, such as elands (*Taurotragus oryx*) and kudus (*Tragelaphus strepsiceros*). Browsing by elands is much more influential (Watson, 1999) and can determine the distribution and survival of certain plant species. Although elands are classified as mixed feeders (Hofmann & Stewart, 1972), Watson (1999) determined that they browsed 94% and grazed only 6% of their annual diet in the Mountain Zebra National Park, South Africa. They can browse up to 2.5 m and are dominant over other browsers such as kudus and duikers (*Sylvicapra grimmia*) (Watson, 1999). Kudus have a maximum feeding height of 2.5 m (Dayton, 1978) and seek leaves with high nutrient value with little fibrous stem material (Owen-Smith & Cooper, 1983). Niche overlaps are common between kudus, elands and giraffes and the competition for woody species is evident (Leuthold, 1978).

Results from chapter six reported on the comparative substitution values of kudus (1.0 BU), elands (2.2 BU) and giraffes (5.2 BU) as browser units (BU) (Table 6.3). Current numbers of browsers within KKNR after the latest aerial census are presented in Table 6.4 (chapter 6), namely kudus (n = 803 = 803 BU), elands (n = 2 086 = 4 589 BU) and giraffes (n = 111 = 577 BU). Table 6.5 (chapter 6) showed the total browser units (BU) the KKNR can sustain within each height stratum <1.5 m, <2.0 m and <5.0 m. From these results it was concluded that the critical period for browse competition was July to October for the strata up to 2.0 m with KKNR exceeding the carrying capacity by 20 %. This would mean that if giraffes are feeding on woody plants below 2.0 m during these four months, they would directly compete with kudus and elands for the same resources possibly adding pressure on them.

The results from this study show that adult giraffes are not competing with kudus or elands when browsing above level three (≥2.0 m). The same was found by Breebaart (2000) who concluded that the average browsing height of giraffes was at 3.15 m, kudus at 1.15 m and elands at 0.97 m.

Females prefer levels three (22%), four (33%) and five (32%) (combined = 87%) (Figure 8.3). Thus, 87% of all female feeding occurred between 2.0 and 3.5 m. When level six is also included, 93% of all female feeding occurred above 2.0 m (Figure 8.3) and only 7% below 2.0 m (levels one and two). When only levels four (33%) and five (32%) are combined, then 65% of all female feeding occurred between 3.0 - 3.5 m in height.

Males prefer levels four (31%) and five (40%) and so 71% of male feeding occurred between 4.0 and 4.5 m (Figure 8.5). When level six is also included, then 81% of male feeding occurred above 4.0 m. Only 19% of male feeding occurred below 4.0 m, (levels one: 1%, two: 4% and three: 14%) (Figure 8.5).

Similar ecological requirements often coexist for African herbivore communities in the same area, and can lead to intense defoliation of resources (Leuthold, 1978). According to Leuthold (1978), kudus and giraffes are fairly directly comparable as they are considered as

100% browsers. Seasonal changes make elands less dominant, as they are considered a mixed feeder (Bothma, 2010).

Leuthold (1978) found in Tsavo East National Park, Kenya, that giraffes avoided competition with other browsers during certain seasons. On average, about 50% of giraffe browsing occurred below 2.0 m (levels kudus could reach), of which 67% was below 2.0 m in the green season versus only 37% in the dry season. Kudu and giraffe diet overlap ranged from 39.3% in the green season to only 29.9% in the dry season (Leuthold, 1978). The actual browsing levels or strata overlap between kudus and giraffes was 48% in the dry season, demonstrating the significance of feeding level overlap (Leuthold, 1978). Dayton (1978) concluded that even if there is tree growth below 2.5 m, it is often modified with stems thicker than 4 mm, because of prolonged browsing of seedlings and shoots by browsers such as kudus and impalas (*Aepyceros melampus*). This could make feeding competition below 2.5 m even more of a problem during critical periods for browsers, and could lead to long term reduction in the carrying capacity for browsing ungulates (Dayton, 1978). Simmons & Scheepers (1996) also found that during the dry season (critical period), giraffes fed from lower shrubs and not tall trees and that females spent over 50% of their time feeding with their necks horizontal. Breebaart (2000) found in the Weenen Nature Reserve, South Africa that elands' browse diet increased during the drier months, adding extra pressure on browsing competition.

Pellew (1984a) found in the Serengeti that giraffes only fed on taller trees during the wet season and not the dry season, which is contrary to the findings of Sauer *et al*. (1982). Giraffes did not avoid interspecific competition with other browsers below 2.0 m in Tsavo National Park (Kenya) and had a 37% diet level overlap (Leuthold & Leuthold, 1972). The diet species overlap between kudus and giraffes (65.5%) and between giraffes and elands (18.2%) can be regarded as extensive; especially between the former, where diet overlap is 56.8% in the dry season (Breebaart, 2000) but this is different for feeding level overlap. Breebaart (2000) found that the percentage of feeding level overlap between kudus and giraffes was only 18.3%, and between elands and giraffes only 7.7%. Only in South Africa were giraffes found to allocate 90% of their time feeding above the average height of kudus and impalas (du Toit, 1990), but lower than was possible with their long necks (5-6 m). Scheepers (1996) found that giraffes fed 50% below shoulder height (3.1 m for males and 2.8 m for females), agreeing with the findings of du Toit (1990) in KNP in South Africa. Young & Isbell (1991) found giraffe feeding levels were 60% at shoulder level in Kenya, East Africa Woolnough & du Toit (2001) concluded that male giraffes derive a nutritional advantage by feeding higher in the canopy than females, and that females fed above the levels accessible to smaller browsing species Breebaart's (2000) results, however, do not indicate whether juvenile giraffes were included in the calculation.

The only study to note juvenile giraffe height and neck length, is Simmons & Scheepers (1996) who found that young giraffes exhibit a leg-to-neck ratio of 1:0.62, compared to adults 1:0.93. This implies that young giraffes exhibit a high neck growth of 23 cm per week (Dagg & Foster, 1976). Based on the results from Breebaart (2000), periods of resource scarcity (July – October) will limit the availability of these resources to smaller bodied herbivores (like kudus), which will be most affected and likely to suffer the greatest mortality. The same could apply to juvenile giraffes, which directly compete for resources against elands and kudus. We could, therefore, further speculate that competition for browse could be one of the main reasons for the high mortality of giraffes younger than one year, and why giraffe

numbers are not increasing within KKNR for the last four years. Table 8.1 shows that juvenile giraffes are involuntarily competing with other browsers, whereas adults can avoid competition by feeding on trees above the average size available to other browsers.

8.4. Conclusion

The following can be concluded from this study:

i) Giraffes show feeding level preferences for certain tree species. For instance, 99% of female feeding occurred ≥3.0 m on *A. erioloba*, 89% occurred ≥3.0 m on *A. mellifera*, 70% occurred ≥3.0 m on *Z. mucronata*, 90% occurred >3.0 m on *B. albitrunca,* but for "*other species*" 69% of feeding occurred ≤1.0 m, probably because of the growth form and size of the "*other species*", such as *A. hebeclada, Rhigozum brevispinosum, Diospyros lycioides and Lycium cinereum.*

ii) Giraffe feeding level preferences showed the same trend for males and females when the body posture is taken into consideration. However, the greater height of males resulted in feeding differences from females, i.e. males, on average, fed 1.0 – 1.5 m higher than females. For instance, 94% of male feeding occurred ≥4.0 m on *A. erioloba*, 90% ≥4.0 m on *A. mellifera*, 92% ≥4.0 m on *Z. mucronata* and 95% >4.0 m on *B. albitrunca.*

iii) Seasonal variation in terms of feeding levels does occur. Preferred feeding levels change over the seasons and the largest differences were found to be between spring and autumn. For instance, feeding level one became more prominent during the autumn (wet and cool) and less so during the spring (dry and hot) season. Level two was more prominent during the summer (wet and hot) and autumn seasons than during the spring, indicating that females selected foliage on lower levels more often during the critical period (autumn) than during the less critical periods (summer and spring). Alternatively, they may be selecting a greater variety of food.

iv) The time of day also has a significant effect on feeding on all preferred tree species by males and females. The reason for these differences in feeding times is unclear, but could possibly be related to peak transpiration rates, photosynthesis, and chemical defence or taste/smell effects.

v) Male giraffes fed on higher levels during the dry season compared to the wet season. Dry season months (July to October) are considered the period of greatest food scarcity and by feeding on higher levels they reduce inter- and intra- specific competition and they utilise resources that were underutilised during the other months.

vi) Both males and females browse on levels that largely exclude direct competition from other browsers (>2.0 m), especially during the dry season. Only 7% of all female feeding occurred below 2.0 m and only 19% of male feeding occurred below 4.0 m. This explains why adult giraffes mostly feed on trees that are above available height for other browsers. Thus, they avoid competition by searching for taller trees.

CHAPTER 9: DAILY ACTIVITY BUDGETS OF GIRAFFES

9.1. Introduction

The specific objectives of this study are:

i. To determine prominent non-feeding activities,
ii. To calculate how much time giraffes spent on each of these activities, and how these activities differed between males, females and juveniles,
iii. To determine if these activities changed over seasons and during the time of day,
iv. To develop a prediction model based on the results.

A deeper look into the social and non-feeding related behaviour of giraffes might show that they devote significant time to various other activities that add to their health and comfort. This might possibly explain why giraffe social structures are complex (Bercovitch & Berry, 2009) and why they devote much time to non-feeding activities.

The recorded activities in this study were the following: (1) Standing, (2) Walking, (3) Browsing, (4) Lying down, (5) Standing-and-ruminating (S/R), (6) Walking-and-ruminating (W/R), (7) Lying-and-ruminating (L/R), (8) Galloping, (9) Looking around, (10) Feeding on bones (osteophagia) and soil (geophagia) and (11) Other/alternative activities which are grouped together because they were not distinctive enough to be individually recognised. The definitions of these activities were described in chapter 3 within the literature review.

Giraffes in Lake Manyara National Park, Tanzania, spent on average 35% of their time browsing between 07:00 and 19:00 (Van der Jeugd & Prins, 2000), of which the morning and late afternoon percentage of time spent browsing was almost twice as high as during midday. Mature bulls browsed significantly less than the cows (Du Toit, 1990; Pellew, 1984), and young calves spent less time still. Browsing time increased during the period of food scarcity.

Activities and different patterns of behaviour have been documented by Seeber *et al.* (2012) in Zimbabwe and in South Africa. Theron (2005) in the Free State found that standing was the second most important daily activity of giraffes. He also found that a relatively small percentage of total daily activity was spent in movement, which differs from the studies of Kok & Opperman (1985) and Pellew (1984). During the day, movement peaked during the early morning (07:00 – 10:00) and late afternoon (14:00 – 17:00). The least movement took place during the heat of the day. Both sexes spent equal time (17%) during the day in movement, and observations demonstrated a significant difference in the movement of giraffes during the various seasons.

Pellew (1984) conducted some activity budgets in the Serengeti National Park in Tanzania and concluded that energy-consuming activities were minimized and energy was conserved at the most demanding times of the day. Although not much time was spent on activities not related to feeding, it is important to know what these activities are and why giraffes are willing to spend time on these activities, which otherwise could have been spent browsing.

9.2. Procedure

9.2.1. Identifying the most prominent non-feeding activities

During the scan sampling method (Altmann, 1974), non-feeding activities of the giraffes were recorded for fifteen months from June 2012 to August 2013. Behavioural observations were recorded every five minutes (chapter five) and also grouped into observations made within the hour. The grouped data of each specific hour of each day of each ten day observation period, for example all 8:00 to 9:00 and all 9:00 to 10:00 data of the June observation period were added, so that time allocation, or percentage of total time (hours) spent on different activities could be calculated for each of the observation periods of each month. Differences in time allocation between adult males and females and adults and juveniles were determined, as well as the differences in time allocation between these groups during different times of the day and different months.

The same herd was monitored for an entire day from sunrise to sunset. Observations were made in the same order with every observation cycle to maintain a clear difference between observations and to ensure that time slots between observations of individual animals were even. The date, wind direction, herd size, as well as the gender of individuals in groups were recorded at the beginning of each day's observation period and a number allocated to each animal. The number was then noted next to the activity with each recording. Every five minutes each observation was recorded on a handheld recorder, and at the end of each day the data were captured in an Excel (2010) spread sheet, with separate sheets for adult cows, adult bulls, sub-adult males, sub-adult females and juveniles. Activity records were modified from Parker & Bernard (2005) and each activity record was defined as one activity performed by one animal during one scan (same as above). Activity records for each animal performed/hour were totalled and expressed as a percentage of all activity records for that hour.

Records for every hour were grouped together in order to express each activity as a percentage/day and then again percentage/month and later per season. Records of individuals were also grouped in the same way in order to compare adult cows, adult bulls, sub-adult males, sub-adult females and juveniles. Total activities were also determined by expressing the total number of records of an activity as a percentage of all observations. Procedures used to identify the most prominent social behaviours (as an activity) of giraffes were as follows:

(1) Standing

A "standing record" was defined as an individual just standing (two individuals just standing is two standing records, etc.) without them doing anything specific such as looking around. The frequency of standing of each individual animal was determined by expressing the number of standing records as a percentage of the total number of standing records recorded for each month. Closely related to standing is the standing-and-ruminating (S/R) activity, when an individual is ruminating while standing.

(2) Walking

A “walking record” was defined as an individual walking without browsing or ruminating (two individuals walking is two walking records, etc.).. The frequency of walking of each individual was determined by expressing the number of walking records as a percentage of the total number of walking records recorded for each month. Closely related to walking is the walking-and-ruminating (W/R) activity, when an individual is ruminating and walking at the same time.

(3) Browsing

A “feeding record” was defined as an individual foraging on one plant (two individuals utilizing the same plant is two feeding records, etc.) and includes chewing up to the point of swallowing. The frequency of utilization of each species was determined by expressing the number of feeding records per plant as a percentage of the total number of feeding records recorded.

(4) Lying down

A “lying record” was defined as an individual lying down (two individuals lying down is two lying records, etc.) without ruminating. The frequency of lying down of each individual was determined by expressing the number of lying records as a percentage of the total number of lying records for each month. Closely related to lying is the lying-and-ruminating (L/R) activity, when an individual is ruminating whilst lying down.

(5) Standing-and-ruminating (S/R)

A “S/R record” was defined as an individual standing while ruminating at the same time (two individuals that S/R is two S/R records, etc.). The frequency of standing-and-ruminating of each individual was determined by expressing the number of S/R records as a percentage of the total number of S/R records recorded for each month.

(6) Walking-and-ruminating (W/R)

A “W/R record” was defined as an individual walking while ruminating at the same time (two individuals that W/R is two W/R records, etc.). The frequency of walking-and- ruminating of each individual was determined by expressing the number of W/R records as a percentage of the total number of W/R records recorded for each month.

(7) Lying-and-ruminating (L/R)

A “L/R record” was defined as an individual lying down while ruminating at the same time (two individuals that L/R is two L/R records, etc.). The frequency of lying-and-ruminating of each individual was determined by expressing the number of L/R records as a percentage of the total number of L/R records recorded for each month.

(8) Galloping (running)

A “gallop record” was defined as an individual galloping or running (two individuals that gallop are two gallop records, etc.) at that specific scanning time. The frequency of galloping of each individual was determined by expressing the number of gallop records as a percentage of the total number of gallop records recorded for each month.

(9) Looking around

A “looking record” was defined as an individual looking around without ruminating (two individuals looking around is two looking records, etc.) and was not just standing. Looking was identified when the individual was focused on something with eyes and ears. The frequency of looking of each individual was determined by expressing the number of looking records as a percentage of the total number of looking records recorded for each month.

(10) Osteophagia (feeding on bones)

An “osteophagia record” was defined as an individual feeding on a bone at that specific moment (two individuals busy with osteophagia is two osteophagia records, etc.). The frequency of osteophagia of each individual was determined by expressing the number of bone feeding records as a percentage of the total number of osteophagia records recorded for each month.

(11) Other/ alternative activities

An “other” activity was defined as an individual performing alternative activities such as defecating, urinating, grooming, rubbing/scratching, suckling (calves), flehmen (males), and sniffing cows (males) – (two individuals doing “other” things is two “other” records, etc.) and these activities are all grouped together. The frequency of “other” of each individual was determined by expressing the number of “other” records as a percentage of the total number of “other” records recorded for each month.

9.2.2. Calculating time spent on each activity for male, female and juvenile giraffes

The sum, standard error of the means, standard deviation and percentages were calculated and presented as descriptive statistics, such as pie charts using Excel (Microsoft, 2010) to determine how much time giraffes spent on each activity.

9.2.3. Evaluating how season and time of day influence activities

Data were further statistically analysed with GenStat® (Payne *et al*., 2012) for each dataset recorded by the GPS collars for each female giraffe (Appendix J). The same procedure was used as described in chapter 5, except for the random model that changed and the Poisson distribution is specified for counts. The GLMM method was applied with the Poisson distribution and the logarithmic link function. The fixed effects were specified as time and gender per monthly analysis (and season per combined analysis) and all the interactions between the fixed effects. The random effect was specified as time (or the time x season interaction in the combined analyses over months). Treatment means were separated using Tukey's least significant difference (LSD) test at the 5% level of significance (Snedecor & Cochran, 1980).

The number of samples used for female giraffes for the untransformed means per season per time of day is displayed in Appendix J Table J.2 and the same for males in Appendix J Table J.7. The same description for the time of day and for the seasons was used as described in chapter 5.

Following the results recorded from the activities, they were further tested with the different techniques from the CANOCO 4 (Ter Braak & Šmilauer, 1998) package by "grouping" the same value information together (Verlinden & Dayot, 2005). All data matrices activities were analysed during the different seasons using the Correspondence Analysis, and the De-trended Correspondence Analysis (DCA) was used for ordination of seasonal variation for each activity (Gauch, 1982; Ter Braak, 1986, 1987). This included multidimensional scaling (MDS) to establish whether there were outlier data within each of the separate data matrices which needed to be removed from the rest of the analyses. Indirect ordination using DCA (unimodal response) was used to extract ordination axes that described the main special compositional gradient, and to establish which activities were related to male, female and juvenile gradients (Ter Braak & Šmilauer, 1998).

9.2.4. Developing a prediction model

Using the results obtained, a model predicting the influence on behaviour of non-feeding activities can be developed. The results will identify each activity and how it might influence other activities and will include the effect of seasons and environmental variables.

9.3. Results and Discussion

9.3.1. Prominent activities performed by giraffe

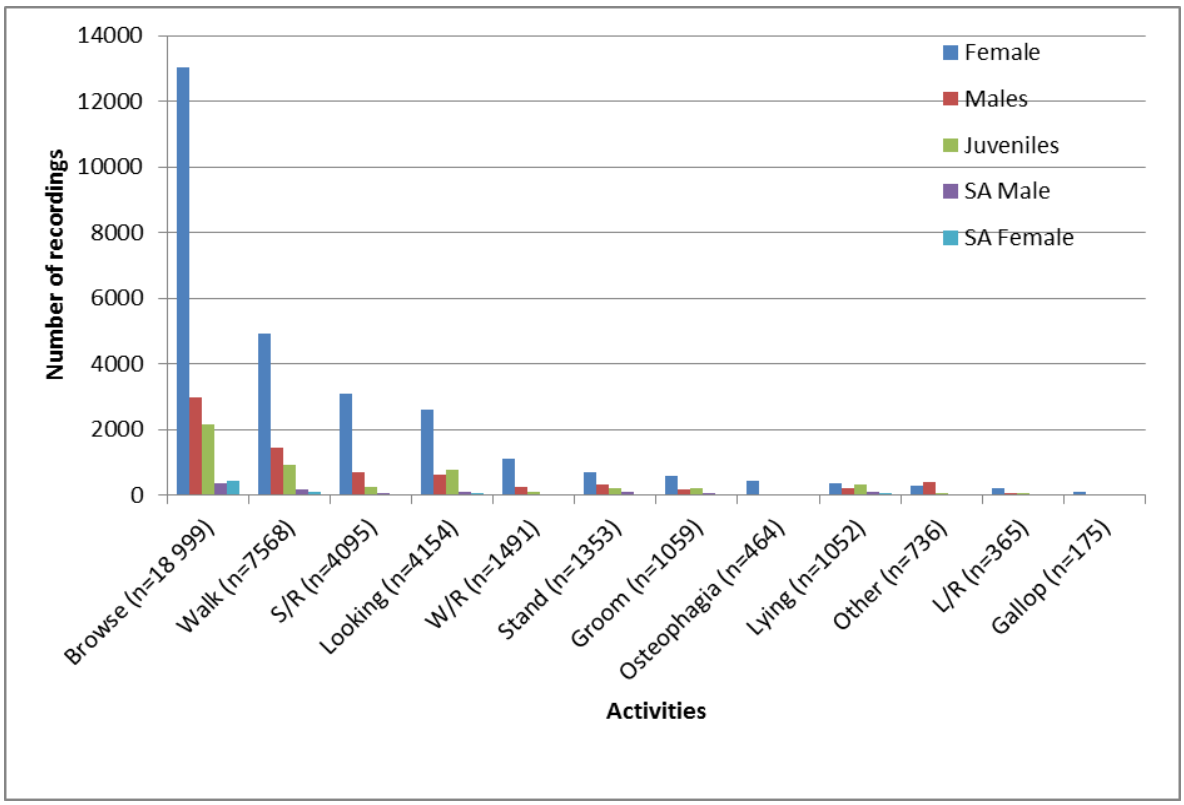


Figure 9.1 Total number of recordings for each identified activity of male, female, sub-adult male, sub-adult female and juvenile giraffes

Browsing (n=18 999) as an activity dominated all other activities for all sexes and age groups (Figure 9.1). The activity least performed was galloping (n=175). Surprisingly, osteophagia (n=465) was recorded more frequently than had been reported in other studies (Wyatt, 1969; Western, 1971; Evans, 1970; Leuthold & Leuthold, 1972; Langman, 1978; Hall-Martin, 1975, Kok & Opperman, 1980). The total number of osteophagia observations by Langman (1978) was only 19. It was unexpected to see such a high number of osteophagia observations within such a short period in this study (Calculating time spent on each activity for male, female and juvenile giraffes). See section 9.3.3 for a more detailed discussion concerning seasonal osteophagia.

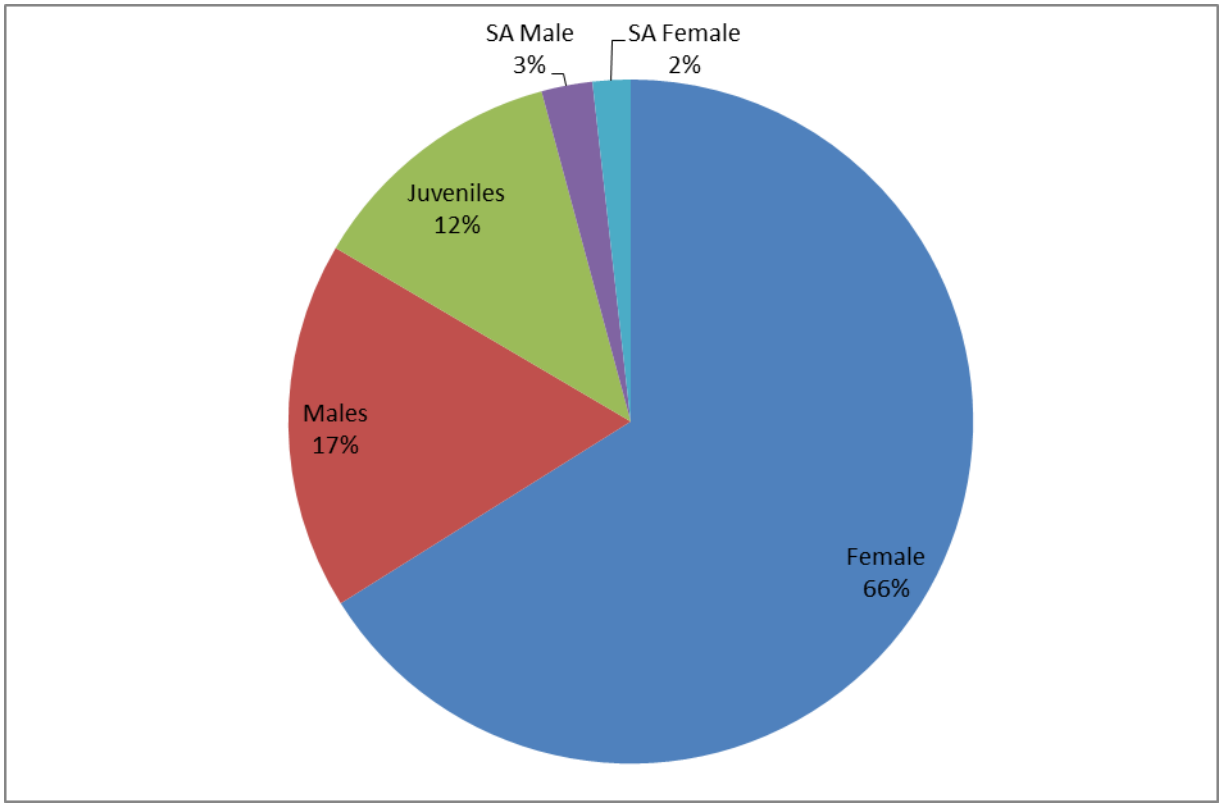


Figure 9.2 Overall herd structure shown as a percentage of 41 511 recordings

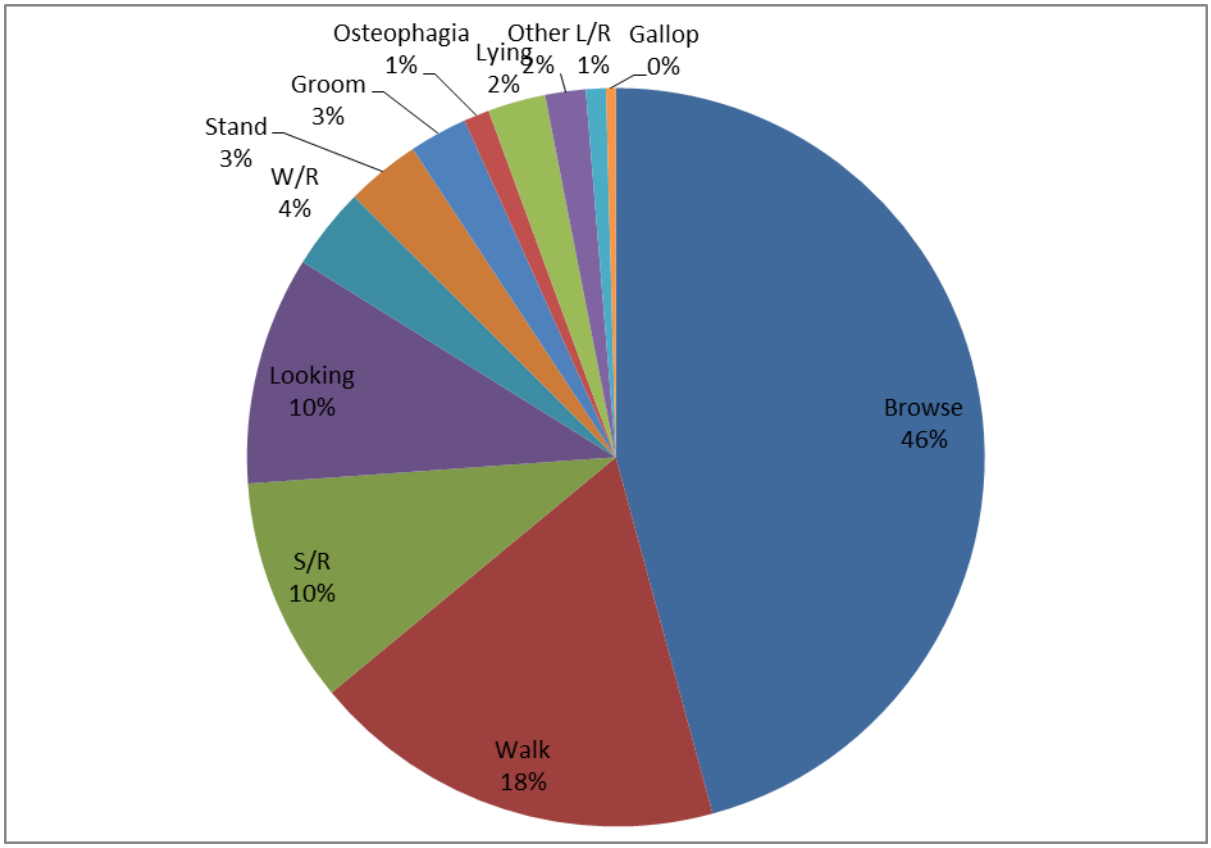


Figure 9.3 Total activities expressed as a percentage of all recordings (n = 41 511)

Figure 9.2 shows the herd structure and the percentage represented by each sex and age group. The average herd structure was predominantly adult females (66%), followed by adult males (17%), juveniles (12%), sub-adult males (3.5%) and sub-adult females (2%).

Figure 9.3 shows the overall percentage of time spent on each activity and indicates that browsing was 46%, walking 18%, S/R 10% and looking around 10%, (totalling 84%) and all the other activities only 16%. Blomqvist & Renberg (2007) found in the Mokolodi Reserve, Botswana that giraffes, on average, devoted 36% of their time to browsing, 20% to walking and 16% to standing-and-ruminating, with the rest of their time devoted to standing, looking around, walking-and-ruminating, lying-and-ruminating, galloping and other activities. Blomqvist & Renberg (2007) and Pellew (1984) found in the Serengeti National Park in Tanzania that giraffes spent between 0% and 10% of their time on 'other' activities not related to feeding. According to Furstenburg (2003), up to 70% of their day is spent browsing in the Kruger National Park, South Africa and Theron (2005) observed that more than half (53%) of the daily activities was active browsing in the Willem Pretorius Nature Reserve in South Africa.

9.3.2. Time spent on each activity

9.3.2.1. Adult female activity budgets

Female giraffes devoted most of their time to feeding and feeding related activities such as lying down and ruminating, walking and ruminating and standing and ruminating. Osteophagia can also be considered as part of feeding. When all these feeding related activities are combined, 68% of a female's time was devoted to feeding and 32% to non-feeding activities (Figure 9.4).

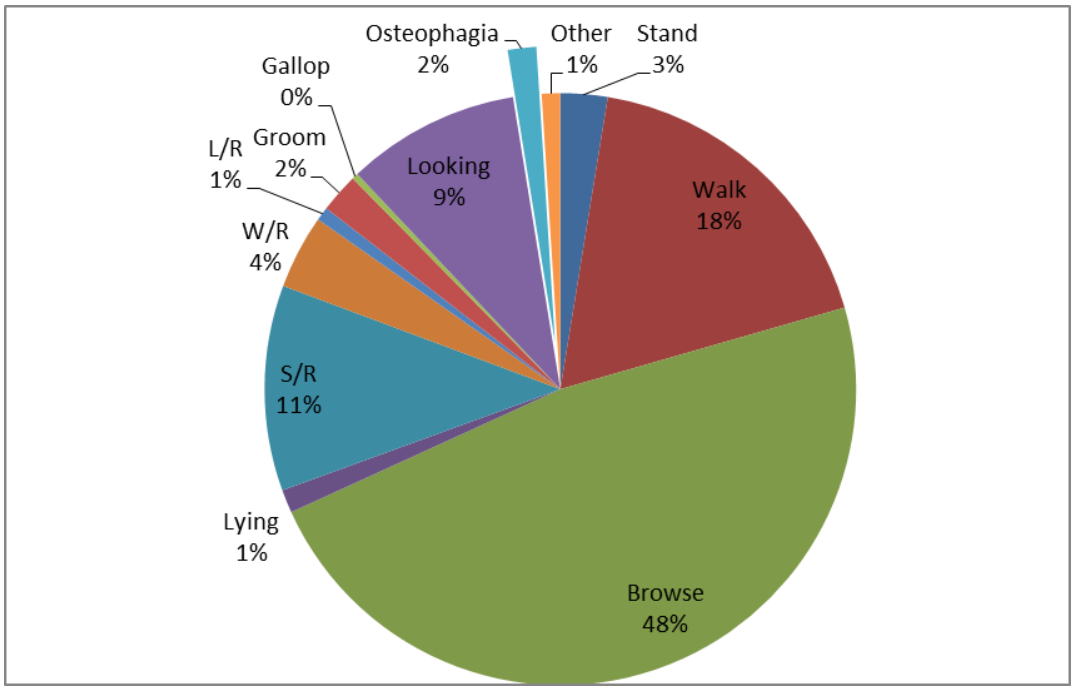


Figure 9.4 Adult female giraffe total activity budgets (n = 27 459) recorded over a period of 15 months from June 2012 – August 2013.

9.3.2.2. *Adult male activity budgets*

Male giraffes spent less of their time on feeding and feeding related activities than females. When all male feeding related activities are combined, 56% of a male's time was devoted to feeding and 44% to non-feeding related activities (Figure 9.5).

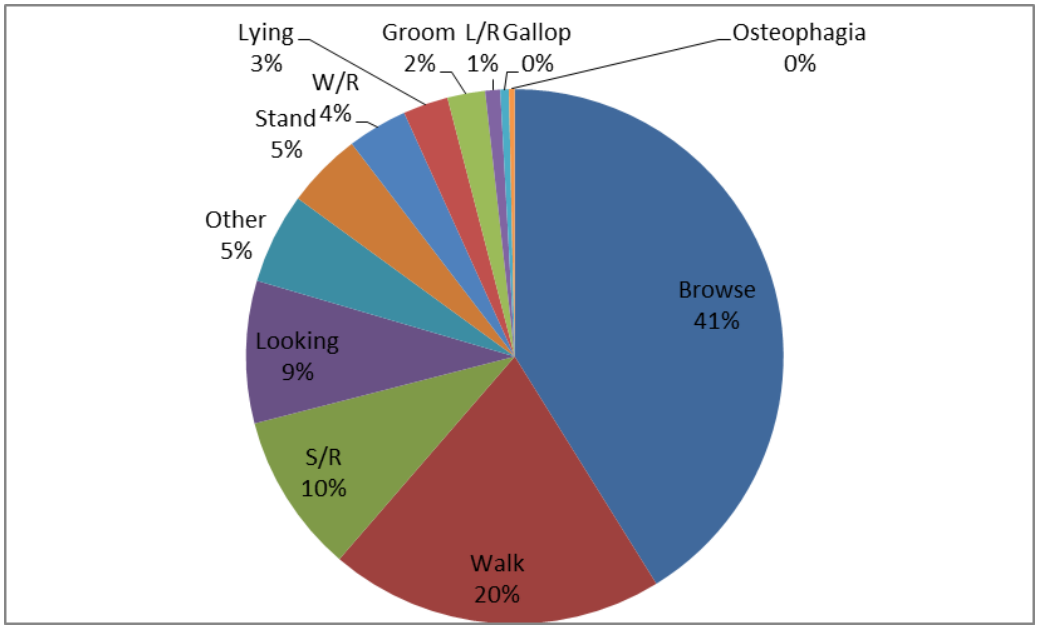


Figure 9.5 Adult male giraffe total activity budgets (n = 7 217) recorded over a period of 15 months from June 2012 – August 2013.

9.3.2.3. *Sub-adult male activity budgets*

Sub-adult male giraffes spent less of their time on feeding and feeding related activities than adults of either sex. . When all their feeding related activities are combined, 46% of their time was devoted to feeding and 54% to non-feeding related activities (Figure 9.6).

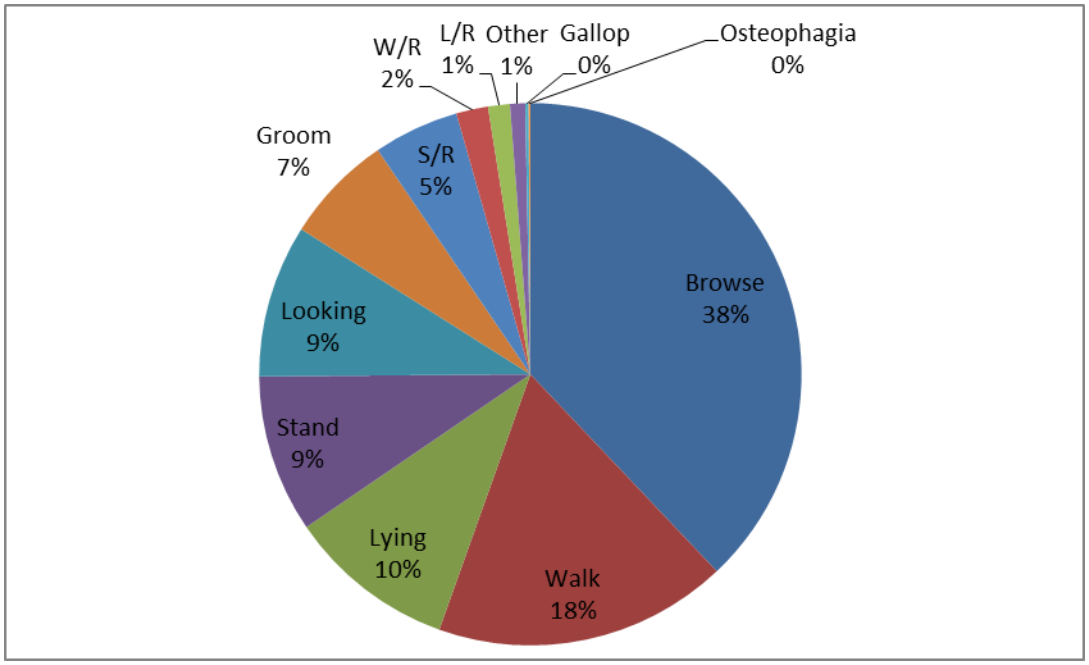


Figure 9.6 Sub-adult male giraffe total activity budgets (n = 999) recorded over a period of 15 months from June 2012 – August 2013.

9.3.2.4. Sub-adult female activity budgets

Sub-adult female giraffes spent a similar amount of time on feeding and feeding related activities as adult females, but more than males and sub-adult males. When all sub-adult female feeding related activities are combined, 67% of their time was devoted to feeding and 33% to non-feeding related activities (Figure 9.7).

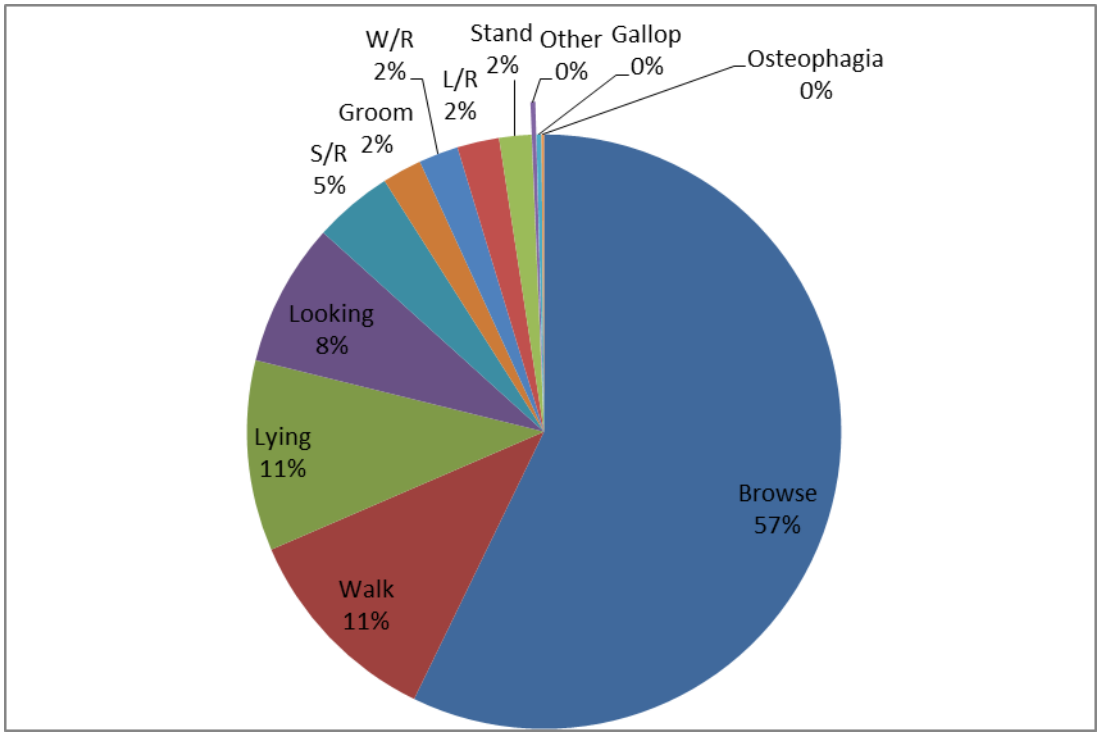


Figure 9.7 Sub-adult female giraffe total activity budgets (n = 743) recorded over a period of 15 months from June 2012 – August 2013.

9.3.2.5. Juvenile activity budgets

Juvenile giraffes spent half their time on feeding and feeding related activities. When all their feeding related activities are combined, 50% of their time was devoted to feeding and 50% to non-feeding related activities (Figure 9.7).

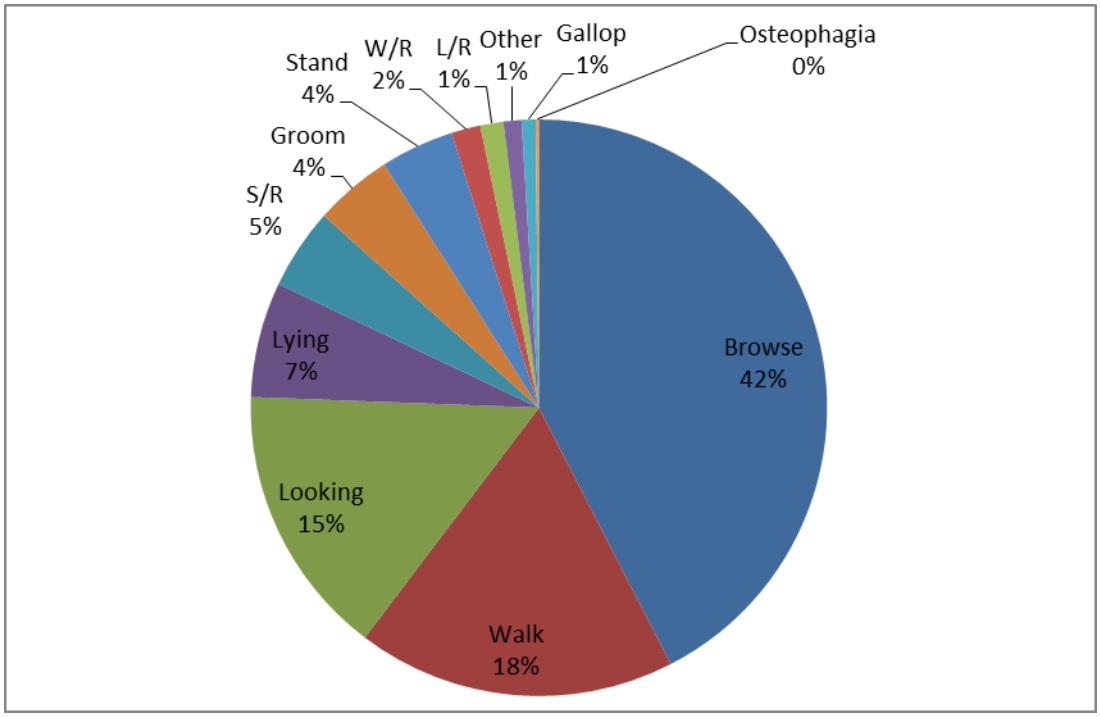


Figure 9.8 Juvenile giraffe total activity budgets (n = 5 121) recorded over a period of 15 months from June 2012 – August 2013.

In the case of adult females almost half of all activities performed were just browsing (48%) (Figure 9.4), which is 9% lower than for sub-adult females (57%) (Figure 9.7). For males only 41% of all activities performed were browsing, while other activities (5%) became more prominent (Figure 9.5). Sub-adult males only browsed 38% of the time, with grooming more prominent at 7% (Figure 9.6). Juveniles spent more time (15%) on looking around than the other other age classes (Figure 9.8). Adults spent 10% of their time on SR, but sub-adults and juveniles spent only 5%. Adult females spent only 1% of their time lying down, bulls 3%, sub-adult males 10%, sub-adult females 11% and juveniles 7%.

Blomqvist & Renberg (2007) found that giraffes in the Mokolodi Nature Reserve, Botswana on average spent less than 5% of time lying down, and noted that females lay down more often than males, and adults more often than sub-adults and juveniles. Giraffes in the Serengeti National Park, Tanzania, devoted only between 0% and 10% to this activity during daytime (Pellew, 1984). Theron (2005) found that only 4% of daily time was spent in lying down, that bulls lay down more than cows, and that animals spent more than double the amount of time lying down during the wet season than during the dry season. This has also been noted by Ginnett & Demment (1997) in the case of G. c. *tippelskirchi* giraffe in Tanzania.

9.3.3. Seasonal changes in activities and influence of the time of day

9.3.3.1. Descriptive statistics for seasonal change

Male, female and juvenile giraffe activities were compared during each season (Figures 9.9 – 9.20). In each figure the standard error (SE) and the standard deviation (SD) are also illustrated.

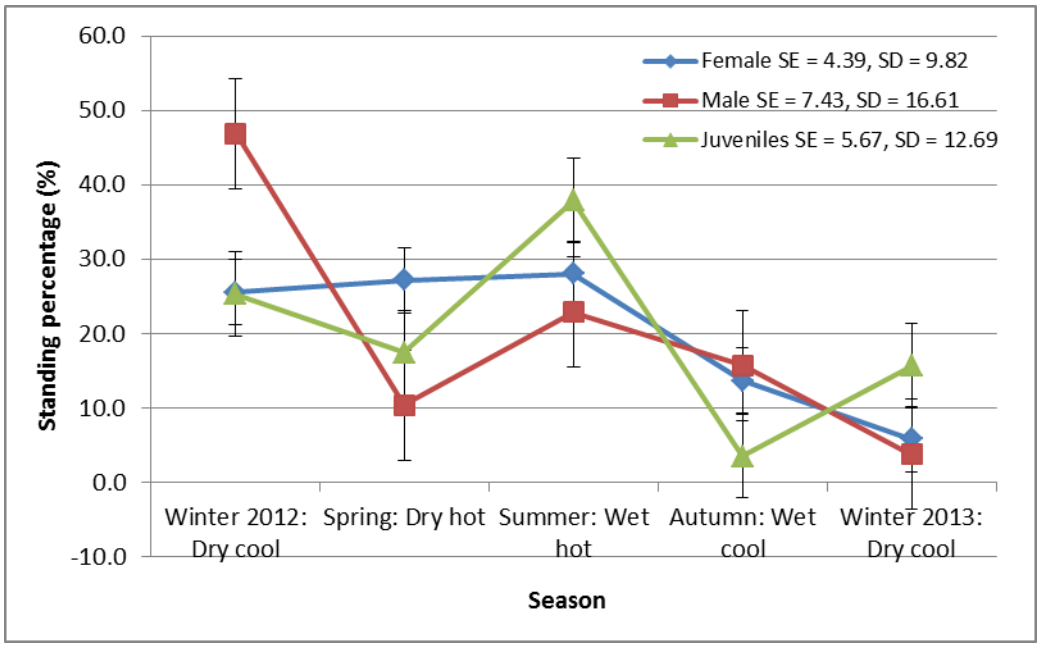


Figure 9.9 Standing as activity during each season for male, female and juvenile giraffes

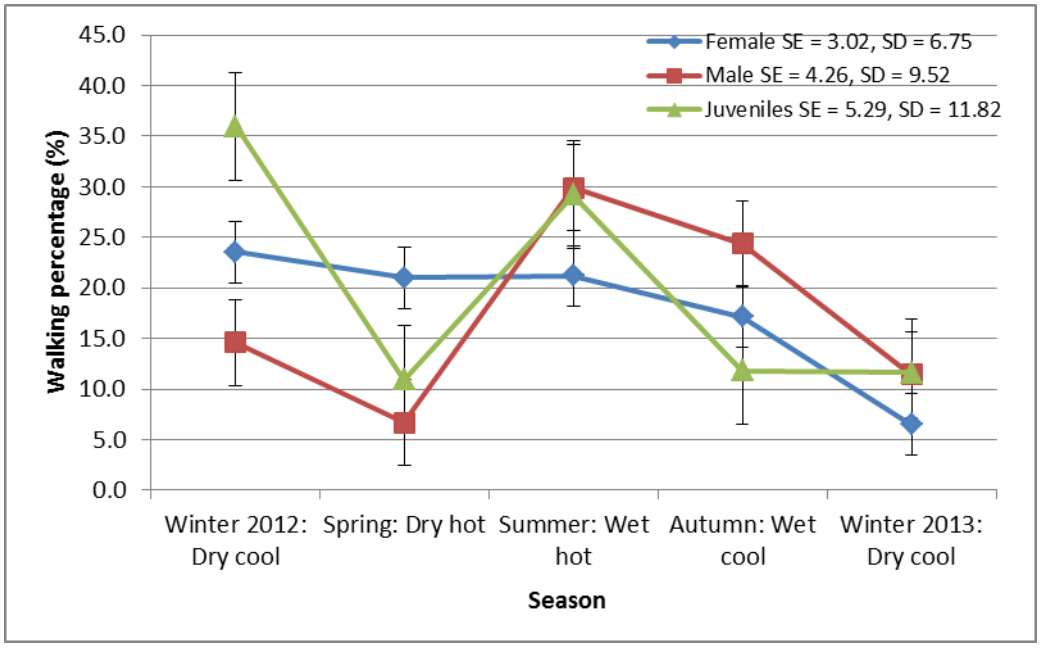


Figure 9.10 Walking as activity during each season for male, female and juvenile giraffes

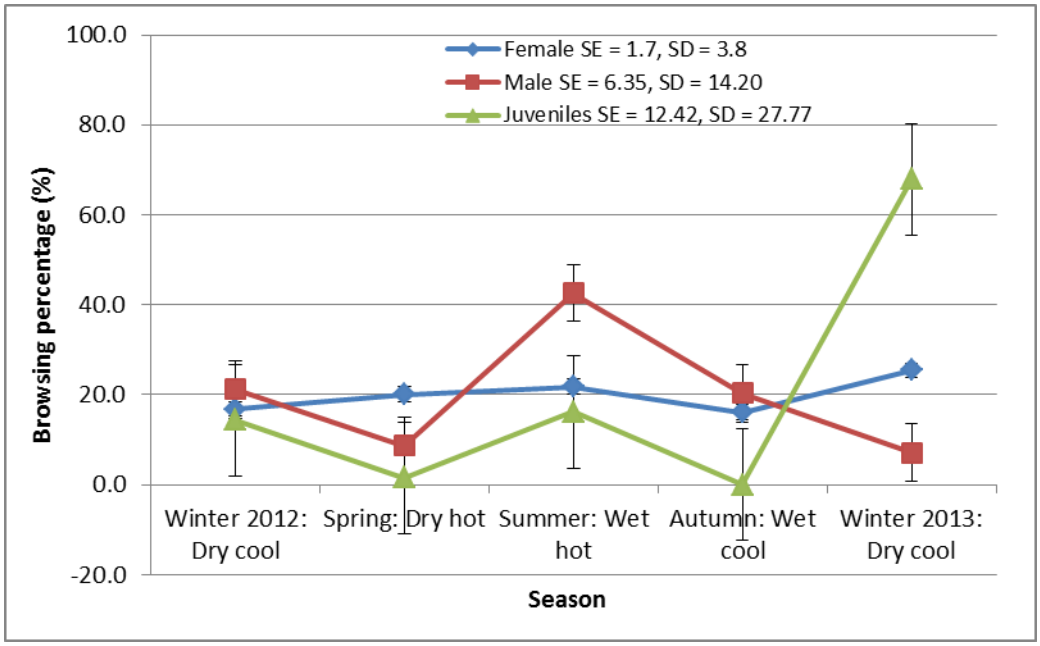


Figure 9.11 Browsing as activity during each season for male, female and juvenile giraffes

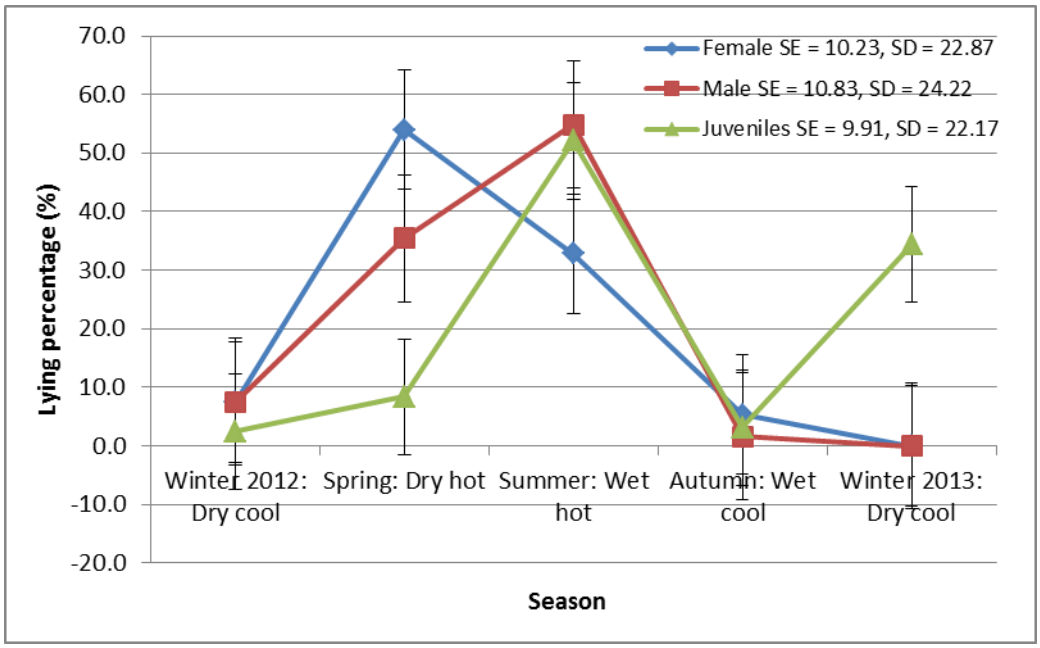


Figure 9.12 Lying as activity during each season for male, female and juvenile giraffes

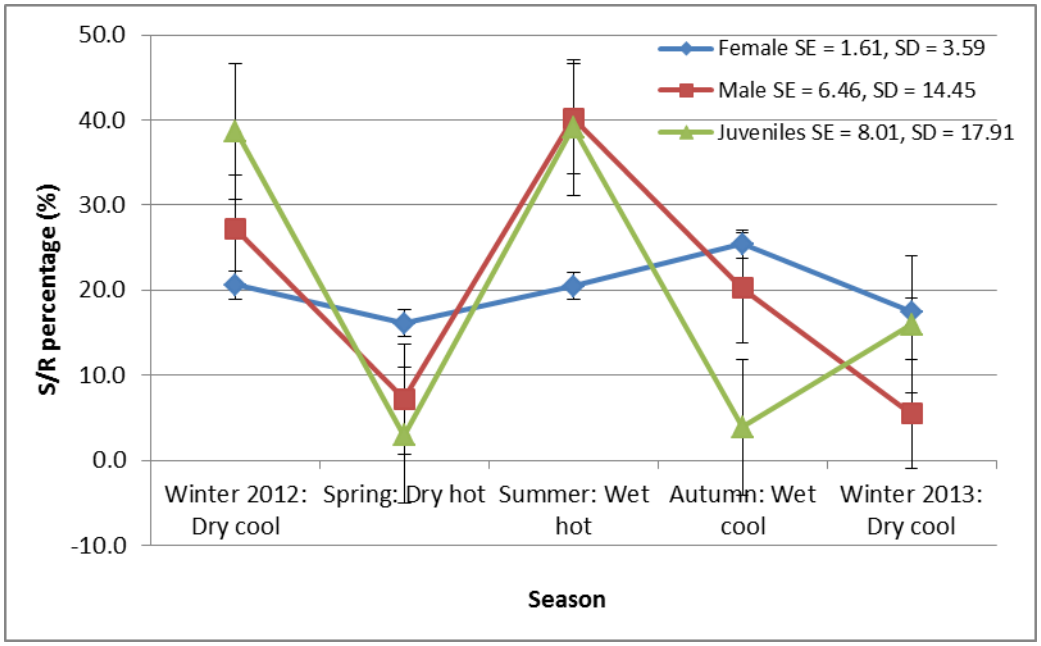


Figure 9.13 Standing & ruminating as activity during each season for male, female and juvenile giraffes

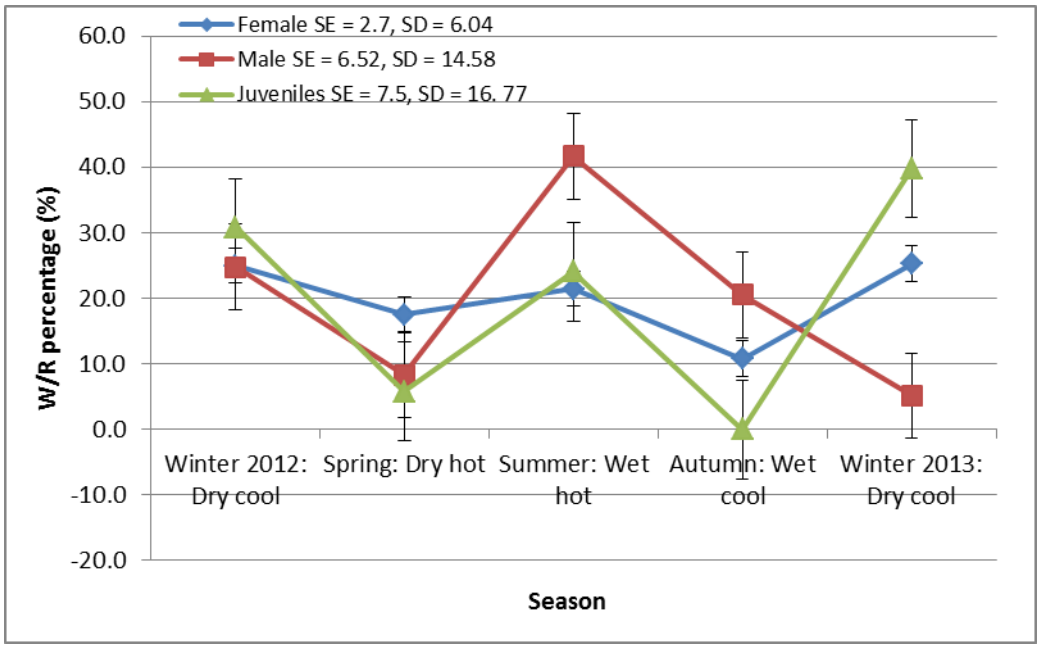


Figure 9.14 Walking & ruminating as activity during each season for male, female and juvenile giraffes

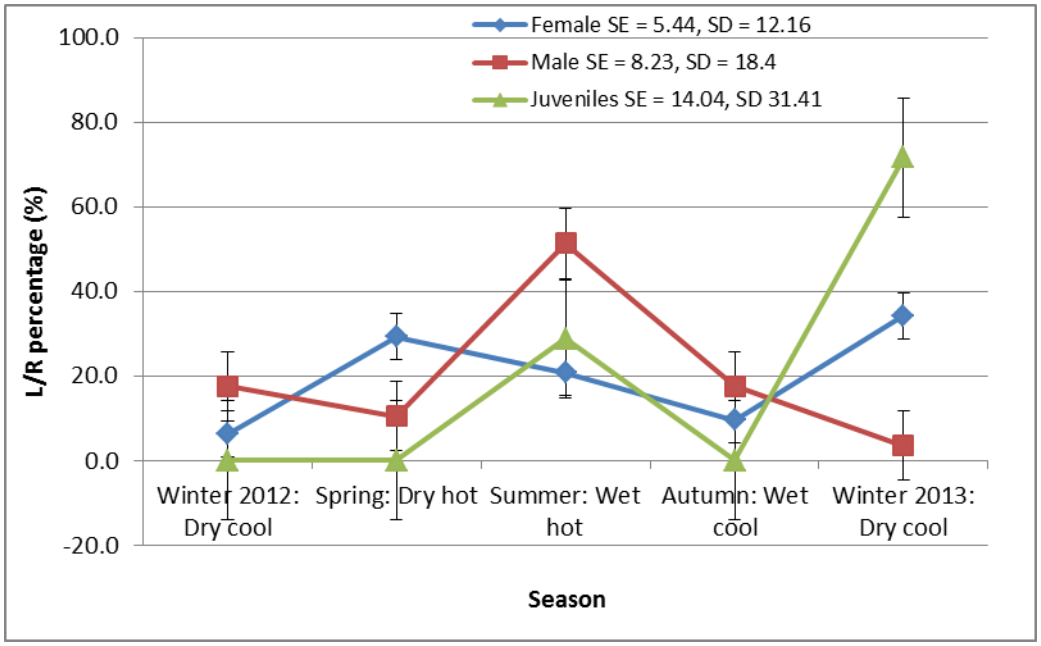


Figure 9.15 Lying & ruminating as activity during each season for male, female and juvenile giraffes

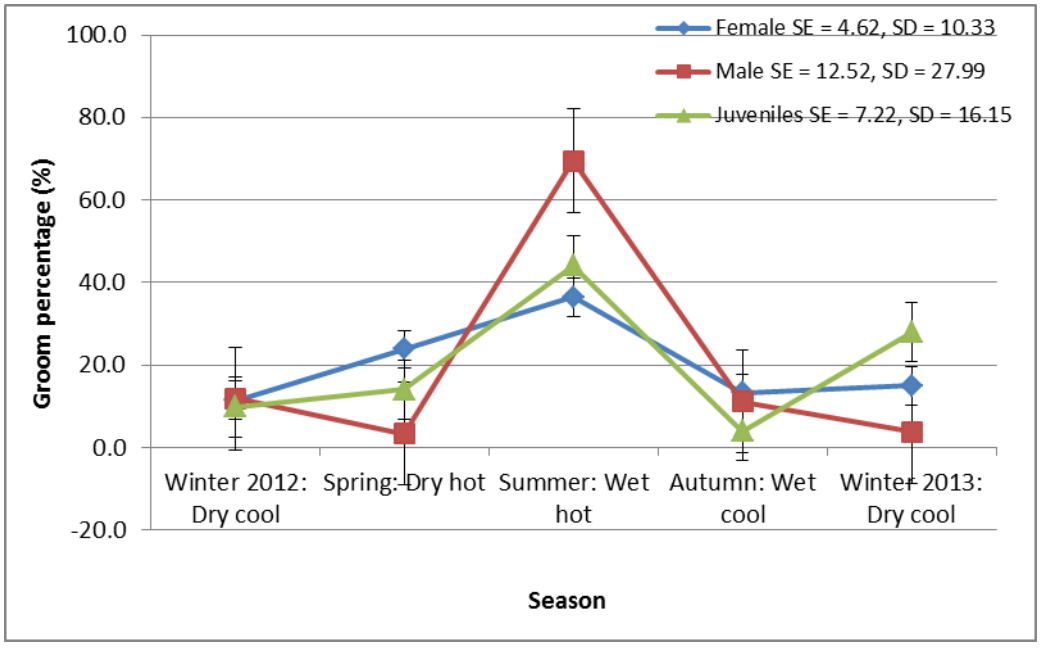


Figure 9.16 Grooming as activity during each season for male, female and juvenile giraffes

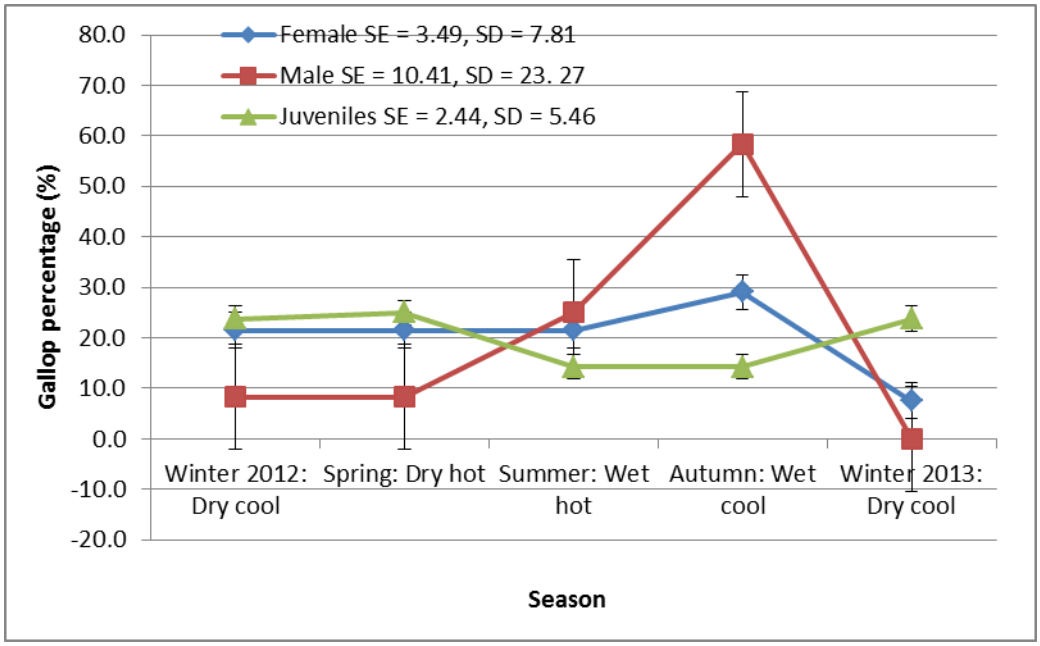


Figure 9.17 Galloping as activity during each season for male, female and juvenile giraffes

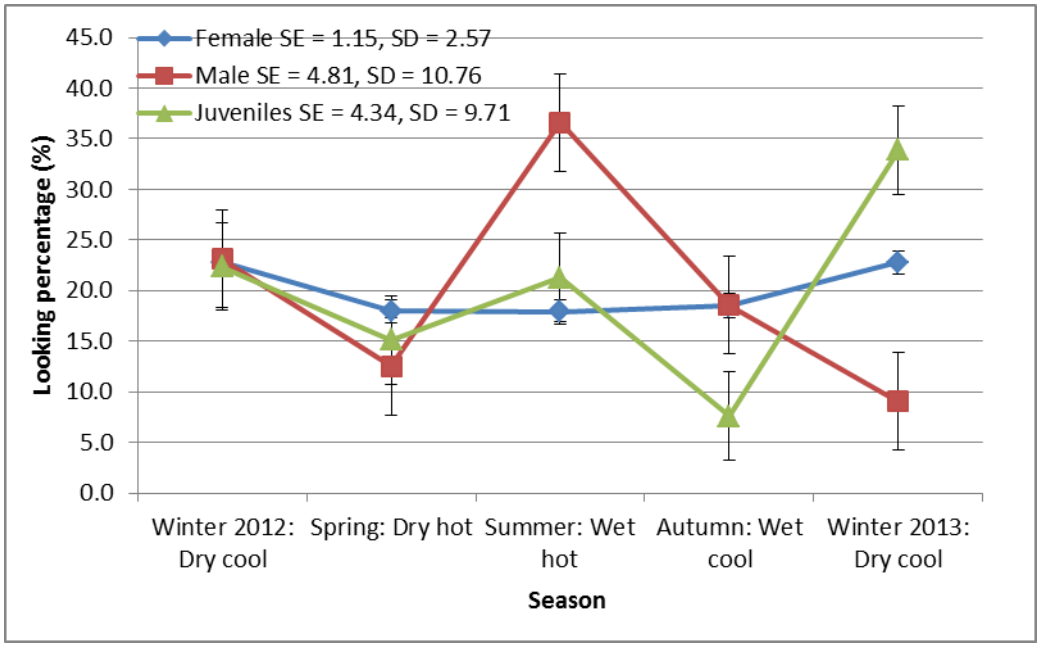


Figure 9.18 Looking around as activity during each season for male, female and juvenile giraffes

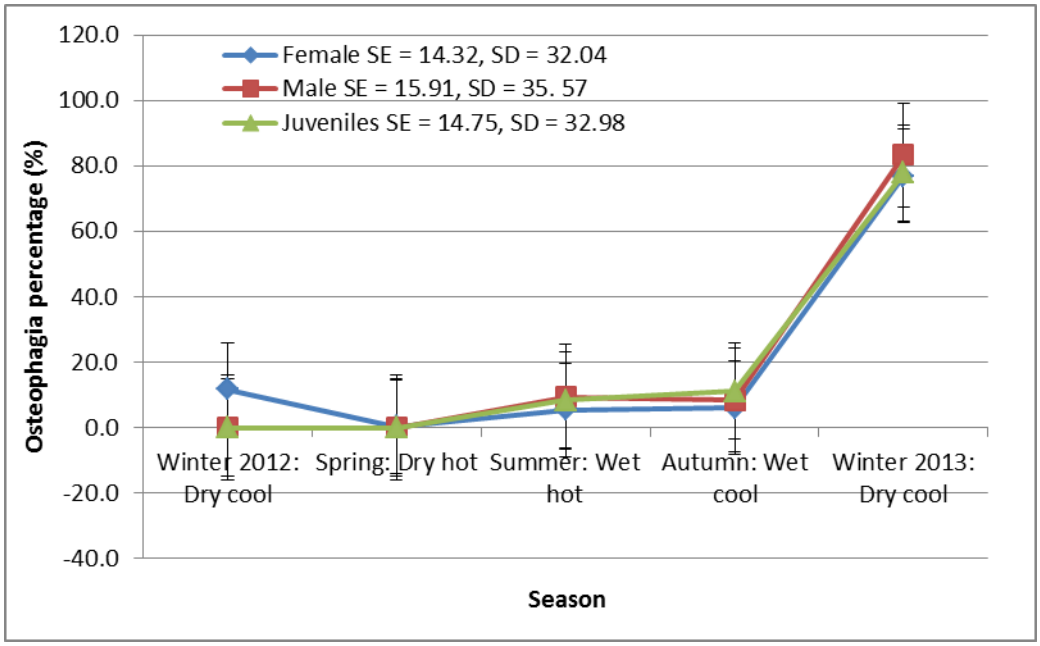


Figure 9.19 Osteophagia as activity during each season for male, female and juvenile giraffes

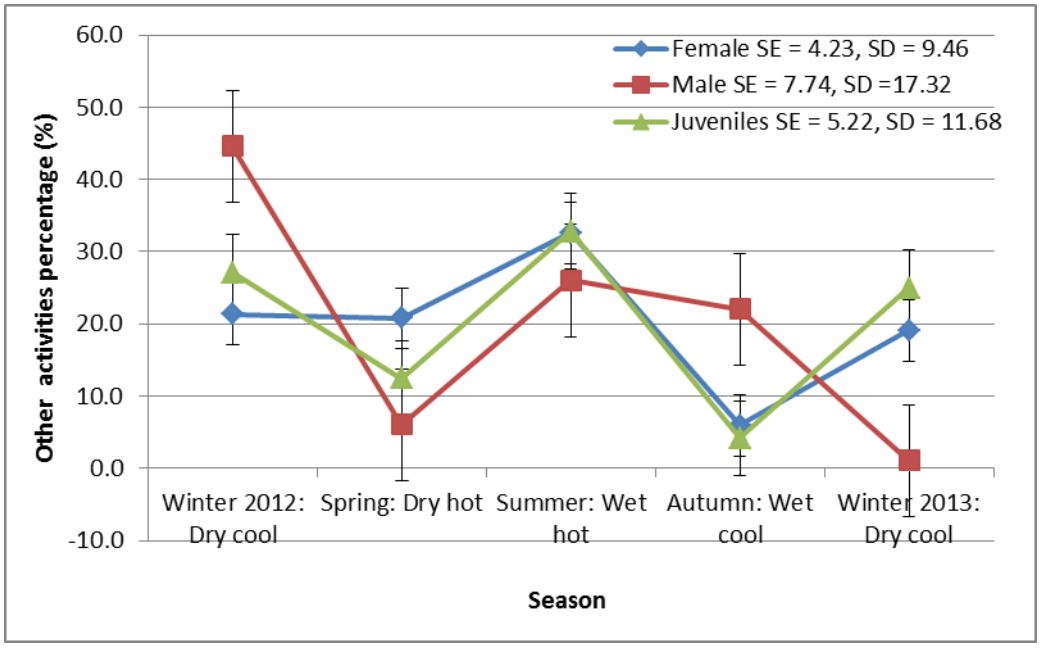


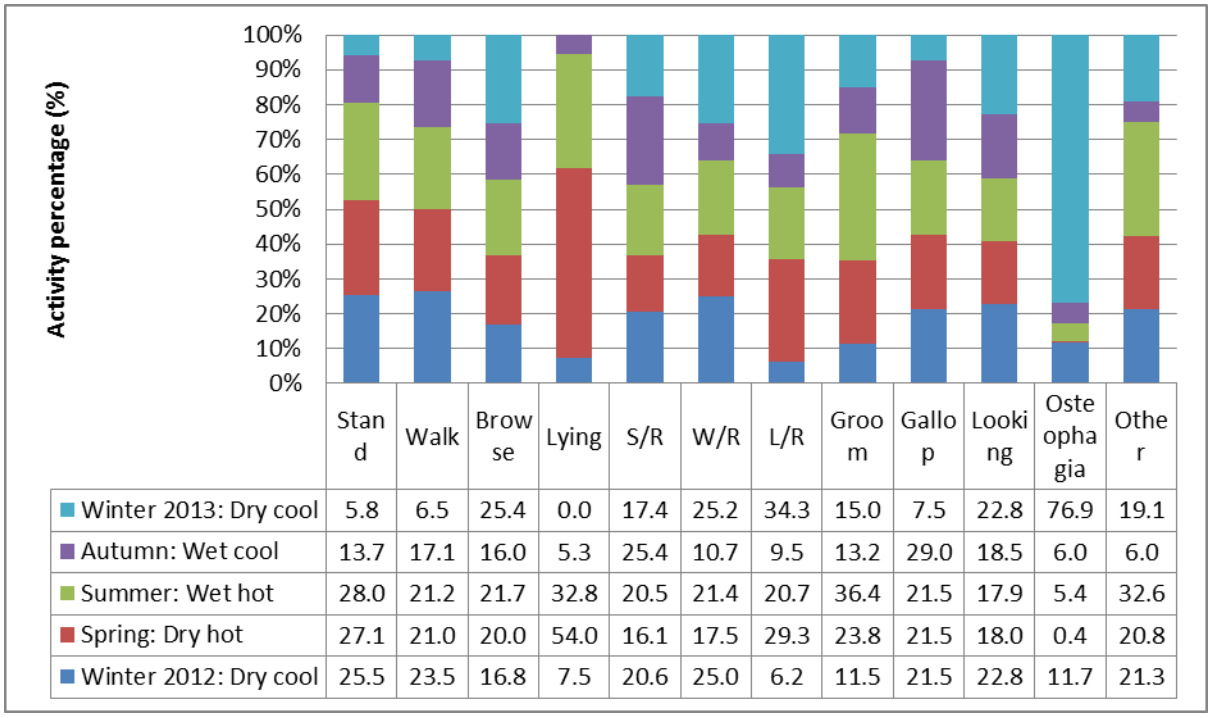
Figure 9.20 "Other" as activity during each season for male, female and juvenile giraffes

Seasonal changes are demonstrated for females (Figure 9.21), males (Figure 9.22) and juveniles (Figure 9.23) to illustrate the change of activities over seasons. Lying down by females was prominent during the spring, grooming in the summer and osteophagia in the winter 2013 season. Little osteophagia was observed during the spring (Figure 9.21).

For males, lying down was prominent during the summer and spring and grooming during the summer (Figure 9.22), Osteophagia by males was prominent during winter 2013 and

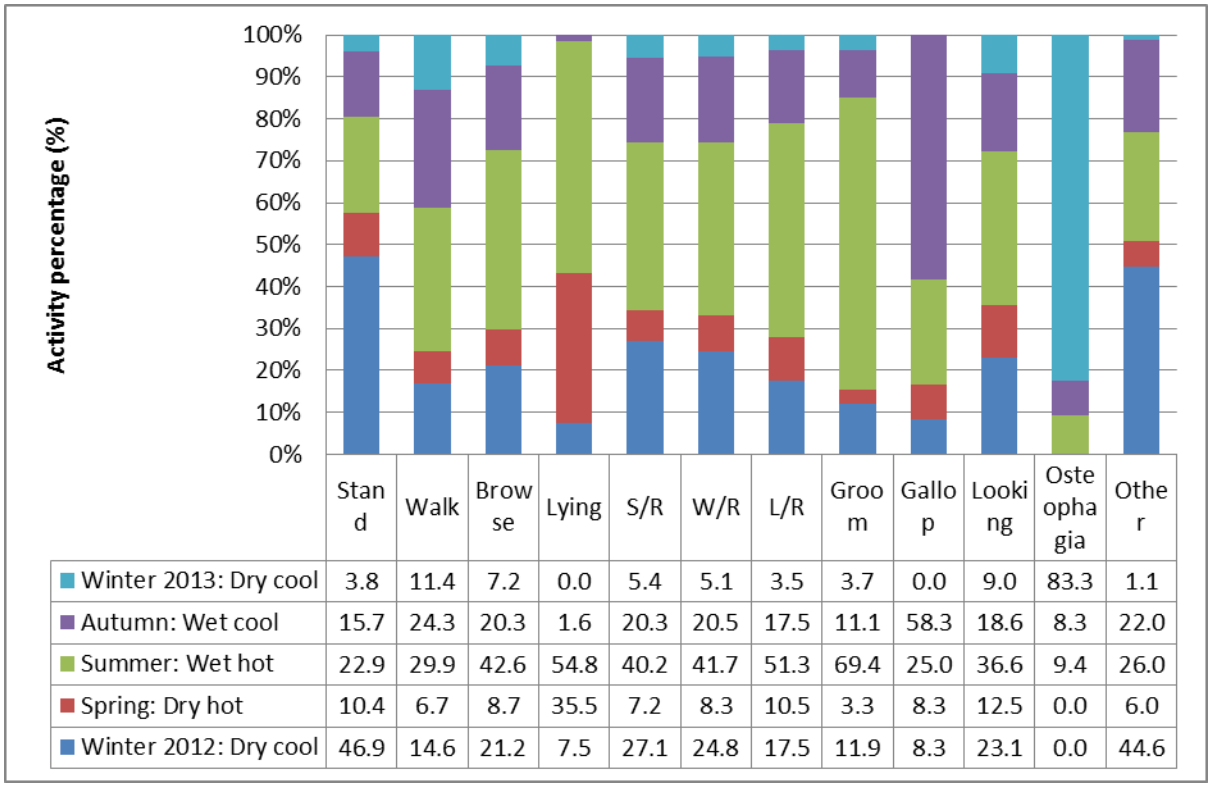
"other" activities were prominent during winter 2012 (Figure 9.22). For juveniles, lying down occurred mostly during the summer, L/R in the summer and winter 2013 seasons and osteophagia during winter 2013 (Figure 9.23).

It would appear that males, females and juveniles spent more time on osteophagia during the winter season of 2013, which could be related to insufficient rain during that year and the inability of the vegetation to provide adequate supplements. Giraffes are highly susceptible to Ca and P imbalances and a high frequency of osteophagia indicates that minerals obtained by osteophagia are important as dietary supplements Langman (1978). It has been reported by de Waal & Koekemoer (1998) that the northern part of the North West Province is lacking minerals such as Ca and P. Langman (1978) found seasonal osteophagia in the Timbavati Nature Reserve in South Africa, with a strong trend (90%) towards the cool-dry and hot-dry seasons from April to October, with only 10% of observations in the wet season (November – March). September and October had 32% of the observations and 58% between April and July (Langman, 1978).



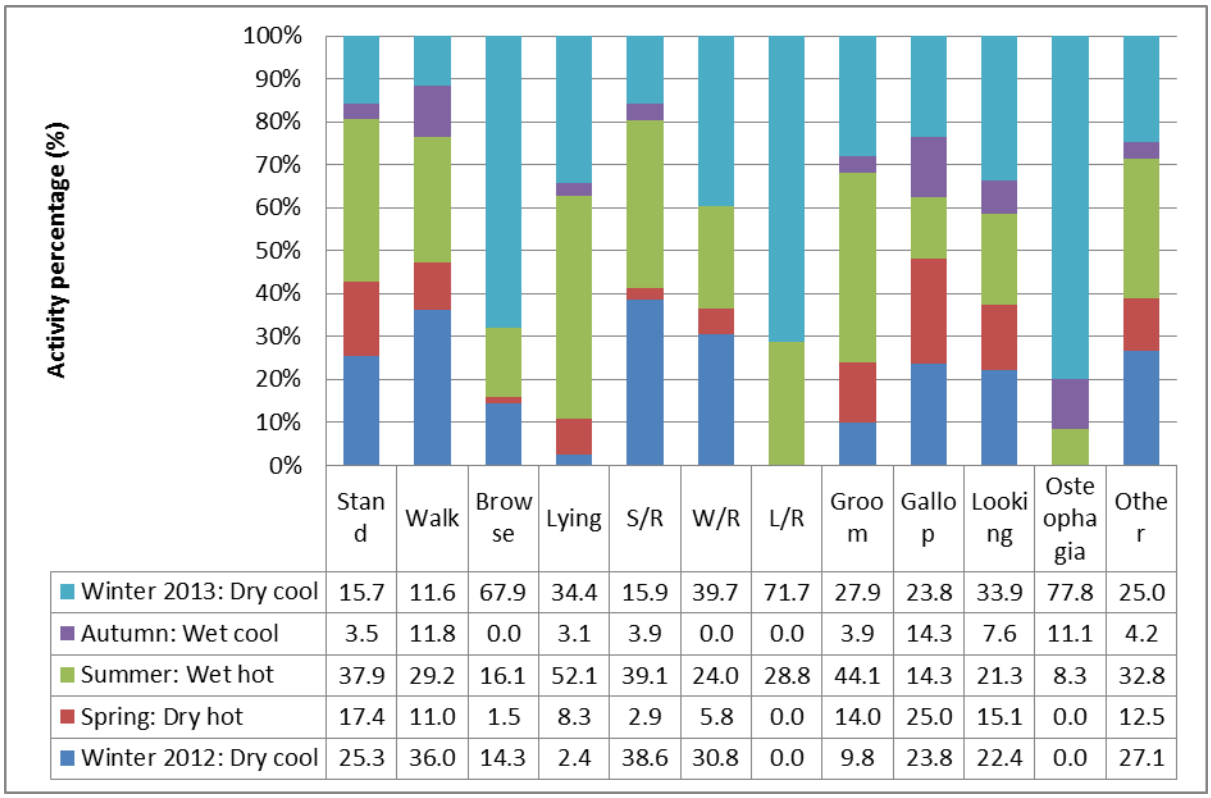
	Stand	Walk	Browse	Lying	S/R	W/R	L/R	Groom	Gallop	Looking	Osteophagia	Other
Winter 2013: Dry cool	5.8	6.5	25.4	0.0	17.4	25.2	34.3	15.0	7.5	22.8	76.9	19.1
Autumn: Wet cool	13.7	17.1	16.0	5.3	25.4	10.7	9.5	13.2	29.0	18.5	6.0	6.0
Summer: Wet hot	28.0	21.2	21.7	32.8	20.5	21.4	20.7	36.4	21.5	17.9	5.4	32.6
Spring: Dry hot	27.1	21.0	20.0	54.0	16.1	17.5	29.3	23.8	21.5	18.0	0.4	20.8
Winter 2012: Dry cool	25.5	23.5	16.8	7.5	20.6	25.0	6.2	11.5	21.5	22.8	11.7	21.3

Figure 9.21 Female giraffe activities over different seasons



	Stand	Walk	Browse	Lying	S/R	W/R	L/R	Groom	Gallop	Looking	Osteophagia	Other
Winter 2013: Dry cool	3.8	11.4	7.2	0.0	5.4	5.1	3.5	3.7	0.0	9.0	83.3	1.1
Autumn: Wet cool	15.7	24.3	20.3	1.6	20.3	20.5	17.5	11.1	58.3	18.6	8.3	22.0
Summer: Wet hot	22.9	29.9	42.6	54.8	40.2	41.7	51.3	69.4	25.0	36.6	9.4	26.0
Spring: Dry hot	10.4	6.7	8.7	35.5	7.2	8.3	10.5	3.3	8.3	12.5	0.0	6.0
Winter 2012: Dry cool	46.9	14.6	21.2	7.5	27.1	24.8	17.5	11.9	8.3	23.1	0.0	44.6

Figure 9.22 Male giraffe activities over different seasons



	Stand	Walk	Browse	Lying	S/R	W/R	L/R	Groom	Gallop	Looking	Osteophagia	Other
Winter 2013: Dry cool	15.7	11.6	67.9	34.4	15.9	39.7	71.7	27.9	23.8	33.9	77.8	25.0
Autumn: Wet cool	3.5	11.8	0.0	3.1	3.9	0.0	0.0	3.9	14.3	7.6	11.1	4.2
Summer: Wet hot	37.9	29.2	16.1	52.1	39.1	24.0	28.8	44.1	14.3	21.3	8.3	32.8
Spring: Dry hot	17.4	11.0	1.5	8.3	2.9	5.8	0.0	14.0	25.0	15.1	0.0	12.5
Winter 2012: Dry cool	25.3	36.0	14.3	2.4	38.6	30.8	0.0	9.8	23.8	22.4	0.0	27.1

Figure 9.23 Juvenile giraffe activities over different seasons

9.3.3.2. Statistical results for seasonal effects on female giraffe activities

Seasonal effects were highly significant (P<0.001) for lying down, grooming and osteophagia (Appendix J Table J.1) and significant (P<0.05) for “other” activities. The back transformed means for each activity performed by females are presented in Appendix J. Season had a significant effect on seven female activities, and time of day had a significant effect on nine of them.

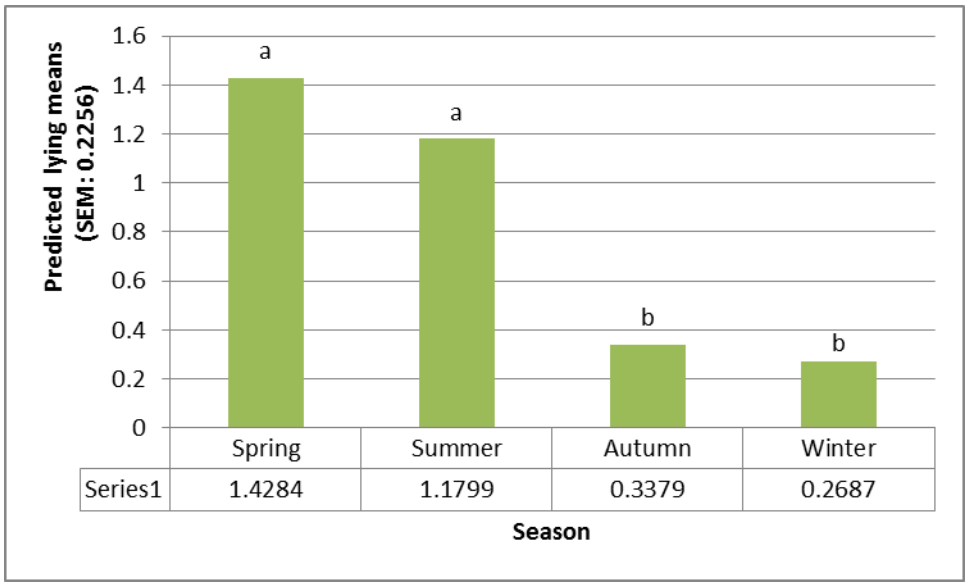


Figure 9.24 Seasonal effect on female giraffe lying down activity

Season has an effect on lying down activity of females, with spring and summer being significantly different (p<0.05) from autumn and winter (Figure 9.24) (untransformed scale). Females did not spend much time lying down during the autumn and winter, but spent more time in this activity during the summer and spring (Figure 9.24). On the transformed scale this would mean that females preferred to lie down during spring (4.2) and summer (3.3) than during autumn (1.4) and winter (1.3). The reason could either be because they avoid moving around during warmer months and try to regulate body temperature or because there is no time for lying down when in search of food during the drier months.

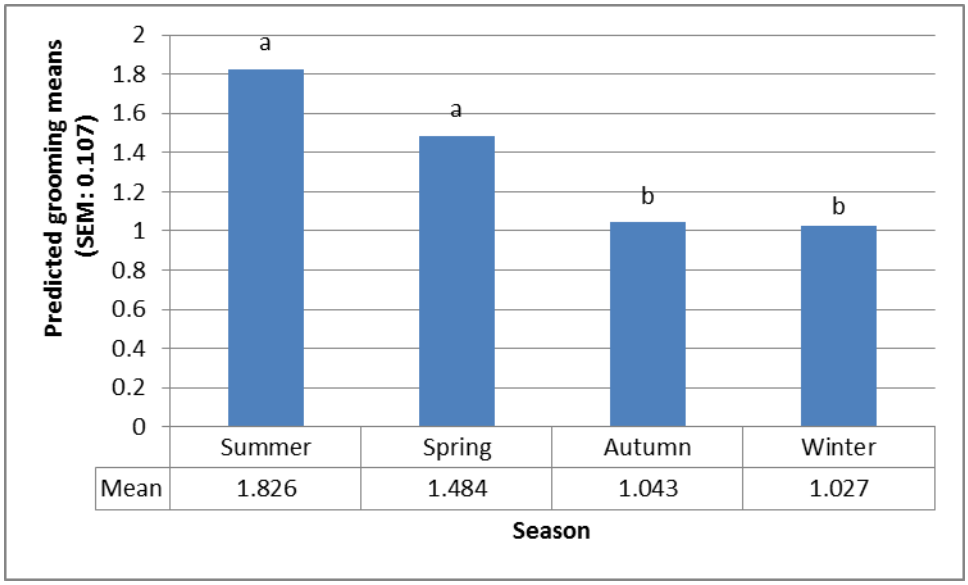


Figure 9.25 Seasonal effect on female giraffe grooming activity

Grooming did not occur during the autumn and winter seasons, but only during the summer and spring (Figure 9.25) (untransformed scale). On the transformed scale this would mean that females would prefer to groom during the spring (4.4) and summer (6.2) rather than during autumn (2.8) and winter (2.8). This may indicate either that females do not have much time for grooming when in search of food resources during autumn and winter,or because ecto-parasites such as ticks and fleas are low in numbers.

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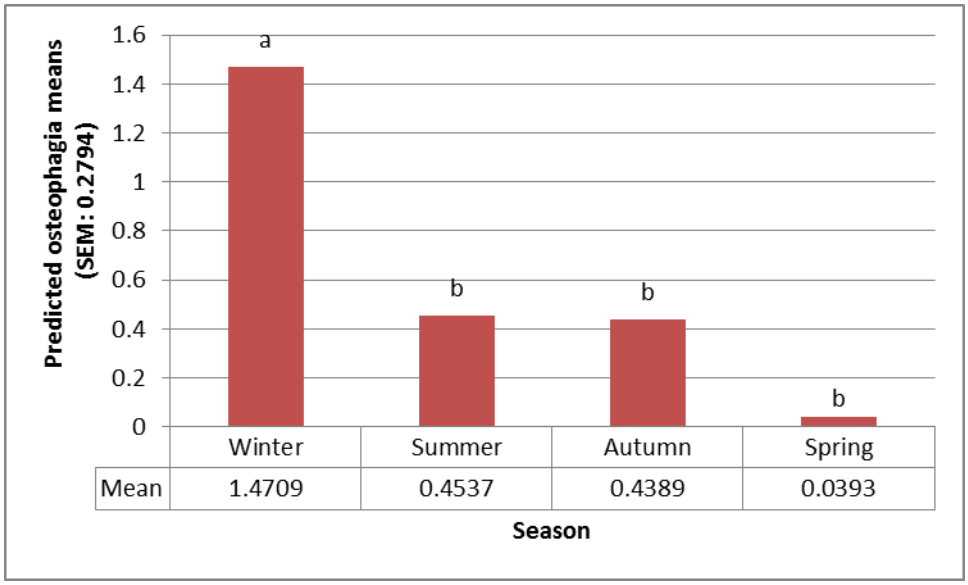

Figure 9.26 Seasonal effect on female giraffe osteophagia

Osteophagia occurred mostly in winter (Figure 9.26) and was highly significantly different from the other months (untransformed scale). On the transformed scale this would mean that females performed osteophagia during winter (4.4) rather than during summer (1.6), autumn (1.6) and spring (1.04). This further motivates that females were in need of supplementary minerals during winter when there was low availability of phosphorus and calcium in their normal diet. Pattern (1940) and Langman (1978) studied the effect on giraffe kidneys of an imbalance of Ca and P in their diet. According to Langman (1978), Blomqvist & Renberg (2007) and Bothma *et al*. (2010), osteophagia is a common feature in the feeding routine of the southern giraffe, especially during the months from April to November. Langman (1978) found that osteophagia occurs at more or less the same frequency in both adults and sub-adults.

For females, it was found that time x season interactions (p=0.052) were all significant with seasonal effects for standing (p=0.027), W/R (p=0.011), other activities (p=0.003) and looking around (Appendix J Table J.1). Standing occurred mostly in the summer (5.6) and spring (5.1) seasons compared to the autumn (2.9) and winter (3.8) (transformed scale) (Appendix J Table J.3). W/R mostly occurred in the winter (7.9) and summer (6.9) seasons compared to the autumn (4.0) and spring (5.7) (transformed scale) (Appendix J Table J.3). Other activities mostly occurred in the summer (3.2) compared to the autumn (1.4), spring (2.3) and winter (2.4) seasons (transformed scale) (Appendix J Table J.3). Looking around as an activity occurred the least during the spring afternoon (7.4) compared to winter (22.4) and autumn (20.3) midday hours.

9.3.3.3. Statistical results for the time of day effect on female giraffe activities

For female giraffes, time of day was highly significant (P<0.001) for standing, walking, lying down, S/R, W/R, osteophagia and grooming, and significant (P<0.05) for looking around and browsing (Appendix J Table J.1).

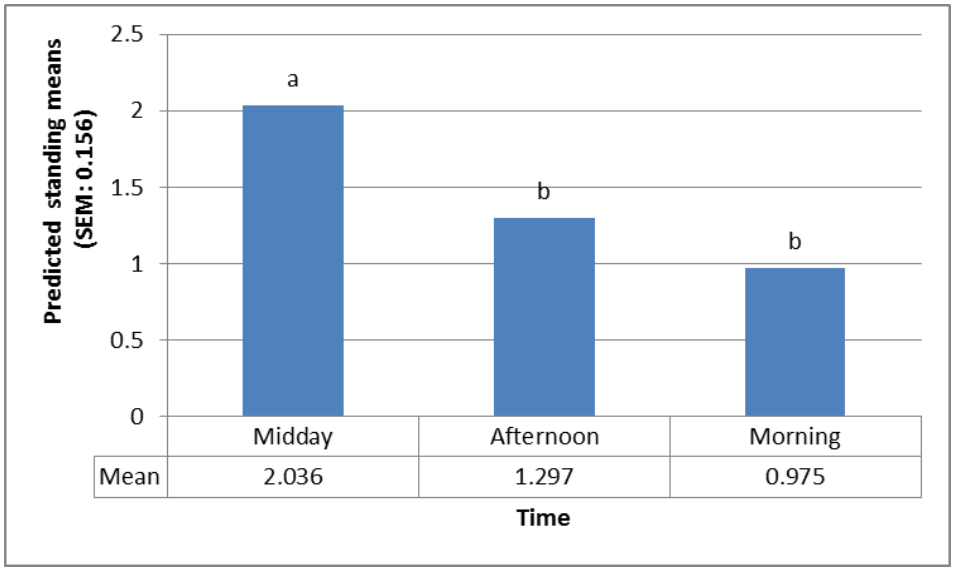

Figure 9.27 Time of day effect on female giraffe standing activity

Females spent more time standing during the midday hours than during the morning or afternoon hours (Figure 9.27) (untransformed scale). On the transformed scale, this would mean midday standing (7.7) occurred much more often than in the morning (2.7) and afternoon (3.7). This would indicate that giraffes were least active during the warmest hours of the day and this is supported by the result shown in Appendix J Table J.3 (the season x time interaction), that females spent more time standing (average 8.1 times) in the midday hours than during the morning (average 2.8 times) or afternoon hours (average 3.8 times). The least standing occurred during the autumn morning (1.5) and afternoon hours (2.4) and the highest occurrence of standing was during the summer (10.3) midday and spring (10.5) midday hours.

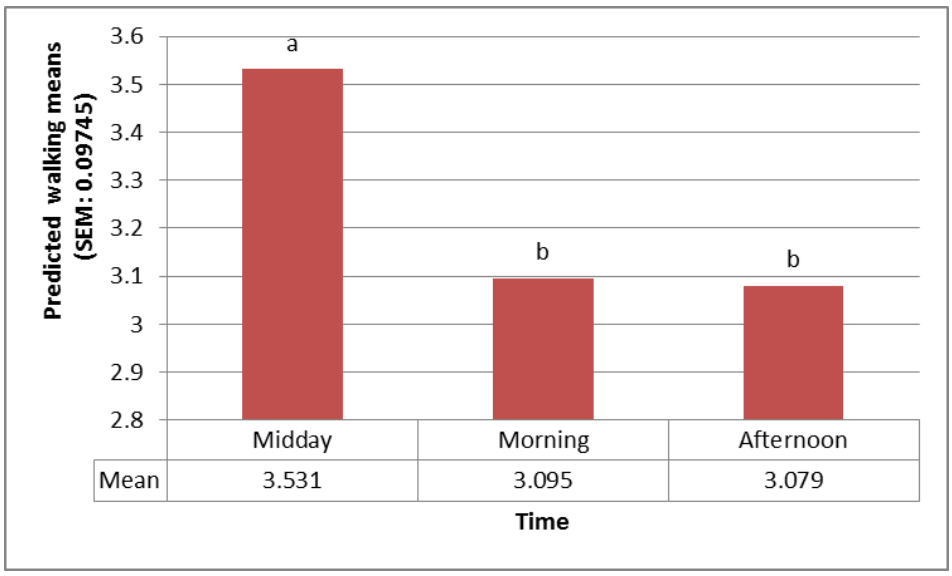

Figure 9.28 Time of day effect on female giraffe walking activity

Females also spent more time walking during the midday hours than during the morning or afternoon hours (Figure 9.28) (untransformed scale). On the transformed scale, this would mean that walking at midday (34.2) occurred more often than during morning (22.1) and afternoon (21.7). This would suggest that females spent more time on feeding during the morning and afternoon hours, and moved to new areas during the midday hours. To explain the apparent contradiction that most standing also happening during the midday hours, the time x season interaction needs to be considered. The time x season interaction indicates that walking mostly occurred during the winter midday (42.4) compared to the winter morning hours (19.3).

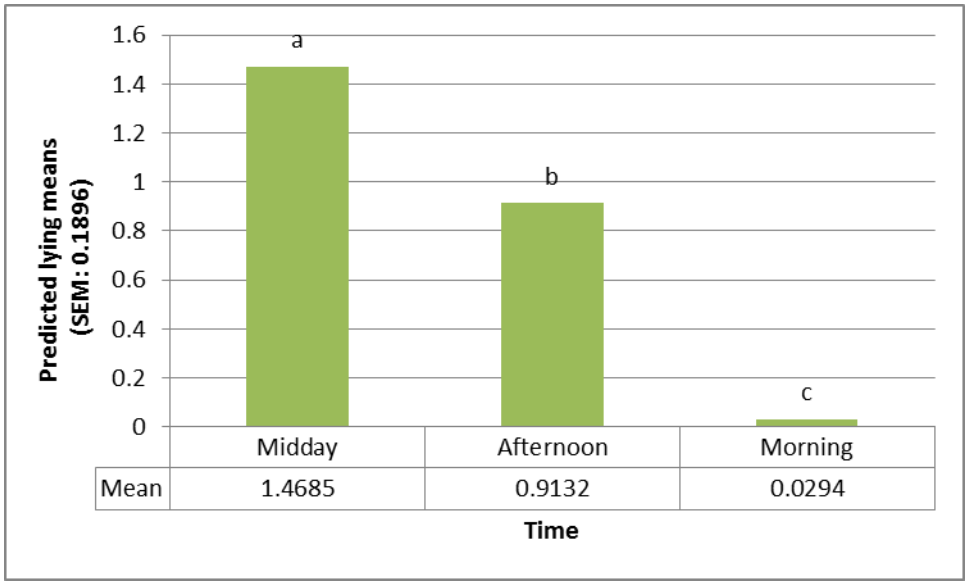

Figure 9.29 Time of day effect on female giraffe lying down activity

Females spent the least amount of time lying down during the morning hours, but lay down during midday more often than during the other hours of the day (Figure 9.29) (untransformed scale). On the transformed scale, this would mean that midday lying (4.3) occurred more often than in the morning (1.03) and afternoon (2.5). This would suggest that giraffes are least active during the warmest hours of the day and this is supported by the result shown in Appendix J Table J.3 (the season x time interaction) that females spent more time lying down (average 5.3 times) during midday than during the morning (average 1.03 times) or afternoon hours (average 3.5 times). The least lying occurred during morning hours (all seasons) and the highest occurrence of lying was during the spring (10.3) midday and spring (7.0) afternoon hours.

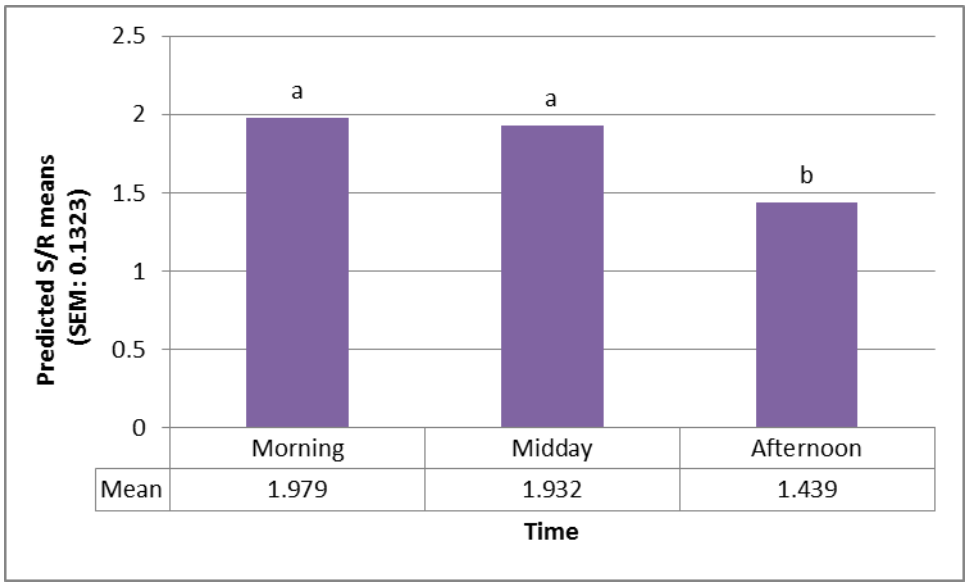

Figure 9.30 Time of day effect on female giraffe standing and ruminating activity

Female giraffes prefer to stand and ruminate during the morning or midday than during the afternoon hours (Figure 9.30) (untransformed scale). On the transformed scale, this would mean that midday S/R (29.6) occurred much more often than in the morning (12.7) and afternoon (9.04). This suggests that females are least active during the warmest hours of the day and this is supported by the result shown in Appendix J Table J.3 (the season x time interaction) that females spent more time in S/R (average 30.0 times) in the midday hours than during the morning (average 12.8 times) or afternoon hours (average 9.4 times).

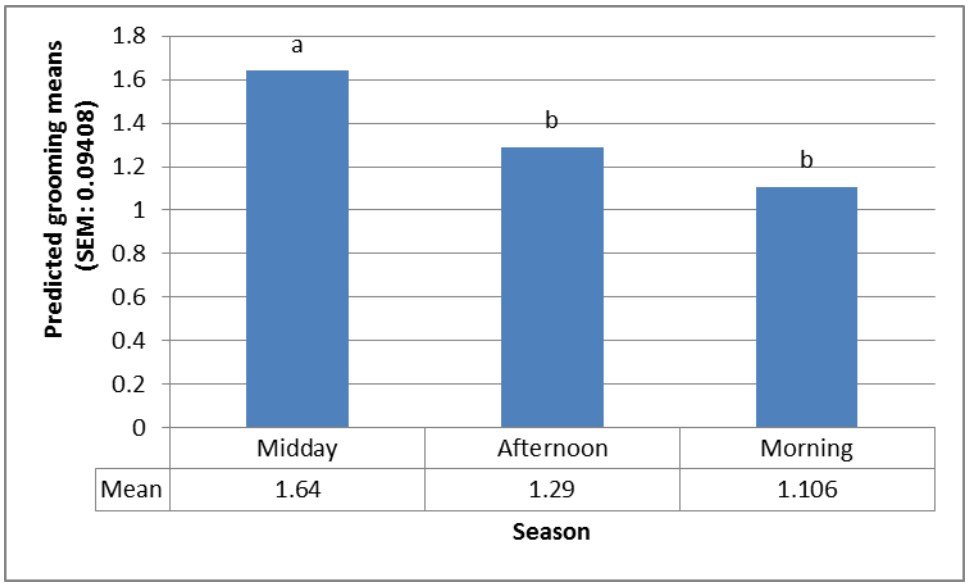

Figure 9.31 Time of day effect on female giraffe grooming activity

Grooming occurred more during the midday hours than during the afternoon or morning hours (Figure 8.31) (untransformed scale). On the transformed scale, this would mean that midday grooming (5.2) occurred more often than in the morning (3.0) and afternoon (3.6). This suggests that grooming is synchronised with midday standing, lying and S/R.

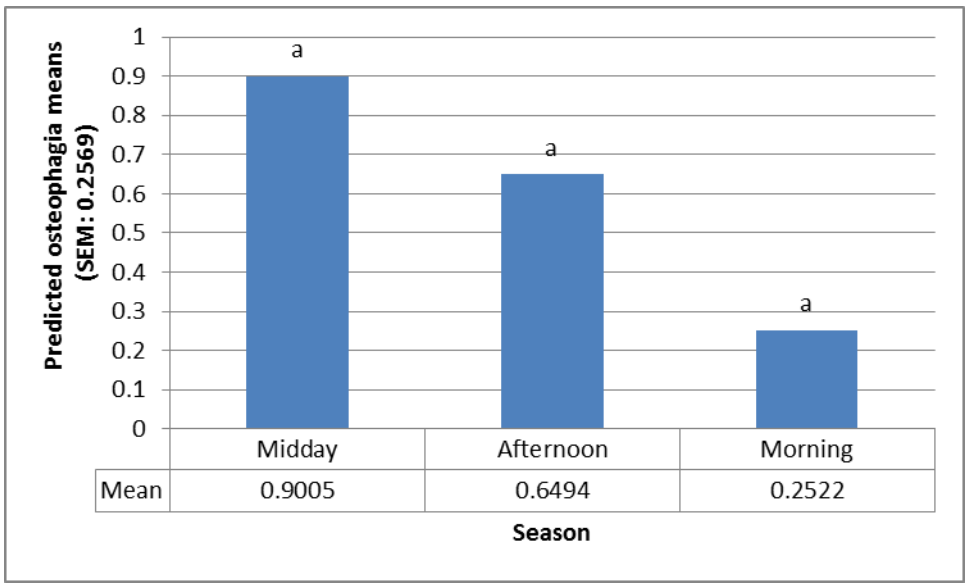

Figure 9.32 Time of day effect on female giraffe osteophagia

Figure 9.32 shows that giraffes will chew on bones whenever they can during the day, but most observations occurred during midday, which was significantly different from other hours of the day (untransformed scale). On the transformed scale, this would mean that midday osteophagia (2.5) occurred more often than in the morning (1.3) and afternoon (1.9). And midday osteophagia in winter (11.0) had by far the highest number of occurrences.

9.3.3.4. Statistical results for seasonal effects on male giraffe activities

Seasonal effects on male activities were highly significant (P<0.001) for walking, lying down, S/R and grooming, but also significant (P<0.05) for looking around, osteophagia and other activities (Appendix J Table J.4). Appendix J Table J.5 demonstrates the back transformed means for each activity performed by male giraffes.

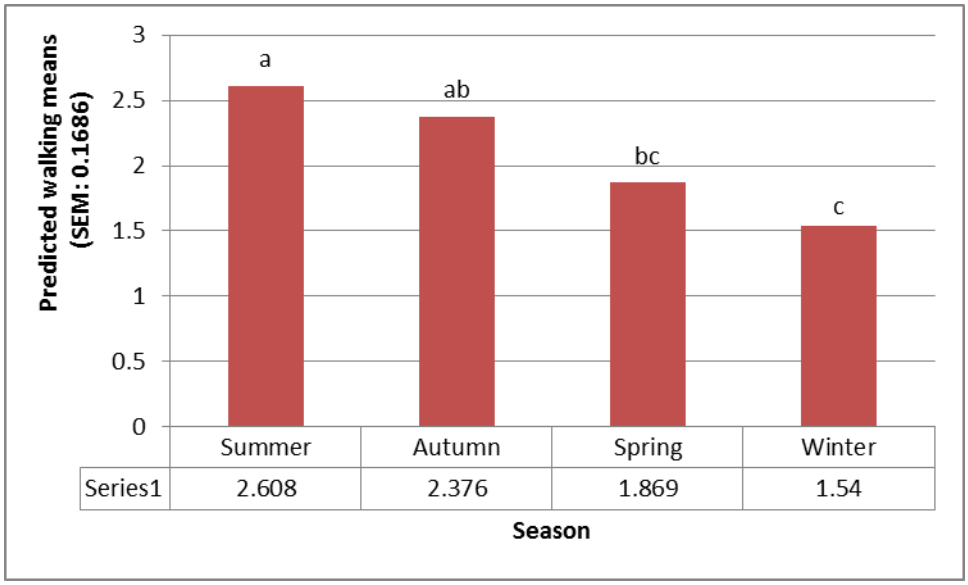

Figure 9.33 Seasonal effects on male giraffe walking activity

Male giraffes spent the most time walking during the summer months and the least in the winter (Figure 9.33) (untransformed scale). On the transformed scale this would mean that males would rather walk around during the summer (13.6) and autumn (10.8) than during spring (6.5) and winter (4.7). The reason may be because they are looking for a female in oestrus or because there is open potable water during and after the rainy season, allowing them to move longer distances in search of female herds. Lack of water may be a limiting factor during winter and early spring seasons.

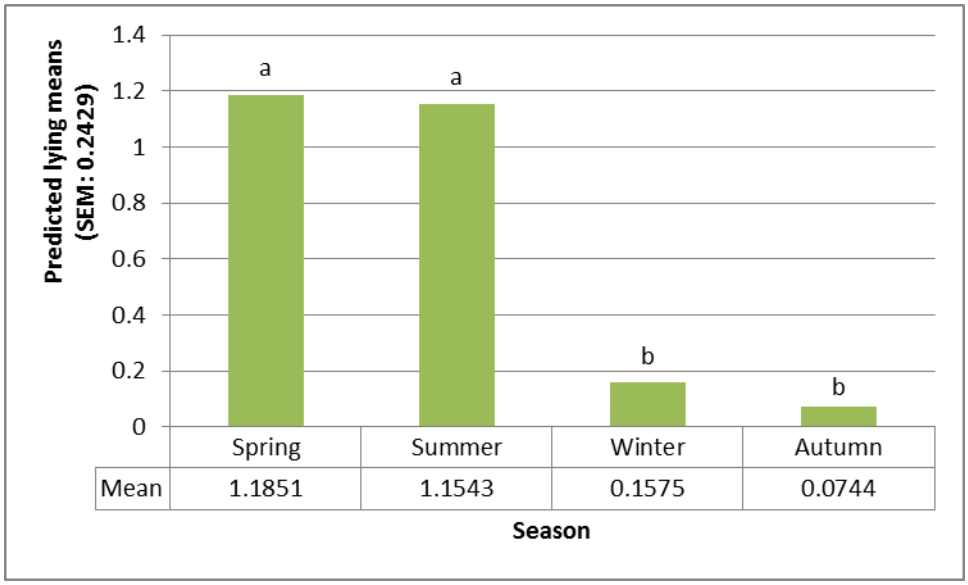

Figure 9.34 Seasonal effects on male giraffe lying down activity

The season also played a significant role in the frequency of lying down by males, as they were often lying down during summer and spring, but very little during winter and autumn months (Figure 9.34) (untransformed scale). On the transformed scale this would mean that males preferred to lie down during the summer (3.2) and spring (3.3) than during autumn (1.1) and winter (1.2). The reason may be because they avoid moving around during warmer months and try to regulate their body temperature or because there is no time for lying down when in search of food during the drier months. This is the same as was found for females.

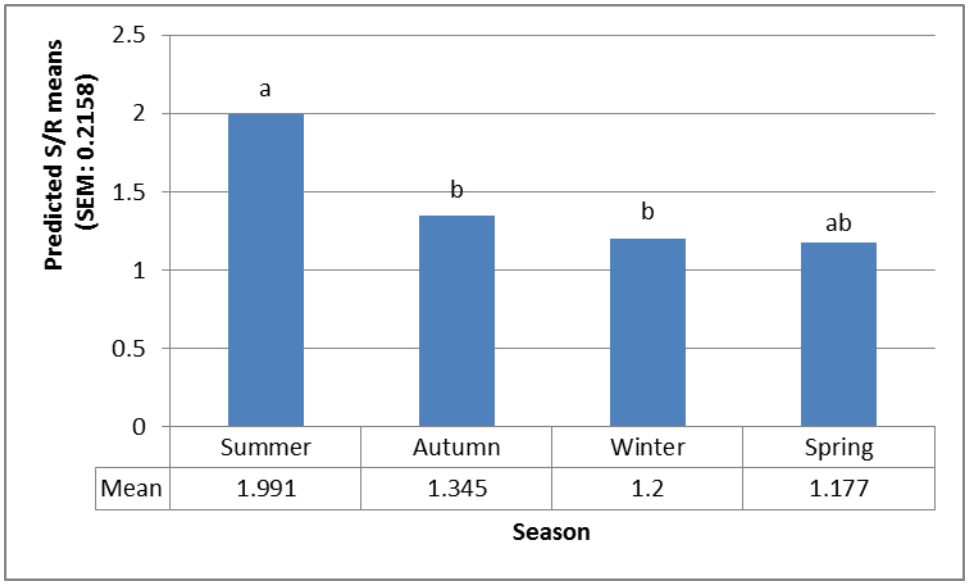

Figure 9.35 Seasonal effects on male giraffe standing and ruminating activity

Males also spent more time standing and ruminating in the summer (Figure 9.35) (untransformed scale). On the transformed scale this would mean that males would rather S/R during the summer (7.3) than during autumn (3.8) and winter (3.3). Thermoregulation may possibly be the reason why males spent more time on S/R during the warmer months than during the other months.

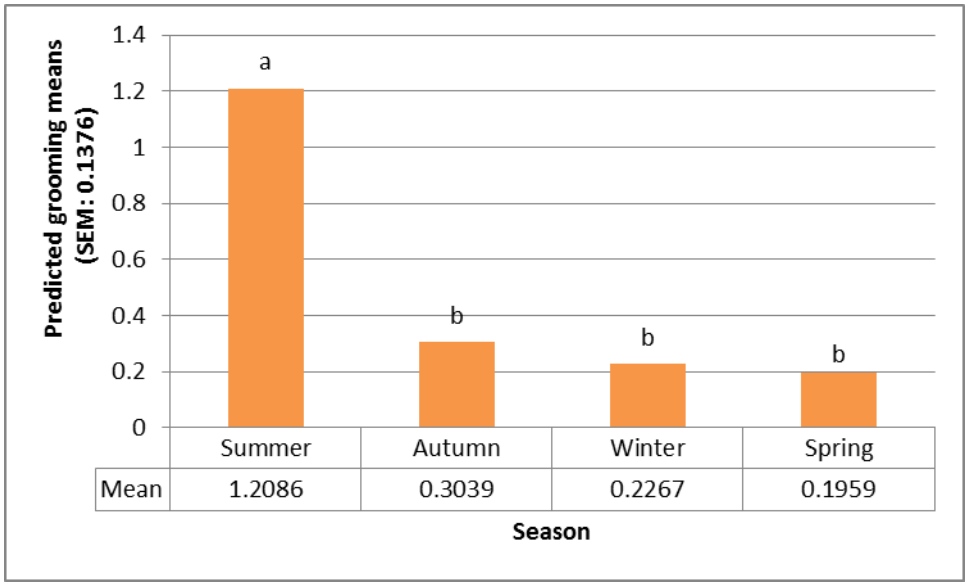

Figure 9.36 Seasonal effects on male giraffe grooming activity

Grooming was influenced by season and the most grooming occurred during the summer (Figure 9.36) (untransformed scale). On the transformed scale this would mean that males would rather groom during the summer (3.3) than during autumn (1.4), winter (1.3) and spring (1.2), which might indicate that ecto-parasites such as fleas and ticks influenced male behaviour, but also perhaps exposing “play” behaviour towards females to get noticed?

Looking around mostly occurred during the summer (6.4) and spring (4.3) rather than during winter (2.9) and autumn (3.7). Looking around would be closely related to S/R. Standing and looking are most frequent in the same season males are walking in search of females.

9.3.3.5. Statistical results for the time of day effects on male giraffe activities

For males, time of day was highly significant (P<0.001) for standing, lying down, S/R, and grooming, but also significant for walking (p=0.031), osteophagia (p=0.013) and time x season interaction for “other” activities (p=0.002) (Appendix J Table J.4).

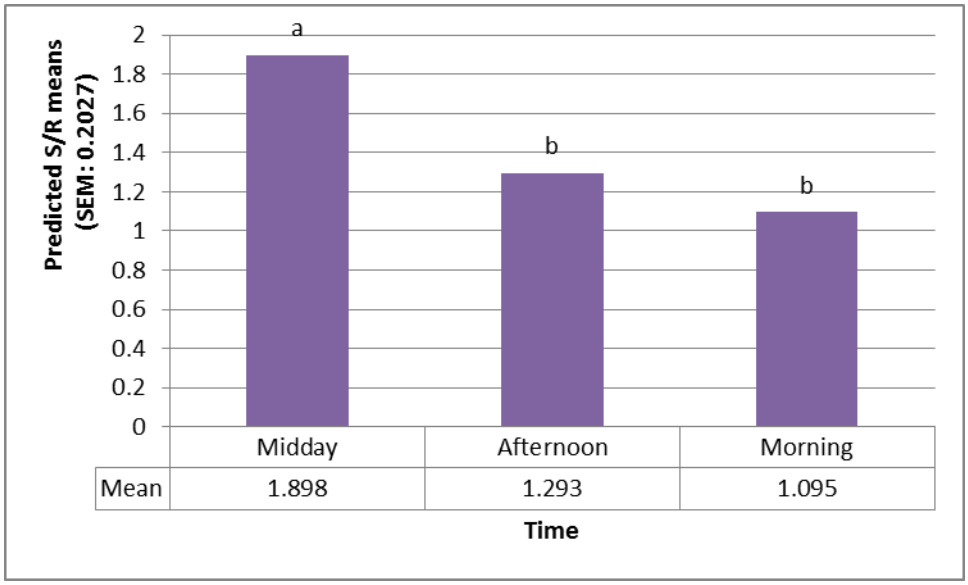

Figure 9.37 Time of day effect on male giraffe standing & ruminating activity

Figure 9.37 demonstrates that males preferred to stand and ruminate during the midday hours (untransformed scale). On the transformed scale this would mean that males would rather S/R during the midday (6.7) than during morning (3.0) and afternoon (3.6).

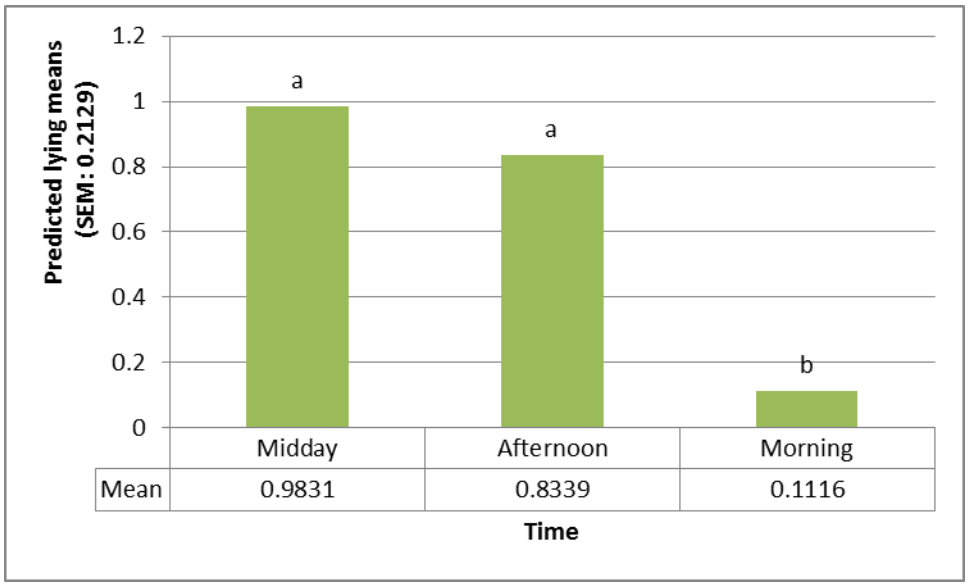

Figure 9.38 Time of day effect on male giraffe lying down activity

Males spent the least amount of time lying down in the morning hours, the same as females, but did not show much difference between midday and afternoon lying (Figure 9.38)

(untransformed scale). On the transformed scale this would mean that males would rather lie down during the midday (2.7) and afternoon (2.3) than during the morning (1.1) hours.

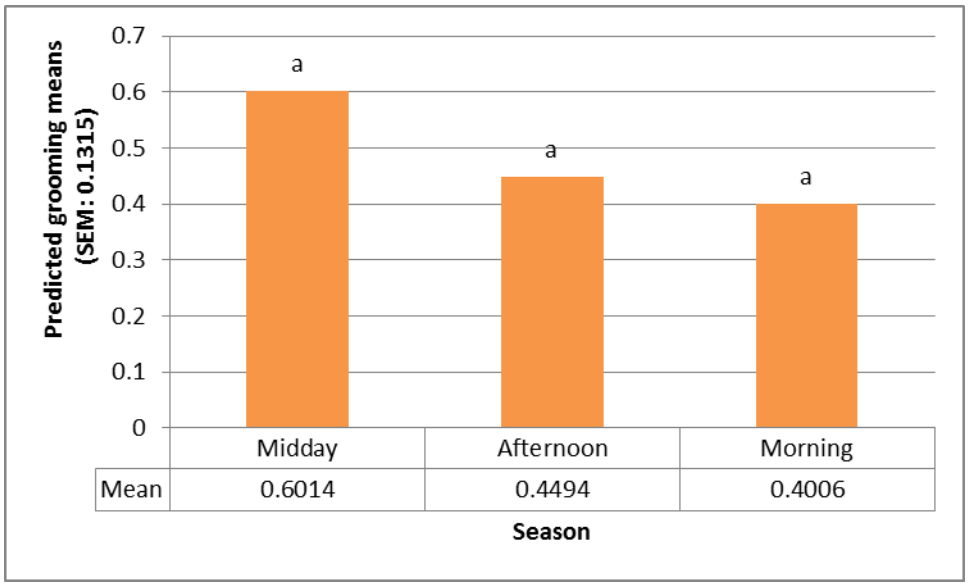

Figure 9.39 Time of day effect on male giraffe grooming activity

Male grooming was recorded mostly during the midday, but they also groomed during other hours of the day (Figure 9.39) (untransformed scale). On the transformed scale this would mean that males would rather groom during the midday (1.8) and afternoon (1.6) than during the morning (1.5) hours.

On the transformed scale male walking mostly occurred during the midday (11.6) rather than the afternoon (7.8) or morning (6.0) hours. Other activities for males were highest during the summer morning hours (6.1), and least during summer afternoons (1.7), but the opposite during autumn, when the highest occurrence of other activities was in the afternoon (5.3) and least in the morning (1.4) (Appendix J Table J.5).

9.3.3.6. Statistical results for seasonal effects on juvenile giraffe activities

For juvenile giraffes seasonal effects were highly significant ($P<0.001$) for lying down, S/R, L/R and grooming and significant ($P<0.05$) for standing ($p=0.002$), walking ($p=0.005$), browsing ($p=0.002$), W/R ($p=0.014$), looking around ($p=0.078$) and for other activities ($p=0.034$) (Appendix J Table J.6). Time interaction with season did not show any significance for any of the activities of juveniles. Appendix J Table J.8 shows the back transformed means for each activity performed by juveniles.

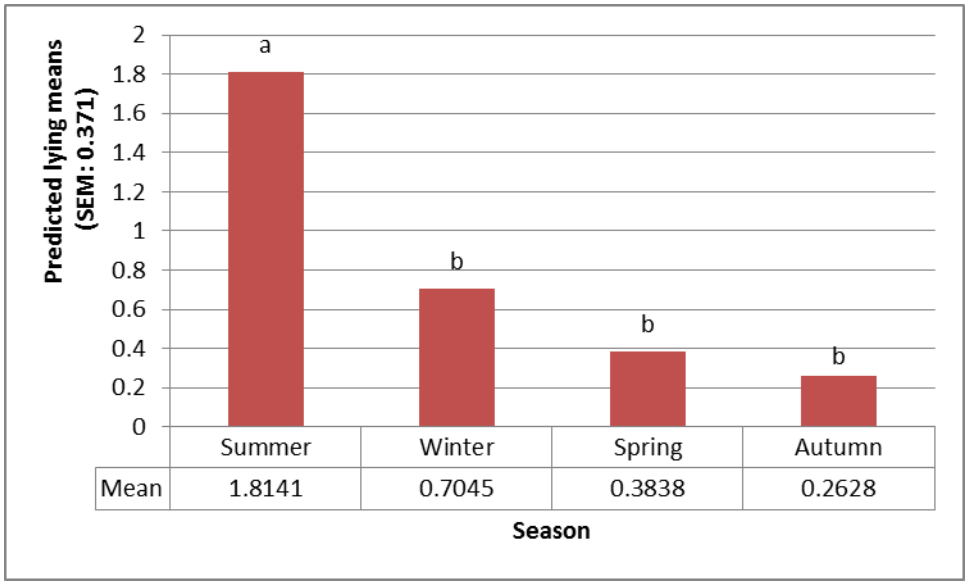

Figure 9.40 Seasonal effect on juvenile giraffe lying down activity

Juveniles showed a preference for lying down during the summer months compared to the other months (Figure 9.40) (untransformed scale). On the transformed scale this would mean that juveniles would rather lie down during the summer (6.1) than during autumn (1.3), winter (2.0) and spring (1.4). This suggests that juveniles are less active and prefer to lie down during the warmer months.

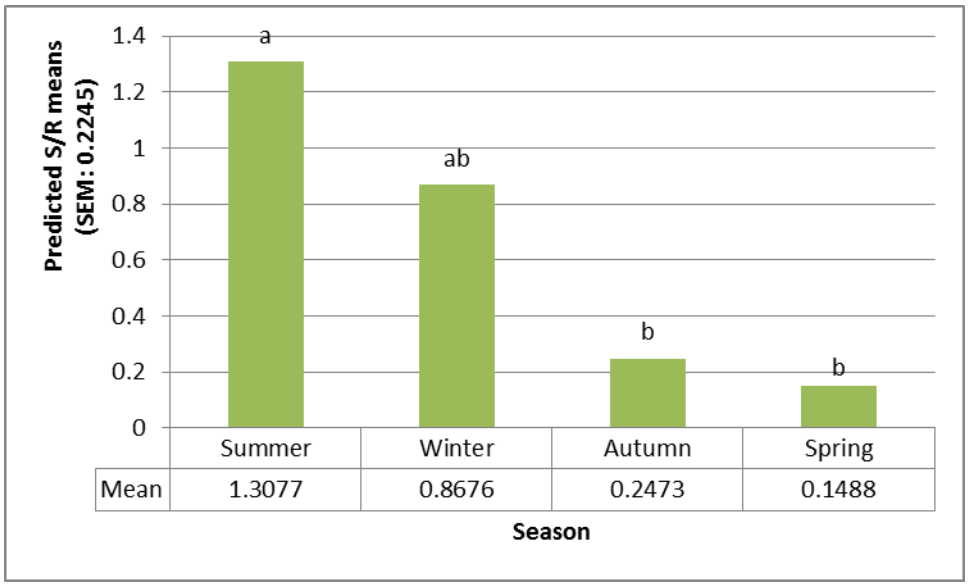

Figure 9.41 Seasonal effect on juvenile giraffe standing & ruminating activity

Juveniles showed a strong preference for standing and ruminating,during the summer season (Figure 9.41) (untransformed scale). On the transformed scale this would mean that

juveniles would rather S/R during the summer (3.7) than during autumn (1.3), winter (2.4) and spring (1.2).

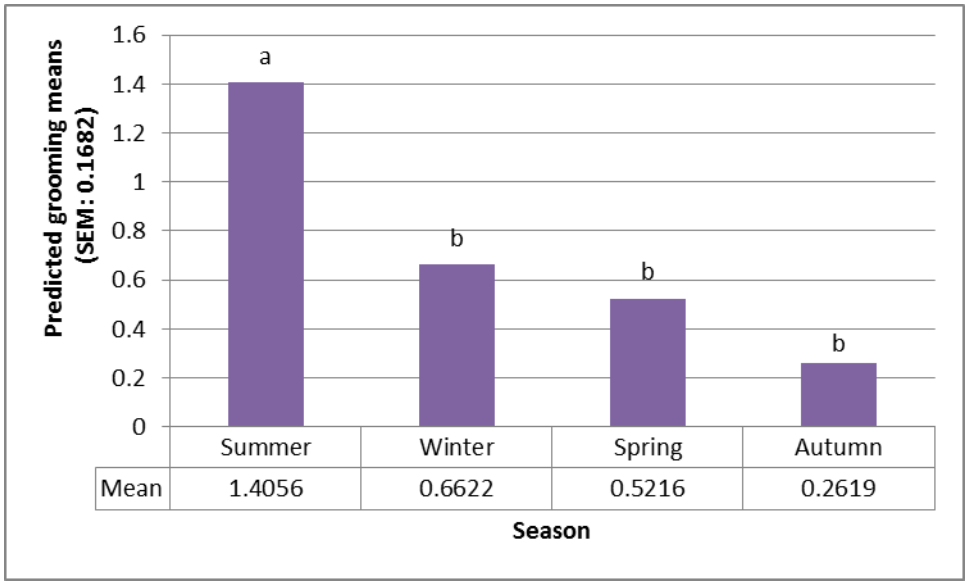

Figure 9.42 Seasonal effect on juvenile giraffe grooming activity

Figure 9.42 shows that juvenile grooming was influenced by seasons. Most grooming took place during summer, similar to males (untransformed scale). On the transformed scale this would mean that juveniles would rather groom during the summer (4.1) than during autumn (1.0), winter (1.4) and spring (1.0).

9.3.3.7. Statistical results for time of day *effects on juvenile giraffe activities*

For juveniles, time of day was highly significant (P<0.001) for lying and ruminating (Appendix J Table J.6), and also significant (P<0.05) for standing and ruminating (p=0.006).

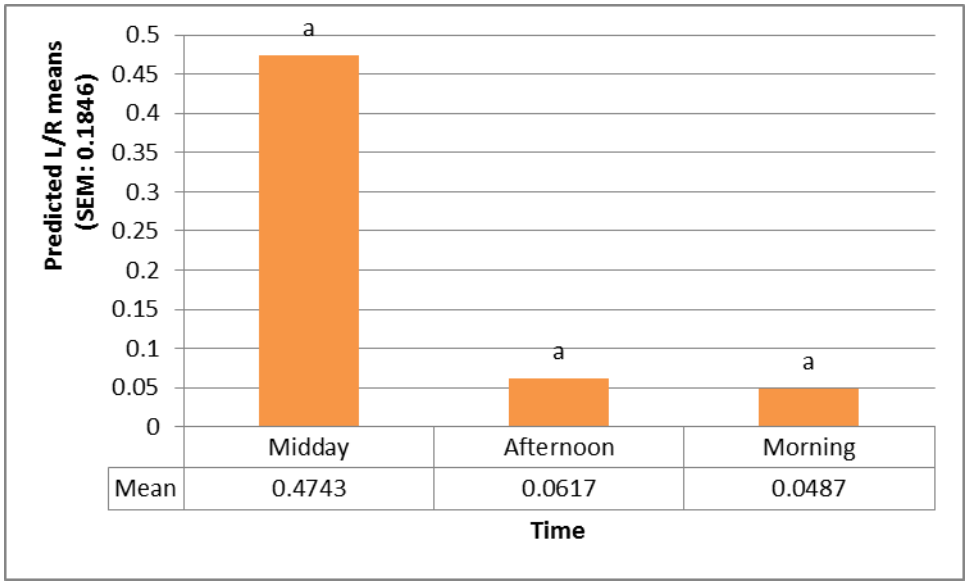

Figure 9.43 Time of day effect on juvenile giraffe lying down & ruminating activity

Lying down while ruminating occurred mostly during the midday hours and seldom during the afternoon and morning (Figure 9.43) (untransformed scale). On the transformed scale this would mean that juveniles would rather lie and ruminate during the midday (1.6) rather than during the afternoon (1.1) and morning (1.1) hours.

Standing and ruminating occurred mostly during the midday hours (2.4) rather than the morning (1.7) or afternoon hours (1.7). All activities for juveniles were insignificant (P>0.001) for time x season interaction effects.

9.3.3.8. Statistical results with ordination similarities between male, female and juvenile giraffe activities

Ordination of the activities (CANOCO 4, TerBraak & Šmilauer, 1998) demonstrates similarities between male, female and juvenile activities, but also differences between seasons (Figures 9.44 – 9.51).

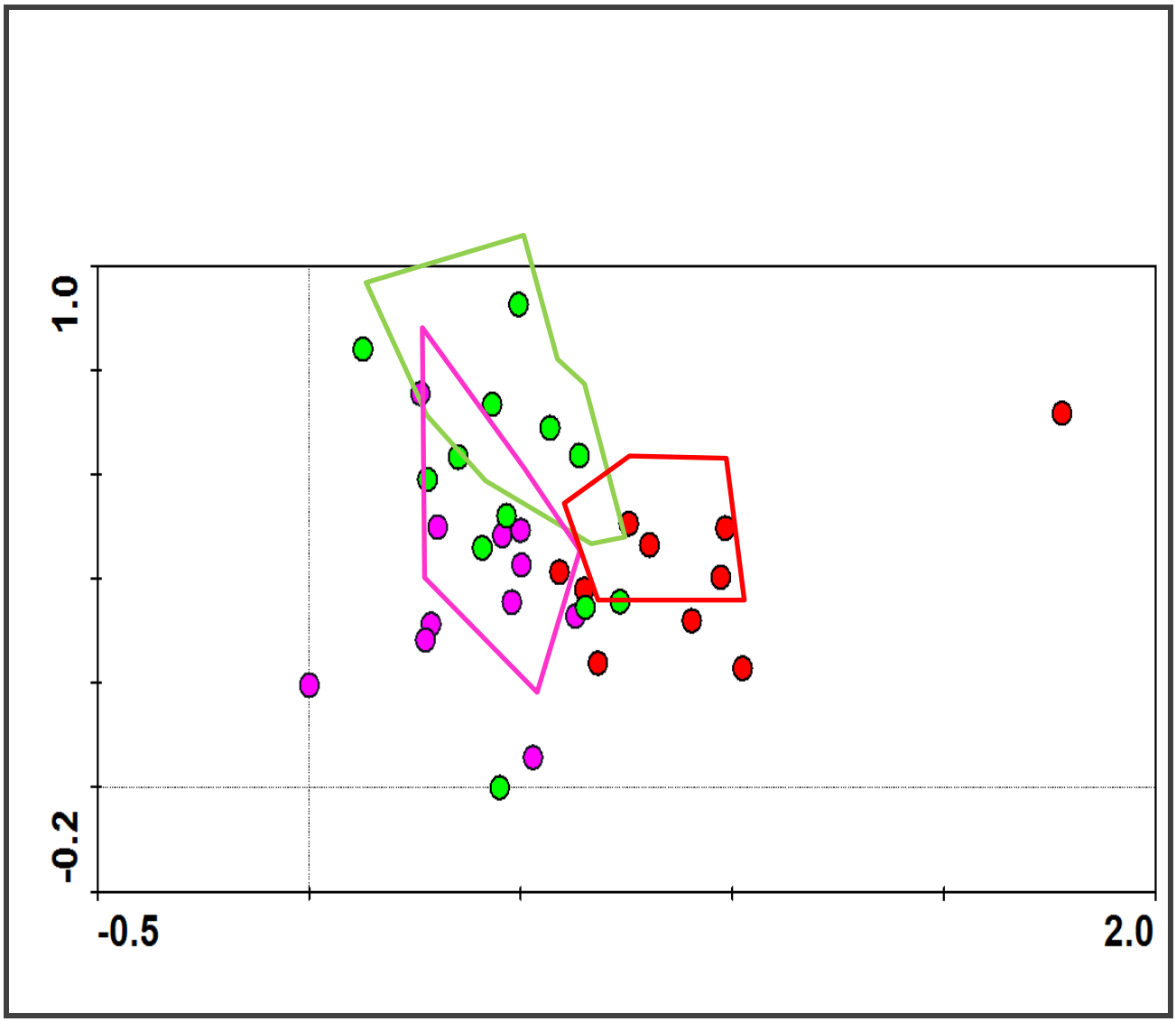

Figure 9.44 Winter (2012) season with all activities ordinated (pink = adult female, red = adult male, green = juvenile)

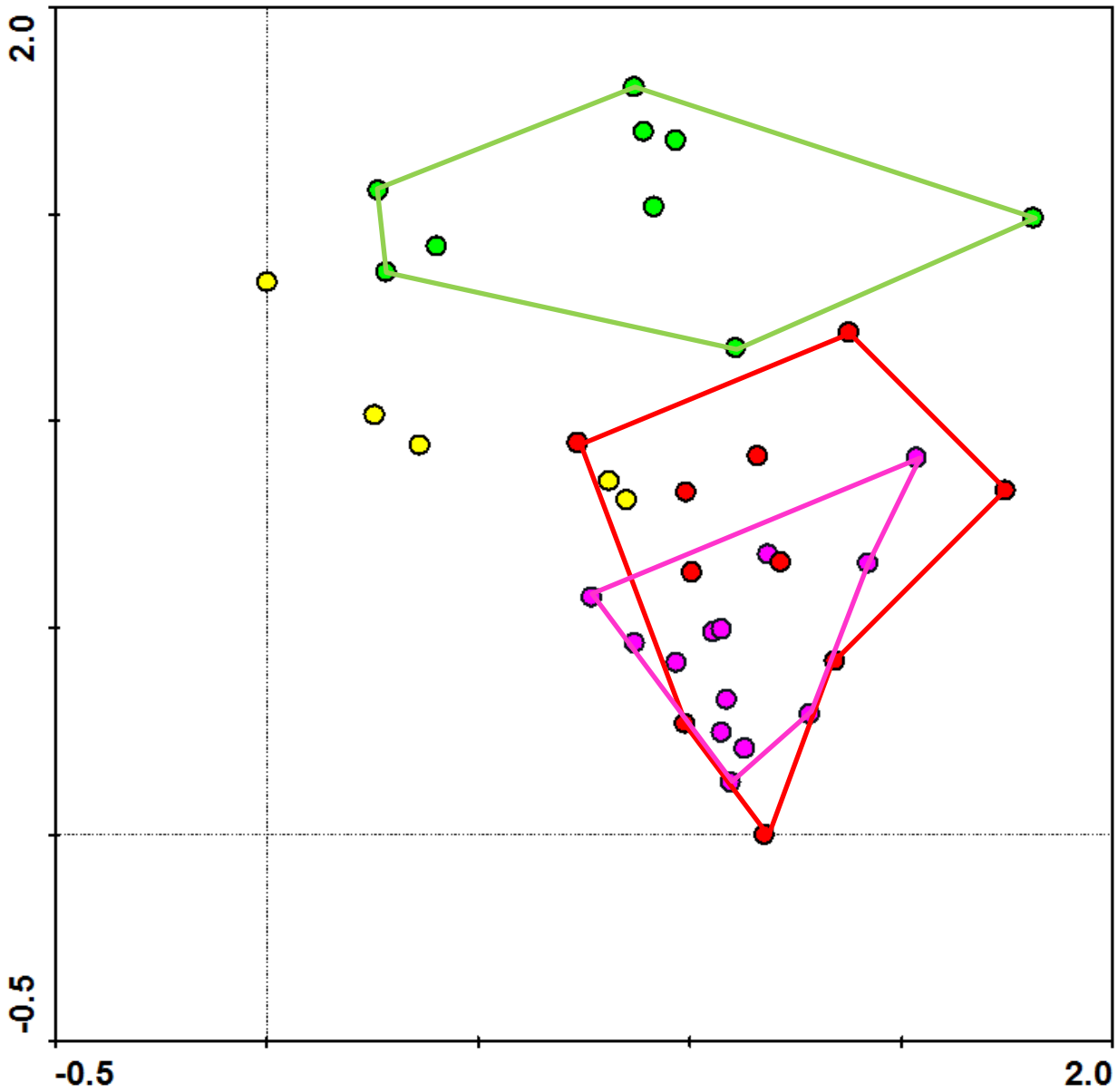

Figure 9.45 Spring season with all activities ordinated (pink = adult female, red = adult male, yellow = sub-adult male, green = juvenile)

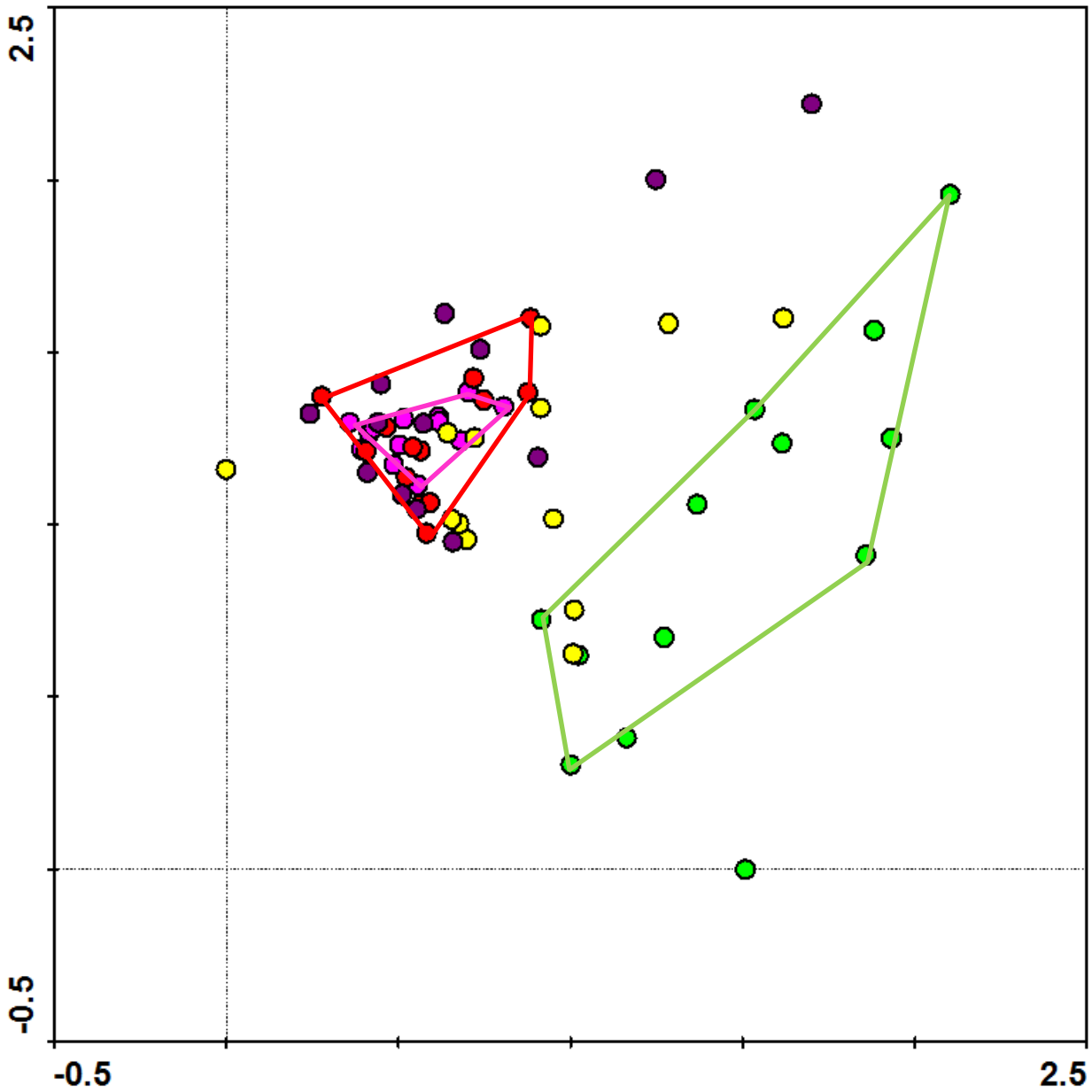

Figure 9.46 Summer season with all activities ordinated (pink = adult female, red = adult male, yellow = sub-adult male, purple = sub-adult female, green = juvenile)

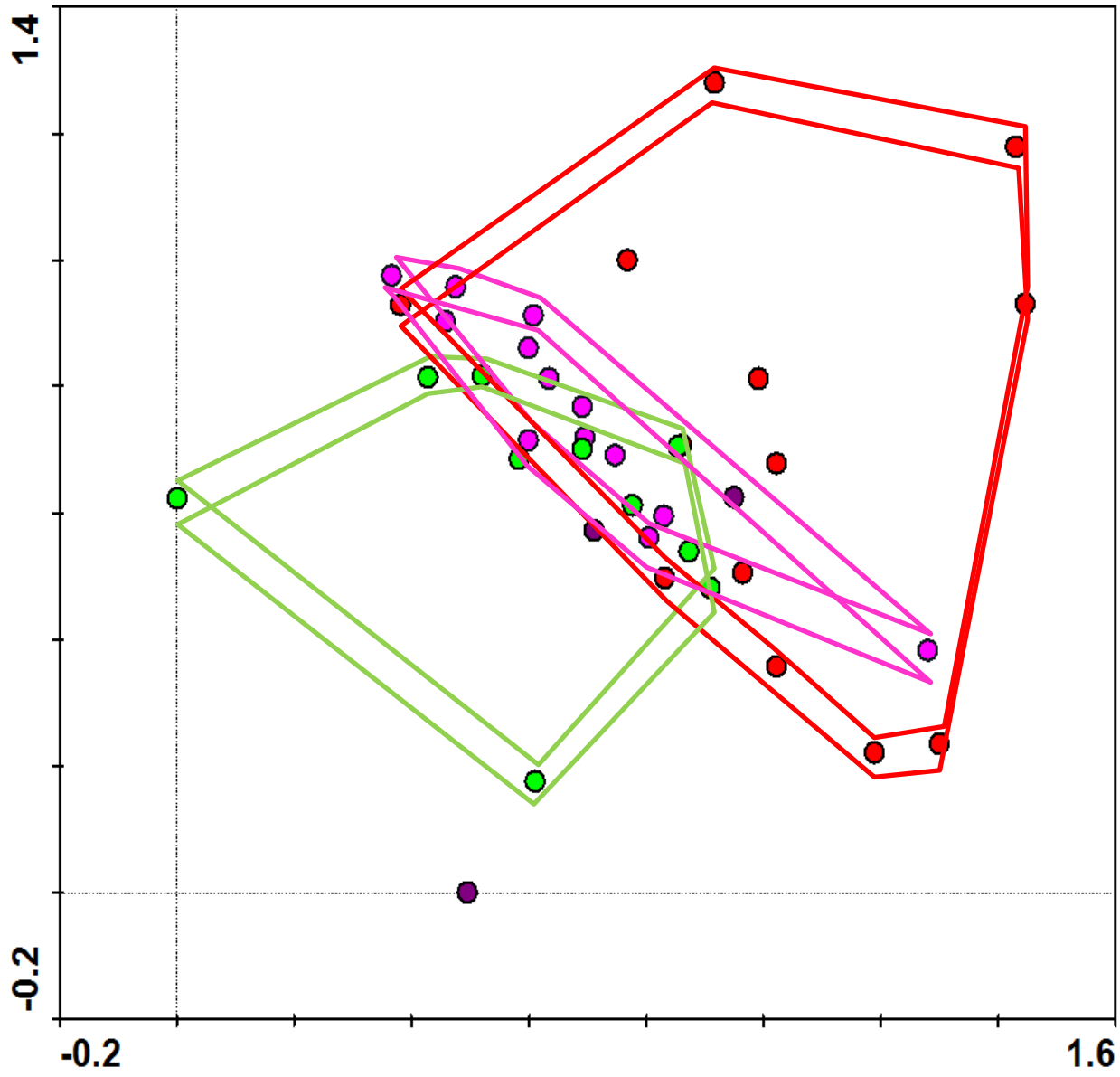

Figure 9.47 Autumn season with all activities ordinated (pink = adult female, red = adult male, purple = sub-adult female, green = juvenile)

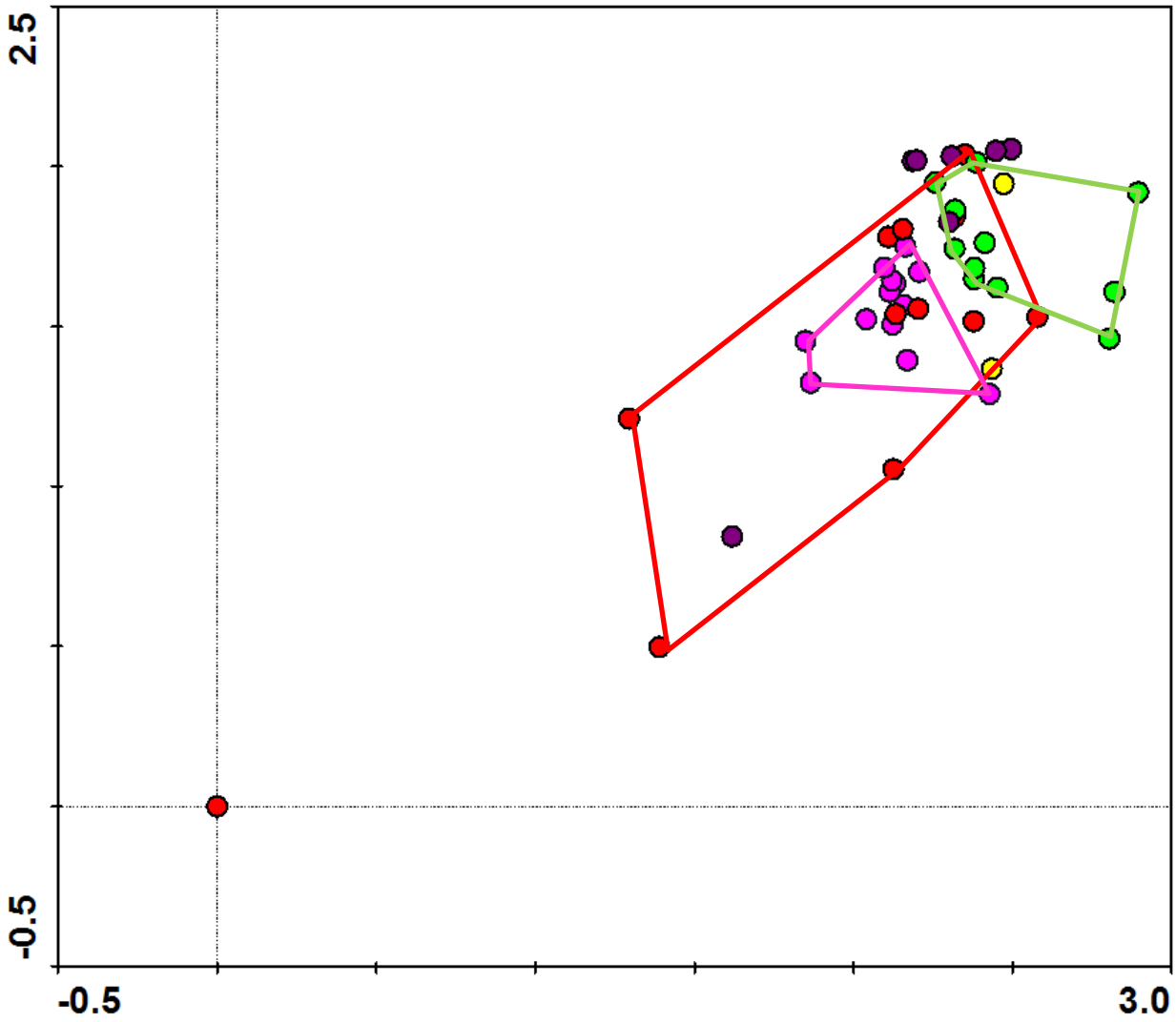

Figure 9.48 Winter (2013) season with all activities ordinated (pink = adult female, red = adult male, yellow = sub-adult male, purple = sub-adult female, green = juvenile)

Figure 9.44 shows that there is little similarity between adult male and female activities, but that there were similarities between female and juvenile activities during winter 2012. In spring, juvenile activities differed significantly from adults, but adult activities showed some similarities (Statistical results for time of *day* effects on juvenile giraffe activities). The same can be seen in summer (Figure 9.45), with adult activities being very similar to each other and juvenile activities completely different. In autumn, there were some similarities between the activities of both adults and juveniles (**Statistical** results with ordination similarities between male, female and juvenile giraffe activities

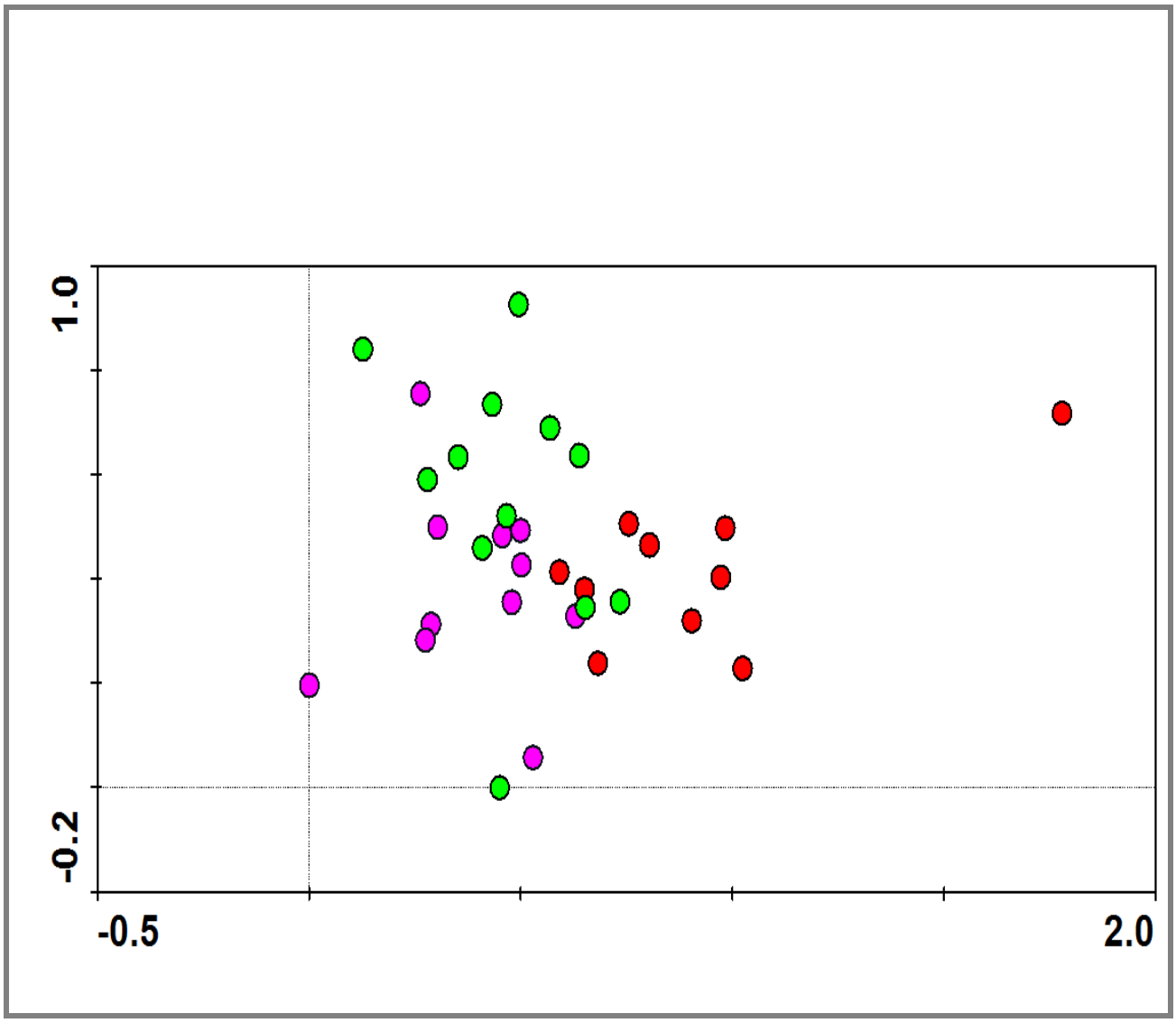

Figure 9.44). During the winter 2013 season, adult female activities were similar to adult males, but differed from juveniles, whereas male activities and juveniles showed some similarities (Figure 9.45).

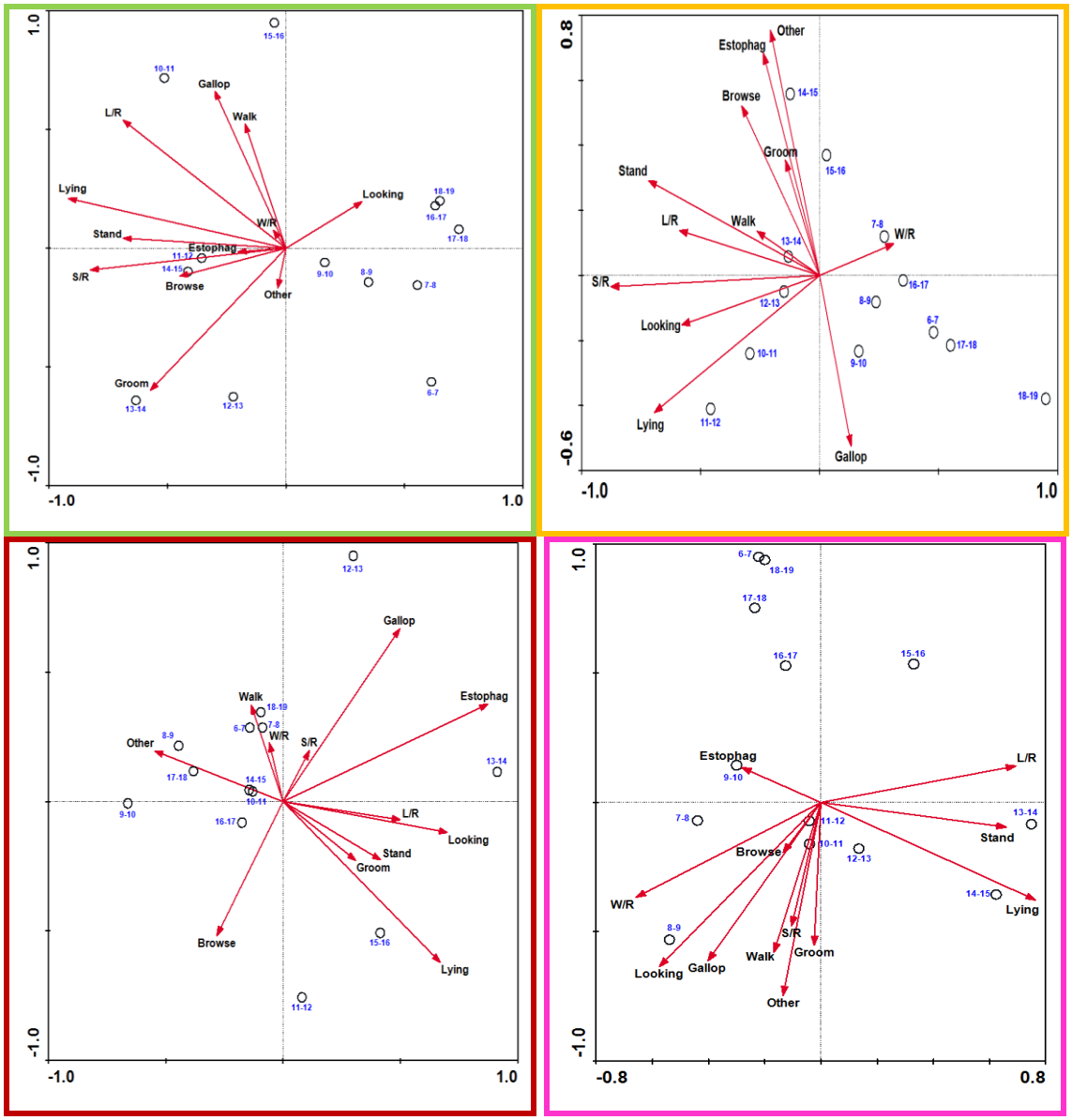

Figure 9.49 Ordination of all giraffe activities observed during the four seasons (Green = summer, orange = autumn, brown = winter and pink = spring)

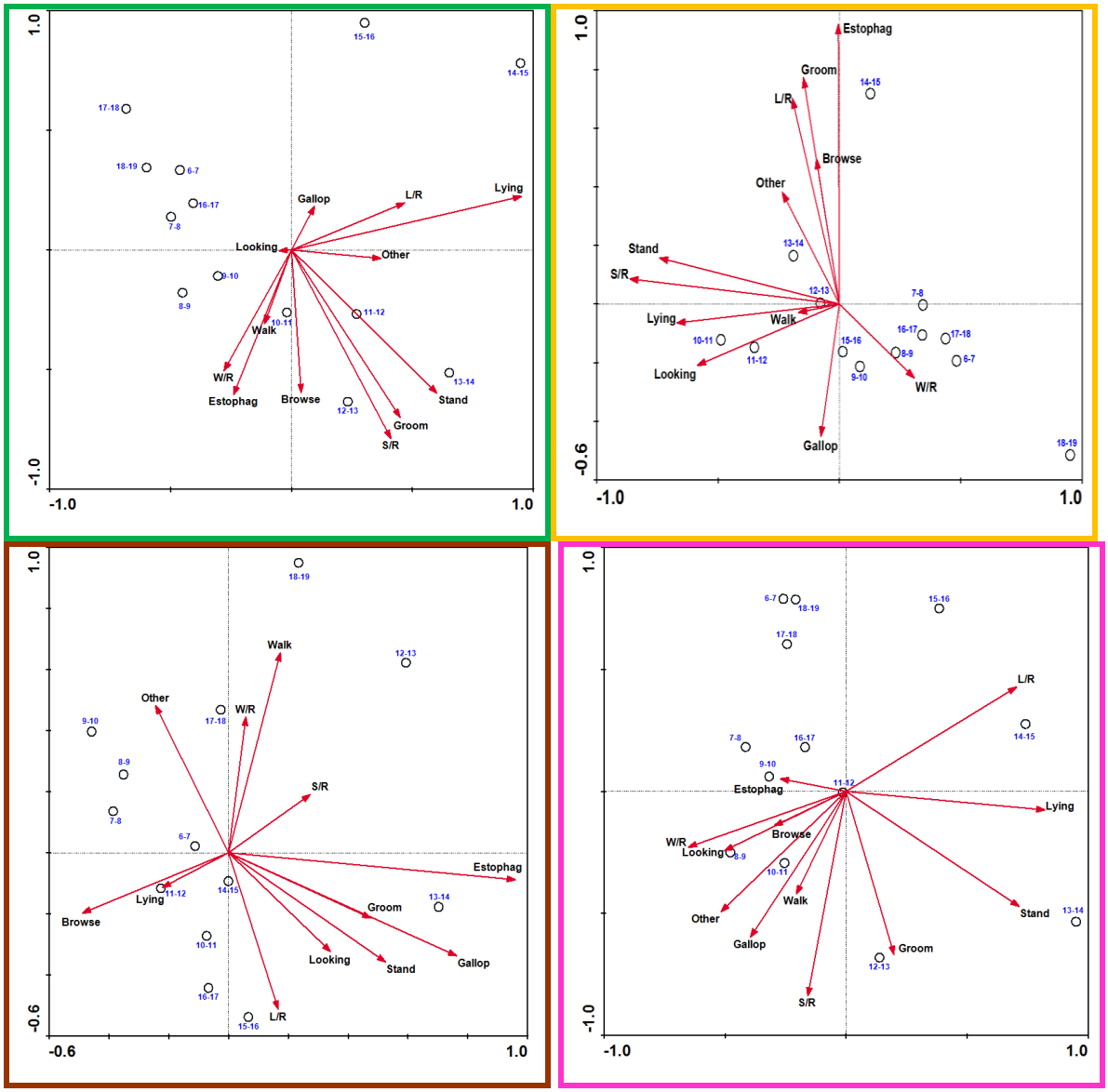

Figure 9.50 Ordination of all adult female activities observed during the four seasons (Green = summer, orange = autumn, brown = winter and pink = spring)

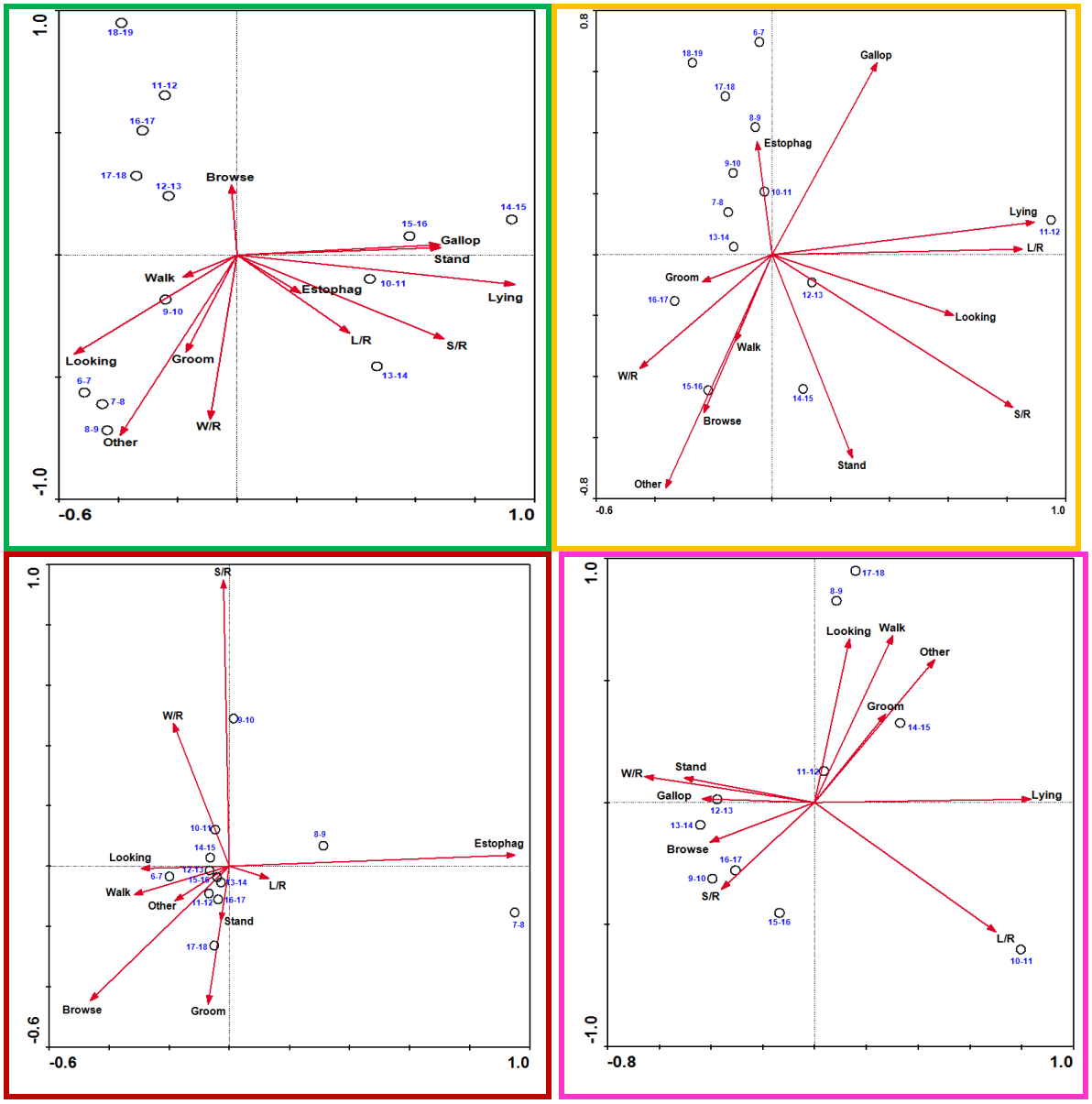

Figure 9.51 Ordination of all adult male activities observed during the four seasons (Green = summer, orange = autumn, brown = winter and pink = spring)

Figure 9.46 demonstrates that during summer months from 06:00 – 10:00 few of the prominent activities occurred. Browsing became important from 11:00 – 12:00 and also 14:00 – 15:00, with the latter being the most prominent hour. There was also a strong tendency towards grooming between 13:00 – 14:00. During the autumn months other activities became prominent during 14:00 – 15:00. Browsing once again mainly occurred between 14:00 – 15:00, with grooming moving to the 15:00 – 16:00 time slot. During the winter months browsing occurred more broadly between 11:00 – 17:00. Other activities were more commonly found, with walking and walking while ruminating being prominent in the early hours from 06:00 – 08:00 and again late in the afternoon from 18:00 – 19:00. During the spring months it was evident that osteophagia was prominent between 09:00 – 10:00. Browsing started earlier from 10:00 – 12:00, with standing without ruminating between 13:00

– 14:00. Between 14:00 – 15:00 lying down was prominent and there was little activity from 15:00 – 19:00.

Figure 9.46 shows variation between the activities from season to season. Even variations within each season are visible. Summer browsing was different from the winter months. During the winter the giraffes browsed for much longer and it can be deduced that they also spent much more time feeding on other species that were not important during summer season. During winter the walking activity and walking while ruminating were noticeable, possibly because giraffes were walking more in search of foliage.

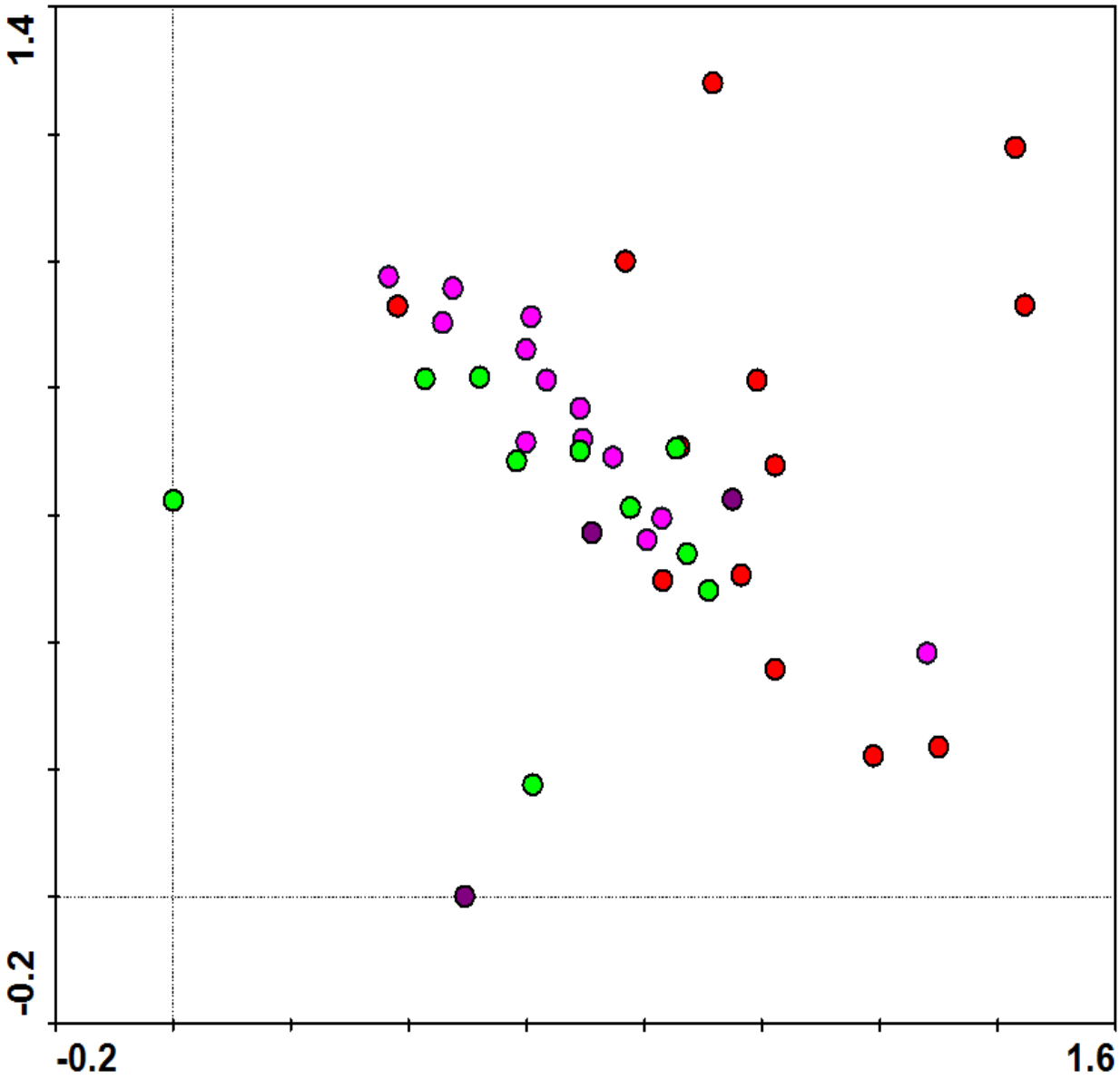

Figure 9.47 demonstrates that during the summer months females were relatively inactive from 06:00 – 10:00 and again from 16:00 – 19:00. Browsing was the most prominent activity

from 10:00 – 13:00 and standing without ruminating during 13:00 – 14:00. There was a strong tendency towards walking from 10:00 – 11:00. During the autumn months browsing was less evident, but occurred mostly between 13:00 – 15:00, with much more walking during the early hours from 06:00 – 10:00 and from 15:00 – 18:00 in the afternoon. Looking around was prominent from 10:00 – 12:00, with grooming between 14:00 – 15:00 in the afternoon. In the winter months lying down between 11:00 – 12:00 was very noticeable, while lying and ruminating occurred in the afternoon from 15:00 – 16:00. Walking and walking while ruminating were only found in the late afternoon from 17:00 – 19:00. Browsing occurred from 06:00 – 12:00. Other activities became more obvious throughout the day. In spring there was little activity during early hours from 06:00 – 08:00 and again in the late afternoon from 16:00 – 19:00, while looking around was prominent from 08:00 – 09:00. Grooming was important from 12:00 – 13:00 and standing without ruminating from 13:00 – 14:00. Osteophagia was prominent from 09:00 – 10:00, while lying down and lying down and ruminating were evident in the afternoon from 14:00 – 15:00. During all four seasons standing and ruminating for females mostly occurred from 12:00 – 13:00.

Figure 9.47 demonstrates that during the summer months males were relatively inactive from 16:00 -19:00. Browsing was more frequent from 12:00 – 13:00, walking from 09:00 - 10:00, looking around from 06:00 – 07:00, and other activities from 07:00 – 09:00. Lying down occurred between 10:00 – 11:00 in the midday and ruminating while lying down in the early afternoon from 13:00 – 15:00. Standing without ruminating was most prominent between 15:00 – 16:00. In autumn, lying down and lying down while ruminating occurred most often between 11:00 – 12:00. Browsing was most prominent during the afternoon from 15:00 – 16:00 and was closely related to the other activities. Standing without ruminating mostly occurred from 14:00 – 15:00, grooming from 16:00 – 17:00 and osteophagia from 08:00 – 10:00. In winter, male browsing occurred mostly from 11:00 – 14:00 and again from 15:00 – 18:00. Grooming was seen in the afternoon from 17:00 – 18:00 and osteophagia from 07:00 – 09:00. Walking and ruminating while walking were associated with periods 06:00 – 07:00, 09:00 – 11:00, 12:00 – 13:00 and 14:00 – 15:00. In spring lying down and lying while ruminating occurred from 10:00 – 11:00. Browsing occurred during most hours, but was associated with periods from 09:00 – 10:00 and again from 12:00 – 17:00. Standing and ruminating was most evident from 09:00 – 10:00 and again between 15:00 – 17:00.

Figure 9.47 demonstrates the prominence of other activities during the summer months that could indicate that bulls were not primarily focused on seeking foliage. Winter months illustrated that most of the time was spent on long hours feeding. This again supports the hypothesis that giraffe bulls spent more time on feeding during the winter months than during other months. Much of the day was spent on walking and ruminating while walking. All grooming occurred in the late afternoon except during the summer months. Lying down was strongly associated with specific hours during spring (10:00 – 11:00) and autumn (11:00 - 12:00), with very little during the winter months. No osteophagia was observed during the spring season.

9.4. Annual Prediction Model

From the results, the following diagram can be used to demonstrate the annual trend/prediction for giraffe activity budgets:

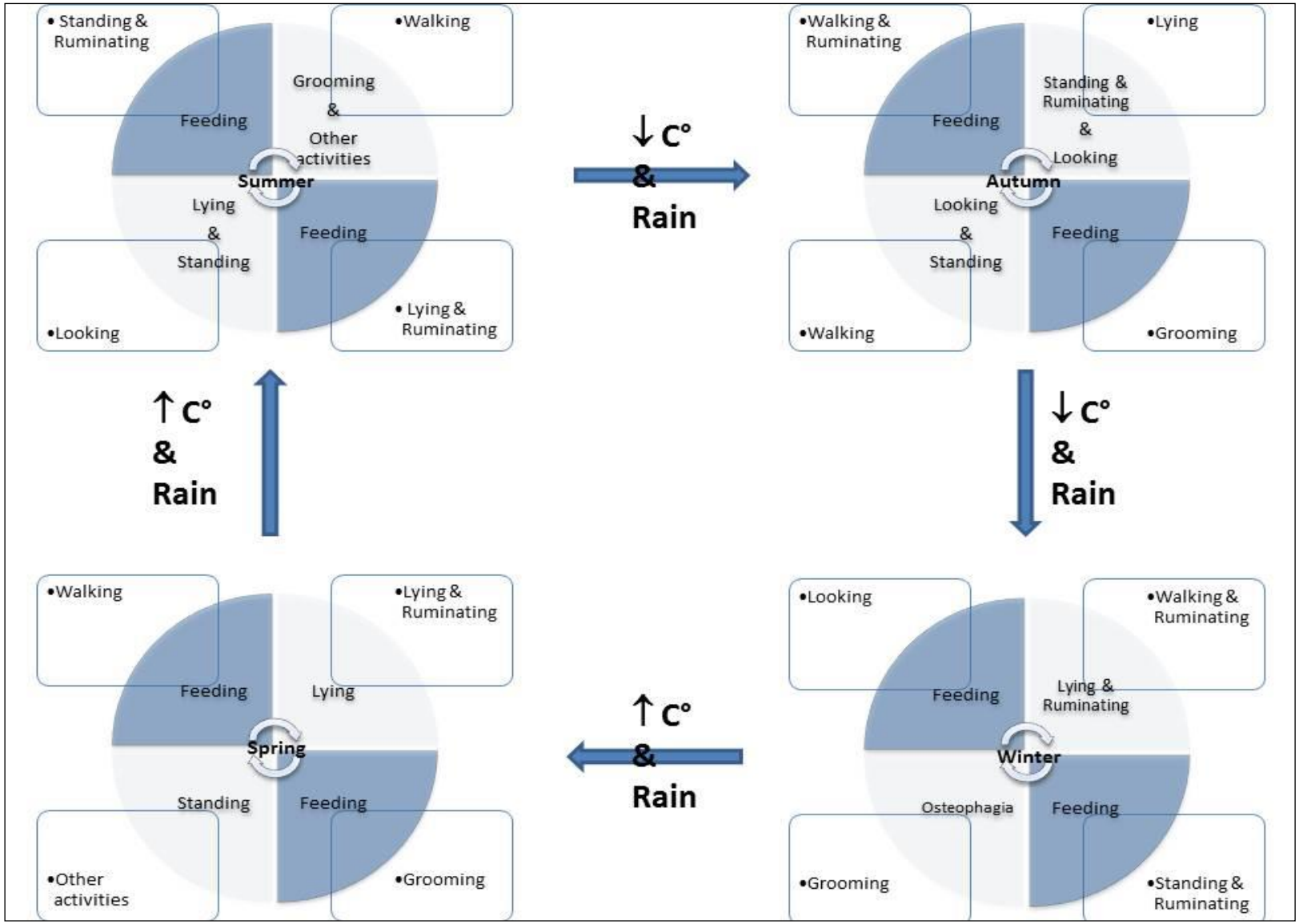

Figure 9.52 Prediction model illustrating how giraffe activities change annually and what influences these changes

9.5. Conclusion

From the results the following can be concluded:

i) Giraffe activity budgets can effectively be studied with field observations to identify how and when daily activities are performed. This in effect generates valuable information to understand more about giraffe non-feeding activities.

ii) Giraffe activities are clearly influenced by changes in season and the time of day. However, seasons are influenced by climatic factors and should be evaluated according to each factor (such as rainfall, temperature, wind etc.) that might influence activities.

iii) There are differences in activity budgets between male, female and juvenile giraffes; however, browsing is the most performed activity for all giraffes.

iv) If all activities relating to browsing (browsing and ruminating) are excluded from daily activity budgets, then 39% of time spent is related to non-feeding activities. For females 36%, males 44%, sub-adult males 54%, sub-adult females 34% and juveniles 51% of time spent is related to non-feeding activities.

v) Bulls lie down more than cows; however, sub-adult animals lie down more than adults and juveniles. Walking is the second highest activity performed by all giraffes, followed by standing while ruminating and then looking around. This, however, varied over seasons. Looking around is the third highest activity performed by juveniles.

vi) Osteophagia for all giraffes was prominent during the winter, indicating that giraffes are in need of supplementary minerals during the dry season.

CHAPTER 10: MANAGEMENT TOOLS FOR GIRAFFES

10.1. Introduction

For the survival of wildlife in natural environments scientists and conservation managers need to have a proactive adaptation to deal with transformation changes associated with land issues, habitat fragmentation, climate change and migration of people (Brenneman, *et al.,* 2009; Ash, *et al*., 2012). As giraffes in South Africa are now mostly confined to fenced national parks, conservation areas such as game reserves, as well as game ranches, the challenge to sustain them becomes significant. Inbreeding, reduced browse resources,

predation and diseases are some of the factors biologists and wildlife managers need to understand and manage. Above all, there is always the concern whether an area can support a viable number of giraffes without causing overutilization of the natural food resources.

Within KKNR the large vegetation areas that were previously influenced by humans are causing a lack of sufficient foliage and habitat for giraffes. These treated areas cover 85% of the total fenced area, and from the GPS distributions, it is evident that giraffes avoid poorly treated areas. This has caused giraffes to double their feeding range in search of food during the dry months to maintain their daily requirements.

Veld management and the management of giraffe populations, in particular, are necessary even in an area as large as the Khamab Kalahari Nature Reserve, because as is evident from the previous chapters, the KKNR is still not large enough to allow a completely natural equilibrium to develop, since giraffe numbers have continued to decline each year since the establishment of the Reserve. This may be either because there are insufficient food resources, or because of irregular and too little rainfall, but currently there is no information available on KKNR on which to base management decisions. And the same concern is found nationally, as there is insufficient scientific information available to conservation managers about giraffes.

The objective of this chapter is to provide information based on scientific principles for wildlife owners who want to keep giraffes. This information is only provisional and updating is an ongoing process as new knowledge from research becomes available. For instance, one concern is how to deal with periodic droughts, which are a natural phenomenon that will likely increase in many areas in the future due to global climate change. These drought periods should be planned for and managed on a continuous basis.

KKNR has the potential to add knowledge to the conservation of wildlife species. However, it should be remembered that with a low average rainfall (333 mm) within an arid region, there are severe limitations involved. Sustainability and habitat recovery depend on management decisions and how scientific information can best be incorporated.

The objectives of this study have been divided into primary (based on the current study) and secondary (the bigger picture) objectives.

Primary objectives are to:

i. identify factors which might influence population growth,
ii. determine management principles for giraffes,
iii. create an expert system via questions and decisions regarding giraffe management in arid regions.

Secondary objectives are to:

iv. promote population growth amongst other sub-species in the rest of Africa,
v. aim for decisions that will aid giraffe population sustainability.

10.2. Rationale

10.2.1. Identifying factors which might influence population growth

10.2.1.1. Habitat suitability

Game ranching and small scale nature reserves need to identify whether giraffes will adapt to the area. It is essential to know the specific habitat requirements of different game species, especially browsers, and also have a detailed analysis of the available habitats within such an area. The availability of food and shelter for wildlife is essential as the environment cannot support more animals than it can supply with food. Most environments can support relatively high numbers of game in the short-term, but at the cost of productivity of the resource. Veld degradation as characterised by an increase in annual pioneer grasses, creation of bare patches and increased runoff of rain water, will in time have a negative influence on animals, with losses to be expected during dry years. Some species also have specific needs regarding shelter, without which they will not reproduce optimally. In order to make decisions regarding the habitat suitability to sustain giraffes, a basic information sheet should provide sufficient information to game ranch managers in relation to the requirements for nature conservation officials to provide permits for keeping giraffes (Appendix K). This information sheet will enable officials to support or prohibit wildlife managers from keeping giraffes within the game ranching industry (see section 10.2.6.1).

The topography and vegetation composition should be such that seasonal habitat selection can take place. Up to the present, many giraffes have been brought into game farms and nature reserves regardless of their natural habitat preferences. One example in the past, was the reintroduction of giraffes into the former Transvaal Province, conducted by the Transvaal Nature Conservation (Hirst, 1966; Lambrechts, 1974). In 1970, the only demand for giraffes was for public and private reserves. Currently, giraffes are also in demand by private owners, stimulating the increase of giraffe numbers in the country. Relocations are based on aesthetical, rather than conservation concerns.

Examples in the past demonstrated that giraffe relocation into the Kalahari thornveld similar to that of the Western Free State was unsuccessful (Theron, 2005) and most of the animals died within two years of relocation, because the redistribution was limited to a few suitable thornveld areas. Steep slopes limit the movement of giraffes (see chapter 4) and vegetation in such areas is seldom utilized. However, Kok & Opperman (1980) found that the distribution and seasonal movement patterns of giraffes especially during drought conditions showed a clear relationship with the availability of food on the steep slopes. In the KKNR altitude variation did not prove to expand diet requirements during seasons, but the home range was found to expand in search of food resources. Thus, the biggest challenge for giraffes was not to take on steep slopes, but to cover long distances. KKNR does not have a big variety of tree species which giraffes can utilize, so for them to meet their daily requirements involved searching and moving to new areas.

Giraffe movements are related to changes in their diet, so it is essential to allow seasonal movements. Therefore, it is recommended that any potential giraffe habitat must include a variety of vegetation growth types, so that seasonal rotation of utilization can take place naturally.

10.2.1.2. Minimum feasible habitat size

According to Bothma (2010), giraffe densities vary from 0.2 to 2.0 animals per 100 ha depending on where they occur. A density of less than 1 giraffe per 100 ha in the arid *Acacia* savannas seems optimal, while densities above 2.6 animals per 100 ha result in mortalities during dry years in the lowveld of the Limpopo Province. According to the habitat suitability and availability of browse material, the stocking rate for giraffes varies from one giraffe per 500 ha to one giraffe per 60 ha. According to Furstenburg (2003), the maximum stocking rate of giraffes for an area with an annual rainfall of 400 mm was 80 ha/giraffe with a habitat size of 1 500 ha.

KKNR has 111 giraffes which equals 0.87 km²/giraffe with an average rainfall of 333 mm annually. This is a much smaller area per giraffe than the 1.9 km²/giraffe with an average rainfall of 600 mm annually in Kenya (Birkett, 2002), or the 1.47 km²/giraffe with an average rainfall of 811 mm annually determined by Pellew (1983b) from 6 different Nature Reserves in South Africa.

Bezuidenhout (2005) demonstrated how dominant and preferred trees may be eradicated at densities of 1.23 giraffes/km². This is especially true when there are limited critical resource areas such as in KKNR. Within KKNR critical resource areas are the areas with abundant *B. albitrunca*. In other reserves or national parks critical resource areas can be anything from ravine areas, hill slopes or open pans.

Results in KKNR indicate whether giraffe impact vegetation between utilized preference areas. Under high stocking densities, favourable trees, especially those species that retain their leaves during the dry season, are often heavily browsed to such an extent that “browse lines” are clearly visible. Results indicate that *B. albitrunca* can be affected by heavy browsing during critical periods. While these large trees are not threatened by this heavy browsing – they have adequate leaves above the browse line for photosynthesis – their ability to replace the browsed material within the browsing zone will diminish. Unlike grasses of which the growth points are protected at the base of the tufts, the growth point of trees is located at the end of the shoots. When complete shoots and branches are frequently removed, new shoots will not grow again in that area, resulting in a loss of potential browsable material and the dispersion of seeds during subsequent seasons.

Kruger (1994) distinguished *A. haematoxylon* as a key food species in the Kgalagadi Transfrontier Park (SA). However, in the present study *A. haematoxylon* was almost absent from the feeding data and feeding preferences of giraffes. KTP and KKNR tree species’ availability have the same value and characteristics; however *A. haematoxylon* was not preferred by giraffes in KKNR. The reason for this is unknown, except that giraffes in KTP were forced to feed in limited space (dry riverbeds) while in KKNR they were free roaming within the fence boundaries. This is a further motivation regarding the need for a habitat analysis to be conducted in advance to identify the correct stocking rate and the preference giraffes have for available woody species, to determine beforehand whether they will adapt to a specific habitat.

The relationship between stocking rate and animal production has a definite influence on the impact giraffes have on the vegetation (Parker, 2004; Deacon *et al*., 2012). Browsing management relies on several principles and practices established through experience and scientific research (Mentis & Collinson, 1979). Stocking rate, defined as the number of animals allotted to an area for a given length of time, is one of the most important browsing

management factors which a reserve can manipulate. This is regardless of the browsing system employed, vegetation type, or kind and class of animals or products produced. Of all the management tools, stocking rate has the largest impact on animal performance and forage resources. It directly influences animal productivity, forage production, forage quality, long-term plant species composition, plant physiology and the profitability of the operation (Mentis & Collinson, 1979).

Two general considerations in establishing an appropriate stocking rate include animal performance and the forage resource. Effective managers will balance animal and forage production over the long term rather than attempting to maximize either factor alone (Ohlenbusch & Watson, 1994). According to Mentis & Collinson (1979), setting an appropriate stocking rate consists of determining (i) the amount of forage required by the type and class of animals raised (forage demand), (ii) amount of forage produced during the year and how much of this is available for animal consumption (available forage) and (iii) how long animals will be using the area under consideration (duration of utilization).

For the advised minimum feasible habitat size for giraffes in arid regions, see the expert system in section 10.2.3.

10.2.1.3. Availability of water

Giraffes require 40 litres of water per day and prefer to drink during daytime at natural watering points (Dagg, 2014). Waterholes play an important role in regulating animal behaviour and they influence the functioning of ecosystems as explained by Bothma (2010) with the following examples:

- Most conflicts between different types of wildlife and between members of the same type occur when waterholes, water supplies or drinking space are limited. Aggressive animals such as the elephant, rhinoceros and African savanna buffalo have been known to injure and even kill each other or other animals at waterholes, especially in times of drought and reduced water availability. It has been observed twice that a white rhino male has killed a giraffe at the 1 800 ha Kwaggafontein Nature Reserve (South Africa) (Personal observation, August 2014) (Appendix L).
- The number and location of waterholes may control animal populations to some degree, but the opposite is also true; where one species is favoured, another may be negatively influenced.
- Mortalities and injuries may result from the congregation of animals at a waterhole during peak drinking times when limited drinking space is available. This may also happen at guzzlers with small drinking troughs. Young animals may also fall into troughs and drown. Giraffe may slip on wet or smooth cement slabs around waterholes and break their legs.
- Waterholes are focal points for animals in the dry season, and predators will lie in wait at such strategic places to obtain their prey more easily. This could easily scare off animals in search of safe new water resources.
- Diseases such as anthrax are spread by animals that contaminate waterholes after scavenging from diseased carcasses. Vultures, in particular, bathe in shallow

waterholes. Consequently, when they have fed on the carcass of an animal that has died of anthrax, they will contaminate the waterhole with anthrax spores.

- High concentrations of salt in the drinking water may lead to chronic kidney damage. When animals in such areas are herded for capture, capture myopathy occurs more easily. A high fluorine content in boreholes in the Rust de Winter area north of Pretoria has also led to fractured legs in young African savanna buffalo bulls (Bothma, 2010). From own observations in the Kgalagadi Transfrontier Park, hundreds of elands died of low water quality and insufficient water provision in 2008.

One obvious example of unplanned management action is the so-called waterhole syndrome (Bothma, 2010). Artificial waterholes are created at random on many wildlife ranches where professional wildlife management and proper planning do not exist. It is usually done either for the convenience of tourists; to control or change the movements and distribution of wild animals; or to make new sections of habitat available for wildlife use. However, when these waterholes are established without careful planning or a thorough study of all the aspects concerned, it often leads to the deterioration of the surrounding habitat, due to trampling, and leading to soil degradation and erosion because of overutilization by wildlife in the vicinity of the waterhole. There is conclusive evidence that the creation of artificial waterholes has a definite ecological influence on the vegetation surrounding them, and even on the number and distribution of rarer animals, which usually avoid such overused or disturbed areas, as a result of their inherent social behaviour or dietary requirements.

KKNR water points are not evenly dispersed within the vegetation units. Water should be distributed so that all the resources are evenly utilized and overutilization of critical resource areas will not happen. KKNR will also get rainwater accumulating in the open pans, which is available for the animals to drink for anything from just a few days to a couple of weeks. This surface water can allow giraffes and other animals to find new resources and explore new environments.

The incorrect location or placement of waterholes in KKNR has resulted in both over- and underutilization of resource areas. This may lead to management problems such as the loss of preferred tree species and bush encroachment of unsuitable tree species. Another problem is that specific types of wildlife may create unique ecological effects that could lead to undesirable results. This has been seen within the KKNR with the lack in utilization of area 4 (chapter 5), as the absence of water was considered the main reason why giraffes did not use this area.

10.2.1.4. Fences

According to the Policy on Fencing and Enclosure of Game, Predators and Dangerous Animals in the Western Cape Province (2014), giraffes need a 2.4 m fence to enclose them. However, each Province has its own regulations and legislation, but the best descriptions for prospective game owners are from prescribed game fences illustrated by the Northern Cape Nature Conservation (Appendix L). Giraffes, and especially males, are considered as fence breakers. The erection of an effective game fence is determined by the nature of the terrain, the type of material, and the availability of material and finances. Each reserve and game

ranch should evaluate the situation and consult the local conservation authority with regard to specific prescriptions or requirements for fences before a fence is erected.

According to Bothma (2010), the requirements for a good fence are that it must be straight, the straining posts must be firmly and vertically planted and anchored, and all posts should be upright and extend to the same height above ground level that is corresponding with the terrain form. The straining posts should not be too far apart and the closer they are together, the firmer the fence. A fence should never be erected with inferior quality material.

Irrespective of the number of wire strands or type of fence used, each strand should be at a specified height above the ground, parallel to the other strands and firmly attached to each line pole, to prevent vertical movement. The more strands used in a fence of a determined height, the closer the strands will be together, and the more difficult it will be for a person or an animal to pass through it.

Droppers should be neatly and evenly spaced vertically between the line posts and the wire strands must be firmly attached to them, so that the space between the strands, as between the line posts, is maintained.

There are three types of posts which are used to erect game fences, namely straining posts (with supports and/or anchors), line posts (spaced in the line between straining posts) and droppers (spaced between line posts).Straining posts are used as anchors so that the fence can be erected in sections. Straining posts must be strong enough not to bend or break, they must be able to withstand the strain and weight of the fence and have a long life-span. The types of material that are suitable for straining posts include: wooden posts - creosote or tanalith-treated bluegum posts (not pine) which carry the SABS stamp, steel rails or metal pipes (Bothma, 2010).

Line posts form the core of the fence and divide the distance between the straining posts into equal sections. The specifications for line posts and the type of materials suitable for line posts are the same as those for straining posts, except that Y-type iron posts can be used instead of rail straining posts. Line posts can be set from 25 to 50 m apart to ensure fence elasticity. The degree of elasticity depends on the distance between the straining posts. It is not necessary to use one type of line post throughout; instead, two types of line posts can be alternated, for example wooden posts alternating with metal posts. Metal posts are more suitable for rocky or mountainous areas and can help make the fence lightning resistant. Line posts must be set vertically and in a straight line at the correct height above the ground. The wire strands are fixed or stapled to each of the line posts at a specified height above the ground and parallel to each other. When staples are used to secure the wire to the line posts, looped wire must be used together with staples for a firmer attachment. When a fence is erected in mountainous terrain, line posts can either be set in concrete and packed rocks or in holes drilled or hammered into the rock (Bothma, 2010).

Droppers are used to divide the spaces between the line posts equally, thereby strengthening the fence. This also ensures that the wire strands are kept evenly spaced. The distance between the droppers can vary from 1 to 3 m. Droppers can be hammered into the ground until the desired height above the ground is reached.

The types of material used for droppers are: wooden droppers - SABS approved creosote or tanalith-treated blue-gum poles (not pine poles) minimum diameter: 60 mm, ridgeback iron

droppers, or cable droppers – old mine cables used singly. It is not necessary to use the same kind of droppers throughout as the above dropper types can be interchanged on the same fence. The spacing of wire strands on droppers must not be done by using cut grooves, because the external tension the dropper concentrates at these grooves during flexing, and this weakens the dropper. Holes should rather be drilled through the axis of the dropper using a hoop iron spacing gauge.

The main advantage of a wooden pole fence is that in sand or loose soil it is more secure than an iron post fence. Disadvantages of a wooden post fence are that it has a shorter life-span than an iron post fence, it is less fire-resistant than iron posts, it takes more time to set wooden posts and it is not lightning resistant. The advantages of an iron post fence are that it is termite and fire resistant, it has a longer life-span than wooden poles, it can be erected more quickly than a wooden pole fence because the iron posts are simply hammered into the ground, and it is lightning resistant. The disadvantages of an iron post fence can be summarized as follows: it rusts quickly in humid conditions, it is more expensive than wooden poles and it is less secure in sand or loose soil (Bothma, 2010).

There are several types of wire available, each with its own characteristics, namely: plain steel wire (smooth), campeon steel barbed wired, veldspan (bonnox) – a square mesh type of wire with horizontal steel wires and vertical soft wires and wire mesh – diamond mesh, jackal or pig wire mesh and welded wire mesh. It is important that fully galvanized wire is used in areas with humid climates (yellow label), while lightly galvanized wire (red label) should be used in areas with a dry climate.

The advantages of plain (smooth) steel wire are that it is cheaper, easier to erect and also more resilient than barbed wire. However, plain steel wire is often stolen and used to make snares.

On the other hand, barbed wire is more visible to game, is ‘respected’ to a certain extent by game and is not used for making snares. Barbed wire is, however, more expensive than plain steel wire, it is difficult to erect and therefore takes longer to put up and can cause more injury to game. Barbed wire also damages the skin of trophy quality animals and tends to break at the barbs when overstrained.

Wires should not be strained too tightly or too loosely. Experience is the best teacher, but a guideline is that wire strands should never be strained to a tension exceeding 2 kN (kiloNewton). If the wire is strained too tightly, the straining posts may be pulled out, wire strands could break as a result of extreme cold, veld fires could damage the wire and game could break their necks when hitting the fence. The wire strands should preferably be placed and strained on the game camp side so that the curve of the posts rather than the staples can withstand the strain (Bothma, 2010).

Shiny objects such as metal sheets or pieces of corrugated iron tied to the fence will help to make the fence more visible to game. To prevent giraffe breaking the fence, the fence can be reinforced by using cables between the line posts, placing line posts closer together and using more droppers. Regular patrolling of fences is essential to detect whether any damage, poaching, game escapes or intrusion by predators or stray dogs occurred.

Electrified fences can be used as well. Electrified fences will keep most game species within the boundaries and are particularly suitable for elephants, hippopotamuses, baboons and

predators. The ideal electrified fence should be planned and designed for the specific animal species which it must control. It will keep giraffes in successfully if they have experienced a shock, although, in some cases it will not be effective for giraffe bulls, but it limits the entry of poachers and thus decreases game losses.

Appendix L demonstrates the fence that currently keeps giraffes within the boundaries of KKNR. Appendix L also illustrates some examples of prescribed game fences, as used by the Northern Cape Nature Conservation for the different game species, which include giraffes. KKNR game fence is 2.4 m in height with a 1.2 m bonnox fence added to the bottom half. The fence has 6 steel wires on top of the bonnox. Added to the fence is an additional 5 wires (20, 80, 120, 160 and 240 cm starting from the bottom), which is electrified with the trip wire and earth wire 10-20 cm above ground and 40 cm away from the fence.

10.2.1.5. Body condition parameters

Quality and quantity of food are the single most important reason for nutrition–related deaths in wild animals (basically the lack of adequate food). Giraffes require about 2 kg of quality food per 100 kg of body weight per day (Bothma, 2010). This food has to be available in a form that satisfies the nutritional needs of giraffes. The quality of the food is influenced mainly by the plant species, climate, weather and soil.

The physical condition of wildlife is directly influenced by nutrition. A problem of free-ranging giraffes is that the protein quality of the vegetation varies, both seasonally and regionally. Therefore, these animals have to move about in search of food that has the highest protein content possible. A protein deficiency in giraffes leads to feeding stress which leads to general deterioration and loss of weight, while a protein deficiency during pregnancy leads to small, weak or stillborn calves. Pica and osteophagia behaviour can be seen as indicators of nutritional stress (Langman, 1978). In KKNR over 500 records (2% of female giraffe diets) were of osteophagia, indicating nutritional stress during the dry season.

10.2.1.6. Competition with other species

A lack of plant species variation might cause herbivores to compete for the same resources. Competition will mostly occur during the critical periods (July – October) when there is a lack of edible nutrition. A bigger variety of tree species limits competition, as most browsing herbivores have preferred tree species in the diet and will avoid competition. The browsing capacity should be a good guideline to indicate whether the herbivore population will be competing for the same resources. Quantifying and evaluating the qualities of the veld will assist in making decisions regarding the animal species composition.

Giraffes are considered as concentrate feeders, which have a highly selective method of feeding. As a consequence, the nutrient content of their diet is much higher than the average for the vegetation on which they feed. Selective feeding is time consuming and therefore game species that can be classified as concentrate feeders spend more time feeding. Selective feeders usually have small mouths that enable them to reach specific plant parts. Due to the smaller amount of feed available that meets their requirements,

potential competition among them can be high and for this reason the concentrate feeders seldom congregate in large numbers. For the same reason, the concentrate feeders are often also low-density game species (Hennemann, 1983).

In KKNR the availability of different food sources during different times of the year had a major influence on the diet selection of giraffes. Results have shown that there was a substantial overlap in the diet selected by different species during periods of abundance, but during periods of low availability the separation between species became bigger (August to November). This is an example of a competition avoidance strategy. However, this may not always be the case and competition may often increase between giraffes and other herbivore species when they have to compete for declining food sources during dry periods. Changes in the diet with changes in the season were notable in the giraffe diet at KKNR. Giraffes, however, can utilize height strata better than other herbivores such as kudus and elands during the drier periods, which is an advantage.

10.2.1.7. Diseases known in giraffes

For optimal production, it is essential that the animals on a wildlife ranch, reserve or national park remain healthy. Prevention of diseases and parasite management are therefore integral parts of wildlife management. However, there is still much that remains unknown. In this section, only those infectious diseases that are currently known to be of practical importance in giraffe health are discussed. The other diseases of this nature are either not economically important, or too little is known about them to allow meaningful discussion.

According to Fowler (1978), “diseases of giraffes are similar to those of other ruminants. Giraffes are susceptible to foot-and-mouth disease, rinderpest, mucosal diseases, tuberculosis and other infectious diseases that affect domestic cattle. Gastritis, fractured pelvis, shock, obstruction of the pylorus, anemia, fibrosis of the liver, pneumonia, heart failure, kidney disorders, tuberculosis and even thunderstorm lightning were reported as causes of mortality. Scurvy, rickets, osteomalacia and hoof deformities are listed as consequences of malnutrition”.

Giraffe can contract anthrax, which is caused by the bacterium *Bacillus anthraxcis* that forms spores when it is exposed to the atmosphere. It therefore thrives in anaerobic conditions. The bacteria themselves are not resistant to stomach juices, high environmental temperatures or decomposition of the carcass, but the spores are exceptionally hardy and can survive for many years in the soil or in old bones (Young, 1970; 1972; Bothma, 2010). Flies that feed on contaminated carcasses will regurgitate the spores onto vegetation at a height of 1.0 m to 2.0 m above the ground (Davis *et al.*, 1981).

Osteophagia, or pica, is the condition where animals chew on bones because of a phosphate deficiency (Bothma, 2010). Osteophagia was commonly found among giraffe feeding habits (see chapter 8). It is known that the bones of contaminated carcasses have initiated outbreaks of anthrax in the Kruger National Park in the past. The greater kudu, giraffe and African savanna buffalo appear to be exceptionally susceptible to anthrax (Bothma, 2010). Anthrax in an animal may be recognized by one or more of the following:

- When an animal dies suddenly without displaying any clinical signs of disease. For example, animals are often found on a footpath where they have simply collapsed and died almost instantaneously.
- Acute depression and the loss of appetite.
- Bloody secretions from the body orifices, such as the nose and anus.
- Listlessness, salivation, watery eye secretions, a drooping head and warm, painful swellings of the body surface.
- Swellings of the skin, but especially the skin of the throat.

Preparation of a stained blood smear for microscopic examination will establish the presence of the disease. Sick animals can be treated with penicillin (Davis *et al.,* 1981). Supplementary mineral licks should be supplied to prevent osteophagia (pica) (Bothma, 2010).

Heartwater is a disease that occurs in ruminants. It is caused by the rickettsial organism *Ehrlichia ruminantium*. The disease is confined to open savannas in tropical and subtropical areas, and is transmitted by bont ticks, especially *Amblyomma hebraeum* in South Africa and *Amblyomma variegatum* further north. The susceptibility of wild ungulates to heartwater varies. The giraffe is susceptible to the infection, but shows no clinical signs of it (Young, 1972).

Botulism is a disease that occurs especially in ruminants and birds. It is caused by a toxin that is produced by the bacterium *Clostridium botulinim* (Karstad, 1978). The toxin is produced particularly in oxygen-poor conditions, such as those that are found in a decomposing carcass or in a polluted pan. Osteophagia often takes place in regions where the soil and crops are poor in phosphates, especially when green grazing is scarce. This can lead to botulism when the desiccated meat on the bones, as well as the bones themselves, are infected by the bacterium *Clostridium botulinim*. In southern Africa, this disease also occurs in domesticated livestock that suffer from a phosphate deficiency and consequently show bone hunger (osteophagia). It also occurs in waterbirds in large eutrophic pans (Bothma, 2010).

The disease is controlled by preventative immunization, removal of carcasses when scavengers are absent, and the prevention of conditions that can lead to the eutrophication of pans.

Cytauxzoonosis, the generic name *Cytauxzoon,* is now widely regarded as a synonym of *Theileria.* Moreover, the disease is also transmitted by ticks and occurs widely in various types of wild ungulate. However, it apparently only causes disease in animals with a low resistance. It is considered to be an important cause of death in giraffes. Infected animals are usually feverish, weak, emaciated, anaemic and have enlarged lymph nodes. As the parasites that transmit this disease are so widely distributed in South Africa, it is not practically possible to prevent such an infection (McCully *et al.,* 1970)

There are various causes of disease other than viruses, bacteria and protozoa. These diseases are also important and are related to aspects of nutrition and poisoning.

10.2.1.8. Parasites known in giraffes

Little is known concerning the influence of parasites on giraffes, but parasites amongst other wildlife are commonly found. During recent intensive parasite surveys in which hundreds of antelopes from various regions of South Africa were examined, clear differences were found in their worm loads (Bothma, 2010). For example, greater kudus in the Kruger National Park had a mean worm load of 2 251 worms per animal, while those in the more arid and hotter Albany Thicket in the Eastern Cape had only 289 worms per animal. Greater kudus in the Etosha National Park in Namibia had 399 worms per animal (Bothma, 2010). Climate appears to be the greatest limiting factor affecting the worm loads of wild antelopes (Horak, 1980).

According to their host preferences, worms are divided into four groups. These are: the host-specific group that is limited to a specific type of animal; the definite parasites that occur in large numbers in most individuals in a herd; the occasional parasites that occur in less than half of the individuals in a herd; and the accidental parasites that occur only in individual animals for a limited time (Bothma, 2010). Some of the worms are limited to certain closely related animals. For example, *Haemonchus veliai* only occurs in browsers, while various species of the genus *Longistrongylus* are abundant in grazers and only exceptionally occur in browsers. *Trichostrongylus deflexus* has a wide range of hosts as it occurs in browsers, grazers and even in some hares (Horak, 1980).

There is a significant difference in the worm burdens of grazing and browsing wildlife. Browsers usually carry around 8 000 worms per animal, while grazers usually carry a mean of 20 000 worms per animal. For example, worm loads in impalas can increase from 20 000 worms per animal under normal conditions to 60 000 worms per animal during a drought. Although a load of 20 000 worms, or even one of 5 000 to 8 000 worms may sound excessive, it is not a heavy load in helminthological terms (Horak, 1980). Where wild animals are concentrated on pastures, a large amount of dung accumulates. This dung may also contain numerous worm eggs.

Roundworms occur seasonally. Adult wireworms are present especially during the wet summer season, while their immature stages are most numerous mainly during the autumn and winter. Adult bankrupt worms are usually most abundant during the winter, because the lower temperatures favour the survival of their infective stages (Horak, 1980). However, the general tendency in the summer rainfall regions is that adult worms are present in animals during the summer, while their immature stages are usually present in their host animals during the winter so that they can escape the adverse external climatic conditions (Bothma, 2010).

To control worms, the use of injections or oral dosing should be confined to animals that have been captured for translocation or other reasons (Bothma, 2010). Animals should not be captured routinely for injections or oral dosing only, as it exposes them to the stress of capture and handling. However, all wild ungulates that are relocated to or from a specific ranch must be treated against worms after capture. This can easily be done by injecting them intramuscularly or subcutaneously with one of the injectable anthelmintics (Horak, 1980). This practice will decrease the chances or introducing foreign parasites to a wildlife ranch or region, and help to prevent large parasite loads from building up in the relocated host animals during the stress of the adaptation period.

It is equally important that overstocking with wild and domesticated animals should be avoided, because this creates conditions that are favourable for the acquisition of worms. The deterioration of the veld that is usually associated with wildlife overstocking, also places animals under stress and can lead to abnormally heavy worm loads (Bothma, 2010).

Exotic wild animals that do not naturally occur in a certain habitat should not be introduced into it. Such animals are usually not adapted to survive in the new area, and are easily infested with worms and normally carry heavy worm loads (Horak, 1980). These large worm burdens serve as an excellent source of infestation for other animals on the ranch.

The two most important control measures for internal parasites are therefore avoidance of overstocking and prevention of cross-contamination (Bothma, 2010). On reserves that are managed with these two golden rules in mind, internal parasites should have no significant effect on the wildlife that might be present there.

10.2.1.9. Predator influence

KKNR did not record any predation by predators on giraffes. Since the lions were released into KKNR they were monitored with GPS collars and a full time student and not one predation observation, carcass found or kill can be related to lions feeding on giraffes. Not even juvenile giraffes were preyed upon. Thus, in KKNR predator influence can be ruled out as the main cause for the decrease in giraffe numbers. However, giraffes falling prey to predators has been reported in other studies where predation on giraffes was common (Brenneman, *et al.,* 2009; Creel *et al*., 2014).

10.2.2. Determining management principles for giraffes

10.2.2.1. Ecological principles

The terms equilibrium and non-equilibrium as used in rangelands, are strongly debated by scientists. The central aspect of this debate is a definition of the degree to which climate or consumers (herbivores) influence vegetation. One view is that consumers reach densities that degrade environments from a previous condition of equilibrium and the other view is that the dynamics of pastoral systems are non-equilibrial and primarily dictated by variability in rainfall (Ellis & Swift, 1988).

Illius & O'Connor (1999) argued that the view that herbivory has little impact on climatically variable systems is unjustified. They proposed an alternative model in which it is assumed that despite the apparent lack of an equilibrium, animal numbers are regulated in a density-dependent manner by the limited forage available in key resource areas utilized during the dry season. Their model asserts that strong equilibrial forces exist over a limited part of the system, with the animal population virtually uncoupled from resources elsewhere in the system.

From the literature it would thus appear that ecosystems can display both equilibrial and non-equilibrial trends. In this regard the degree of aridity is important, where arid ecosystems are less stable (non-equilibrial), while mesic ecosystems are often more stable (equilibrial) (Smit, 2004).

Despite the lack of equilibrium, animal numbers are regulated in a density-dependent manner by the limited forage that is available in key resource areas, especially during droughts. Herbivores may not have an influence on the vegetation at all times, but they do influence the key resources at critical points in the seasonal cycle. For example, during the dry season the browsers will have a great impact on the vegetation surrounding waterholes and on plant species that remain palatable during this time. The key question is not really how changes in equilibrium occur, but rather how much variation there is, and at what spatial and temporal scales it occurs. If there is a lack in species variation, the equilibrium can easily be disturbed with negative effects. For instance, if there is a food shortage created by the decline in preferred species, it can be detrimental to giraffes in the long-term (Brenneman, *et al.,* 2009).

The primary consideration in arid lands is rainfall and the ability of the soil to retain moisture. In essence, arid rangeland management means learning to live with uncertainty. Management needs to plan in advance how best to apply ecological principles to achieve sustainability and how to adapt to episodic climatic events. It is a process of calculating probabilities and of acting on any advantageous windows of opportunity. The fluctuating climatic conditions of arid regions create episodic events that in turn create an environment in which rainfall, and not forage availability, may ultimately be the variable that will be limiting to herbivore population growth. Therefore, planning for uncertainty is, in such a scenario, considered to be more realistic than the above assumptions of equilibria, which are not always viable in an arid environment (Bothma, 2010). Planning the carrying capacity during critical months is a basic management principle for managing game. Principal and preferred food species are equally important for the survival of herbivores.

In KKNR the preferred food species were *A. erioloba, A. mellifera, Z. mucronata* and *B. albitrunca* which were proportionally more frequent in the diet of giraffes. Under natural equilibrium circumstances the availability of these browsable tree species in KKNR would only have been influenced by the following:

- Density of the woody plants
- Amount of leaf material within reach of a giraffe
- Species composition of the woody vegetation
- Palatability and digestibility of the woody vegetation
- Growth potential of the woody plant species
- Phenology of the woody species, including deciduous nature and the times when the leaves, flowers and fruits are available to browsers

Unfortunately, large scale herbicide application by previous landowners has resulted in a catastrophic decline in woody species that maintain the giraffe population and can be seen in large areas within KKNR. Although the application of arboricides has led to an increase in grass production in the short term, it eventually led to total degradation of diverse and species rich ecosystems. Trees and grasses are elements of this ecosystem and if excessive disturbances occur in the one element it will also influence the other. Trees play an important role in the ecosystem where they provide shade and cooler, moister conditions for grass and other forb species preferring such conditions. Apart from also being a source of food for browsers, they act as resting and sleeping places for animals and generally have a higher diversity of species growing underneath them. Grasses are important in protecting the soil from erosion and exposure to the environment. They also provide nutrients to the soil

due to decomposition of dead material while being the only source of food for grazers. Although there is constant competition between the grass and tree layer there is also interspecific competition between different tree species, as well as between the different grass species themselves. Thus a disturbance in any part of the tree or grass layer will not only have an influence on the grass-tree interaction, but also on grass-grass and tree-tree interactions. In KKNR it did lead to a complete change in species composition and undesirable dominance of unfavoured species for giraffes and other browsers such as kudus.

The removal of trees in KKNR by previous landowners to provide improved grazing for domesticated animals was, unfortunately, poorly executed in large areas. In areas where selective removal was effected; it did indeed improve the production potential of the veld,, demonstrated by GPS locations which showed that giraffes did prefer these areas. However, large scale non-selective clearing also took place, which has led to an increase in production of the grass layer in the short term due to the higher nutrient condition of the soil where trees used to be. But, once these nutrient sources have been depleted over a few years the high production grasses died off quickly, to be permanently replaced by pioneer and low production grasses and unsuitable woody species. These areas were avoided by giraffes, as was clearly illustrated by the GPS locations.

Many of these changes have been observed within the study area, where various species such as *Grewia flava* and *Acacia mellifera* have become prominent in areas where large-scale tree removal has taken place and poor recovery followed after the unselective treatment. The grass layer in these areas has also become very homogeneous with only one or two grass species dominating. Thus a loss in biodiversity has occurred in these unselectively treated areas. *Grewia flava* densification took place in places previously cleared of *Acacia mellifera,* which resulted in a degrading of these areas of the reserve.

However, for management purposes the future focus of KKNR should be on habitat recovery. Large areas typical of *Acacia erioloba* and *Boscia albitrunca* veld are still present with higher species richness than the poorly cleared areas. It is therefore advisable and important for the survival of the remaining giraffes that permanent monitoring plots are placed within these variously affected areas to monitor the woody component as well as species composition.

It is suggested that, in poorly treated areas in KKNR, a start should be made with active rehabilitation measures and not to wait for natural recovery, because of the low rainfall and poor soil qualities. Introducing new plantings (seedlings) should be successful and will aid in the early establishment of saplings. Hopefully nearby sources of seeds from less treated, adjacent and untreated areas will disperse and accelerate the recovery proses. According to Bezuidenhout, *et al.* (2015) Tebuthiuron (Molopo arboricede's active ingredient) can leach out and can metabolise over an extended period in the shallower soil horizons where seedlings/saplings are rooted.

10.2.2.2. Legislation

Each province has its own regulations and legislation for prospective game ranches and reserves. The Northern Cape Nature Conservation Act, 2009 (ACT NO. 9 OF 2009) is the most comprehensive legislation for keeping giraffes applicable to arid and semi-desert

areas. Within this act, giraffes are listed under common indigenous species that require a detailed habitat analysis before ownership is granted. If this legislation is correctly implemented in more regions in the country (with professional conduct) it will limit environmental losses such as habitat and wildlife species. Natural and historical distribution are important in decision making for legislators, and the current status of giraffe populations within the country will assist in maintaining genetic material and the protection of giraffes throughout the country (Appendix N).

10.2.2.3. Immobilization / capture techniques

Bothma (2010) discussed in detail how to immobilize and capture wildlife. The ultimate success of the capture, transport and re-establishment of wild animals on wildlife ranches is not determined only by the capture of the animals. Rather, it is more often determined by how the animals are handled, transported and kept after their capture, and whether they adapt to and breed successfully in their new environment.

There can also be deaths due to maladaptation to the new habitat. In the past there were often heavy and unnecessary losses, but with the present knowledge and more efficient capture, handling and transport methods, most losses can and must be minimized.

Capture stress: Underlying factors such as disease, young or old age, advanced pregnancy, nutritional and mineral deficiencies, weaknesses that are caused by internal parasites and other factors that are not obvious, may have severe adverse effects on the animals, lower their resistance to stress and make them more susceptible to capture stress and exhaustion.

Many animals, but especially browsers such as the greater kudu and giraffe, lose physical condition during the winter because of the reduced availability of food and lower energy levels in the vegetation. It is therefore not advisable to capture these animals at the end of the winter.

Successful capture is dependent on proper planning before undertaking an operation. All the facets that are involved have to be considered, including the terrain, weather, the choice of method and equipment, transport, the permits and the distance to and nature of the final destination. Management of any possible potential problems before they occur is therefore paramount for successful wildlife capture (Bothma, 2010).

Following the results in this study, giraffes can be captured successfully with immobilizing drugs. According to Bothma (2010) there are also many advantages of chemical immobilization and it is a safe and effective capture method when it is applied correctly and competently. It has the following main advantages:

- It is the safest and most economical method for capturing giraffes. However, it must be emphasized that a responsible and experienced person must perform the capture operation and administer the drugs.
- It is more economical than other methods when only a small number or single animals are to be captured.
- It is the safest method for capturing, handling, loading and transporting large and/or aggressive animals.

- It is a useful method for removing aggressive or injured animals from holding pens or transport crates.
- Because there are antidotes to reverse the effect of some of the drugs and wide tolerance dosage levels in many cases, even an overdose of these capture drugs is unlikely to kill an animal, especially when an antidote is available.

Disadvantages of chemical immobilization (Bothma 2010) include:

- The three main immobilizing drugs that are currently available for herbivores in South Africa are M-99 (Novartis) or etorphine hydrochloride, fentanyl (Janssen Pharmaceutica) or fentanyl citrate, and A3080 (Wildlife Pharmaceuticals). All these drugs are strictly controlled by the Medicines Control Council. According to current legislation, these immobilizing drugs are classified as Schedule 6 medicines and may not be sold to any person other than a veterinarian.
- The handling of the darting equipment, immobilizing drugs and the immobilized animals after capture requires knowledge of the drugs being used and a high level of professional expertise.
- The firing range of some dart guns is limited, and animals are often too far away for this immobilization method to be used. Animals in a group or herd are often disturbed by the shot and may run away. It then becomes difficult to approach them again.
- When a dart does not penetrate a suitable muscle, absorption and action of the immobilizing drug is delayed. The animal may then exhaust itself before the drug becomes effective, which could result in the animal dying of exhaustion or capture myopathy.
- If a dart does not function properly or is incorrectly loaded, or if only a small portion of the drug is injected or the dose is inadequate, the animal can exhaust itself by running too far. This can lead to capture myopathy. The immobilizing drug is then often erroneously blamed.
- The tracking of immobilized animals in dense bush or rocky areas may damage the retrieval vehicles. It can also result in the immobilized animal not being reached in time.
- When the animal cannot be darted from the ground or from a vehicle, a helicopter has to be used. This can be expensive.
- The best capture equipment and immobilizing drugs available on the market are imported and therefore expensive.
- Some drugs may have adverse and untreatable effects or side-effects on an animal.
- Most of the immobilizing drugs are safe if used correctly, but animals can die from overdoses if the correct antidotes or other life-saving respiratory and cardiac stimulants are not available and administered.

According to Bothma (2010), the two terms immobilization and tranquilization are often confused. Immobilization occurs when the animal that has been drugged is brought to a standstill, is unaware of its surroundings and is usually anaesthetized. The voluntary muscles of the animal are immobilized. The animal usually lies down, can be handled easily and without danger, and feels no pain (Hirst, 1996). Tranquilization occurs when an animal is aware of its surroundings, but does not appear to mind where it is, even if in a strange and unfamiliar place. The animal can usually stand, but it may also lie down. However, it cannot be handled easily and reacts to stimuli such as pain or noises.

Tranquilizers modify the behaviour of the animal, and tranquilized animals often lose their fear of humans. They may also lose their aggression. High doses or an overdose of a tranquilizer may act as a sedative and cause the animal to fall asleep. Excessive doses of some tranquilizers have a cataleptic or stiffening effect on the body, so that the animal remains immobile and in a fixed position for several hours. When this condition persists, the animal does not eat or drink and it may eventually die of starvation or dehydration (Openshaw, 1993).

Tranquilizers are used primarily for the relief of anxiety and fear, and the decrease of motor activity. They are usually mixed with immobilizing drugs for the capture of most types of animals. The combined effect of these drugs is more powerful than that of any one alone and consequently enhances immobilization and improves muscle relaxation. Tranquilizers must be used in combination with the immobilizers M-99, Fentanyl and A3080 for immobilizing animals such as the eland, greater kudu, nyala, waterbuck and gemsbok, because these animals become excited before immobilization is effective (Langman, 1973). Tranquilizers will also help to prevent unnecessary struggling, shock and anxiety. Moreover, they keep the animal calm after the effects of the immobilizing drugs have been reversed (Hirst, 1996).

In Southern Africa, doses for chemical immobilization of healthy wild animals, such as giraffes, with M-99 are 8-12 mg of M-99, (fentanyl is not recommended) and 60-80 mg of the tranquilizer azaperone are recommended (Morkel, 1992). 16-24 mg doses of antidote M-5050 are also recommended for giraffes. Another option for immobilizing drug and tranquilizer is 12 mg of A3080 and 100 mg azaperone (Burroughs, 1993).

Narcotics, or dissociative anaesthetics, are usually combined with a sedative or tranquilizer. Narcotics that are used alone often cause muscular tremors, while the cyclohexylamine dissociative anaesthetics often produce a state of excitement or convulsions. Although the use of each drug is next described separately, combinations of drugs should always be used in practice. The following are the main types of drugs:

- Etorphine (M-99) (Novartis), A3080 (Wildlife Pharmaceuticals) or carfentanyl (Janssen Pharmaceutica) usually used either with xylazine (V-tech), detomidine (V-tech) or azaperone (V-tech)stresnil (Janssen Pharmaceutica)
- Anaket (Bayer) or ketamine (V-tech) usually used with xylazine (V-the), Demosedan (Pfizer)/detomidine (V-tech) or Domitor (Pfizer)/ medetomidine (V-tech)
- Zoletil (Virbac) which is a combination of the dissociative anaesthetic tiletamine with the sedative zolazepam.

According to Burroughs (1993) and Bothma (2010), etorphine hydrochloride (M-99) (Novartis) has a wide therapeutic index rendering the accidental overdosing of animals less likely. The drug can be reversed quickly and effectively should complications occur or when crating is complete. This is an important consideration when releasing free-ranging animals back into the wild. The drug is rapidly absorbed into the system and produces quick anaesthesia. Where good deep muscular injection is achieved, the knockdown time is usually seven to ten minutes. This can, however, extend to 13 to 15 minutes when the drug induction has been poor, for example as a result of a poorly placed dart that injected the drug subcutaneously or near a bone.

According to Langman (1973), experience has shown repeatedly that darts that are placed into the shoulder muscles provide for quicker knockdown times than those placed in the rump muscles. Where a major blood vessel is struck, for example near the base of the tail, knockdown times are reduced to two minutes. Mixing the drug with Hyalase (Merck Gen), an enzyme that is available in powder form in vials of 2 000 to 5 000 international units (IU), considerably accelerates the absorption of the drug in the muscle and reduces the knockdown times to three to six minutes. The mixture is perfect for capture situations requiring rapid knockdown times, and is the ideal answer for the giraffe. Upon reversing the drugs intravenously, the time from the reversal drug injection to the animal standing up is generally two minutes, with possible extension to eight minutes when it is administered by deep muscular injection. Generally the reversal drug of choice is diprenorphine (M-5050) (Novartis), although naltrexone (V-tech) is longer acting.

According to Burroughs (1993) and Bothma (2010), A3080 (Wildlife Pharmaceuticals) as narcotic has shown promise particularly for the excitable types of herbivores such as the nyala, eland, giraffe and waterbuck, where the known reaction times with A3080 generally have been reported to be less than three minutes. The drug is approximately half to three-quarters the strength of M-99 and is also reversed using M-5050 or naltrex-one (V-tech) (Morkel, 1992). The dosage rates that are used differ much, even between experts, each finding their own comfortable margins. The dosage rates that appear in most capture publications tend to be nearer to the upper limits of tolerance. Rather determine the general requirement for the type of animal in question, which can then be marginally increased or decreased depending upon the situation at hand. However, it is best to reach an operating situation in which the dosage rates are kept simple and with little variation.

Handling immobilized animals should be under the expert care of an experienced wildlife veterinarian (Openshaw, 1993, SABS 0331). The veterinarian is able to monitor the whole immobilization process and will know what to do should something go wrong. Ruminants must always lie on their sternums, with their legs folded under their bodies in a resting position and their heads and necks held higher than their chest to avoid bloat (Langman, 1973). The head of the animal must be held upright, and usually one person is needed just for this task. The mouth must be lower than the rest of the head so that any excess saliva can drain away, because the animal cannot swallow when it is immobilized. Immobilized animals should never lie in the sun for too long. When it is hot, shade should be provided for the animal (Hirst, 1996).

Some animals do not close their eyes and cannot blink when they are immobilized. Their eyes must therefore be protected against the sun and wind by tying a dark, soft blindfold over them. This keeps the dust out and prevents damage to the cornea (Openshaw, 1993). Animals can hear well while they are immobilized and therefore it is advisable to make as little noise as possible around any immobilized animal (Langman, 1973).

10.2.2.4. Translocation

Giraffes may only be transported in purpose made vehicles and trailers in accordance with SANS 10331 specifications (SABS 0331). The information concerning the specifications can

be acquired from each province's nature conservation office. According to DETEA new laws will be released at the end of 2015 with detailed regulations for transporting each species.

Currently, regulations for the transport of wild animals say: Legally captured "common" game may be transported if the person transporting them is in possession of a valid transport, export, import or game trader permit or a letter from the owner of the land in the case of ordinary game being transported within the province.

It is essential that special crates designed for transportation are used when transporting giraffes, and the animals should only be transported by competent and experienced people. 2.40 square metres is the approximate floor space per adult giraffe when loaded into a mass crate and transported over short distances and 5 giraffes per crate is recommended (Bothma, 2010). Tranquilized animals must not be mixed with non-tranquilized ones. A short-acting tranquilizer is recommended for transporting giraffes that have been captured recently. This relieves stress and reduces aggression and fighting during transport. If animals are to be confined in pens or bomas at their destination, the injection of long-acting tranquilizers should be considered to make their adaptation to captivity less stressful (Bothma, 2010). A competent veterinarian with some knowledge of tranquilizers and their effect on giraffes should administer the tranquilizers.

When transporting giraffes, 10 – 20 mg of short-acting haloperidol is the recommended maximum dose of tranquilizer to be used (10 mg for females and 20 mg for males). 100 mg of long acting perphenazine enanthate is recommended as the maximum dose for female giraffes and 150 mg for male giraffes. All giraffes coming into or leaving a province require a transport permit provided by the nature conservation office for that province.

10.2.2.5. Nutrition / supplementary feeding

On game reserves and game ranches that are stocked with several herbivore species, information on the quality of forage available for each species will greatly aid management decisions (Erasmus *et al.,* 1978). An important component of wildlife management is the monitoring of the nutritional status, as this is related to their productivity, survival and fertility (Wrench *et al*., 1997). Giraffes in their unrestrained natural environment have little need for supplementary feeding, as their free ranging habits enable them to pursue more nutritious browsing and therefore satisfy their requirements. With the advent of game ranches and reserves with fences, giraffes are confined to limited areas, and this creates some form of need for supplementary feeding. If for instance there is a lack of sufficient browse, the manager needs to supply feed to meet the giraffes' requirements. According to Kok & Opperman (1980), due to a relative food shortage during the dry season, giraffes were forced to utilize other food reserves which were normally not eaten on a large scale. During this season, giraffes moved from the lower-lying plains to the hills and ravine thickets. The critical periods for giraffe feeding in the central Free State were during the late dry and early wet seasons, namely August to October, and not the whole dry season.

Supplementary feed for giraffes (under normal conditions) to augment nutritional deficiencies, was viewed by Oates (1971) as undesirable. Supplementation suggests that the habitat does not comply with the feeding requirements of the giraffe. Such a habitat is viewed as unsuitable for giraffes (Oates, 1971). Suitable habitats are therefore determined at

the end of the dry season, based on their food availability during the critical period. The quantity of food depends on the available leaf material for browsing, tree density and the presence of other browsers (Oates, 1969). According to Furstenburg (1991) and Skinner & Smithers (1990), giraffes had a predilection for salt licks, but were dependent on other game species to break it up.

Giraffes are considered to be selectors of juicy, concentrated herbage and are characterized by small stomachs normally filled to only 50-60% of their capacity, but with concentrated food composed mostly of leaves, flowers and fruits of forbs, shrubs and trees (Hofmann, 1973).

Free ranging wildlife may expend 25 -100% more energy than confined animals (Holleman *et al*., 1979); thus the daily requirements may differ for animals in fenced off areas. Browsers such as giraffes may require higher levels of protein (14-16%) for maintenance, but during growing phases and during lactation up to 18% more (Meissner, 1982). Fowler (1978) said the diet of an adult non-lactating giraffe should contain 15%-18% crude protein and growing calves and lactating females should receive 18%-20% protein.

It was found in the Hans Merensky Nature Reserve that an adult giraffe need 6.148 kg dry material per day (Oates, 1971) and that, during the critical five months (May – September), it would need 922 kg dry material to survive, but from plant surveys they determined there was only 10 700kg of dry material available that could sustain only 11.6 giraffes (Oates, 1971). Fowler (1978) found giraffe food consumption varied between 1% and 2% of its body weight per day, depending on age, activity, climate and reproductive status.

One way of measuring whether the nutritional requirements are being supplied for mammalian herbivores is by measuring the nitrogen levels in faeces (Leslie *et al.,* 2008). It has been well documented as an indicator of the nutritional status of kudus (Van der Waal *et al.,* 2003) and can be used effectively for giraffes in semi-arid savanna areas. Faecal nitrogen concentration has been promoted as a non-destructive, inexpensive indicator of diet quality of ungulates in southern Africa (Erasmus *et al.,* 1978; Buys, 1990; Grant *et al*., 1995; Wrench *et al*., 1996). This is important since, in certain areas and at certain times of the year shortages occur, with nitrogen being the most limiting nutrient in winter (dry season) in Africa (Van Soest, 1994; Wrench *et al.,* 1997; Jacobs, 2005).

In KKNR the high percentage occurrence of osteophagia indicates high levels of nutritional stress. Currently, giraffes are showing the need for supplementary feeding and the recovery of nutritional woody species in treated areas could solve the problem. If large percentages of poorly treated areas can be recovered, it will surely bring back nutritional qualities that giraffes desperately need during critical periods in the dry months. If poorly treated areas are recovered, the total above ground biomass and consumable material available might increase and possibly stabilize the decreasing giraffe population. For the moment and until these areas recover, it is strongly advised that KKNR should follow the example of the Free State Nature Conservation (DETEA, 2013) that in areas where food shortages occurred (Willem Pretorius Nature Reserve and Maria Moroko Nature Reserve) one of two options should be implemented, namely:, either bring down population numbers or provide supplemental foliage such as lucerne, balanced game pellets and a suitable salt lick during the dry season. In the latter case, special feeding troughs would have to be erected for this purpose, to prevent the other game from eating it.

10.2.3. Combining research with management

Conservation achieves its highest level of success when research results and management applications complement each other (Sands *et al.,* 2012). The research done within KKNR based on measuring the natural resources available to giraffes implies the necessity of managing those resources through the scientific process. This is an opportunity to improve the relationship and interaction between management and research. If this can be achieved it will enable us to achieve critical conservation goals for the survival of giraffes as a species.

According to Sands *et al.* (2012), unfortunately, there appears never to have been a strong relationship between wildlife management and research, even if the profession has striven to link the two. Wildlife managers manipulate systems to achieve a management objective rather than to find out how the system works and wildlife researchers try to generate knowledge to be used as a guide to support management. However, as countries, habitats and landscapes become more fragmented and wildlife species become pressurized to survive on limited resources, wildlife managers and researchers will have to work together on complex and dynamic problems in the long run. We (including biologists, researchers, conservationists and all role-players regarding giraffes) need to start thinking outside the box and leave emotional decisions behind, as this time around saving giraffes from extinction might just be our last chance to get it right.

Charismatic megafauna such as elephants, rhinos and giraffes often represent flagship species for the conservation movement and the same methods (including lethal ones: hunting & culling and non-lethal: fencing & translocation) used in the past to depress their numbers are now being used to conserve them (Reindinger & Miller, 2013). How do we save wildlife from extinction if habitat fragmentation is not managed by specialists and practitioners who understand conservation, and if public policies are not forward-looking and conservation-oriented legislators are not involved? One example is the remarkable restoration programs that initiated the recovery of many game species and conservation areas paid for by funds provided by recreational and sport hunting (VerCauteren, 2003). Hunting in South Africa saved the rhino from extinction (see Appendix O) and could this be an option to save more wildlife species in Africa? Much debate and controversy follow this topic; however, hunting contributes largely to the success of species richness through ownership and management of wildlife by both consumptive and non-consumptive ways in South Africa. KKNR is no different and resources within the reserve need to be managed by keeping wildlife numbers below the carrying capacity through sales or translocation or hunting the surplus numbers annually, including giraffes.

10.2.4. Expert system

The need to create the expert system derived from previous research and expert knowledge from arid wildlife management systems to aid in decision making in favour of both the giraffe and its environment. The objective of such an expert system is to use the information derived from this research project in combination with information from the literature to aid with decisions specifically regarding giraffe management within arid regions. The current success and increase of wildlife numbers (WRSA) from the wildlife industry and giraffe

management at Provincial and National level aim to provide answers that can possibly be adapted throughout Africa. The expert system should make any future decisions regarding the keeping and the management of giraffes easier, as it is based on scientific information.

The development of this expert system is an ongoing process and will need much more information and research before it can be used as a final document. The expert system emphasizes the management of giraffes and is divided into three forms of decisions: adaptive, reactive and on-going good management. Adaptive decisions are mostly related to periods of protracted low rainfall and drought periods. Key strategies regarding key elements influencing giraffe management are discussed, and ideas are created regarding decisions for the wellbeing of both the giraffe as a species and the habitat they prefer as part of the wider ecosystem.

Ten question proposal as an expert system for keeping giraffes (ongoing draft)

Question 1: What size is the fenced area/reserve?

1. >6 000 ha: Go to question 3
2. <6 000 ha: Go to question 2

Question 2: Is the average rainfall <500 mm

Yes: Decision 1

No: Question 3

Decision 1: It is advisable not to keep more than six giraffes on less than 6 000 ha when the rainfall is below 500 mm. When the rainfall is more than 500 mm giraffes can be kept on areas below 6 000 ha in size. When the rainfall is >500 mm, habitat suitability and other factors should be investigated to determine if more giraffes will have sufficient foliage during the critical period. KKNR has 870 ha/giraffe and the population is decreasing. If KKNR can allow 1 000 ha/giraffe and recover poorly treated areas, then possibly population numbers will increase.

Question 3: Does the area have on average <700 woody plants/ha?

Yes: Decision 2

No: Question 4

Decision 2: If the area has on average less than 700 woody plants/ha (edible tree species such as *A. erioloba, A mucronata, Z. mucronata* and *B. albitrunca*), then it is advisable not to keep more than six giraffes for that area. When the area has more than 700 plants/ha, it should preferably not exceed 1 100 plants/ha which will also not be favoured by giraffes.

Question 4: What is the average height of the trees present?

1. ≥3m: Go to question 5
2. ≤3m: Decision 3

Decision 3: The preferred feeding level for a female giraffe is three metres and above and for male giraffes four metres and above. When foliage is below three metres it is not advisable to keep giraffes.

Question 5: Has a habitat evaluation been done?

Yes: Question 6

No: Decision 4

Decision 4: It is advisable to let an expert ecologist or nature conservation official do a habitat analysis before proceeding with arrangements to keep giraffes. Untreated and dense *A. mellifera* areas are just as much avoided as poorly treated areas with unsuitable *G. flava* as replacement species. A habitat analysis will determine both.

Question 6: Is the total annual dry material production more than 2 847 kg DM ha^{-1} (including leaf and shoot mass) (determined by the BECVOL method in chapter 6)?

Yes: Question 7

No: Decision 5

Decision 5: If there is not an average of 2 847 kg DM ha^{-1} production available annually, it is not advisable to keep giraffes in high numbers. 2 847kg DM ha^{-1} was the production within the highly preferred areas, preferred by giraffes in KKNR. The critical period (July – October) will determine the carrying capacity. Otherwise the natural vegetation would not be able to sustain giraffes sufficiently and supplementary feeding needs to be added and provided during the critical periods.

Question 7: Is there a variety of edible plant species, including evergreen and deciduous trees?

Yes: Question 8

No: Decision 6

Decision 6: If there is an insufficient variety of edible tree species, this might be a problem for keeping giraffes. The bigger the variety of trees, the more easily the giraffes can vary their diet over seasons. It is therefore also crucial that there are sufficient evergreen trees, as the giraffes will rely on them during the critical periods. Supplementary feeding should be considered if the habitat cannot provide sufficient browse, and if this is the case, it is advisable not to keep giraffes.

Question 8: Is there open/natural water available for giraffes to drink?

Yes: Question 9

No: Decision 7

Decision 7: Giraffes prefer to drink during daytime at natural watering points every 2/3 days in the summer months, and every 4/5 days during the winter months. It is advisable to have more than one water point to distribute herds evenly and to limit habitat destruction around water points. Water can be effectively used to stimulate giraffe movements to new or underutilized areas.

Question 9: Are there any bush cleared areas or arboricide treated areas?

Yes: Decision 8

No: Question 10

Decision 8: Before keeping giraffes, the range of the treated areas should be determined and the percentage recovery. Giraffes will preferably avoid poorly treated areas, but also too dense untreated areas.

Question 10: To what extend will management be involved?

Intensive: Get expert advice on fences, diseases, nutrition, monitoring etc.

Extensive: Then the carrying capacity should be determined and management principles should include annual monitoring for both the game species and the habitat available.

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CHAPTER 11: GENERAL CONCLUSION

11.1. Introduction

This study set out to explore the diet selection, habitat preferences and spatial ecology of giraffes in the Kalahari region of South Africa. Further objectives of the study were to assess the impact of the reintroduction of giraffes on the habitat, particularly on the critical resource areas and also to assess the influence of the habitat on the giraffes.

Finding and then regulating an equilibrium with respect to giraffe numbers depends on the availability of browse and the numbers of other herbivores within the fenced boundaries of the reserve. In the KKNR giraffe numbers were in decline at the time of the study. The reason for this is largely unknown and guidelines for the active management of the resources and the giraffe population were lacking. A big concern is that there are no regulations or guidelines set for minimum habitat requirements for giraffes, and currently the literature on the subject is lacking specific scientific information for managing giraffe populations nationally and specifically in arid regions such as the Kalahari. In most other studies the focus was mainly on specific aspects of the giraffe as a species. However, this study attempted a holistic approach that included the environment as well as the giraffe with the outcome contributing to science and the practical management of the species.

The first objective of this research project was to design and develop efficient and safe GPS collars for giraffes with the objective of assessing the following:

i. The habitat selection and spatial ecology of giraffes relative to seasonal effects.
ii. The habitat selection and spatial ecology of giraffes relative to the influence of habitat resources (browse and water) and plant species composition.
iii. Diet selection of giraffes in relation to browse availability.
iv. Daily activities of giraffes in terms of feeding and non-feeding activity budgets.
v. The final objective of the study was to assist with management of giraffes in arid regions to ensure the sustainability of populations and to aid in making future decisions to benefit both the giraffes and the environment.

11.2. Empirical Findings

The main empirical findings are chapter specific and were summarized within the respective chapters, namely: chapter 4 - Development and testing of custom made GPS collars for giraffes; chapter 5 - Spatial ecology and home range patterns of the giraffe; chapter 6 - The impact on the vegetation of utilization by giraffes; chapter 7 - Giraffe diet selection and feeding preferences determined by field observations; chapter 8 - Feeding height preferences of giraffes in relation to interspecific competition; chapter 9 - Daily activity budgets of giraffes; chapter 10 - Management tools for giraffes. This section synthesizes the empirical findings to answer the study's objectives.

11.2.1. Designing and developing functional and safe GPS collars for giraffes

The results of this study demonstrated that the head harness collar can be fitted effectively on giraffes (with the necessary planning) and can be very valuable for monitoring giraffe activities. The data supplied by the collars showed how biologists can gain a better understanding of the spatio-temporal use of habitat by giraffes and how interactions between different giraffe herds can be studied.

The main advantage of using the GPS collars was the effective location of the animals at any time, resulting in less labour-intensive fieldwork, higher position accuracy, the collection of data in the winter and at night, better control of sampling schedules and fewer disturbances to the animals. Another advantage demonstrated was the ability of the collar to create opportunities to address biological questions that could never previously have been answered for giraffes, such as the accuracy of location, precise home range, altitude, temperature and distances travelled.

11.2.2. Assessing the habitat selection and spatial ecology of giraffes relative to seasonal effects

The use of the GPS collars fitted on female giraffes proved to be invaluable in the study of daily movements and long term spatial patterns of the giraffe herds. Without the aid of the GPS collars it would have been impossible to identify accurately which areas giraffes preferred and which were avoided. This accuracy eliminated human subjectivity which could be a problem if relying on only visual monitoring of habitat preferences of giraffes.

From the study it was concluded that daily temperature did not have a significant ($P>0.05$) influence on average daily distances travelled. However, in summer, the giraffes preferred to travel during the cooler hours of the day, and during winter they travelled more during the warmer hours. Seasonal temperature changes did have an influence on giraffe movements, i.e. on the average seasonal distances travelled by the giraffes. In the colder months giraffes moved on average faster and longer distances than during the warmer months.

Day- and night-time travelling differed significantly ($P<0.05$) and it was found that giraffes were more active and moved faster and longer distances during the day than at night. Rain

also had an influence on giraffe spatial distribution – the average daily distance moved and speed of movement of giraffes increased with an increase in rainfall.

Different vegetation types had an influence on the home ranges of the giraffes, which was also significantly ($P<0.05$) influenced by seasons. The giraffes increased their home range during the critical periods (dry months, July to October) and home range overlap of the collared females was observed during different seasons. The GPS collars provided information on how much time each collared giraffe spent in the different vegetation types and how frequently these vegetation types were visited. The GPS location results clearly identified how giraffes avoided arboricide treated areas that had recovered poorly, but also untreated areas subject to bush encroachment. Giraffes were more habitat-selective during critical dry periods, which resulted in an increase in home range. This increase was directly related to seasonal changes in vegetation, phenology, rainfall patterns and recovery of areas from past poor management.

The average daily movement was 5.1 km (calculated from the average of the eight collared females; highest 6.6 km, lowest 4.2 km). Most females travelled for longer hours and distances during the winter months compared to other seasons. This study found a seasonal increase of average distances moved, with the lowest in autumn (5.05 km/day), summer (5.1 km/day), spring (5.2 km/day) and the highest in winter (5.75 km/day). The eight giraffes moved at an average speed of 0.21 km/h.

Results indicate that the time of day during which giraffes travel plays an 87.5% significant ($P<0.05$) role in daily distances, demonstrating that they travel only at certain times of the day. Time x season interactions showed that giraffes travel the longest distances in summer mornings and least in the afternoons, but the opposite during the winter. Results also indicated that the least travelling occurred during the morning hours in the winter.

Giraffes in the Kalahari region needed an average home range of 206.0 km² (20 602 ha) to find sufficient forage to sustain their daily requirements. In the wet, hot season (summer) when food was abundant, giraffes frequented smaller areas (average 177 km²), while in the dry, cool season (winter) they needed to extend their home range (average 245 km²) to fulfil their daily needs.

11.2.3. Assessing the habitat selection and spatial ecology of giraffes relative to the abundance of habitat resources (browse and water) and plant species composition

Ultimately, resource availability will determine the distribution and success of giraffes in a fenced area. The spatial distribution of giraffes was successfully employed to identify preferred areas for purposes of vegetation surveys. These areas had certain habitat characteristics which giraffes favoured, such as an abundance of, woody tree species. Giraffes in the KKNR preferred tree densities of 744 to 1 084 plants/ha^{-1}, combined with a high (>5 600) Total Evapotranspiration Tree Equivalent (ETTE ha^{-1}), where they can select very specific woody species to browse.

Preferred food species in abundance, as well as their principal food species, were essential for the success of the giraffe population. Giraffes rely on key plant species for their main diet.

They preferred areas with *B. albitrunca* and *Z. mucronata*, but were more influenced by the browsing capacity of an area with an abundance of *A. erioloba*. What influences the calculation of browsing capacity for giraffes is the acceptability of the available plant species, the habitat type, the height distribution of the browse material and seasonal variations in availability of browse. The lack of woody species diversity resulted in lower dry matter (kg DM $^{-1}$) preferred by giraffes, which may directly influence their survival and reproduction.

Giraffes were further influenced by the seasonal cycle of tree phenology and this will influence the utilization factor for trees. Results demonstrated that giraffes experienced difficulty finding preferred browse material during the critical dry period from July – October and they increase their home range in response. The giraffe population in general is influenced by the browsing capacity within a fenced area due to the competition with other browsers for the same resources, because of the deciduous nature of woody plants in arid regions. During this time (July – October), areas that can be described as "critical resource areas", such as *B. Albitrunca*-abundant areas, had a significant (P<).05) role in the survival of giraffes during this pre-season dry period.

Giraffes clearly favoured areas (53% of all locations) that were selectively treated (more than 13 years ago) with arboricides, which had recovered very well, but they avoided untreated areas (underutilizing these areas by 62% compared to availability). Giraffes avoided poorly recovered areas (underutilizing these areas by 233% compared to availability), indicating that they can select for or avoid certain habitat types. Poorly treated areas are one of the main reasons why giraffes need to increase their habitat to maintain their daily requirements during the critical dry period.

Giraffes also favour areas with high shoot availability (<2.0 mm) within the high preference areas (1 545 kg ha^{-1}), which is two times more than in the low preference areas (873 kg ha^{-1}), indicating that this is one of the main attractions influencing habitat selection other than tree species.

The results indicate that browsers feeding below 2.0 m will experience difficulty finding browsing forage material during the critical period from July – October and during this period at this feeding stratum the reserve is 20% overstocked (if only relying on woody species for food). From the results, there are 1 070 more browsers than the KKNR fenced area can sustain on height strata up to 2.0 m. However, having a mixed diet and utilizing herbs and plants from the herbaceous layers, contribute to the survival of browsers other than giraffes.

Two of the main concerns for the wellbeing of giraffes in KKNR are the small variety of preferred tree species (a) available for browsing and (b) available during critical dry periods, thus adding to nutritional stress. Assessing the diet selection of giraffes in relation to browse availability.

11.2.4. Assessing the diet selection of giraffes in relation to browse availability

It was found that browsing/feeding is undoubtedly the most important activity performed by giraffes, during the day. Giraffe diet varied over months and seasons, and each season had a significant effect on the preferred tree species, as well as on giraffe diet.

The giraffes spent more time on browsing and seeking foliage during the dry months than during the wet season. *A. erioloba, Z. mucronata, B. albitrunca* and *Acacia mellifera* were the tree species mostly preferred in the majority of giraffe diet, and are considered to be critical resource species, especially the evergreen *B. albitrunca*.

The season determines how giraffe diet varies and what type of foliage is available. Giraffes also showed a feeding level preference for certain woody species. For instance, 99% of female feeding occurred ≥3.0 m on *A. erioloba*, 89% occurred ≥3.0 m on *A. mellifera*, 70% occurred ≥3.0 m on *Z. mucronata* and 90% occurred >3.0 m on *B. albitrunca*. But for "*other species*" 69% of feeding occurred ≤1.0 m, possibly because of the growth form and size of the "*other species*" such as *A. hebeclada, Rhigozum brevispinosum, Diospyros lycioides* and *Lycium cinereum* which are mostly shrubs.

Giraffe feeding level preferences showed the same trend for males and females when the body posture is taken into consideration. However, the extra height of male giraffes resulted in differences, with males, on average, feeding 1.0 – 1.5 m higher than females. For instance, 94% of male feeding occurred ≥4.0 m on *A. erioloba*, 90% occurred ≥4.0 m on *A. mellifera*, 92% occurred ≥4.0 m on *Z. mucronata* and 95% occurred >4.0 m on *B. albitrunca.*

Seasonal variation in terms of preferred feeding levels also occurred. The largest differences were between spring and autumn seasons. For instance, feeding level one (0.0 m – 1.0 m) became more prominent during the autumn (wet and cool) season and less so during the spring (dry and hot) season. Level two (1.0 m - 2.0 m) was also more prominent during the summer (wet and hot) and autumn seasons than during the spring, indicating that females were selecting foliage at lower levels more often during the critical dry period (autumn) than during the summer and spring., Alternatively, they might be selecting a greater variety of food.

Male giraffes were feeding on higher levels during the dry season compared to the wet season. Dry season months (July to October) were considered the period of highest food scarcity and by feeding on higher levels they create less inter- and intra-specific competition and utilize resources that were under-utilized during the other months.

Male and female giraffes were browsing on levels that largely excluded direct competition from other browsers (>2.0 m), especially during the dry season. Only 7% of all female feeding occurred below 2.0 m and only 19% of all male feeding occurred below 4.0 m. This explains why adult giraffes mostly feed on trees that are above the average height of other browsers and by doing that they avoid competition by utilizing bigger trees.

When all activities relating to browsing (browse and ruminate) are excluded from daily activity budgets, then an average of 39% of time spent was related to non-feeding activities. There were differences between sex and age groups with female 36%, male 44%, sub-adult male 54%, sub-adult female 34% and juvenile 51% devoted to non-feeding activities. Bulls lie down more than females, and sub-adult animals lie down more than adults and juveniles. Walking was the second highest activity performed by all giraffes, followed by standing-while-ruminating and then looking around. This, however, varied over seasons. Looking around was the third highest activity performed by juveniles, which was more than for adults or sub-adults.

Osteophagia as an activity for all giraffes was prominent during the winter, indicating that the giraffes were in need of supplementary minerals during the dry season and that they were under nutritional stress. Nutritional stress is a potential reason for their declining numbers. Winter, when osteophagia was most common, is also the season when leaf senescence of the deciduous trees occurs and when the browsing capacity is the lowest. These are all indicators of the importance of having giraffe numbers in equilibrium with the environment. Osteophagia also creates favourable conditions for disease and may render giraffes more susceptible to pathogens.

11.2.5. Management tools for giraffes in arid regions

Developing management tools should assist in ensuring the sustainability of giraffe populations in future situations, which will be in the interests of both the giraffes and the environment. Conservation achieves its highest level of success when research results and management applications of these results intersect. The research done within KKNR, which involved assessment of the natural resources, implies that those resources should be well managed through the scientific process and that the importance of understanding and improving the relationship between management and research should be acknowledged. If this can be achieved it will be central to achieving conservation goals critical for the survival of the giraffe as a species.

The development of the expert system derived from previous research and knowledge from arid wildlife management systems should aid in decision making in favour of both the giraffe and its environment. However, the development of the expert system is an on-going process and will need more information and research before it can be used effectively. The expert system emphasizes the management of giraffes and is divided into three forms of decisions, namely: adaptive, reactive and on-going good management. Adaptive decisions are mostly related to periods of protracted low rainfall and drought. Strategies regarding key elements influencing giraffe management are discussed, and ideas are created regarding decisions for the wellbeing of both the giraffe as a species and the habitats they prefer.

Management should aim at finding the equilibrium for optimum habitat use without affecting the resources or the animals' condition. Despite the current lack of equilibrium in KKNR, animal numbers should be regulated in a density-dependent manner by the limited forage that is available in key resource areas, especially during droughts. Giraffes may not have an influence on the vegetation at all times, but they influence the key resources at critical points in the seasonal cycle. The results indicate there is a lack of variety of woody species, so the equilibrium can easily be upset, with negative consequences for the environment. For instance, if there is a food shortage created by the decline in preferred species, it may be detrimental to the giraffes in the long-term.

The primary consideration in arid lands is rainfall and the ability of the soil to retain moisture. In essence, arid rangeland management means learning to live with uncertain conditions created by nature. Management must plan in advance how best to apply ecological principles to achieve sustainability and how to adapt to episodic climatic events. It is a process of calculating probabilities and of acting on any advantageous windows of opportunity. The fluctuating climatic conditions of arid regions create episodic events that in

turn create an environment in which rainfall, and not forage availability, may ultimately be the variable that will be limiting to herbivore population growth. Therefore, planning for uncertainty in such a scenario is considered to be more realistic than the assumption of equilibrium, which may not be viable in an arid environment. Planning the carrying capacity during critical months is a basic management requirement for managing game species. Unfortunately, large areas of preferred woody species have been mismanaged in the past. Large scale herbicide application by previous landowners has resulted in a catastrophic decline in some woody species that are necessary for the maintenance of the giraffe population.

Although the application of arboricides led to an increase in grass production in the short term, it eventually led to total degradation of diverse and species rich ecosystems. In KKNR it resulted in a complete change in species composition and the undesirable dominance of unfavoured woody species such as *Grewia flava* and *Acacia mellifera,* which have become prominent in areas where large-scale tree removal has taken place and poor recovery followed after the unselective treatment. These areas were avoided by giraffes, as could be seen from the GPS location distributions.

Management should therefore focus on habitat recovery. Large areas typical of *Acacia erioloba* and *Boscia albitrunca* veld are still present, with higher species richness than in the poorly cleared areas. It is advisable for the survival of the remaining giraffes that permanent monitoring plots be placed within these variously affected areas to monitor the woody component as well as species composition.

It is suggested that a start should be made with active rehabilitation measures in poorly treated areas in KKNR, and not wait for natural recovery, because of the low rainfall and poor soil qualities. Introducing new recruitment (seedlings) should be successful and will aid in the early establishment of saplings.

In KKNR water distribution is not evenly dispersed within the vegetation units. Water should be distributed so that all the resources are evenly utilized and that over-utilization of critical resource areas will not occur. The incorrect location or placement of waterholes in KKNR has resulted in both over- and under-utilization of resource areas. This may lead to long-term management problems, such as the loss of preferred tree species and/or bush encroachment of unfavoured tree species.

The academic implications of this study need to be considered as an on-going process as new information becomes available. This project was aimed at developing new skills and techniques for research to address complex animal-environment interactions with applicability to other arid regions of southern Africa.

11.3. Research Implications

This study has used empirical findings to show that giraffe survival relies on human decisions. As soon as giraffes are fenced, the responsibility becomes that of human intervention where managers need to find ways to improve the quality of life for the animals, without over-utilizing the habitat.

Results emanating from this study show that not only KKNR management will benefit from information gained, but scientists also will be able to use this technology for giraffe populations across the continent to investigate population levels by conducting a proper evaluation of the habitat.

Combining research and management ideas will develop conservation management plans that will enable scientists to conduct future research and demonstrate that management options are determined by the intention to save giraffes from future mortalities.

11.4. Limitations and Recommendation for Future Research

This study has offered an evaluative perspective on an important species and was conducted in a remote environment. As a direct consequence of this methodology, the study encountered a number of limitations, which need to be considered. The first and probably the same for most research projects was funds. This project needed R700 000 (± $ 70 000) to be accomplished. These funds were raised with public interest and people with a generous heart for giraffes and conservation (see acknowledgements). Marketing and public relations took much time, as the project relied on these funds for its achievement. Acquiring and maintaining the eight GPS collars was the biggest expense, followed by fuel and operational costs. If more funds were available, then fieldwork could have been 24 months and not only 15 months, and 15-20 giraffes (including male and juvenile giraffes) could have been collared.

The second biggest challenge was the distance to the study area and its remoteness. The study area was almost 700 km from the University and 250 km from the nearest town, for purchasing fuel and groceries. A total of 30 900 km were travelled for the project to be completed, of that 17 400 km was travelled between the study area and the University, 9 200 km in the KKNR spending time with the giraffes, and 4 300 km doing plant monitoring and the tree phenology.

The third challenge was technology, as the study area initially had almost no cell phone cover, and to find the GPS locations for each giraffe herd relied on internet access. It was necessary to travel very long distances to get sufficient cell phone cover, sometimes even outside the reserve. As mentioned in chapter 5, not all the collars operated correctly, and the VHF telemetry also made it difficult to keep up with the giraffes.

The fourth big challenge was time, as it was very difficult to have a fulltime job lecturing, to be a husband and recently also to be a father. Fieldwork in total took two weeks each month for two years and that needed major planning and plenty of help and assistance to complete.

Regardless of the constraints, this project was worth every effort, every day and every hour. The passion for knowledge and the restless mind searching for answers to questions continually motivated me, in the end leaving me with more questions than answers, but definitely the need to continue research.

The process of how to achieve success by managing giraffe populations in such a way that numbers will increase is extensive and multifaceted. To generate achievable strategies and develop targets with regard to diversification, there is a need for more case studies on

giraffes to allow further assessment of management options. Exploring the following ideas as future research strategies can facilitate the attainment of this goal:

- Habitat fragmentation

More holistic research is needed that does not only focus on the animals, but also on suitable habitat conservation by determining precise habitat qualities. The assumption is made that the primary reason why giraffe numbers are decreasing is habitat fragmentation. Future research should focus much more on the habitat qualities, than the animals within the habitat.

- Genetic concerns/management

Minimum genetic populations for giraffes are a real concern, as inbreeding is considered one of the biggest reasons why giraffe populations are not increasing within fenced ecosystems. Among other things, inbreeding leads to the loss of genetic fitness, increased mortality in young animals, reduced fertility and depressed growth (inbreeding depression). The number of breeding animals present in the herd or social group is extremely important, because these breeding animals influence the effective population size and the rate of inbreeding in each generation. No research has been done on giraffe inbreeding and genetic diversity in game reserves and game ranches.

- Milk quality

If lactating females are provided with sufficient quality forage and there is no nutritional stress, then possibly more juvenile giraffes will survive to adulthood. The assumption is made that the main reason why few juveniles reach adulthood, is possibly because of poor milk quality from lactating females. Giraffe milk quality has never been tested in the wild on the same individuals during different seasons.

- Parasites

Game species constrained in fenced environments are more susceptible to parasite infestation than free roaming game. Parasites might have a major effect on impairing dry matter and nitrogen digestibility and parasites may also have a detrimental effect to deter browsing. Especially young giraffes may be affected the most, as they are feeding on lower levels that could possibly be contaminated by parasite larvae.

Future research should focus on giraffes that are under social, environmental or nutritional stress, which may succumb to parasite infestation. Faecal egg count should be conducted to establish the degree of parasite infestation. Parasites and pathogens have been well documented on giraffes in captivity, but little is known about giraffes in the wild. The concern is that giraffes in fenced areas are involuntarily being exposed to harmful organisms, and we don’t really know the extent of some of these diseases.

Future research in fenced areas should also investigate how giraffes are influenced by water quality, water salinity and suitability for animal use in general. Water quality may determine the success of adaptation of reintroduced animals, as well as the distribution within habitats.

Finally, the proposed expert system should be investigated and expanded throughout the country in different habitats with different rainfall patterns and environmental qualities. This

system should be used as a baseline study and should be implemented in other regions, where it can assist us to understand better the needs of giraffes.

There are many unanswered questions relating to the survival of giraffes as a flagship species, and this research provides the groundwork that will be the basis of future research to ensure the survival and growth of giraffe populations.

Every day I'm not in the field – I loose data!

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APPENDICES

Appendix A Ethical Clearance

Dec 2010 FORM

INTERFACULTY ANIMAL ETHICS COMMITTEE OF THE UFS

RESEARCH PROTOCOL FOR THE USE OF LIVE VERTEBRATES

FOR OFFICE USE ONLY	**ANIMAL EXPERIMENT NR.**
Date received:	Date to Control Committee:
Progress report:	Final report:

PLEASE COMPLETE AS COMPREHENSIVELY AS POSSIBLE, THUS EXPEDITING THE CONCLUSION HEREOF. COMPLETED DOCUMENTS MUST BE SUBMITTED TO THE ADMINISTRATION OFFICE OF THE INTERFACULTY ANIMAL ETHICS COMMITTEE, BLOCK D, ROOM 108, DEAN'S DIVISION, FRANCOIS RETIEF BUILDING, FACULTY OF HEALTH SCIENCES, UFS.

Project title: Understanding the spatial ecology of giraffes by testing a specially designed GPS collar transmitter for giraffes in a wildlife ranch - Preliminary Phase.

Study leader: Prof. Nico Smit
Project coordinator: Mr. Francois Deacon

Title: Mr.	**Initials:** F	**Surname:** Deacon
Department: Animal, Wildlife and Grassland Sciences		**Qualifications:** M.Sc.
Telephone (Home): 0847026202		**Telephone (Work):** 051-4013554
Registration Authority U.F.S.		**Registration number** 0854065

Collaborators:

NAME	DEPT	RESPONSIBILITIES	TEL	SIGNATURE
Dr Floris Coetzee	Private Veterinarian	Animal immobilisation and anaesthetics	0828291296	
Mr. Martin Haupt	Technician and designer of transmitter	Fitting the custom made collar	0123291788	Africa Wildlife Tracking 106 Nuffield Rietondale, 0084 Pretoria Gauteng South Africa Tel : +27 (12) 329 1788 Fax : +27 (12) 329 1784 E-mail : sales@awt.co.za VAT Reg. No. 4670197187 Reg. No. CK 99/60578/23

1. Type of research (Mark with an X)

(i) Basic research X

Contract research

Training

Background and objective: GPS tracking is used to study spatial patterns of wildlife under field conditions. This is the first study to use the latest satellite technology and GPS equipped collars to improve the scope and efficiency of field-based research, allowing the collection of the most comprehensive data on home ranges, seasonal movements, human/giraffe interaction zones, territory size and occupation, migration routes and duration of migration. The information gathered by this project may prove to be of considerable value in the wildlife industry. The game industry has grown significantly over the last decade. By advising game owners of the limitations and challenges of of stocking giraffes on their farms, possible unnecessary deaths of animals and much wasteful expenditure may be avoided. Nature conservation authorities can also use this information for proper planning and law enforcement in the wildlife industry and law enforcement agencies will be enabled to base decisions on the results of the research. The challenge will be to see whether the specially designed GPS collars will function correctly under field conditions, endure environmental factors and provide programmed data.

Testing GPS transmitter equipment on a giraffe:

Object: To test if a specially designed GPS collar for free-roaming giraffe will fit, be tolerated by the giraffe without affecting its eating, drinking and breathing abilities, work correctly, endure environmental factors and provide programmed data. Testing will include: whether the designed collar hinders or irritates the animal, whether chafing or rubbing occurs, and whether the animal experiences any limitations to its movements, feeding, drinking or social behaviour. These activities will be monitored through daily behaviour observations and scan sampling by following the animal in the veld at Woodland Hills Wildlife Estate for a period of one year. Mr. Martin Haupt from Africa Wildlife Tracking (AWT) is well-known and respected for the collaring of many herbivore and wildlife species. This, however, will be the first custom designed collar used on giraffes.

This preliminary study is also part of a bigger research proposal, where it is planned to fit four giraffes in the Khamab Kalahari Nature Reserve (KKNR) with this type of specially designed GPS collar (changes might be necessary after preliminary testing). If this preliminary testing of a GPS collar at Woodland Hills Wildlife Estate is successful and has a positive outcome, then we will apply for further funds and animal ethics approval to collar four giraffes in the KTP. The project proposal has already been approved by KKNR to study the spatial patterns, which has never been done before. Satellite tracking is proving to be an extremely valuable tool in the wildlife environment. The unit is based on a mobile global two-way communication platform, utilising two-way data satellite communication complete with GPS systems. This allows us to see if the specially designed GPS collars for free roaming giraffes will fit, function correctly, endure environmental factors and provide programmed data.

Satellite tracking allows us to track animals day and night, while we monitor their movements remotely from the computer. These systems allow efficient control and monitoring of wildlife in all weather conditions in near-to-real time. We can even communicate with the animals, call up their current position or change the tracking schedules.

The Aim is to test a custom-designed GPS collar on a giraffe in a wildlife estate near Bloemfontein.

Experimental animals required:

Species	**Phylum**	**Sex**	**Age/mass**	**Number**
Giraffe		Male	3 years (1 100kg)	01

Are the abovementioned animals available at the Animal Experimentation Unit?

YES	NO **X**

Drugs:

Drug/compound	**Route Dosage Frequency**
8 mg A30-80 (Phianil), 4 mg Etorphine (M99), 70 mg Azaperoon (Stressnil)	Twice: when fitting the collar on the giraffe and one year later to check for chafing,

	rubbing or irritation of the skin, and to remove the collar or replace the battery pack. However, if the need arises to remove, adjust or examine, the collar, an additional immobilisation may be required.
Dr Floris Coetzee will be the professional veterinarian, who has performed the immobilisation for the last two years for nature conservation and the private wildlife industry in the Free State.	

Legal regulations require that either a medical, or a dental practitioner, or a veterinarian should exercise control over the use of drugs.

Explanation of experimental design:

One 3-year old male giraffe from the Woodland Hills Wildlife Estate near Bloemfontein will be chemically immobilised (using wildlife anaesthetics) by a registered veterinarian. A custom designed collar with a GPS tracker will be fitted around the neck, using the harness to keep the device on the upper side of the neck. The behaviour of the animal, its mobility, and eating and drinking behaviour will be monitored initially twice daily (08h00 and 16h00) for two weeks. After the first month the giraffe will be observed and monitored once a week. The daily social roaming and feeding patterns and tracks will be monitored electronically over a period of one year. An extension for an additional year may be required.

Additional information:

*** Specifications of the collar: size, weight, fitment area on the neck, etc.**

The weight of the collar is 670 g. The three year old giraffe bull has a body weight of 1 100 kg. Therefore, the collar is less than 0.06% of the weight of the animal. The collar will be custom fitted and adjusted on the giraffe, on the neck, just below the head,, with a small harness anchored on the horns - preventing it from moving up and down the neck. The collar is designed by AWT (for more information on them visit: http://www.awt.co.za), who are probably the most experienced people in this field in southern Africa. Mr. Martin Haupt of AWT will fit and adjust the collar in the field.

*** Ensure that the collar will not interfere with normal behaviour**

Response: One of the objectives of the project is to evaluate the effect of the collar on the behaviour of the giraffe. For this purpose a relatively tame giraffe was selected, which can be closely observed for any change in behaviour or evident discomfort. Only if we are satisfied that the collar poses no problems for the anima,l will the collars be fitted on the main group of experimental animals in the KKNR.

*** Might the collar get hooked onto high branches, etc?**

Response: It is highly unlikely, but of course, it is just one of the many aspects that will be closely monitored.

*** What procedures are in place if the collar has a negative effect on the animal?**

Response: The giraffe will be closely observed daily and if any discomfort is observed, the collar will be removed by the same experienced team that fitted it.

*** Information regarding the anaesthetics monitoring procedure (since giraffe anaesthetics is a high risk procedure).**

Response: Because this is a highly specialised procedure, we acquired the services of a professional wildlife veterinarian. Dr. Floris Coetzee, a vet who has extensive experience of game capture, including giraffes, will conduct the capture operation and will administer the anaesthetic.

Duration of study: The maximum continuous period that will be allocated to the project is twelve months. Renewals, extensions and amendment of existing projects must be submitted for approval.

Date of commencement	**Date of completion**
03 June 2011	03 June 2012

The period any animal or treatment group will be subjected to the procedure.

Location: (Indicate the venue where this experimental/training procedure will be conducted.)
Woodland Hills Wildlife Estate, Bloemfontein.

After-care: Could normal veterinary services be utilised if you or your collaborators cannot be reached during an emergency? **Please note that the costs associated with this service will be for your own account.**

YES **X**	NO

May the personnel of the Animal Experimentation Unit administer analgesics if deemed necessary?

YES **X**	NO

a) Anaesthesia: 8 mg A30-80 (Phianil), 4 mg Etorphine (M99), 70 mg Azaparone (Stressnil)

b) Euthanasia: Please indicate the method of euthanasia that will be used on completion of your study or during your training experiment, e.g. CO_2 inhalation, i.v./i.p. injection of a recognised agent, cervical paratopia, exsanguination under anaesthetic. If an alternative method is used, please motivate in full the reason for using the method concerned.

n.a.

Researcher's own judgment of severity of the procedure: (Slight/Moderate/Severe)

Slight to moderate. Wildlife immobilisation is a routine procedure on game farms. It has its risks, but to a large extent it is a very safe procedure. We acknowledge the fact that the collar might cause some discomfort initially, but most animals get used to it within a few days and would be able to keep it on for months or years without major discomfort. The animal will not be harmed or in any pain, discomfort or distress with the tranquilizer shot from a distance. There is no surgical procedure or any physical injury done to the animal.

How hav the three R's (Replacement/Reduction/Refinement) been addressed?

Please indicate ownership of the animals concerned. Are all applicable permits (where necessary) available? Please attach.

YES **X**	NO

R1- Using a giraffe is essential to test a GPS collar specially designed for giraffes.

R2- Only one giraffe (animal) will be used for this preliminary study, aiming at testing the collar.

R3- This free roaming giraffe will be confined to a relatively small game farm to allow close supervision for this preliminary trial.

Ownership of animals:

The giraffe belongs to Mr. Pieter Malan, Woodland Hills Wildlife Estate, Bloemfontein.

Radio Isotopes: Does this study require the use of Radio Isotopes?

YES	NO **X**

If **YES,** the approval of the Radio Isotope Control Committee must be appended

Statement

I, the undersigned hereby certify that the conducting hereof will occur according to existing University regulations regarding the use of experimental animals, and that

I am appropriately qualified to conduct this study or to supervise the conducting thereof;

this study may result in the broadening of biological knowledge or is essential for the training of students;

this study is not a replication of similar research of which the results are known;

this study is designed in such a way that no animals are wasted;

this study is designed in such a way that the animal's discomfort, stress and anxiety are restricted to the absolute minimum.

all alternative methods have been investigated and it would be impossible to achieve the goal of this study without making use of experimental animals;

I am familiar with the regulations contained in the NATIONAL CODE FOR THE HANDLING OF ANIMALS FOR RESEARCH, TRAINING, DIAGNOSIS AND TESTING OF AGENTS AND RELATED SUBSTANCES IN SOUTH AFRICA. (Available at the Administration office of the Interfaculty Animal Ethics Committee of the UFS, Block D, Room 108, Francois Retief Building, Faculty of Health Sciences).

I will comply with any restrictions or changes recommended by the Control Committee for Animal Experimentation with regard to this study;

I undertake to report in writing to this body on a regular basis, as recommended by the Interfaculty Animal Ethics Committee of the UFS, with regard to the progress that has been made with this project, and furthermore that on completion of this study I will without delay provide the committee with copies of all publications proceeding from this study; and

if according to the personnel of the Experimental Animal Unit any animal involved in this study has endured unnecessary pain and they have been unable to reach me telephonically, or if I am unable to react to their call immediately, they hereby receive my authorisation to terminate the life of the animal(s) concerned as soon as possible and in an humane manner. (**NB. In such a case only one telephone call will be made to your office and if you fail to act within 1 hour of the call, the life of the animal(s) will be terminated).**

_____ _____

SIGNATURE OF APPLICANT **DATE**

_____ _____

SIGNATURE OF HEAD OF DEPARTMENT **DATE**

INTERFACULTY ANIMAL ETHICS COMMITTEE OF THE UFS

ANIMAL EXPERIMENT NR:.....

Name of applicant:.....

Department:.....

Project title:.....

.....

.....

Classification of study:

Research ☐

Contract research ☐

Training ☐

ANIMAL SPECIES	NUMBER	EXPIRY DATE

....

CHAIRMAN: **DATE**

INTERFACULTY ANIMAL ETHICS COMMITTEE OF THE UFS

INFORMATION: BEFORE ANIMALS WILL BE SUPPLIED TO HIM/HER THE RESEARCHER MUST PROVIDE THE ANIMAL EXPERIMENTATION UNIT WITH A COPY OF THIS. PLEASE STATE THE ABOVEMENTIONED NUMBER IN ALL CORRESPONDENCE AND ENSURE THAT THIS IS FILLED IN ON THE INTERNAL ORDER FORM WHENEVER ANIMALS ARE REQUESTED FOR THIS SPECIFIC PROJECT. PLEASE NOTE THAT THIS APPROVAL IS ONLY VALID FOR A LIMITED PERIOD. IN THE CASE OF ANY EXTENSION OF OR AMENDMENT TO THIS STUDY, AS EXPLAINED IN YOUR APPLICATION, THE RENEWAL OR AMENDMENT FORM HAS TO BE COMPLETED AND SUBMITTED TO THE ADMINISTRATION OFFICE OF THE INTERFACULTY ANIMAL ETHICS COMMITTEE OF THE UFS, BLOCK D, ROOM 108, FRANCOIS RETIEF BUILDING, DEAN'S DIVISION, FACULTY OF HEALTH SCIENCES. FAILURE TO COMPLY WITH THE GUIDELINES OUTLINED ABOVE WILL RESULT IN THE SUMMARY SUSPENSION OF THIS PROJECT.

NSPCA: RESEARCH ETHICS REVIEWER'S CHECKLIST AND COMMENTS

APPLICATION NO:	

TITLE:	

SPECIES	**TOTAL**	**SEVERITY CATEGORY**	**FATE OF ANIMALS @ END OF STUDY**

	N/A	YES	UNSURE	NO
Is there sufficient justification for the proposed research?				
Are the specific aims, hypotheses and research questions clearly identified?				
Is the experimental design of the project in keeping with the aims of the proposal?				
Does the protocol adequately justify the use of live animals?				
Does the proposed animal model make sense for the research project?				
Is there adequate statistical or technical justification for the number of animals requested?				
Have the “Three Rs” (replacement, reduction and refinement) been adequately addressed?				
Have all surgical and non-surgical procedures been clearly and completely described, consistent with the experimental design outline?				
Has pain, discomfort and distress to the animal(s) been minimized or avoided to the fullest extent possible?				
Is there any appropriate plan for monitoring animals for pain, discomfort and distress, including criteria for determining early euthanasia (humane endpoint)?				
Are the members of the research team qualified and experienced in the procedures to be performed?				
Is the harm to animal interest reasonable in relation to potential benefits of the proposal?				

NSPCA RECOMMENDATION:

Approved without changes:		Rejected, but may be resubmitted following substantial changes:	
Conditionally approved subjected to required changes:		Rejected:	

GENERAL COMMENTS:	
REVIEWED BY:	
DATE:	

Appendix B GLLM analysis

GLLM with the Tukey's LSD test results on distances travelled

Table B.1 Test for fixed effects for all eight collared females

		^					
SAT305Ca		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	790.74	3	262.7	295.8	<0.001
		Season	11.29	3	3.76	3747.2	0.01
		Time x season	133.21	9	14.8	3775.9	<0.001
		Altitude	7.35	1	7.35	3703.3	0.007
SAT306Kem		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	0.03	2	0.01	3697	0.985
		Season	10.91	3	3.64	3697	0.012
		Time x season	4.87	6	0.81	3697	0.561
		Temp	138.81	1	138.81	3697	<0.001
SAT307Pi		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	22.68	3	7.41	14.3	0.003
		Season	2.63	3	0.88	2758.3	0.453
		Time x Season	80.67	9	8.96	2956.5	<0.001
SAT308Da		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	42.22	2	21.11	3778	<0.001
		Season	29.79	3	9.93	3778	<0.001
		Time x season	9.25	6	1.54	3778	0.16
SAT309Ni		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	13.55	2	6.77	3423	0.001

		Season	20.83	3	6.94	3423	<0.001
		Time x season	15.68	6	2.61	3423	0.016
		Temp	281.81	1	281.81	3423	<0.001
SAT310He		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	1.36	3	0.45	3.2	0.733
		Season	27.01	3	9	3604.9	<0.001
		Time x season	77.61	9	8.62	3605.7	<0.001
		Temp	8.6	1	8.6	3208.7	0.003
SAT311Wi		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	3.58	3	1.19	11.6	0.356
		Season	8.11	3	2.7	3483.6	0.044
		Time x season	61.29	9	6.81	3485.7	<0.001
SAT312Ke		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time	2.08	3	0.68	5.3	0.597
		Season	23.96	3	7.99	3776.2	<0.001
		Time x season	65.43	9	7.27	3777.3	<0.001
		Altitude	16.52	1	16.52	3775.8	<0.001
		*****					
SAT306Kem		**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
		Time x season	5.59	6	0.93	3697	0.47
		Temp	138.81	1	138.81	3697	<0.001

^ Sequentially adding terms to fixed model,

* Dropping individual terms from full fixed model

Home range overlap in different seasons

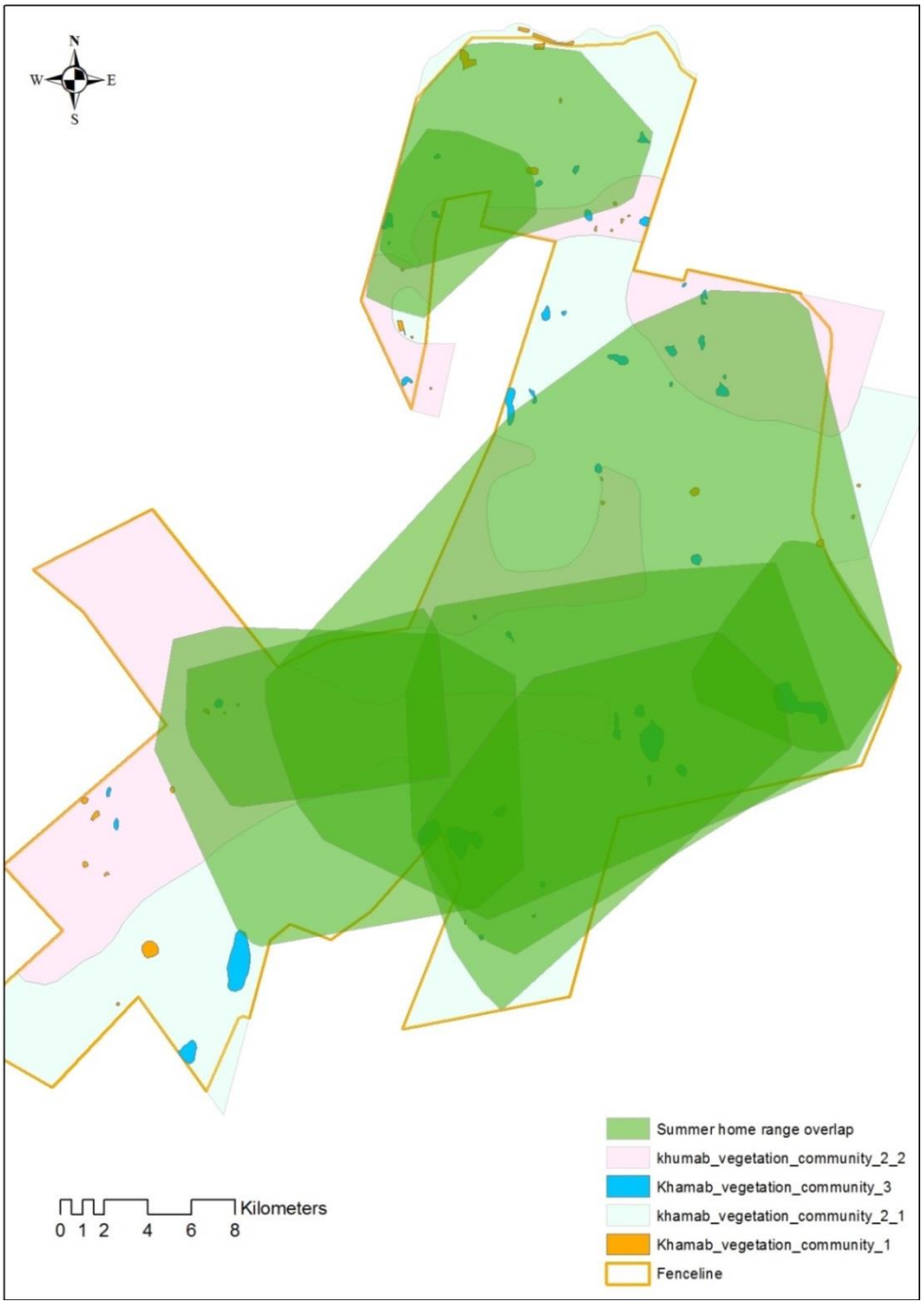


Figure B.1 Home range overlap over the summer season recorded by the GPS collars on the eight female giraffes

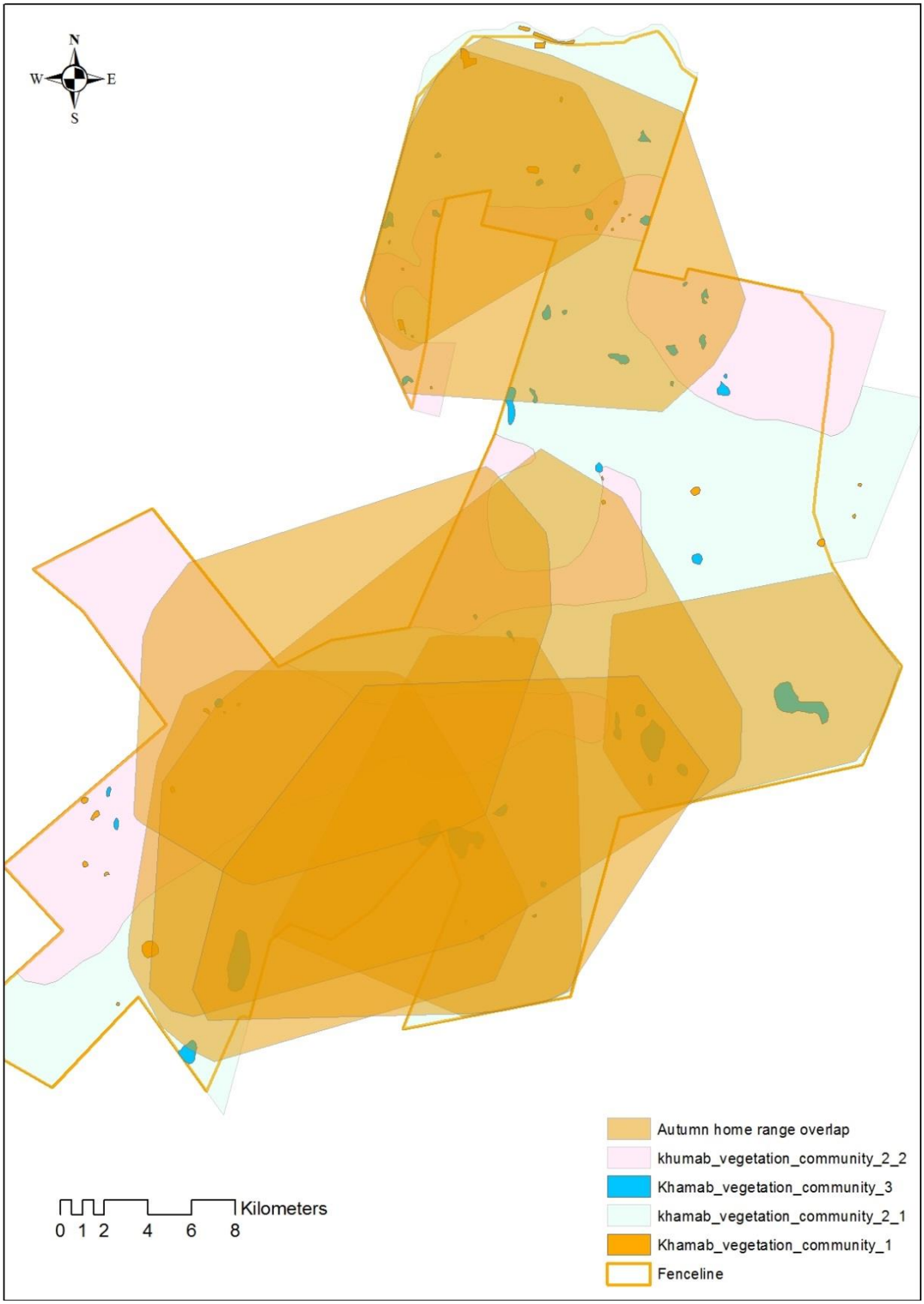


Figure B.2 Home range overlap over the autumn season recorded by the GPS collars on the eight female giraffes

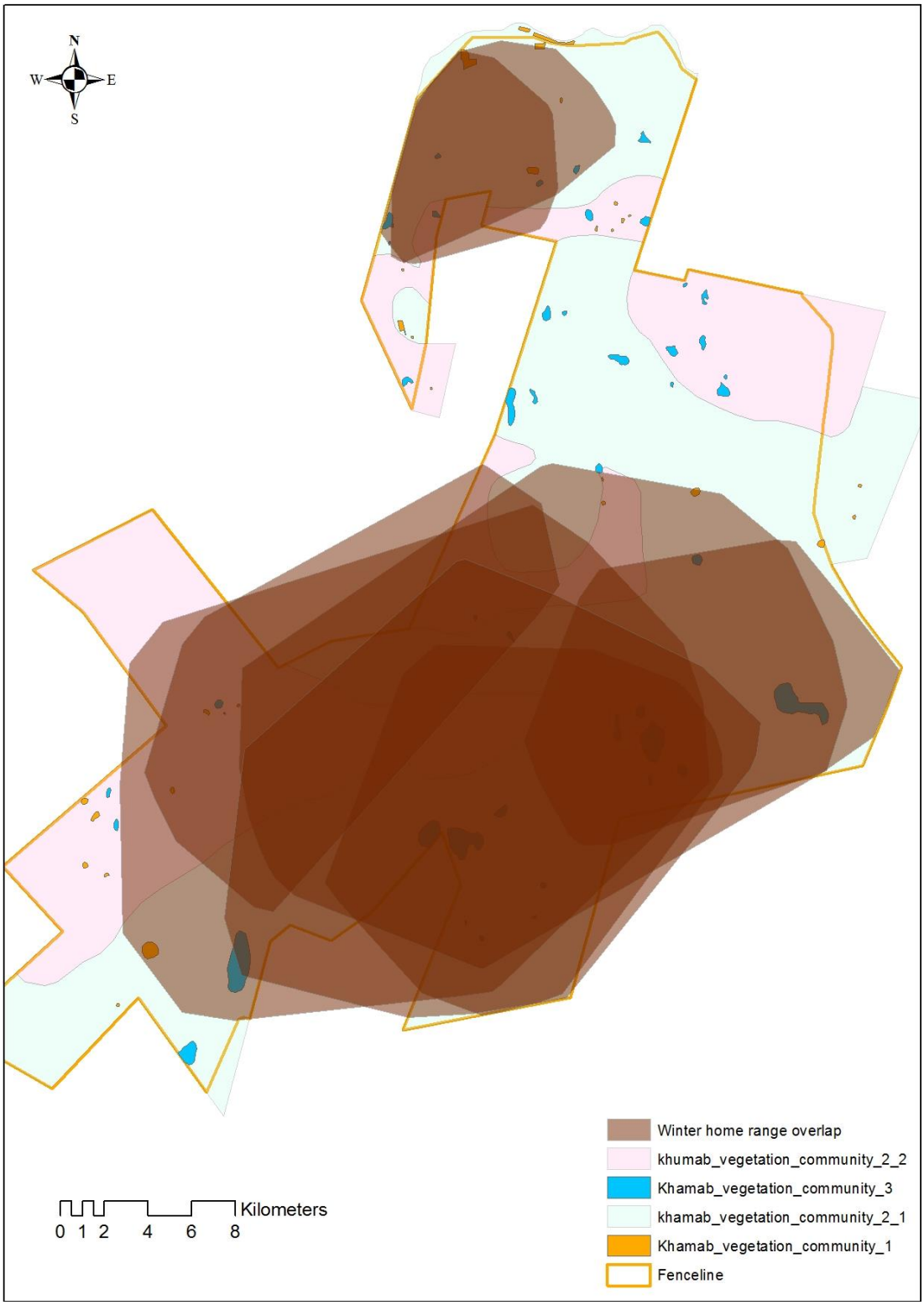


Figure B.3 Home range overlap over the winter season recorded by the GPS collars on the eight female giraffes

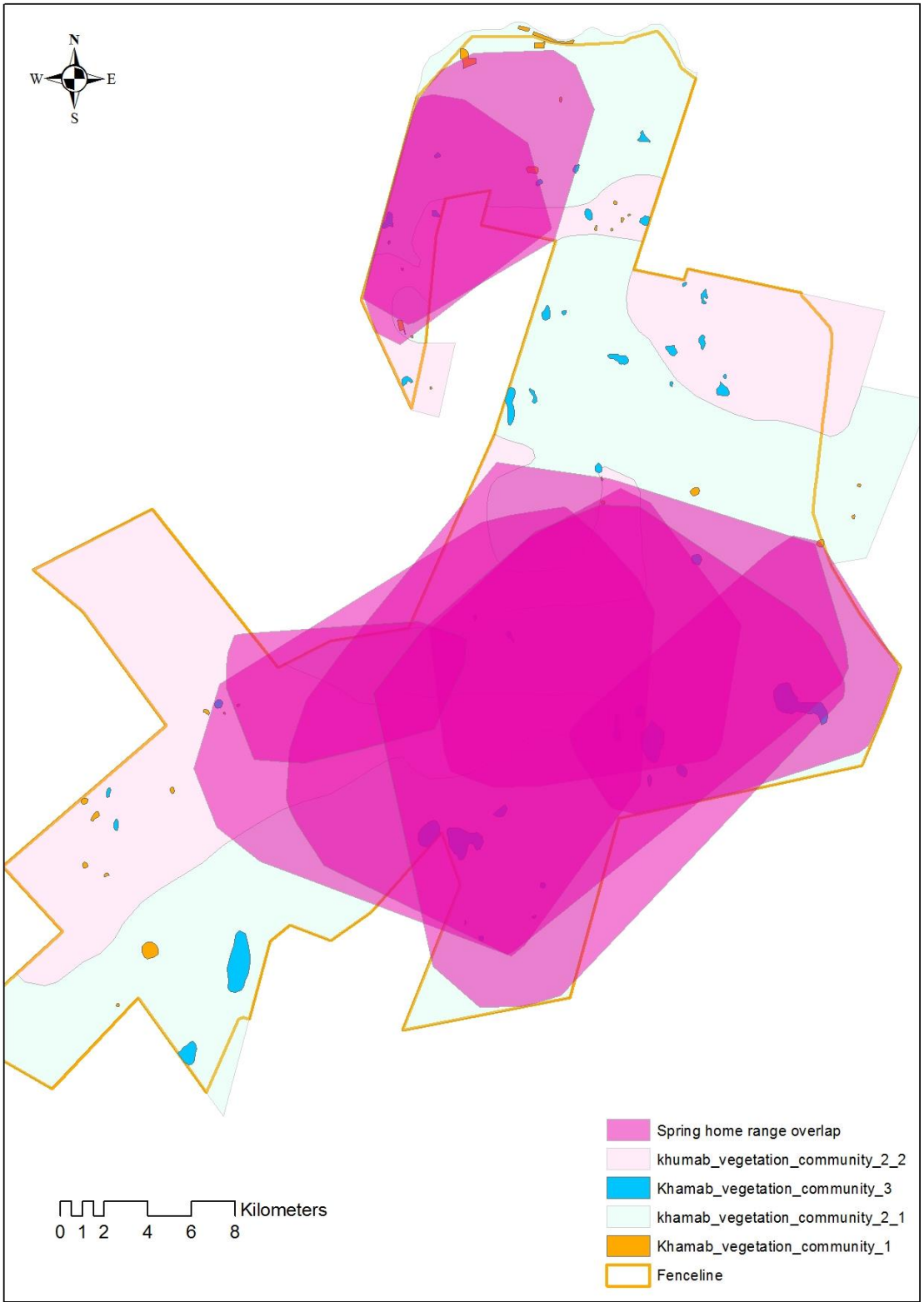


Figure B.4 Home range overlap over the spring season recorded by the GPS collars on the eight female giraffes

Appendix C Home ranges versus time of day

Figure C.1 Home range versus time of day with female SAT312Ke as illustration

Appendix D Descriptive units for the BECVOL 3

BECVOL 3 (Smit, 2014) is a quantitative description of woody plant communities that aimed at aiding studies on estimation of food for browsing herbivore species. Compensation for differences in tree height were proposed by Teague *et al.* (1981), who defined a Tree Equivalent (TE) as a tree, 1.5 m high. Thus a tree with a height of 4.5 m represents 3 TE's. The use of the TE is less suitable for heterogeneous tree communities since it does not compensate for structural differences between tree species.

To quantify browse material, Teague *et al.* (1981) defined a Browse Unit (BU) as a tree with a height of 1.5 m. The difference between the BU and TE is that all unacceptable species are excluded in the calculation of the BU, as well as those individuals of which the lowest browsable material is above 1.5 m.

Bearing in mind the three main ecological dynamics of trees mentioned above, the following three quantitative descriptive units were proposed by Smit (1989a):

- Evapotranspiration Tree Equivalent (ETTE): The leaf volume equivalent of a 1.5 m single-stemmed tree.
- Browse Tree Equivalent (BTE): The leaf mass equivalent of a 1.5 m single stemmed tree.
- Canopied Sub-habitat Index (CSI): The canopy spread area of those trees in a transect under which associated grasses like *Panicum maximum* are most likely to occur, expressed as a percentage of the total transect area (Smit & Van Romburgh, 1993).

From harvested 1.5 m *Acacia karroo* trees, Smit (1989a) defined the values of an ETTE and BTE as 500 cm^3 leaf volume and 250 g leaf dry mass, respectively, (rounded off median values of ten harvested trees).

The calculation of the ETTE and BTE is based on the relationship between the spatial volume of a tree and its true leaf dry mass and true leaf volume, respectively. The description of an ideal tree provides the basis for the calculation of spatial volume of any tree, regardless of shape or size. An ideal tree is regarded as a single stemmed tree with a canopy consisting of a dome-shaped crown and a cone-shaped base (Smit, 1989a; 2004).

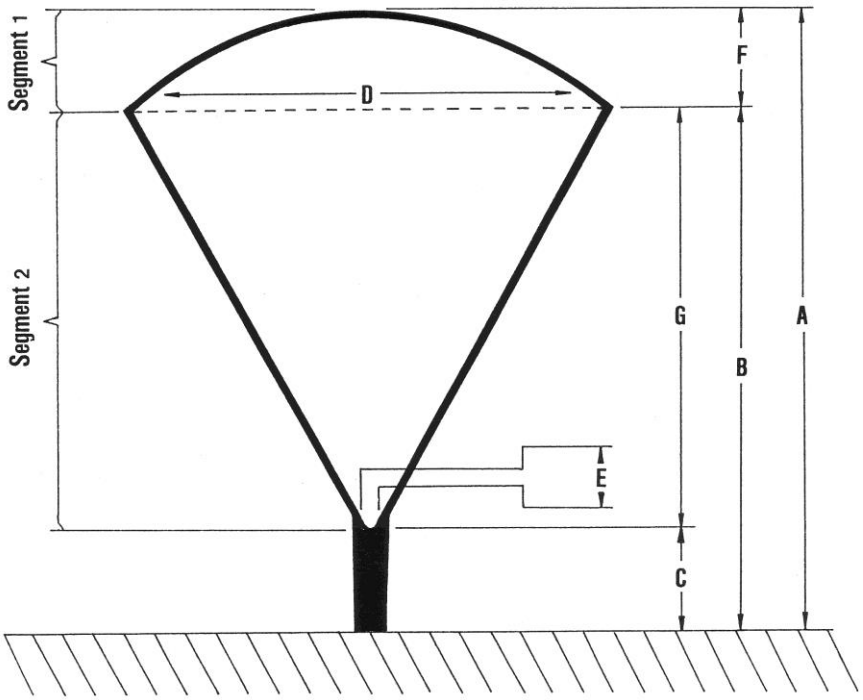


Figure D.1 Schematic illustration of an ideal tree, with measurements and structure (Smit, 1989a)

Individuals with a height of less than 0.5 m were only counted and handled as saplings. Measurements and the specific collection dates of these data sets were done in May 2013 within KKNR. The dimensions of each tree in the specific transect comprised the following (Smit, 1989a; 2004):

(i) Tree height (A)
(ii) Height of maximum canopy diameter (B)
(iii) Height of first leaves or potential leaf bearing stems (C)
(iv) Maximum canopy diameter (D_1)
(v) Maximum canopy diameter perpendicular to D_1 (D_2)
(vi) Base diameter of the foliage at height C (E_1)
(vii) Base diameter of the foliage at height C perpendicular to E_1 (E_2).

The tree height was taken as the height of the main tree crown, ignoring any small stems protruding from the crown. Since the theoretical canopy is considered circular, the maximum canopy diameter was calculated as the average of two measurements at right angles to each other (D_1 & D_2) whenever the tree canopy is elliptic (horizontally). The same principle applies to the base diameter E (E_1 & E_2). All measurements were based on live tree parts only.

Considerable variations in tree shape and structure occurred. A few diverse examples of possible tree shapes and their measurements are illustrated. In the first example the base of the tree (segment 2) is cylindrical and not cone-shaped as a. In the second example, the dome-shaped crown (segment 1) is absent and the maximum canopy diameter occurs at the

top of the tree as b. Segment 2 represents an incomplete cone shape. In the third example only segment 1 is represented as c.

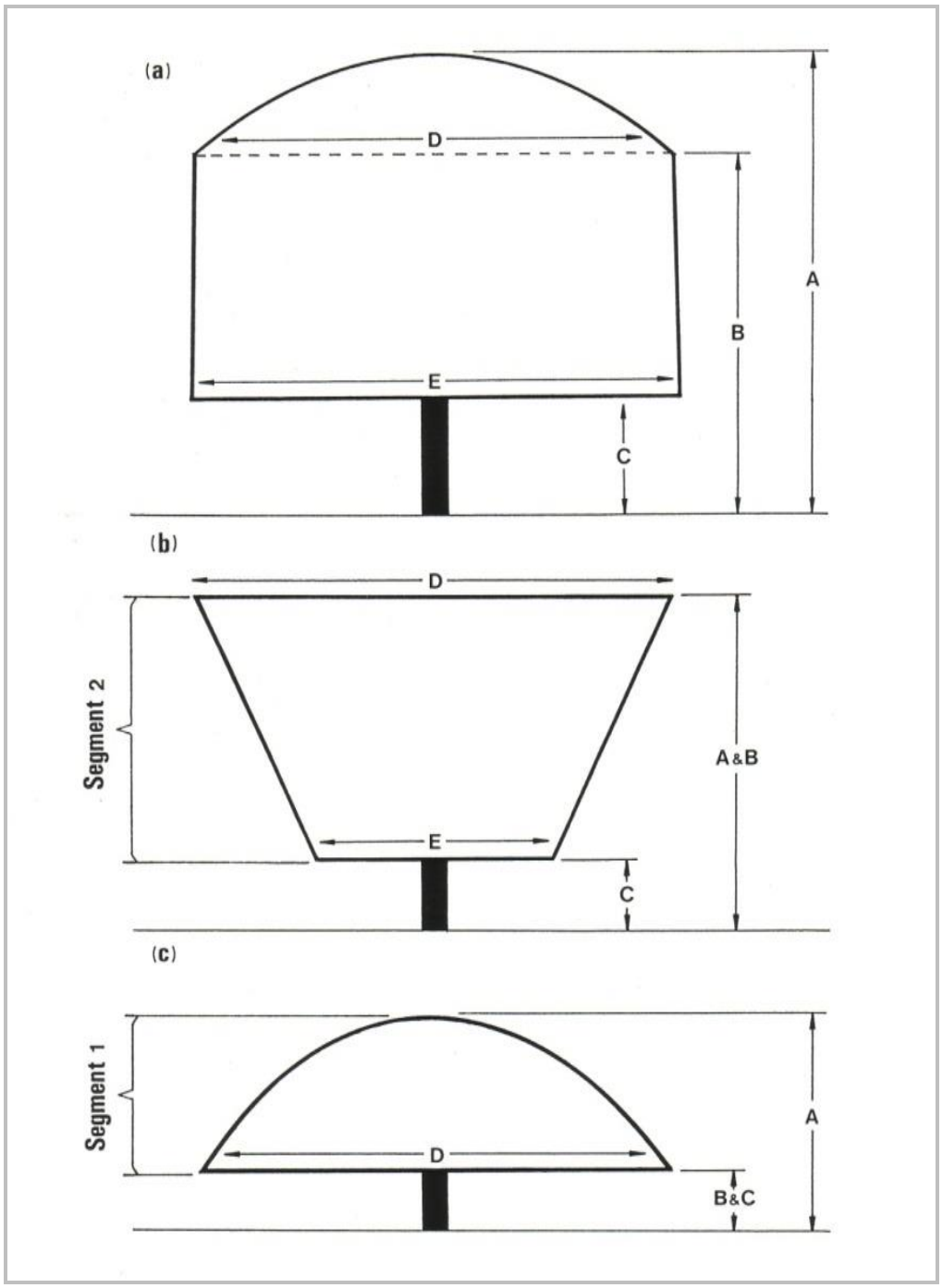


Figure D.2 Schematic illustration of a few non-ideal trees, with measurements and structures (Smit, 1989a)

Appendix E GLLM analysis

GLLM analysis with the Tukey's LSD test results from the different utilized areas

Table E.1 Number of samples per utilized area, per season

Utilized area	1	2	3	4	N observed
Season					
Summer	12	12	12	12	48
Autumn	9	9	9	9	36
Winter	9	9	9	9	36
Spring	6	6	6	6	24
N observed	36	36	36	36	**144**

Table E.2 Test for fixed effects for the BC x season x feeding strata analysis - sequentially adding terms to fixed model.

Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Season	565.9	3	188.63	96	<0.001
Utilized area	9.12	3	3.04	96	0.033
Feeding strata	1303.97	2	651.98	96	<0.001
Season.Utilized area	2.45	9	0.27	96	0.981
Season.Feeding strata	10.69	6	1.78	96	0.111
Utilized area.Feeding strata	39.21	6	6.53	96	<0.001
Season.Utilized area.Feeding strata	0.33	18	0.02	96	1.000

Table E.3 Summary of the back-transformed means for the season, feeding strata and utilized area x feeding strata interactions

Back-transformed Means (on the original scale)			
Season			
Summer	6.36		
Autumn	6.49		
Winter	12.58		
Spring	15.83		
Feeding strata			
1.5 m	17.35		
2.0 m	11.69		
5.0 m	4.26		
Feeding strata	1.5 m	2.0 m	5.0 m
Utilized area			
1	19.26	12.69	3.39
2	16.6	10.88	3.81
3	16.99	11.5	5.22
4	16.69	11.77	4.88

Table E.4 Total number of samples per utilized area and per season

	N observed				
Utilized area	**1**	**2**	**3**	**4**	**N observed**
Season					
Summer	4	4	4	4	16
Autumn	3	3	3	3	12
Winter	3	3	3	3	12
Spring	2	2	2	2	8
N observed	12	12	12	12	**48**

Table E.5 Back-transformed means for season (original scale)

	BC_1.5 m	BC_2.0 m	BC_5.0 m
Summer	11.28	7.56	3.02
Autumn	11.18	7.68	3.184
Winter	23.7	15.88	5.294
Spring	30.32	20.26	6.45

Table E.6 Back-transformed means for utilized area x season interaction (original scale)

Utilized area	**1**	**2**	**3**	**4**
Season				
Summer	2.475	2.65	3.675	3.45
Autumn	2.633	2.833	3.9	3.533
Winter	4.1	4.733	6.633	6.1
Spring	4.95	5.9	7.8	7.6

Table E.7 Back-transformed means for utilized area x season interaction (original scale)

Utilized area	**BC_5.0 m Means**	
1	3.391	
2	3.805	
3	5.218	
4	4.876	

Table E.8 Back-transformed means for utilized area x season interaction (original scale)

1.5 m	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Season	176	3	58.67	32	<0.001
	Utilized area	4.02	3	1.34	32	0.279
	Season. Utilized area	0.91	9	0.1	32	0.999
2.0 m	**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
	Season	193.8	3	64.6	32	<0.001
	Utilized area	3.55	3	1.18	32	0.331
	Season. Utilized area	0.9	9	0.1	32	0.999
5.0 m	**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
	Season	227.52	3	75.84	32	<0.001
	Utilized area	71.52	3	23.84	32	<0.001
	Season. Utilized area	1.04	9	0.12	32	0.999

Table E.9 Most prominent woody species with allocated species

Species Number	Species
1	*Acacia erioloba*
2	*Acacia luederitzii*
4	*Acacia hebeclada*
5	*Acacia mellifera*
6	*Boscia albitrunca*
8	*Dichrostachys cinerea*
9	*Diospyros lycioides*
10	*Ehretia rigida*
11	*Grewia flava*
12	*Grewia flavescens*
14	*Lycium cinereum*
15	*Rhigozum brevispinosum*
16	*Searsia tenuinervis*
17	*Terminalia sericea*
18	*Ziziphus mucronata*

Note: Species number 3, 7 & 13 did not contribute significantly and were left out from calculations

Table E.10 Summary of number of samples per utilized area and season

	N observed				
Utilized area	**1**	**2**	**3**	**4**	**N observed**
Species					
1	1	1	1	1	4
2	1	1	1	1	4
4	1	1	1	0	3
5	1	1	1	1	4
6	1	1	1	1	4
8	0	0	1	1	2
9	0	1	1	0	2
10	0	1	1	0	2
11	1	1	1	1	4
12	1	1	1	0	3
14	1	1	1	1	4
15	0	0	1	1	2
16	1	1	1	1	4
17	1	1	1	1	4
18	1	1	1	1	4
N observed	11	13	15	11	**50**

Table E.11 Test for fixed effects for the BECVOL x species analysis - sequentially adding terms to fixed model.

Response variate: PL_HA					
Fixed term	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
Species	487.04	14	34.79	42	<0.001
Utilized area	6.58	3	2.19	42	0.103
Response variate: ETTE					
Species	151.74	14	10.84	42	<0.001
Utilized area	8.92	3	2.97	42	0.042
Response variate: LMAS					
Species	166.48	14	11.89	42	<0.001
Utilized area	10.9	3	3.63	42	0.02
Response variate: LEAF MASS 1.5 M					
Species	446.69	14	31.91	42	<0.001
Utilized area	2.35	3	0.78	42	0.51
Response variate: LEAF MASS 2.0 M					
Species	310.11	14	22.15	42	<0.001
Utilized area	2.12	3	0.71	42	0.554
Response variate: LEAF MASS 5.0 M					
Species	173.65	14	12.4	42	<0.001
Utilized area	6.45	3	2.15	42	0.108
Response variate: SHOOT DIAMETER (<2.0 MM)					
Species	139.95	14	10	42	<0.001
Utilized area	59.33	3	19.78	42	<0.001
Response variate: BROWSE UP TO 1.5 M					
Species	500.35	14	35.74	42	<0.001
Utilized area	2.07	3	0.69	42	0.562
Response variate: BROWSE UP TO 2.0 M					
Species	321.56	14	22.97	42	<0.001
Utilized area	1.25	3	0.42	42	0.742
Response variate: BROWSE UP TO 5.0 M					
Species	175.81	14	12.56	42	<0.001
Utilized area	5.16	3	1.72	42	0.177
Response variate: CSI_2					
Species	211.92	14	15.14	42	<0.001
Utilized area	10.09	3	3.36	42	0.027
Response variate: CSI_4					
Species	166.96	14	11.93	42	<0.001
Utilized area	22.11	3	7.37	42	<0.001

Table E.12 Back-transformed Means for BECVOL x species interaction (original scale)

Response variate	PL_HA	ETTE	LMAS	LEAF MASS 1.5 M	LEAF MASS 2.0 M	LEAF MASS 5.0 M	SHOOT DIAMETER (<2.0 MM)	BROWSE UP TO 1.5 M	BROWSE UP TO 2.0 M	BROWSE UP TO 5.0 M	CSI_2	CSI_4
Species												
1	147.82	1173.8	277.49	18.93	40.35	233.33	4658.7	11.97	22.46	100.04	10.28	8.181
2	39.68	605.6	144.25	19.92	37.86	134.32	2556.2	10.97	21.21	59.68	6.558	4.981
4	4.91	9	3.08	3.35	3.29	3.15	1.6	2.03	2	1.92	0.944	0.92
5	133.93	821.5	192.65	58.28	102.63	194.56	1408.7	21.44	37.93	65.37	8.974	2.623
6	32.74	314.3	69.92	2.24	2.24	51.11	423.5	2.74	2.99	27.49	3.92	3.826
8	45.19	114.3	28.17	12.48	18.84	26.91	84.9	6.74	9.93	13.16	1.933	1.243
9	4.52	3.1	1.55	1.41	1.39	1.5	1.7	0.96	0.96	1.01	1.038	1.143
10	8.13	7.3	2.07	1.41	1.85	2	4	0.96	1.44	1.52	1.09	1.143
11	372.04	845	157.2	134.74	156.68	158.76	309	64.57	75.1	76.02	3.402	0.962
12	16.69	31.5	6.47	5.03	6.58	6.61	12.5	3.05	3.67	3.83	1.164	0.92
14	48.61	38.8	9.29	9.46	9.47	9.38	3.1	3.99	3.99	3.96	0.986	0.962
15	7.03	13.8	4.29	1.92	2.98	4.1	7.5	1.44	1.49	1.72	1.23	1.243
16	45.64	29.2	7.33	6.97	7.47	7.41	10	2.99	3.24	3.22	0.986	0.962
17	19.84	261.8	58.68	8.72	20.18	59.26	309.7	4.99	10.48	26	3.747	2.575
18	20.83	319.5	70.9	22.17	34.87	71.6	459.4	12.46	19.21	33.68	4.018	2.43

						Utilized area					Utilized area	
						1	168.96				1	2.626
						2	82.8				2	1.794
						3	27.05				3	1.241
						4	39.62				4	1.551

Appendix F Area classification

Area classification based on observations, experience & estimates of the effect of poison in KKNR

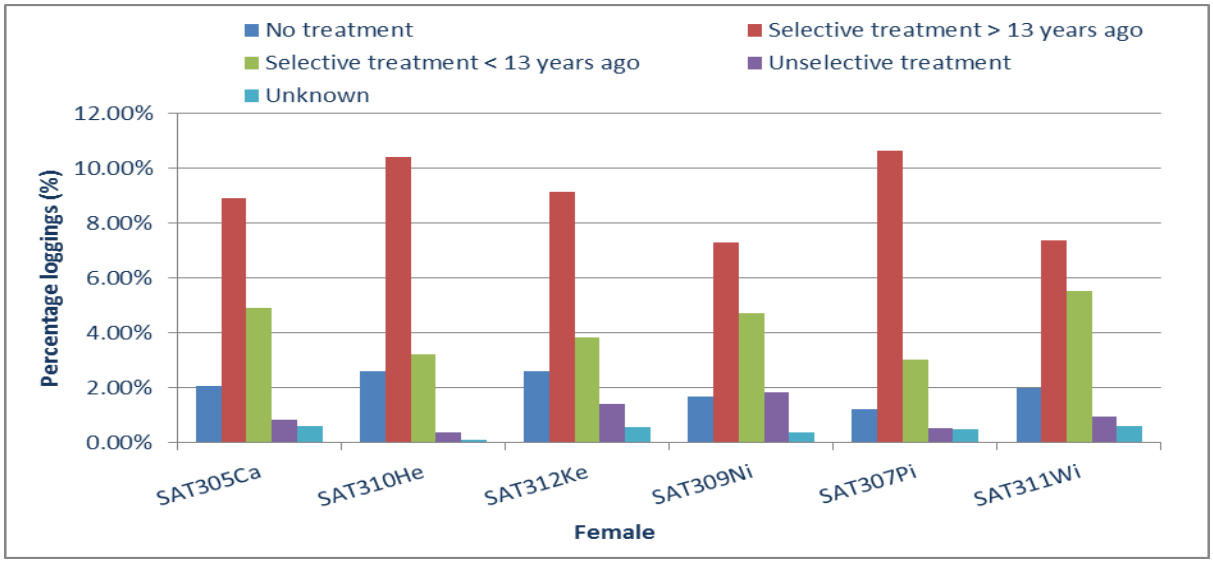


Figure F.1 Habitat selection of the six collared female in the central and southern region of KKNR

Figure F.2Illustration of selective treatment done on *Acacia mellifera*

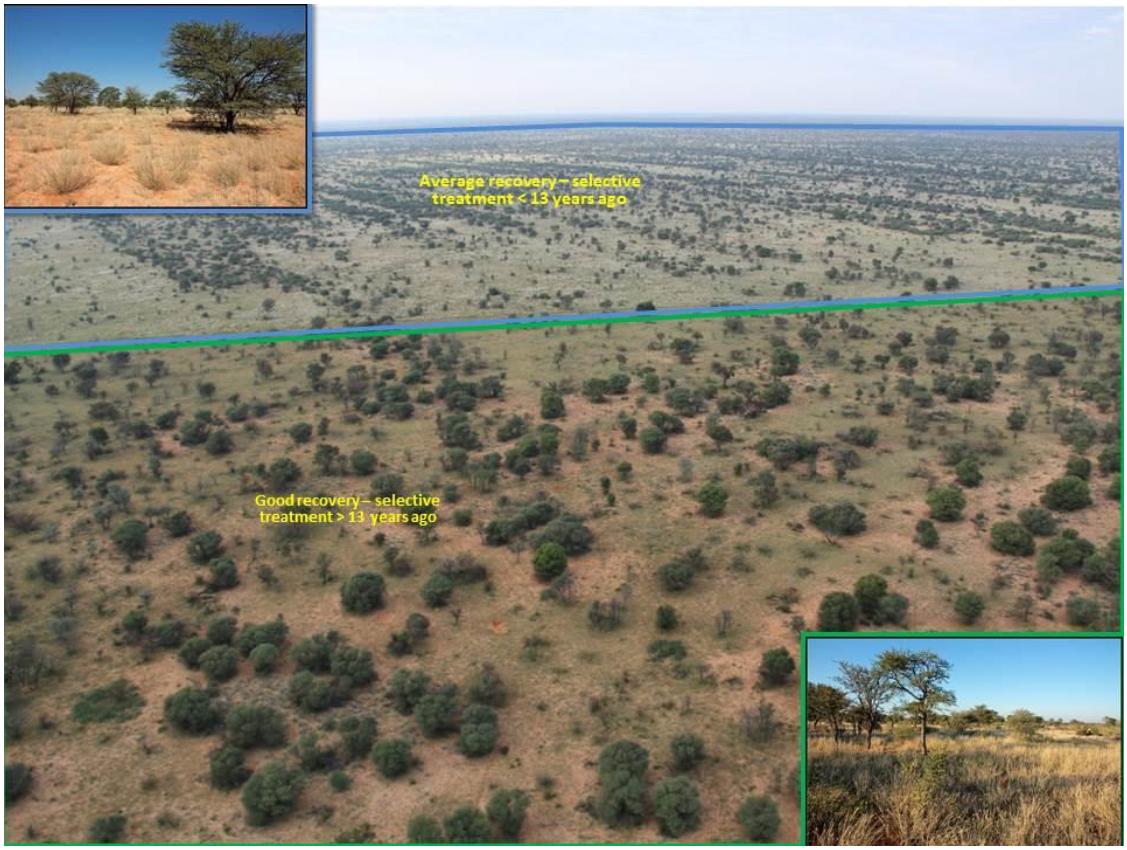


Figure F.3 Good to average recovery areas after arboricide treatment

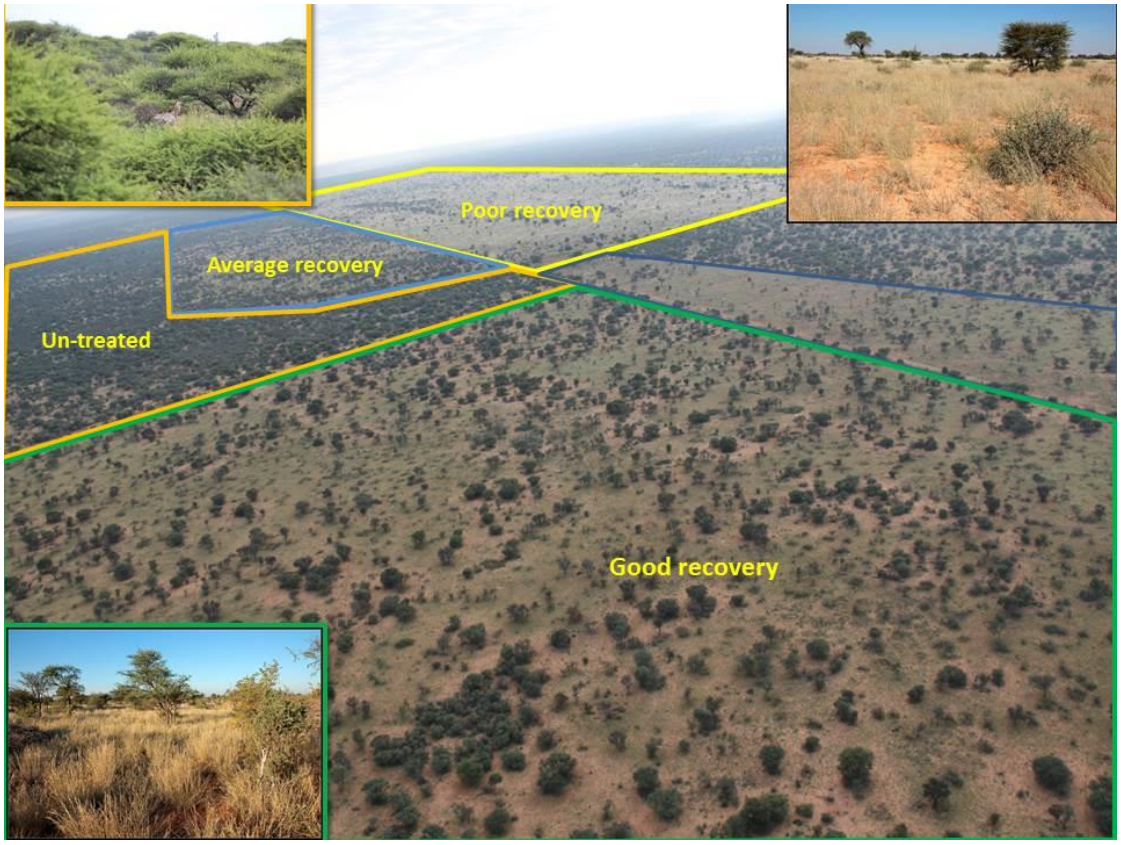


Figure F.4 Good to poorly recovered and un-treated areas after arboricide treatment

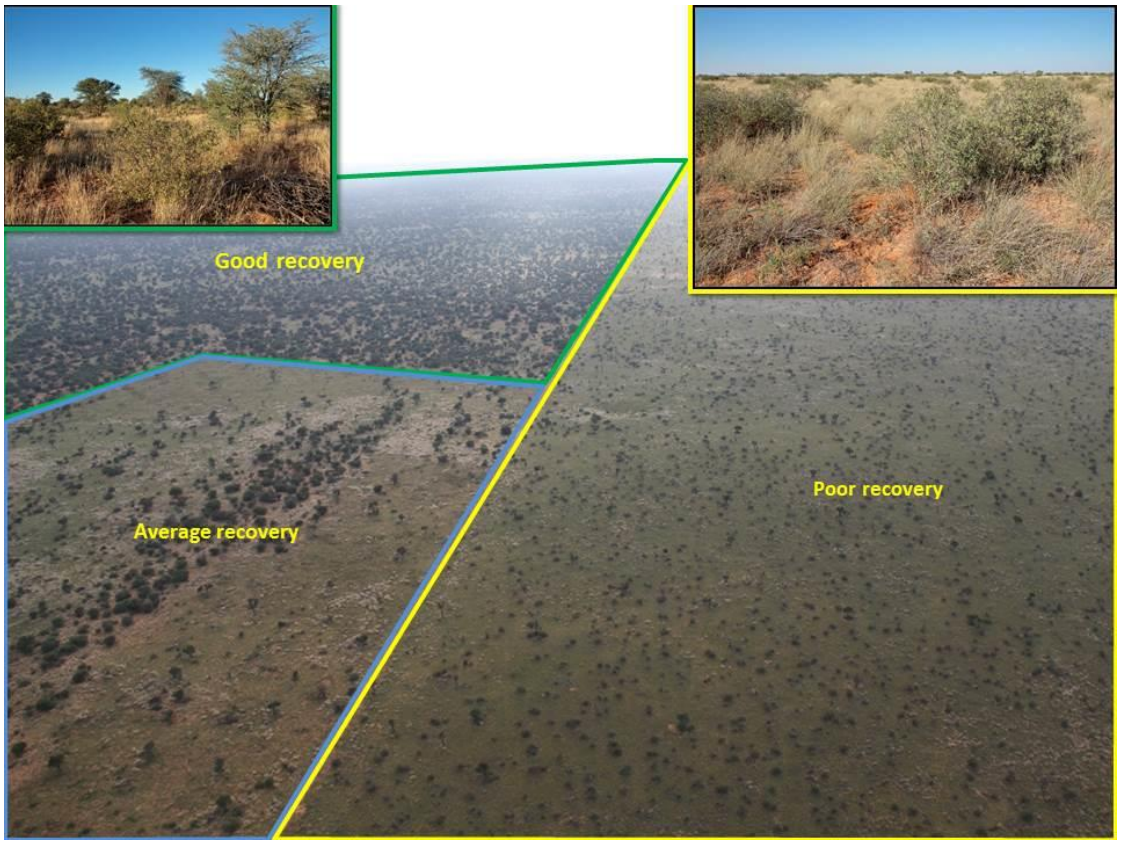


Figure F.5 Good to poor recovery after arboricide treatment

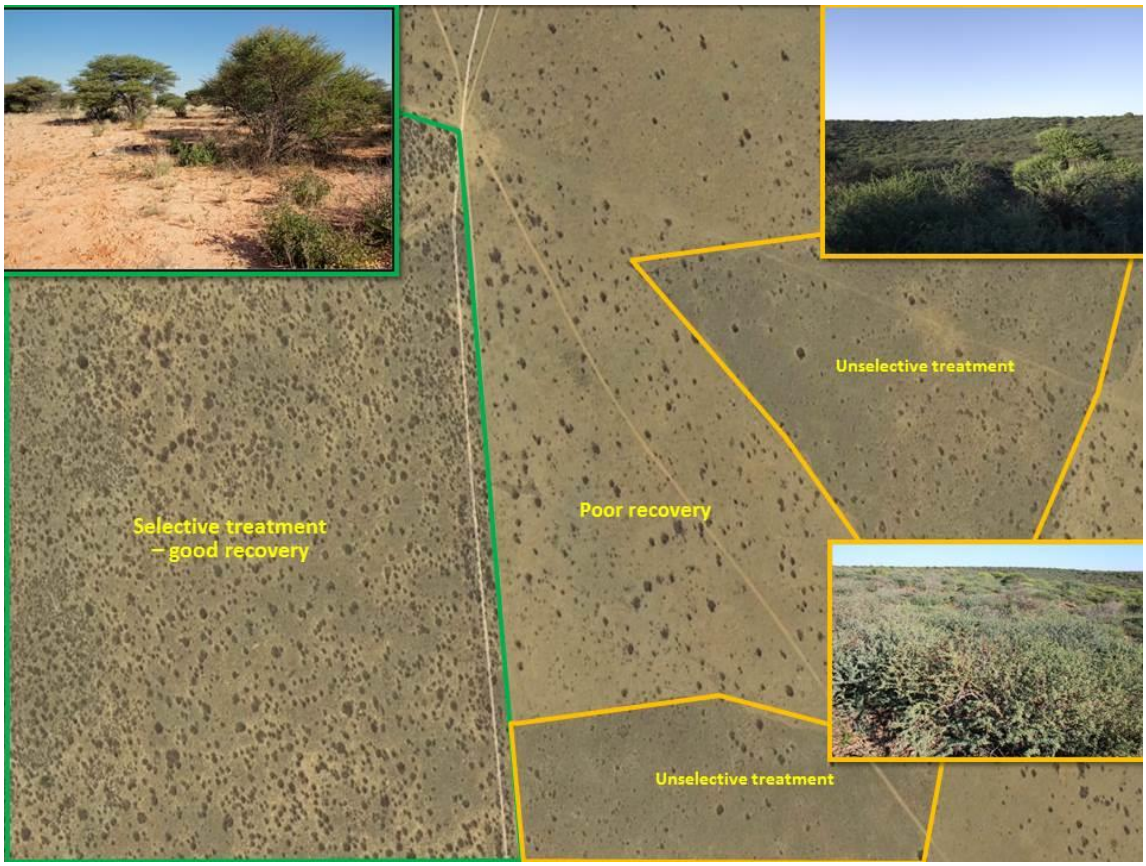


Figure F.6 Selective and unselective treatment recovery after arboricide treatment

Appendix G Ordinations

Ordinations done with CONOCO between male and female tree utilization over seasons

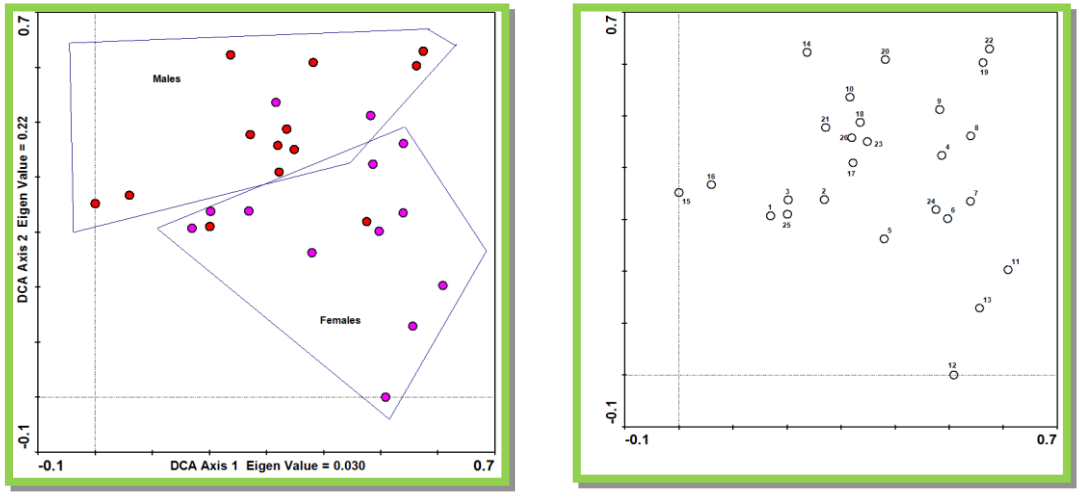


Figure G.1 Ordination values of male vs female for the summer season illustration on the left, value of each data set on the right with the legend of values in the following table.

Table G.1 Legend values used for male vs female in the summer season

Female	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	"Other species"
1	7.5	5.7	10.5	2.0	0.5	0.7	0.0	0.2
2	15.7	12.0	17.5	3.0	1.5	0.5	0.2	0.5
3	30.2	25.5	32.7	8.5	5.5	2.7	0.7	0.5
4	44.0	28.0	27.5	3.5	2.2	3.0	2.0	0.7
5	30.0	29.0	28.7	5.5	1.0	2.0	0.7	0.5

6	35.2	34.0	26.7	2.7	1.7	0.5	0.2	1.0
7	33.0	29.0	20.2	1.5	2.2	1.2	1.0	0.0
8	29.2	19.7	18.5	1.2	1.2	1.5	0.2	2.0
9	29.5	13.7	17.5	2.0	1.7	2.0	1.7	0.7
10	24.5	11.5	17.2	2.2	2.7	0.7	0.0	0.5
11	20.2	23.5	12.2	2.7	0.5	1.2	1.7	0.2
12	10.2	21.2	17.7	1.7	0.2	0.5	1.2	0.2
13	9.0	17.2	9.7	0.7	1.2	1.7	0.2	0.5
	24.5	**20.8**	**19.7**	**2.9**	**1.7**	**1.4**	**0.8**	**0.6**
Male	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	“Other species”
14	2.7	0.5	2.5	0.0	0.2	0.0	0.0	0.0
15	5.7	3.0	6.2	2.7	0.2	0.2	0.0	0.0
16	10.5	7.2	11.0	4.2	1.7	0.7	0.0	0.0
17	14.2	10.0	8.5	2.7	1.2	0.5	0.0	0.0
18	15.0	9.5	7.2	2.5	1.5	2.2	0.0	0.0
19	25.0	11.5	8.5	1.0	0.2	1.2	0.0	0.5
20	19.0	9.7	5.7	2.5	2.5	0.7	0.0	0.2

21	9.7	4.7	10.0	0.2	1.2	0.7	0.0	0.0
22	17.5	7.2	8.2	0.2	1.0	1.0	0.5	1.0
23	6.2	3.7	3.7	1.2	0.2	0.2	0.0	0.2
24	12.5	11.2	11.7	0.5	0.2	1.2	0.0	0.5
25	5.7	3.5	8.7	0.7	0.0	0.5	0.0	0.0
26	7.5	4.5	7.7	0.2	1.0	1.0	0.0	0.2
	11.6	**6.6**	**7.7**	**1.4**	**0.9**	**0.8**	**0.0**	**0.2**

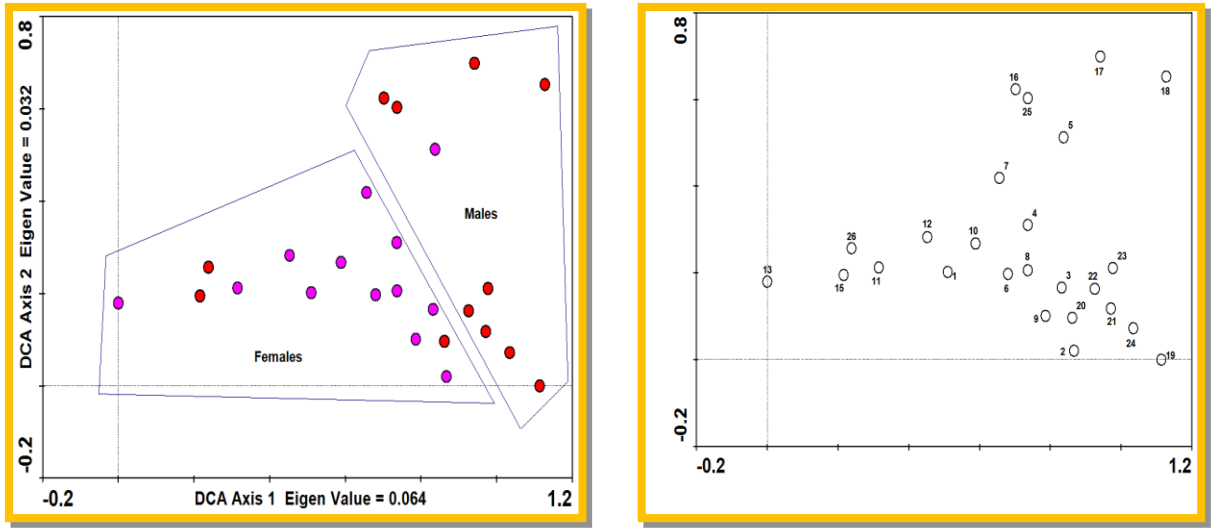


Figure G.2 Ordination values of male vs female for the autumn season illustration on the left, value of each data set on the right with the legend of values in the following table.

Table G.2 Legend values used for male vs female in the autumn season

Female	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	"Other species"
1	1.6	1.0	1.0	0.0	0.0	0.6	0.0	0.0
2	9.0	9.3	3.3	0.0	0.0	0.6	0.0	2.3
3	42.3	25.6	10.0	0.0	0.0	2.0	0.0	2.6
4	35.3	15.6	8.6	3.0	0.6	3.3	0.0	1.3
5	24.6	8.3	3.3	1.0	0.0	2.3	1.3	1.3

6	25.6	15.6	10.3	2.6	0.3	1.6	0.0	1.6
7	49.8	14.3	15.3	3.3	0.6	2.0	0.6	2.0
8	39.6	23.3	12.6	2.0	0.3	4.0	0.0	2.6
9	40.0	30.0	12.3	3.3	0.3	0.6	0.0	0.0
10	28.0	13.3	13.6	1.0	0.3	2.6	0.3	0.0
11	20.0	10.3	21.6	2.6	0.3	1.3	0.0	1.3
12	15.6	6.0	9.0	2.0	0.0	0.6	0.0	0.0
13	1.6	0.6	3.0	0.0	0.0	0.0	0.0	0.0
	25.6	**13.3**	**9.5**	**1.6**	**0.2**	**1.7**	**0.2**	**1.2**
Male	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	“Other species”
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	3.6	1.6	4.3	0.3	0.0	0.0	0.0	0.0
16	9.6	0.6	1.3	0.6	0.0	0.0	0.0	0.6
17	9.3	1.0	0.6	0.3	0.6	0.0	0.0	0.0
18	4.6	1.6	1.0	0.3	1.3	0.0	0.0	0.0
19	2.3	2.0	0.0	0.0	0.0	0.0	0.0	0.0
20	13.3	9.6	3.0	0.3	0.0	0.3	0.0	0.3

21	16.0	11.6	1.0	1.3	0.0	0.3	0.0	0.6
22	11.3	8.6	3.6	0.0	1.0	0.0	0.0	0.3
23	9.6	5.6	1.0	0.3	0.3	0.0	0.0	0.0
24	8.0	6.6	1.0	0.0	0.3	0.0	0.0	0.0
25	8.6	0.6	1.3	0.0	0.0	0.3	0.0	1.0
26	2.0	0.6	2.0	0.0	0.0	0.0	0.0	0.0
	7.6	**3.8**	**1.5**	**0.3**	**0.3**	**0.1**	**0.0**	**0.2**

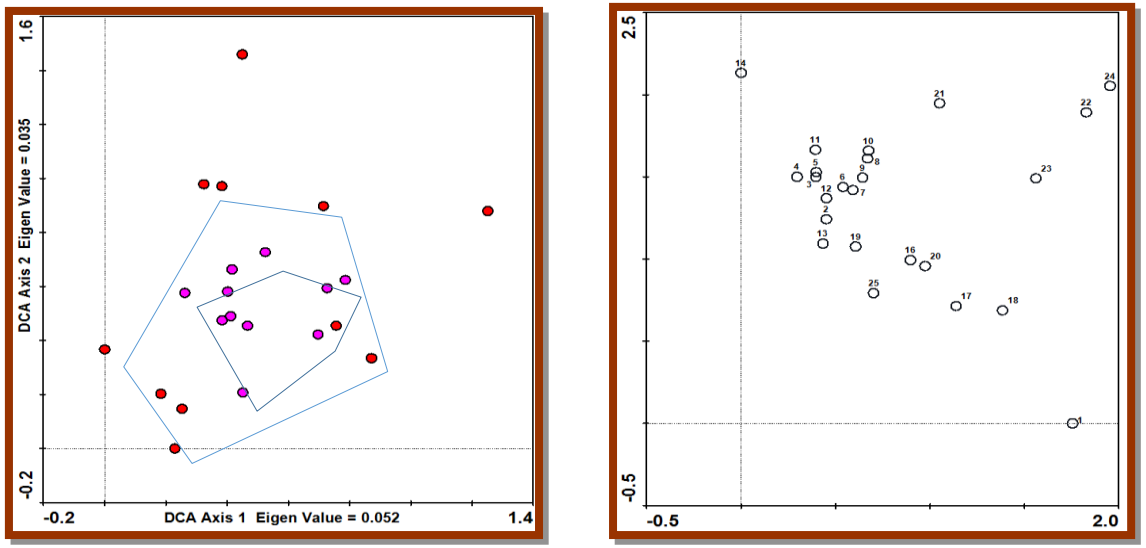


Figure G.3 Ordination values of male vs female for the winter season illustration on the left, value of each data set on the right with the legend of values in the following table.

Table G.3 Legend values used for male vs female in the winter season

Female	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	"Other species"
1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	26.3	0.3	7.3	0.0	0.3	0.0	0.0	0.0
3	67.6	7.6	15.6	11.0	6.0	0.0	0.0	0.3
4	79.3	14.3	31.0	8.6	1.3	0.0	0.0	11.0
5	85.0	10.6	24.3	12.0	4.6	0.0	0.0	0.6

6	86.3	9.0	21.3	16.0	5.0	0.0	0.0	1.0
7	52.0	5.3	8.3	11.0	9.6	0.0	0.0	1.3
8	44.6	8.0	11.0	14.3	4.0	0.3	0.0	1.6
9	61.0	7.6	16.3	15.3	5.3	0.0	0.0	1.3
10	52.3	12.0	22.3	19.0	5.3	0.0	0.0	3.0
11	43.6	23.6	22.0	6.0	5.0	0.0	0.0	2.0
12	23.3	9.6	4.0	2.0	0.6	0.0	0.0	0.0
13	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	47.9	**8.3**	**14.1**	**8.9**	**3.6**	**0.0**	**0.0**	**1.7**
Male	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	“Other species”
14	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
17	1.6	1.0	0.0	0.0	0.0	0.0	0.0	0.0
18	3.0	0.0	0.0	0.3	0.6	0.0	0.0	0.0
19	9.0	0.3	0.0	0.6	0.0	0.0	0.0	0.0
20	5.3	0.0	0.0	0.6	0.0	0.0	0.0	0.0

21	2.6	1.3	0.0	2.6	0.0	0.0	0.0	0.0
22	1.3	0.0	0.0	1.6	0.3	0.0	0.0	1.0
23	4.3	2.3	2.6	2.6	0.3	0.0	0.0	0.6
24	3.0	0.3	2.0	3.0	0.3	0.0	0.0	0.0
25	3.6	2.6	0.0	0.0	0.6	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	2.6	**0.6**	**0.4**	**0.9**	**0.2**	**0.0**	**0.0**	**0.1**

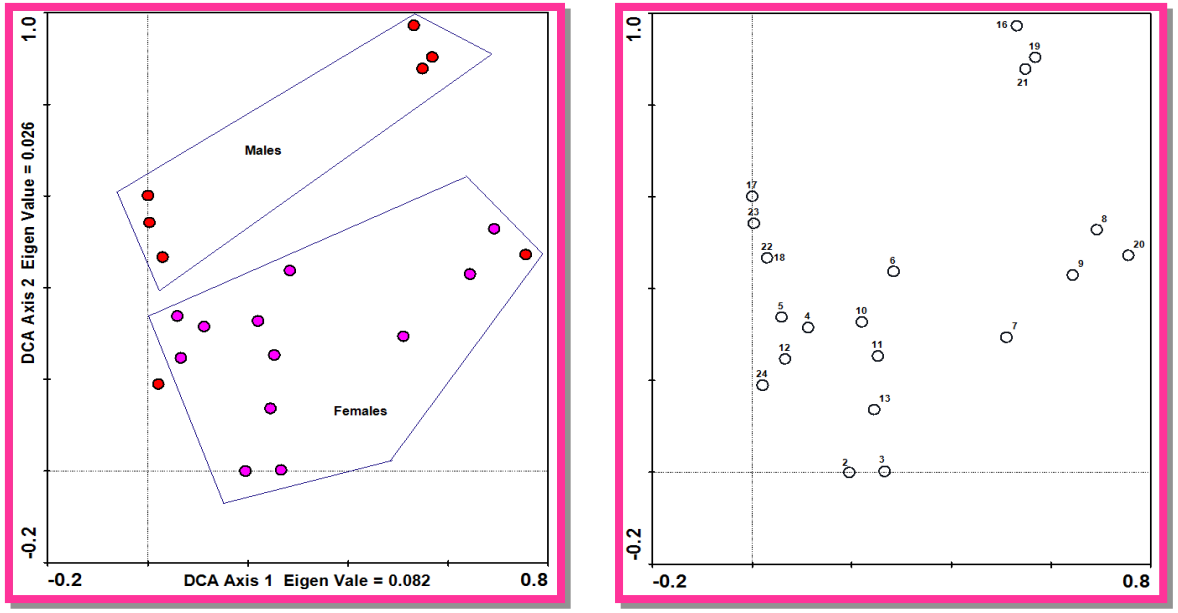


Figure G.4 Ordination values of male vs female for the spring season illustration on the left, value of each data set on the right with the legend of values in the following table

Table G.4 Legend values used for male vs female in the spring season

Female	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	"Other species"
1	4.5	9.5	0.0	0.0	3.0	0.0	0.0	2.0
2	29.0	16.5	0.0	2.0	2.0	0.0	0.0	3.0
3	40.5	25.0	2.5	5.0	3.0	0.5	0.0	2.0
4	69.0	19.5	0.0	6.0	3.5	0.0	0.0	0.0
5	70.0	14.5	0.0	6.0	1.5	0.5	0.5	0.5

6	72.5	20.5	0.0	18.5	8.0	0.0	0.0	1.0
7	32.5	26.5	0.0	13.5	2.5	0.5	0.0	0.5
8	13.0	11.5	0.0	11.0	1.0	0.0	0.0	0.0
9	23.5	22.0	0.0	17.0	1.5	0.0	0.0	0.5
10	53.0	18.5	1.0	9.5	0.0	0.0	0.0	0.0
11	49.5	22.5	1.0	8.0	3.5	0.0	0.0	0.0
12	29.0	8.0	0.0	1.5	1.5	0.0	0.0	0.5
13	12.5	8.0	0.0	1.0	0.5	0.0	0.0	0.0
	38.3	**17.1**	**0.3**	**7.6**	**2.4**	**0.1**	**0.0**	**0.8**
Male	A. erioloba	A. mellifera	Z. mucronata	B. albitrunca	A. luederitzii	G. flava	T. sericea	“Other species”
14	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	1.5	0.0	0.0	1.0	0.0	0.0	0.0	0.0
17	7.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
18	4.5	0.5	0.0	0.5	0.0	0.0	0.0	0.0
19	5.0	0.5	0.0	3.5	0.0	0.0	0.0	0.0
20	6.5	4.0	0.0	5.0	0.5	1.0	0.0	0.0

21	4.5	0.5	0.0	3.0	0.0	0.0	0.0	0.0
22	9.0	1.0	0.0	1.0	0.0	0.0	0.0	0.0
23	12.0	0.5	0.0	1.5	0.0	0.0	0.0	0.0
24	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0
25	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	4.0	**0.6**	**0.0**	**1.3**	**0.0**	**0.1**	**0.0**	**0.0**

Table G.5 Test for fixed effects from the female preferences per time of day and season (Tukey's LSD test)

A. erioloba	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	12.79	2	6.4	183	0.002
	Season	8.29	3	2.76	183	0.043
	Time.Season	1.37	6	0.23	183	0.967
A. mellifera	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	4.92	2	2.46	183	0.088
	Season	29.13	3	9.71	183	<0.001
	Time.Season	1.75	6	0.29	183	0.941
Z. mucronata	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	4.53	2	2.26	183	0.107
	Season	20.25	3	6.75	183	<0.001
	Time.Season	4.28	6	0.71	183	0.639
B. albitrunca	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	17.17	2	8.58	183	<0.001
	Season	24.67	3	8.22	183	<0.001
	Time.Season	7.66	6	1.28	183	0.27
A. luederitzii	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	6.69	2	3.35	183	0.037
	Season	16.4	3	5.47	183	0.001
	Time.Season	6.9	6	1.15	183	0.336
G. flava	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	4.18	2	2.09	183	0.127
	Season	14.95	3	4.98	183	0.002
	Time.Season	2.86	6	0.48	183	0.825
T. sericea	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	0.39	2	0.2	183	0.823
	Season	29.61	3	9.87	183	<0.001
	Time.Season	4.55	6	0.76	183	0.604

“Other species”	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
	Time	2.59	2	1.29	183	0.276
	Season	2.87	3	0.96	183	0.414

Table G.6 Number of samples and untransformed means per season per time of day for female giraffes

A. mellifera	**Season**	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
	Morning	16	17.81	12	12.92	24	5.46	8	17.62
	Midday	16	27.94	12	15.42	24	8.92	8	18.25
	Afternoon	20	17.45	15	12.07	30	7.9	10	15.8
Z. mucronata	**Season**	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
	Morning	16	22.06	12	5.75	24	10.63	8	0.62
	Midday	16	23.56	12	10.42	24	20.08	8	0
	Afternoon	20	14.9	15	11.93	30	13	10	0.4
B. albitrunca	**Season**	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
	Morning	16	4.25	12	0.75	24	3.917	8	3.25
	Midday	16	2.75	12	2.25	24	12.917	8	12.25
	Afternoon	20	1.9	15	1.8	30	7.6	10	7.4
A. luederitzii	**Season**	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
	Morning	16	2.438	12	0.167	24	1.375	8	2.875
	Midday	16	1.562	12	0.333	24	4.5	8	3.25
	Afternoon	20	1.3	15	0.2	30	2.5	10	1.4

T. sericea	**Season**	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
	Morning	16	0.75	12	0	24	0.0417	8	0
	Midday	16	0.5625	12	0.5	24	0.0417	8	0.125
	Afternoon	20	1	15	0.0667	30	0	10	0

Table G.7 Summary of the back-transformed means for the female preferences per time of day and season interactions (on the original scale)

	Season	Mean	Time	Mean
Acacia mellifera	Summer	21.58		
	Autumn	14.4		
	Winter	8.29		
	Spring	18.19		
Ziziphus mucronata	Summer	20.81		
	Autumn	9.99		
	Winter	15.08		
	Spring	1.32		
Boscia albitrunca	Summer	3.851	Morning	3.722
	Autumn	2.516	Midday	6.885
	Winter	8.38	Afternoon	4.921
	Spring	7.792		
A. luederitzii	Summer	2.726	Morning	2.465
	Autumn	1.231	Midday	2.989

	Winter	3.576	Afternoon	2.194
	Spring	3.406		
Terminalia sericea	Summer	1.762		
	Autumn	1.17		
	Winter	1.028		
	Spring	1.04		
A. erioloba	Summer	25.4	Morning	27.79
	Autumn	26.31	Midday	41.14
	Winter	35.64	Afternoon	26.34
	Spring	39.33		
Grewia flava	Summer	2.428		
	Autumn	2.682		
	Winter	1.728		
	Spring	1.12		

Table G.8 Male giraffe back-transformed means on the original scale

Species	Season	Mean		Time	Mean						
A. erioloba	Summer	12.267		Morning	5.275						
	Autumn	8.437		Midday	11.845						
	Winter	5.045		Afternoon	8.619						
	Spring	8.39									
A. mellifera	Summer	7.552		Morning	2.182						
	Autumn	4.173		Midday	4.839						
	Winter	2.179		Afternoon	3.641						
	Spring	1.89									
Z. mucronata	Summer	8.456									
	Autumn	2.534									
	Winter	2.074									
	Spring	1									
								Summer	**Autumn**	**Winter**	**Spring**
B. albitrunca	Summer	1.62		Morning	1.633		Time				
	Autumn	1.287		Midday	2.99		Morning	2	1.333	1.333	2
	Winter	2.447		Afternoon	1.599		Midday	2.125	1.5	3.583	7
	Spring	3.037					Afternoon	1	1.067	3.067	2
G. flava	Summer	1.454									
	Autumn	1.076									
	Winter	1.075									
	Spring	1.145									
A. luederitzii	Summer	1.596		Morning	1.208						
	Autumn	1.275		Midday	1.417						
	Winter	1.212		Afternoon	1.216						
	Spring	1.077									

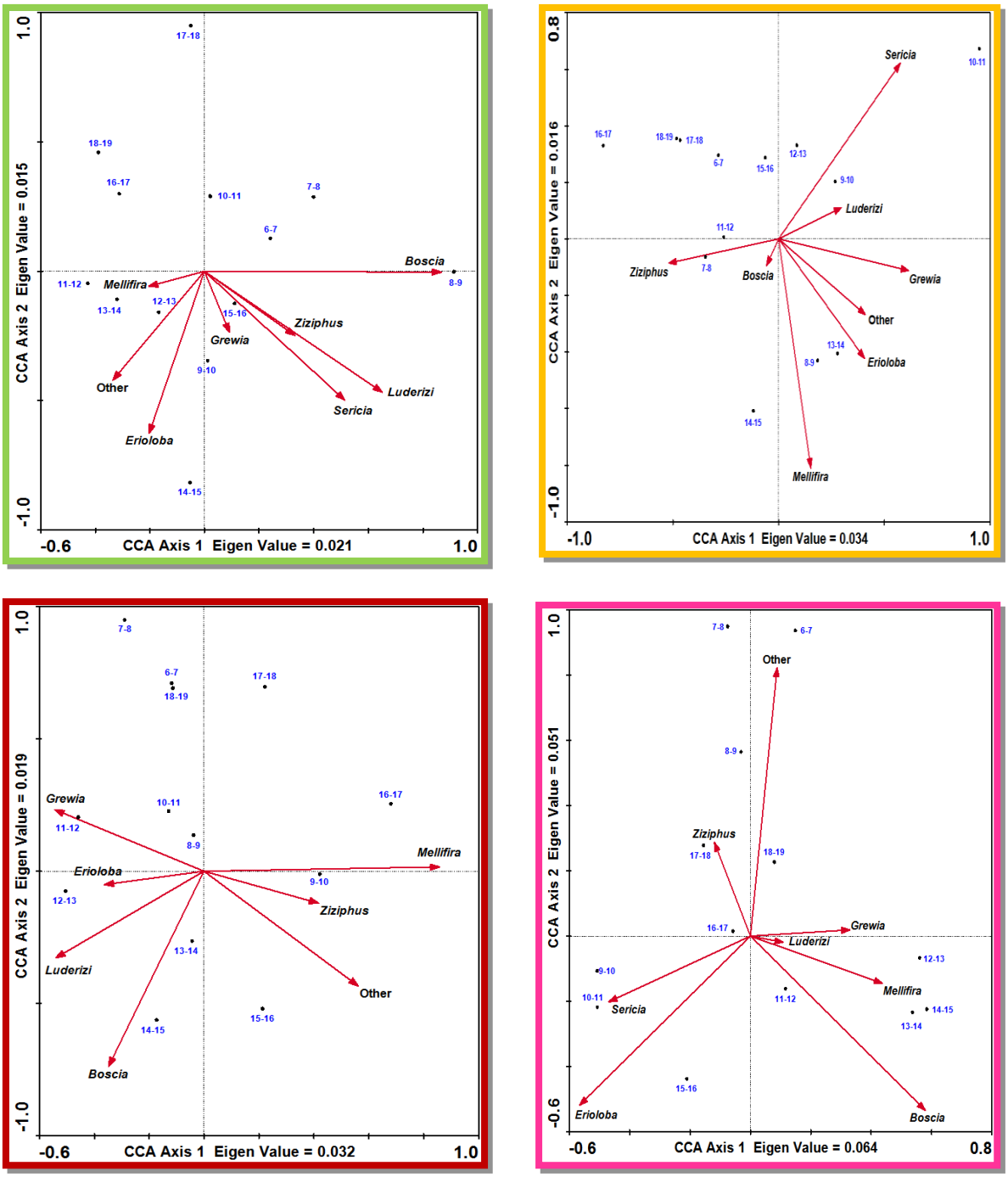


Figure G.5 All giraffes tree species preference changes over seasons. Green = summer preferences, Orange = autumn preferences, Brown = winter preferences, Pink = spring preferences

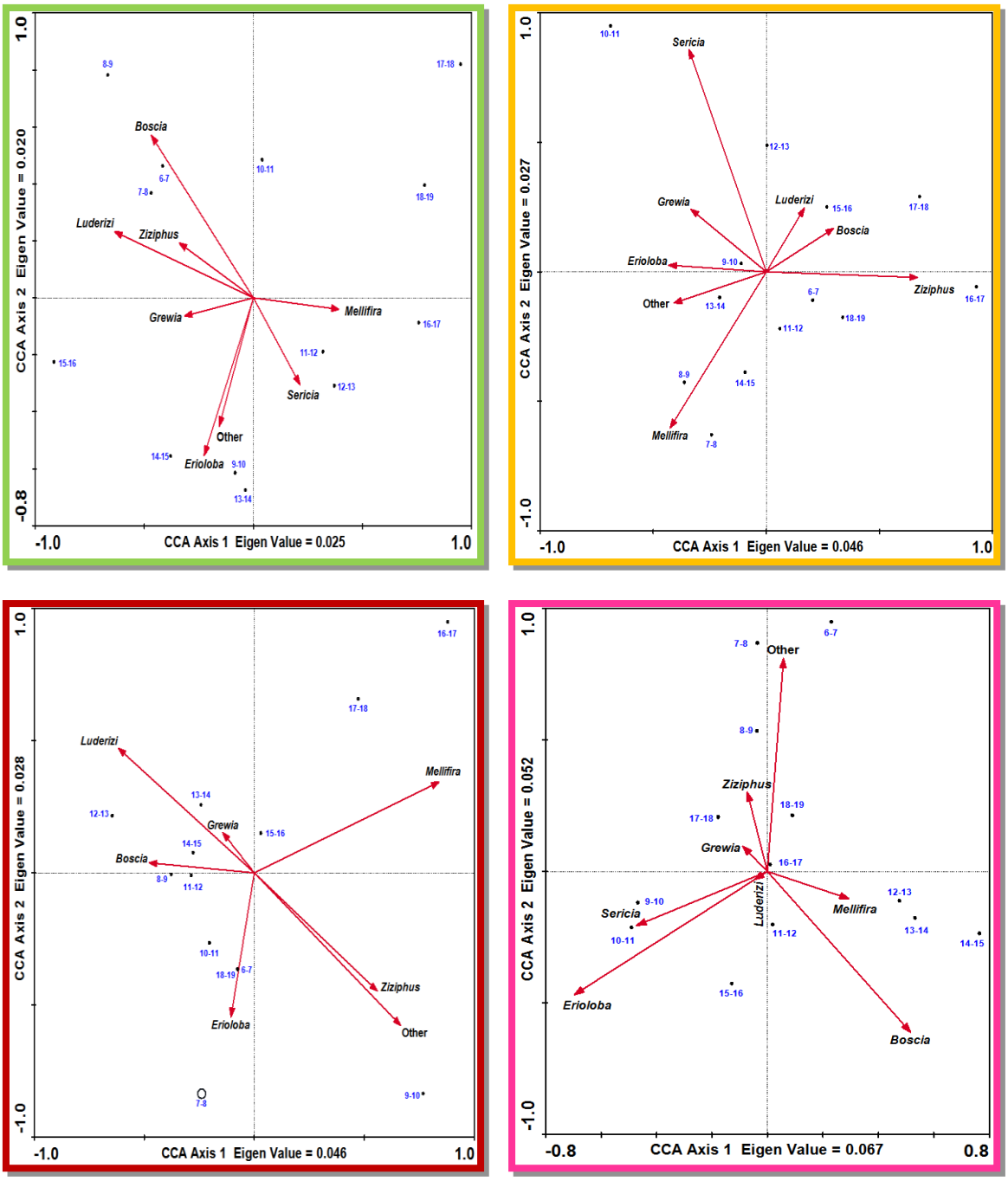


Figure G.6 Female giraffe tree species preference changes over seasons. Green = summer preferences, Orange = autumn preferences, Brown = winter preferences, Pink = spring preferences

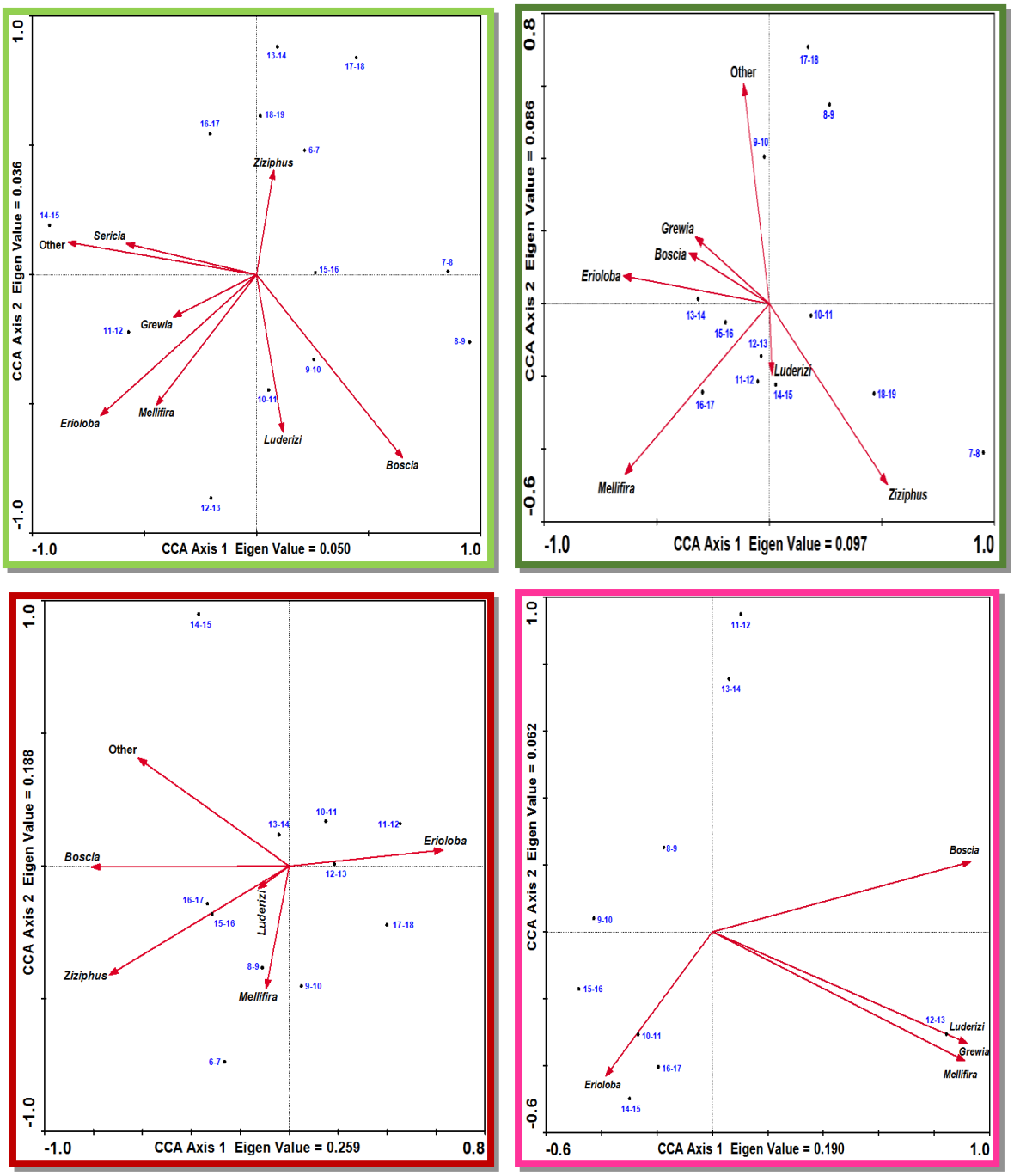


Figure G.7 Male giraffe tree species preference changes over seasons. Green = summer preferences, Orange = autumn preferences, Brown = winter preferences, Pink = spring preferences

Appendix H GLLM Analysis

GLLM Analysis done with the Tukey's LSD test on giraffe feeding strata preference on different woody species:

Table H.1 Test for fixed effects from levels of feeding of female giraffes per time of day and season (Tukey's LSD test)

Highly significant (P<0.001)								Significant (P<0.05)						
	Fixed term	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**			**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
Level3E	Time	5.47	2	2.73	183	0.068		**Level1E**	Time	4.92	2	2.46	183	0.088
	Season	22.48	3	7.49	183	<0.001			Season	8.27	3	2.76	183	0.044
	Time.x Season	0.53	6	0.09	183	0.997			Time.Season	2.93	6	0.49	183	0.816
Level4E	Time	12.89	2	6.45	183	0.002		**Level2E**	Time	7.63	2	3.82	183	0.024
	Season	17.29	3	5.76	183	<0.001			Season	5.04	3	1.68	183	0.173
	Time.x Season	3.39	6	0.57	183	0.757			Time.Season	13.31	6	2.22	183	0.043
Level1M	Time	12.2	2	6.1	183	0.003		**Level5E**	Time	9.02	2	4.51	183	0.012
	Season	62.21	3	20.74	183	<0.001			Season	2.76	3	0.92	183	0.432
	Time.x Season	5.93	6	0.99	183	0.435			Time.Season	2.65	6	0.44	183	0.85
Level2M	Time	13.6	2	6.8	183	0.001		**Level6E**	Time	11.55	2	5.77	183	0.004
	Season	16.66	3	5.55	183	0.001			Season	2.34	3	0.78	183	0.506
	Time.x Season	6.49	6	1.08	183	0.375			Time.Season	6	6	1	183	0.427
Level3M	Time	3.23	2	1.62	183	0.201		**Level3B**	Time	7.02	2	3.51	183	0.032
	Season	22.33	3	7.44	183	<0.001			Season	10.46	3	3.49	183	0.017
	Time.x Season	2.94	6	0.49	183	0.815			Time.Season	6.8	6	1.13	183	0.345
Level4M	Time	4.79	2	2.39	183	0.094		**Level6B**	Time	5.43	2	2.71	183	0.069
	Season	31.93	3	10.64	183	<0.001			Season	11.19	3	3.73	183	0.012
	Time x.Season	0.82	6	0.14	183	0.991			Time.Season	2.78	6	0.46	183	0.835

Level5M	Time	2.06	2	1.03	183	0.358		**Level1G**	Time	8.38	2	4.19	183	0.017
	Season	23.05	3	7.68	183	<0.001			Season	7.46	3	2.49	183	0.062
	Time.x Season	4.76	6	0.79	183	0.576			Time.Season	9.02	6	1.5	183	0.18
Level2Z	Time	2.19	2	1.09	183	0.337		**Level2G**	Time	5.66	2	2.83	183	0.062
	Season	22.87	3	7.62	183	<0.001			Season	14.85	3	4.95	183	0.003
	Time.x Season	4.33	6	0.72	183	0.632			Time.Season	3.09	6	0.51	183	0.797
Level3Z	Time	3.72	2	1.86	183	0.158		**Level3G**	Time	0.27	2	0.13	183	0.875
	Season	19.52	3	6.51	183	<0.001			Season	11.46	3	3.82	183	0.011
	Time.x Season	3.76	6	0.63	183	0.708			Time.Season	7.31	6	1.22	183	0.299
Level4Z	Time	2.93	2	1.47	183	0.233		**Level3L**	Time	10.61	2	5.3	183	0.006
	Season	21.77	3	7.26	183	<0.001			Season	7.25	3	2.42	183	0.068
	Time x.Season	6.33	6	1.05	183	0.392			Time.Season	4.5	6	0.75	183	0.61
Level5Z	Time	6.53	2	3.27	183	0.04		**Level4L**	Time	1.71	2	0.85	183	0.428
	Season	19.72	3	6.57	183	<0.001			Season	14.59	3	4.86	183	0.003
	Time.x Season	1.35	6	0.22	183	0.968			Time.Season	4.07	6	0.68	183	0.667
Level4B	Time	22.56	2	11.28	183	<0.001		**Level5L**	Time	8.28	2	4.14	183	0.017
	Season	21.38	3	7.13	183	<0.001			Season	13.42	3	4.47	183	0.005
	Time.x Season	7.83	6	1.31	183	0.257			Time.Season	7.84	6	1.31	183	0.256
Level5B	Time	11.63	2	5.82	183	0.004		**Level6L**	Time	1.18	2	0.59	183	0.556
	Season	26.2	3	8.73	183	<0.001			Season	10.31	3	3.44	183	0.018
	Time.x Season	6.7	6	1.12	183	0.355			Time.Season	11.19	6	1.86	183	0.089
Level4O	Time	6.08	2	3.04	183	0.05		**Level3S**	Time	4.67	2	2.34	183	0.1
	Season	49.2	3	16.4	183	<0.001			Season	12.24	3	4.08	183	0.008
	Time.x Season	23.66	6	3.94	183	<0.001			Time.Season	4.78	6	0.8	183	0.573
Level5S	Time	1.83	2	0.92	183	0.402								
	Season	28.25	3	9.42	183	<0.001								
	Time.x Season	3.3	6	0.55	183	0.769								

Table H.2 Number of samples and untransformed means per season per time of day for female giraffes

	Season	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
Level3E	Morning	16	1.938	12	2.5	24	4.667	8	6
	Midday	16	2.375	12	4.083	24	7.75	8	8
	Afternoon	20	1.75	15	2.2	30	5.367	10	5.6
Level4E	Morning	16	7.81	12	8.5	24	9.54	8	12.5
	Midday	16	8.56	12	11.5	24	17.83	8	20.75
	Afternoon	20	4.2	15	8.4	30	9.23	10	15.8
Level1M	Morning	16	0.1875	12	2	24	0.0833	8	0.25
	Midday	16	0.125	12	1.9167	24	0.25	8	0
	Afternoon	20	0.05	15	0.6	30	0.0333	10	0
Level2M	Morning	16	1.75	12	1.5	24	0.333	8	0.875
	Midday	16	2.813	12	1.583	24	1	8	0.375
	Afternoon	20	0.75	15	0.667	30	0.4	10	0.8
Level3M	Morning	16	5.937	12	3.667	24	1.875	8	5.625
	Midday	16	9.688	12	3.917	24	3.167	8	6.625
	Afternoon	20	5.55	15	4.333	30	3.033	10	7.9
Level4M	Morning	16	5.313	12	4	24	1.917	8	7
	Midday	16	8.75	12	5.167	24	2.667	8	8.875
	Afternoon	20	6.25	15	4	30	2.4	10	6.2
Level5M	Morning	16	4.125	12	1.667	24	1	8	3.875
	Midday	16	6.562	12	2.75	24	1.708	8	2.375
	Afternoon	20	4.65	15	2.867	30	1.8	10	0.9
Level2Z	Morning	16	1.875	12	0.3333	24	0.75	8	0

	Midday	16	1.875	12	0.9167	24	1.4583	8	0
	Afternoon	20	1.45	15	1.2	30	0.8333	10	0
Level3Z	Morning	16	8	12	2.333	24	4.25	8	0.25
	Midday	16	8.688	12	4.417	24	7.208	8	0
	Afternoon	20	5.55	15	5.133	30	4.6	10	0.3
Level4Z	Morning	16	8.062	12	2.167	24	3.417	8	0.25
	Midday	16	7.813	12	3.25	24	6.25	8	0
	Afternoon	20	4.25	15	4.333	30	4.667	10	0.1
Level5Z	Morning	16	3.688	12	0.583	24	2.083	8	0.125
	Midday	16	4.875	12	1.333	24	4.833	8	0
	Afternoon	20	3.1	15	1	30	2.533	10	0
Level4B	Morning	16	1.375	12	0.083	24	1.083	8	0.75
	Midday	16	1.063	12	0.917	24	4.625	8	4.125
	Afternoon	20	0.6	15	0.333	30	2.033	10	2.5
Level5B	Morning	16	2.188	12	0.5	24	2.167	8	2
	Midday	16	1.438	12	0.833	24	6.083	8	6.875
	Afternoon	20	1	15	0.6	30	4.567	10	3.7
Level4O	Morning	16	0	12	0	24	0	8	1
	Midday	16	0	12	0	24	0.125	8	0.25
	Afternoon	20	0	15	0	30	0.0333	10	0.2
Level5S	Morning	16	0.5	12	0	24	0	8	0
	Midday	16	0.25	12	0.0833	24	0	8	0
	Afternoon	20	0.7	15	0	30	0	10	0

Table H.3 Summary of the back-transformed means for female preferences per time of day and seasonal interactions (on the original scale)

Highly significant (P<0.001)										
	Time		**Season**			**Season x Time**				
Level3E			Summer	3.01			**Summer**	**Autumn**	**Winter**	**Spring**
	Morning	4.494	Autumn	3.847		Morning	2.937	3.5	5.667	7
	Midday	6.063	Winter	6.809		Midday	3.375	5.083	8.75	9
	Afternoon	4.385	Spring	7.464		Afternoon	2.75	3.2	6.367	6.6
Level4E			Summer	7.6						
	Morning	10.45	Autumn	10.37		Morning	8.81	9.5	10.54	13.5
	Midday	14.88	Winter	12.67		Midday	9.56	12.5	18.83	21.75
	Afternoon	9.57	Spring	17.02		Afternoon	5.2	9.4	10.23	16.8
Level1M			Summer	1.119						
	Morning	1.482	Autumn	2.41		Morning	1.187	3	1.083	1.25
	Midday	1.423	Winter	1.119		Midday	1.125	2.917	1.25	1
	Afternoon	1.148	Spring	1.077		Afternoon	1.05	1.6	1.033	1
Level2M			Summer	2.638						
	Morning	2.036	Autumn	2.208		Morning	2.75	2.5	1.333	1.875
	Midday	2.281	Winter	1.551		Midday	3.813	2.583	2	1.375
	Afternoon	1.647	Spring	1.668		Afternoon	1.75	1.667	1.4	1.8
Level3M			Summer	7.86						
	Morning	4.983	Autumn	4.965		Morning	6.937	4.667	2.875	6.625
	Midday	6.392	Winter	3.642		Midday	10.687	4.917	4.167	7.625
	Afternoon	5.951	Spring	7.661		Afternoon	6.55	5.333	4.033	8.9
Level4M			Summer	7.642						
	Morning	5.209	Autumn	5.362		Morning	6.313	5	2.917	8
	Midday	6.831	Winter	3.313		Midday	9.75	6.167	3.667	9.875

	Afternoon	5.458	Spring	8.286		Afternoon	7.25	5	3.4	7.2
Level5M			Summer	6.027						
	Morning	3.398	Autumn	3.382		Morning	5.125	2.667	2	4.875
	Midday	4.013	Winter	2.475		Midday	7.563	3.75	2.708	3.375
	Afternoon	3.283	Spring	3.15		Afternoon	5.65	3.867	2.8	1.9
Level2Z			Summer	2.726						
	Morning	1.609	Autumn	1.778		Morning	2.875	1.333	1.75	1
	Midday	1.918	Winter	1.991		Midday	2.875	1.917	2.458	1
	Afternoon	1.773	Spring	1		Afternoon	2.45	2.2	1.833	1
Level3Z			Summer	8.297						
	Morning	3.746	Autumn	4.802		Morning	9	3.333	5.25	1.25
	Midday	4.556	Winter	6.226		Midday	9.688	5.417	8.208	1
	Afternoon	4.135	Spring	1.176		Afternoon	6.55	6.133	5.6	1.3
Level4Z			Summer	7.485						
	Morning	3.548	Autumn	4.156		Morning	9.063	3.167	4.417	1.25
	Midday	4.059	Winter	5.661		Midday	8.812	4.25	7.25	1
	Afternoon	3.635	Spring	1.112		Afternoon	5.25	5.333	5.667	1.1
Level5Z			Summer	4.833						
	Morning	2.253	Autumn	1.948		Morning	4.688	1.583	3.083	1.125
	Midday	2.99	Winter	3.991		Midday	5.875	2.333	5.833	1
	Afternoon	2.32	Spring	1.04		Afternoon	4.1	2	3.533	1
Level4B			Summer	1.986						
	Morning	1.75	Autumn	1.404		Morning	2.375	1.083	2.083	1.75
	Midday	3.267	Winter	3.288		Midday	2.062	1.917	5.625	5.125
	Afternoon	2.182	Spring	3.155		Afternoon	1.6	1.333	3.033	3.5
Level5B			Summer	2.495						
	Morning	2.596	Autumn	1.639		Morning	3.188	1.5	3.167	3
	Midday	3.973	Winter	4.998		Midday	2.437	1.833	7.083	7.875

	Afternoon	3.025	Spring	4.806		Afternoon	2	1.6	5.567	4.7
Level4O			Summer	1						
	Morning	1.189	Autumn	1		Morning	1	1	1	2
	Midday	1.089	Winter	1.051		Midday	1	1	1.125	1.25
	Afternoon	1.055	Spring	1.442		Afternoon	1	1	1.033	1.2
Level5S			Summer	1.472						
	Morning	1.107	Autumn	1.027		Morning	1.5	1	1	1
	Midday	1.079	Winter	1		Midday	1.25	1.083	1	1
	Afternoon	1.142	Spring	1		Afternoon	1.7	1	1	1

Significance (P<0.05)										
Level1E			Summer	1.179						
	Morning	1.057	Autumn	1.027		Morning	1.25	1	1	1
	Midday	1.111	Winter	1.04		Midday	1.25	1.083	1.125	1
	Afternoon	1.012	Spring	1		Afternoon	1.05	1	1	1
Level2E			Summer	1.552						
	Morning	1.416	Autumn	1.205		Morning	1.313	1.167	1.75	1.5
	Midday	1.596	Winter	1.367		Midday	2.375	1.25	1.25	1.75
	Afternoon	1.26	Spring	1.579		Afternoon	1.2	1.2	1.167	1.5
Level5E			Summer	13.25						
	Morning	11.78	Autumn	10.86		Morning	13.19	9.83	10.33	14.38
	Midday	16.73	Winter	14.39		Midday	16.12	14.92	20.37	16
	Afternoon	11.22	Spring	13.91		Afternoon	10.95	8.73	14.17	11.7
Level6E			Summer	3.661						
	Morning	3.393	Autumn	4.01		Morning	2.875	3.083	3.417	4.375

	Midday	4.854	Winter	4.289		Midday	4.875	5.917	5.5	3.5
	Afternoon	3.152	Spring	3.076		Afternoon	3.5	3.533	4.2	1.9
Level3B			Summer	1.232						
	Morning	1.271	Autumn	1.141		Morning	1.313	1.083	1.333	1.375
	Midday	1.519	Winter	1.616		Midday	1.187	1.083	2.208	1.875
	Afternoon	1.407	Spring	1.668		Afternoon	1.2	1.267	1.433	1.8
Level6B			Summer	1.058						
	Morning	1.128	Autumn	1.304		Morning	1.062	1.083	1.25	1.125
	Midday	1.35	Winter	1.564		Midday	1.062	1.333	1.875	1.25
	Afternoon	1.385	Spring	1.253		Afternoon	1.05	1.533	1.633	1.4
Level1G			Summer	1.307						
	Morning	1.28	Autumn	1.46		Morning	1.375	1.667	1.042	1.125
	Midday	1.386	Winter	1.186		Midday	1.25	1.75	1.5	1.125
	Afternoon	1.103	Spring	1.082		Afternoon	1.3	1.067	1.067	1
Level2G			Summer	1.583						
	Morning	1.419	Autumn	1.853		Morning	1.75	1.917	1.208	1
	Midday	1.587	Winter	1.342		Midday	1.563	2.167	1.667	1.125
	Afternoon	1.278	Spring	1.04		Afternoon	1.45	1.533	1.2	1
Level3G			Summer	1.433						
	Morning	1.184	Autumn	1.324		Morning	1.625	1	1.208	1
	Midday	1.21	Winter	1.152		Midday	1.25	1.583	1.083	1
	Afternoon	1.255	Spring	1		Afternoon	1.45	1.467	1.167	1

Level3L			Summer	1.17						
	Morning	1.082	Autumn	1.123		Morning	1.125	1	1.083	1.125
	Midday	1.35	Winter	1.384		Midday	1.187	1.25	1.792	1.25
	Afternoon	1.196	Spring	1.157		Afternoon	1.2	1.133	1.367	1.1
Level4L			Summer	1.48						
	Morning	1.547	Autumn	1.027		Morning	1.813	1.083	1.667	1.75
	Midday	1.612	Winter	2.038		Midday	1.375	1	2.458	2
	Afternoon	1.393	Spring	1.698		Afternoon	1.3	1	2.067	1.4
Level5L			Summer	1.887						
	Morning	1.716	Autumn	1.078		Morning	2.313	1.083	1.458	2.375
	Midday	1.964	Winter	1.94		Midday	1.938	1.083	2.833	2.5
	Afternoon	1.502	Spring	2.203		Afternoon	1.5	1.067	1.767	1.8
Level6L			Summer	1.114						
	Morning	1.181	Autumn	1		Morning	1.063	1	1.125	1.625
	Midday	1.207	Winter	1.23		Midday	1	1	1.417	1.5
	Afternoon	1.137	Spring	1.389		Afternoon	1.3	1	1.167	1.1
Level3S			Summer	1.098						
	Morning	1.015	Autumn	1.027		Morning	1.062	1	1	1
	Midday	1.065	Winter	1		Midday	1.188	1.083	1	1
	Afternoon	1.012	Spring	1		Afternoon	1.05	1	1	1

Table H.4 Test for fixed effects from levels of feeding of male giraffes per time of day and season (Tukey's LSD test)

Highly significant (P<0.001)								Significant (P<0.05)						
	Fixed term	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**			**Fixed term**	**Wald statistic**	**n.d.f.**	**F statistic**	**d.d.f.**	**F pr**
Level3E	Time	24.88	2	12.44	170	<0.001		**Level2E**	Time	3.47	2	1.74	170	0.179
	Season	35.99	3	12	170	<0.001			Season	12	3	4	170	0.009
	Time.x Season	13.8	6	2.3	170	0.037			Time.Season	7.28	6	1.21	170	0.301
Level4E	Time	12.12	2	6.06	170	0.003		**Level5E**	Time	8.05	2	4.02	170	0.02
	Season	19.62	3	6.54	170	<0.001			Season	12.48	3	4.16	170	0.007
	Time.x Season	1.65	6	0.27	170	0.948			Time.Season	5.64	6	0.94	170	0.468
Level1M	Time	0.58	2	0.29	170	0.75		**Level6E**	Time	12.03	2	6.02	170	0.003
	Season	27.79	3	9.26	170	<0.001			Season	2.21	3	0.74	170	0.532
	Time.x Season	0.78	6	0.13	170	0.993			Time.Season	4.45	6	0.74	170	0.616
Level2M	Time	5.06	2	2.53	170	0.083		**Level4B**	Time	12.5	2	6.25	170	0.002
	Season	55.78	3	18.59	170	<0.001			Season	11.13	3	3.71	170	0.013
	Time.x Season	5.53	6	0.92	170	0.481			Time.Season	14.65	6	2.44	170	0.027
Level3M	Time	2.48	2	1.24	170	0.292		**Level5B**	Time	4.3	2	2.15	170	0.119
	Season	32.54	3	10.85	170	<0.001			Season	11.66	3	3.89	170	0.01
	Time.x Season	3.38	6	0.56	170	0.759			Time.Season	17.32	6	2.89	170	0.011
Level4M	Time	13.03	2	6.51	170	0.002		**Level1G**	Time	4.54	2	2.27	170	0.106
	Season	32.81	3	10.94	170	<0.001			Season	8.08	3	2.69	170	0.048
	Time.x Season	10.4	6	1.73	170	0.116			Time.Season	11.71	6	1.95	170	0.075
Level5M	Time	14.84	2	7.42	170	<0.001		**Level3G**	Time	0.43	2	0.22	170	0.805
	Season	38.8	3	12.93	170	<0.001			Season	13.52	3	4.51	170	0.005
	Time.x Season	7.02	6	1.17	170	0.325			Time.Season	1.73	6	0.29	170	0.942

Level2Z	Time	10.21	2	5.11	170	0.007		**Level5O**	Time	4.32	2	2.16	170	0.119
	Season	51.09	3	17.03	170	<0.001			Season	8.14	3	2.71	170	0.047
	Time.x Season	6.64	6	1.11	170	0.36			Time.Season	2.57	6	0.43	170	0.859
Level3Z	Time	2.07	2	1.03	170	0.358		**Level3L**	Time	2.54	2	1.27	170	0.284
	Season	70.25	3	23.42	170	<0.001			Season	10.07	3	3.36	170	0.02
	Time.x Season	2.01	6	0.33	170	0.918			Time.Season	1.97	6	0.33	170	0.921
Level4Z	Time	0.32	2	0.16	170	0.851		**Level5L**	Time	7.9	2	3.95	170	0.021
	Season	89.93	3	29.98	170	<0.001			Season	5.15	3	1.72	170	0.165
	Time.x Season	0.78	6	0.13	170	0.993			Time.Season	7.44	6	1.24	170	0.288
Level5Z	Time	0.87	2	0.44	170	0.647								
	Season	37.91	3	12.64	170	<0.001								
	Time.x Season	3.75	6	0.62	170	0.71								
Level3B	Time	10.22	2	5.11	170	0.007								
	Season	71.95	3	23.98	170	<0.001								
	Time.x Season	40.45	6	6.74	170	<0.001								
Level2G	Time	7.9	2	3.95	170	0.021								
	Season	20.3	3	6.77	170	<0.001								
	Time.x Season	10.42	6	1.74	170	0.115								
Level4G	Time	3.06	2	1.53	170	0.22								
	Season	23.89	3	7.96	170	<0.001								
	Time.x Season	5.2	6	0.87	170	0.521								
Level4L	Time	0.46	2	0.23	170	0.796								
	Season	22.2	3	7.4	170	<0.001								
	Time.x Season	3.73	6	0.62	170	0.713								

Table H.5 Number of samples and untransformed means per season per time of day for male giraffes

	Season	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
Level3E	Morning	16	0.5625	12	0.3333	24	0	4	0.75
	Midday	16	2.75	12	0.1667	24	0.25	4	0.25
	Afternoon	20	0.6	15	0	30	0.1	5	0.6
Level4E	Morning	16	2.312	12	1.667	24	0.25	4	1
	Midday	16	5.312	12	2.75	24	2.167	4	3.5
	Afternoon	20	3.2	15	2.333	30	1.067	5	2.8
Level1M	Morning	16	0.3125	12	0	24	0	4	0
	Midday	16	0.25	12	0	24	0	4	0
	Afternoon	20	0.4	15	0	30	0	5	0
Level2M	Morning	16	0.375	12	0.0833	24	0.0417	4	0
	Midday	16	0.75	12	0.0833	24	0.0417	4	0
	Afternoon	20	1	15	0	30	0.0667	5	0
Level3M	Morning	16	1.6875	12	0.1667	24	0.3333	4	0
	Midday	16	2.125	12	1.4167	24	0.2917	4	0.5
	Afternoon	20	1.6	15	0.9333	30	0.1333	5	0.4
Level4M	Morning	16	1.375	12	0.417	24	0.458	4	0
	Midday	16	2.938	12	3.333	24	0.292	4	2
	Afternoon	20	1.75	15	3.267	30	0.433	5	0.4
Level5M	Morning	16	1.375	12	0.1667	24	0.2083	4	0
	Midday	16	2.8125	12	1.3333	24	0.4167	4	0.25
	Afternoon	20	1.25	15	0.1333	30	0.5667	5	0
Level2Z	Morning	16	0.1875	12	0	24	0	4	0
	Midday	16	0.8125	12	0.0833	24	0.0833	4	0
	Afternoon	20	0.8	15	0	30	0.0667	5	0
Level3Z	Morning	16	1.6875	12	0.5	24	0.0833	4	0
	Midday	16	2.4375	12	0.25	24	0.2917	4	0
	Afternoon	20	1.85	15	0.3333	30	0.3333	5	0
Level4Z	Morning	16	2.6875	12	0.5	24	0.125	4	0
	Midday	16	2.875	12	0.6667	24	0.3333	4	0
	Afternoon	20	2.75	15	0.9333	30	0.4	5	0

Level5Z	Morning	16	2.375	12	0.4167	24	0.2083	4	0
	Midday	16	1.75	12	0.0833	24	0.8333	4	0
	Afternoon	20	1.7	15	0.2667	30	0.4	5	0
Level3B	Morning	16	0.0625	12	0.0833	24	0	4	0
	Midday	16	0	12	0	24	0.0833	4	1.25
	Afternoon	20	0	15	0	30	0.0333	5	0.4
Level2G	Morning	16	0	12	0	24	0.0417	4	0
	Midday	16	0.5	12	0.1667	24	0	4	0
	Afternoon	20	0.4	15	0.0667	30	0.0667	5	0
Level4G	Morning	16	0.0625	12	0	24	0	4	0
	Midday	16	0.3125	12	0	24	0	4	0
	Afternoon	20	0.2	15	0	30	0	5	0
Level5S	Morning	16	0.4375	12	0	24	0.0417	4	0
	Midday	16	0.5	12	0.0833	24	0.0417	4	0
	Afternoon	20	0.25	15	0.1333	30	0.1	5	0

Table H.6 Summary of the back-transformed means for male preferences per time of day and seasonal interactions (on the original scale)

Highly significant (P<0.001)										
	Time		**Season**			**Season x Time**				
Level3E			Summer	2.109			**Summer**	**Autumn**	**Winter**	**Spring**
	Morning	1.382	Autumn	1.159		Morning	1.562	1.333	1	1.75
	Midday	1.617	Winter	1.112		Midday	3.75	1.167	1.25	1.25
	Afternoon	1.295	Spring	1.518		Afternoon	1.6	1	1.1	1.6
Level4E			Summer	4.445						
	Morning	2.168	Autumn	3.218		Morning	3.312	2.667	1.25	2
	Midday	4.286	Winter	2.015		Midday	6.313	3.75	3.167	4.5
	Afternoon	3.238	Spring	3.246		Afternoon	4.2	3.333	2.067	3.8
Level1M			Summer	1.319						
	Morning	1.07	Autumn	1		Morning	1.313	1	1	1
	Midday	1.057	Winter	1		Midday	1.25	1	1	1
	Afternoon	1.088	Spring	1		Afternoon	1.4	1	1	1
Level2M			Summer	1.688						
	Morning	1.116	Autumn	1.055		Morning	1.375	1.083	1.042	1
	Midday	1.185	Winter	1.05		Midday	1.75	1.083	1.042	1
	Afternoon	1.209	Spring	1		Afternoon	2	1	1.067	1
Level3M			Summer	2.795						
	Morning	1.43	Autumn	1.76		Morning	2.688	1.167	1.333	1
	Midday	1.956	Winter	1.25		Midday	3.125	2.417	1.292	1.5
	Afternoon	1.681	Spring	1.281		Afternoon	2.6	1.933	1.133	1.4
Level4M			Summer	2.952						
	Morning	1.488	Autumn	2.97		Morning	2.375	1.417	1.458	1
	Midday	2.852	Winter	1.392		Midday	3.938	4.333	1.292	3
	Afternoon	2.203	Spring	1.613		Afternoon	2.75	4.267	1.433	1.4

Level5M			Summer	2.731						
	Morning	1.353	Autumn	1.456		Morning	2.375	1.167	1.208	1
	Midday	1.992	Winter	1.389		Midday	3.813	2.333	1.417	1.25
	Afternoon	1.414	Spring	1.077		Afternoon	2.25	1.133	1.567	1
Level2Z			Summer	1.571						
	Morning	1.044	Autumn	1.027		Morning	1.188	1	1	1
	Midday	1.208	Winter	1.049		Midday	1.812	1.083	1.083	1
	Afternoon	1.177	Spring	1		Afternoon	1.8	1	1.067	1
Level3Z			Summer	2.975						
	Morning	1.446	Autumn	1.357		Morning	2.688	1.5	1.083	1
	Midday	1.535	Winter	1.231		Midday	3.437	1.25	1.292	1
	Afternoon	1.5	Spring	1		Afternoon	2.85	1.333	1.333	1
Level4Z			Summer	3.77						
	Morning	1.579	Autumn	1.691		Morning	3.688	1.5	1.125	1
	Midday	1.713	Winter	1.281		Midday	3.875	1.667	1.333	1
	Afternoon	1.785	Spring	1		Afternoon	3.75	1.933	1.4	1
Level5Z			Summer	2.926						
	Morning	1.55	Autumn	1.248		Morning	3.375	1.417	1.208	1
	Midday	1.529	Winter	1.458		Midday	2.75	1.083	1.833	1
	Afternoon	1.479	Spring	1		Afternoon	2.7	1.267	1.4	1
Level3B			Summer	1.02						
	Morning	1.036	Autumn	1.027		Morning	1.062	1.083	1	1
	Midday	1.249	Winter	1.038		Midday	1	1	1.083	2.25
	Afternoon	1.097	Spring	1.466		Afternoon	1	1	1.033	1.4
Level2G			Summer	1.281						
	Morning	1.01	Autumn	1.076		Morning	1	1	1.042	1
	Midday	1.15	Winter	1.036		Midday	1.5	1.167	1	1

	Afternoon	1.123	Spring	1		Afternoon	1.4	1.067	1.067	1
Level4G			Summer	1.187						
	Morning	1.015	Autumn	1		Morning	1.062	1	1	1
	Midday	1.07	Winter	1		Midday	1.312	1	1	1
	Afternoon	1.047	Spring	1		Afternoon	1.2	1	1	1
Level4L			Summer	1.392						
	Morning	1.106	Autumn	1.071		Morning	1.437	1	1.042	1
	Midday	1.141	Winter	1.061		Midday	1.5	1.083	1.042	1
	Afternoon	1.117	Spring	1		Afternoon	1.25	1.133	1.1	1
Significant (P<0.05)										
2E			Summer	1.069						
	Morning	1	Autumn	1		Morning	1	1	1	1
	Midday	1.015	Winter	1		Midday	1.062	1	1	1
	Afternoon	1.036	Spring	1		Afternoon	1.15	1	1	1
5E			Summer	6.411						
	Morning	3.335	Autumn	4.742		Morning	5.875	3.583	1.958	3
	Midday	6.259	Winter	3.252		Midday	7.937	5.25	5.667	6.5
	Afternoon	4.981	Spring	4.945		Afternoon	5.65	5.667	3.1	6.2
6E			Summer	2.239						
	Morning	1.545	Autumn	2.273		Morning	1.562	2.083	1.167	1.5
	Midday	2.576	Winter	1.891		Midday	3.125	2.917	2.417	2
	Afternoon	1.966	Spring	1.613		Afternoon	2.3	1.933	2.4	1.4
4B			Summer	1.389						
	Morning	1.254	Autumn	1.106		Morning	1.625	1.083	1.125	1.25

	Midday	1.807	Winter	1.357		Midday	1.5	1.25	1.625	3.5
	Afternoon	1.107	Spring	1.636		Afternoon	1.1	1	1.367	1
5B			Summer	1.818						
	Morning	1.528	Autumn	1.159		Morning	2.375	1.167	1.125	1.75
	Midday	2.011	Winter	1.865		Midday	1.687	1.25	2.583	3
	Afternoon	1.439	Spring	1.847		Afternoon	1.5	1.067	2.233	1.2
1G			Summer	1.079						
	Morning	1.015	Autumn	1		Morning	1.063	1	1	1
	Midday	1.151	Winter	1.025		Midday	1.125	1	1.042	1.5
	Afternoon	1.021	Spring	1.145		Afternoon	1.05	1	1.033	1
3G			Summer	1.174						
	Morning	1.04	Autumn	1		Morning	1.125	1	1.042	1
	Midday	1.057	Winter	1.014		Midday	1.25	1	1	1
	Afternoon	1.036	Spring	1		Afternoon	1.15	1	1	1
5O			Summer	1.053						
	Morning	1.03	Autumn	1		Morning	1	1	1.125	1
	Midday	1.036	Winter	1.176		Midday	1.062	1	1.083	1
	Afternoon	1.1	Spring	1		Afternoon	1.1	1	1.333	1
3L			Summer	1.119						
	Morning	1.03	Autumn	1		Morning	1.125	1	1	1
	Midday	1.055	Winter	1.014		Midday	1.188	1	1.042	1
	Afternoon	1.012	Spring	1		Afternoon	1.05	1	1	1

5L			Summer	1.304						
	Morning	1.085	Autumn	1.182		Morning	1.188	1.167	1	1
	Midday	1.312	Winter	1.129		Midday	1.625	1.25	1.167	1.25
	Afternoon	1.126	Spring	1.077		Afternoon	1.15	1.133	1.233	1

Appendix I GLLM Analysis

GLLM Analysis done with the Tukey's LSD test on giraffe daily activity budgets:

Table I.1 Female giraffe activities: test for fixed effects with Tukey's LSD test

	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Stand	Time	28.96	2	14.48	183	<0.001
	Season	9.36	3	3.12	183	0.027
	Time x Season	5.47	6	0.91	183	0.487
Walk	Time	23.95	2	11.98	183	<0.001
	Season	2.85	3	0.95	183	0.418
	Time x Season	4.33	6	0.72	183	0.632
Lying down	Time	35.59	2	17.8	183	<0.001
	Season	47.42	3	15.81	183	<0.001
	Time x Season	7.77	6	1.3	183	0.261
S/R	Time	64.08	2	32.04	183	<0.001
	Season	4.52	3	1.51	183	0.214
	Time x Season	2.05	6	0.34	183	0.914
L/R	Time	16.75	2	8.38	183	<0.001
	Season	11.42	3	3.81	183	0.011
	Time x Season	6.66	6	1.11	183	0.358
Groom	Time	22.15	2	11.07	183	<0.001
	Season	53.44	3	17.81	183	<0.001
	Time x Season	5.23	6	0.87	183	0.517
Osteophagia	Time	45.66	2	22.83	183	<0.001
	Season	39.11	3	13.04	183	<0.001
	Time x Season	9.92	6	1.65	183	0.135

Browse	Time	11.5	2	5.75	183	0.004
	Season	3.06	3	1.02	183	0.385
	Time x Season	2.34	6	0.39	183	0.885
W/R	Time	10.48	2	5.24	183	0.006
	Season	3.79	3	1.26	183	0.288
	Time x Season	4.77	6	0.8	183	0.575
Looking around	Time	9.9	2	4.95	183	0.008
	Season	3.02	3	1.01	183	0.392
	Time x Season	12.76	6	2.13	183	0.052
Other	Time	1.88	2	0.94	183	0.392
	Season	14.39	3	4.8	183	0.003
	Time x Season	4.37	6	0.73	183	0.628

Table I.2 Female giraffe activities: number of samples with untransformed means per season per time of day

	Time		**Season**			**Season x Time**				
Stand			Summer	5.572			**Summer**	**Autumn**	**Winter**	**Spring**
	Morning	2.651	Autumn	2.896		Morning	3.813	1.5	3.292	2.625
	Midday	7.659	Winter	3.797		Midday	10.312	6.75	4.708	10.5
	Afternoon	3.658	Spring	5.095		Afternoon	4.4	2.4	3.533	4.8
Walk			Summer	26.82						
	Morning	22.09	Autumn	21.79		Morning	23.5	18.42	19.29	28.5
	Midday	34.17	Winter	26.68		Midday	33.44	28.58	42.42	33.63
	Afternoon	21.73	Spring	26.72		Afternoon	24.55	19.67	23.2	19.9
Lying down			Summer	3.254						
	Morning	1.03	Autumn	1.402		Morning	1.125	1	1	1
	Midday	4.343	Winter	1.308		Midday	6.125	2.583	2.167	10.375
	Afternoon	2.492	Spring	4.172		Afternoon	5	1.067	1.033	7

S/R			Summer	15.19						
	Morning	12.74	Autumn	18.91		Morning	13.69	14.75	11.46	11.37
	Midday	29.6	Winter	14.86		Midday	31.06	37.58	26.29	25
	Afternoon	9.04	Spring	12.02		Afternoon	8.25	12.2	10.9	6.1
L/R			Summer	6.902						
	Morning	7.232	Autumn	4.003		Morning	9.063	5	7.208	8.375
	Midday	6.906	Winter	7.907		Midday	8.437	3.5	11.625	6.625
	Afternoon	4.217	Spring	5.735		Afternoon	4.3	3.667	5.9	3.4
Groom			Summer	6.211						
	Morning	3.021	Autumn	2.838		Morning	5.687	2.083	1.875	3.75
	Midday	5.157	Winter	2.792		Midday	8.688	3.5	3.958	5.875
	Afternoon	3.631	Spring	4.413		Afternoon	4.85	3.133	2.933	3.9
Osteophagia			Summer	1.574						
	Morning	1.287	Autumn	1.551		Morning	1.5	1.083	1.5	1.125
	Midday	2.461	Winter	4.353		Midday	2	1.667	11	1
	Afternoon	1.914	Spring	1.04		Afternoon	1.3	2.067	5	1
Browse			Summer	73.48						
	Morning	57.76	Autumn	53.94		Morning	74.94	45.92	51.33	63
	Midday	84.93	Winter	69.23		Midday	91.44	69.08	99.71	82.63
	Afternoon	57.7	Spring	67.73		Afternoon	57.9	49.47	64.83	59.7
W/R			Summer	6.902						
	Morning	7.232	Autumn	4.003		Morning	9.063	5	7.208	8.375
	Midday	6.906	Winter	7.907		Midday	8.437	3.5	11.625	6.625
	Afternoon	4.217	Spring	5.735		Afternoon	4.3	3.667	5.9	3.4
Looking around			Summer	13						

	Morning	13.24	Autumn	12.92		Morning	14.06	10.58	10.67	19.37
	Midday	16.86	Winter	15.54		Midday	13.06	20.25	22.42	13.63
	Afternoon	10.87	Spring	12.5		Afternoon	11.95	10.07	15.7	7.4
Other			Summer	3.219						
	Morning	2.089	Autumn	1.363		Morning	2.875	1	2.208	3
	Midday	2.645	Winter	2.383		Midday	3.625	1.583	2.625	3.25
	Afternoon	1.985	Spring	2.332		Afternoon	3.2	1.6	2.333	1.3

Table I.3 Female giraffe activities with back transformed means

	Time		Season			Season X Time				
Stand			Summer	5.572			**Summer**	**Autumn**	**Winter**	**Spring**
	Morning	2.651	Autumn	2.896		Morning	3.813	1.5	3.292	2.625
	Midday	7.659	Winter	3.797		Midday	10.312	6.75	4.708	10.5
	Afternoon	3.658	Spring	5.095		Afternoon	4.4	2.4	3.533	4.8
Walk			Summer	26.82						
	Morning	22.09	Autumn	21.79		Morning	23.5	18.42	19.29	28.5
	Midday	34.17	Winter	26.68		Midday	33.44	28.58	42.42	33.63
	Afternoon	21.73	Spring	26.72		Afternoon	24.55	19.67	23.2	19.9
Lying down			Summer	3.254						
	Morning	1.03	Autumn	1.402		Morning	1.125	1	1	1
	Midday	4.343	Winter	1.308		Midday	6.125	2.583	2.167	10.375
	Afternoon	2.492	Spring	4.172		Afternoon	5	1.067	1.033	7
S/R			Summer	15.19						
	Morning	12.74	Autumn	18.91		Morning	13.69	14.75	11.46	11.37
	Midday	29.6	Winter	14.86		Midday	31.06	37.58	26.29	25
	Afternoon	9.04	Spring	12.02		Afternoon	8.25	12.2	10.9	6.1
W/R			Summer	6.902						
	Morning	7.232	Autumn	4.003		Morning	9.063	5	7.208	8.375
	Midday	6.906	Winter	7.907		Midday	8.437	3.5	11.625	6.625

	Afternoon	4.217	Spring	5.735		Afternoon	4.3	3.667	5.9	3.4
Groom			Summer	6.211						
	Morning	3.021	Autumn	2.838		Morning	5.687	2.083	1.875	3.75
	Midday	5.157	Winter	2.792		Midday	8.688	3.5	3.958	5.875
	Afternoon	3.631	Spring	4.413		Afternoon	4.85	3.133	2.933	3.9
Osteophagia			Summer	1.574						
	Morning	1.287	Autumn	1.551		Morning	1.5	1.083	1.5	1.125
	Midday	2.461	Winter	4.353		Midday	2	1.667	11	1
	Afternoon	1.914	Spring	1.04		Afternoon	1.3	2.067	5	1

Table I.4 Male giraffe activities: test for fixed effects with Tukey's LSD test

	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Stand	Time	14.42	2	7.21	170	<0.001
	Season	1.18	3	0.39	170	0.758
	Time x Season	2.17	6	0.36	170	0.902
Walk	Time	7.06	2	3.53	170	0.031
	Season	34.2	3	11.4	170	<0.001
	Time x Season	6.65	6	1.11	170	0.36
Lying down	Time	15.64	2	7.82	170	<0.001
	Season	36.53	3	12.18	170	<0.001
	Time x Season	4.28	6	0.71	170	0.64
S/R	Time	15.12	2	7.56	170	<0.001
	Season	17.68	3	5.89	170	<0.001
	Time x Season	2.24	6	0.37	170	0.895
Groom	Time	16.23	2	8.11	170	<0.001
	Season	84.54	3	28.18	170	<0.001
	Time x Season	12.18	6	2.03	170	0.064
Looking around	Time	4.98	2	2.49	170	0.086
	Season	14.62	3	4.87	170	0.003
	Time x Season	15.28	6	2.55	170	0.022
Osteophagia	Time	8.92	2	4.46	170	0.013
	Season	3	3	1	170	0.394
	Time x Season	6.84	6	1.14	170	0.341

Other	Time	0.8	2	0.4	170	0.67
	Season	1.37	3	0.46	170	0.713
	Time x Season	22.26	6	3.71	170	0.002

Table I.5 Male giraffe activities: back transformed means

	Time		**Season**			**Season x Time**				
Stand			Summer	2.794			**Summer**	**Autumn**	**Winter**	**Spring**
	Morning	1.397	Autumn	2.018		Morning	2.125	1	1.792	1
	Midday	4.164	Winter	2.851		Midday	3.875	3.083	4.792	5.25
	Afternoon	2.485	Spring	2.19		Afternoon	2.65	2.667	2.7	2
Walk			Summer	13.572						
	Morning	5.989	Autumn	10.764		Morning	13.437	7.417	2.458	5.25
	Midday	11.63	Winter	4.665		Midday	16.25	14.25	8.542	9.25
	Afternoon	7.776	Spring	6.479		Afternoon	11.45	11.8	4.833	5
Lying down			Summer	3.172						
	Morning	1.118	Autumn	1.077		Morning	1.562	1	1	1
	Midday	2.673	Winter	1.171		Midday	4.75	1.25	1.375	6.25
	Afternoon	2.302	Spring	3.271		Afternoon	4.3	1	1.167	5.6
S/R			Summer	7.324						
	Morning	2.988	Autumn	3.837		Morning	6.25	2.083	2.042	3
	Midday	6.67	Winter	3.321		Midday	10.563	6.667	5.917	4.75

	Afternoon	3.643	Spring	3.246		Afternoon	5.95	4.067	3.033	2.4
Groom			Summer	3.349						
	Morning	1.493	Autumn	1.355		Morning	3.437	1.333	1.083	1
	Midday	1.825	Winter	1.254		Midday	4.75	1.167	1.333	1.5
	Afternoon	1.567	Spring	1.216		Afternoon	2.3	1.6	1.367	1.2
Looking around			Summer	6.385						
	Morning	3.345	Autumn	3.708		Morning	8.25	3.5	1.333	3.25
	Midday	6.008	Winter	2.912		Midday	6.375	5.083	4.875	8.25
	Afternoon	3.566	Spring	4.317		Afternoon	4.95	2.867	3.8	3
Osteophagia			Summer	1.057						
	Morning	1.202	Autumn	1.053		Morning	1	1.167	1.792	1
	Midday	1.03	Winter	1.228		Midday	1.125	1	1	1
	Afternoon	1.021	Spring	1		Afternoon	1.05	1	1.033	1
Other			Summer	3.161						
	Morning	2.229	Autumn	2.496		Morning	6.125	1.417	1.625	1.75
	Midday	2.681	Winter	2.864		Midday	3.125	2.083	5.292	1.5
	Afternoon	2.905	Spring	1.99		Afternoon	1.65	5.267	2.733	3

Table I.6 Juvenile giraffe activities: test for fixed effects with Tukey's LSD test

	Fixed term	Wald statistic	n.d.f.	F statistic	d.d.f.	F pr
Lying down	Time	2.83	2	1.42	157	0.246
	Season	17.42	3	5.81	157	<0.001
	Time x Season	2.35	6	0.39	157	0.883
S/R	Time	10.53	2	5.27	157	0.006
	Season	18.22	3	6.07	157	<0.001
	Time x Season	1.3	6	0.22	157	0.971
L/R	Time	19.14	2	9.57	157	<0.001
	Season	3.58	3	1.19	157	0.315
	Time x Season	4.05	6	0.68	157	0.67
Groom	Time	2.76	2	1.38	157	0.255
	Season	34.26	3	11.42	157	<0.001
	Time x Season	6.54	6	1.09	157	0.37
Stand	Time	1.7	2	0.85	157	0.43
	Season	15.97	3	5.32	157	0.002
	Time x Season	6.4	6	1.07	157	0.385
Walk	Time	4.27	2	2.13	157	0.122
	Season	13.14	3	4.38	157	0.005
	Time x Season	5.11	6	0.85	157	0.532
Browse	Time	4.55	2	2.27	157	0.106
	Season	15.57	3	5.19	157	0.002

	Time x Season	0.22	6	0.04	157	1
W/R	Time	1.27	2	0.63	157	0.532
	Season	10.87	3	3.62	157	0.014
	Time x Season	6.99	6	1.16	157	0.328
Looking around	Time	1.1	2	0.55	157	0.578
	Season	6.93	3	2.31	157	0.078
	Time x Season	12.97	6	2.16	157	0.049
Other	Time	1.73	2	0.86	157	0.423
	Season	8.86	3	2.95	157	0.034
	Time x Season	3.9	6	0.65	157	0.691

Table I.7 Juvenile giraffe activities: number of samples and untransformed means per season per time of day

	Season	**Summer**		**Autumn**		**Winter**		**Spring**	
		Nobservd	Mean	Nobservd	Mean	Nobservd	Mean	Nobservd	Mean
	Time								
Lying down	Morning	12	4.833	8	0	24	0	8	0
	Midday	12	6.333	8	1	24	3.208	8	1.875
	Afternoon	15	4.4	10	0.1	30	0.967	10	0.1
S/R	Morning	12	2.333	8	0	24	0.875	8	0.25
	Midday	12	4.417	8	0.5	24	2.542	8	0.25
	Afternoon	15	1.8	10	0.4	30	1.033	10	0
L/R	Morning	12	0.1667	8	0	24	0.0417	8	0
	Midday	12	1.5	8	0	24	1.6667	8	0
	Afternoon	15	0.2	10	0	30	0.0667	10	0
Groom	Morning	12	4.083	8	0.125	24	0.458	8	1.125
	Midday	12	3.083	8	0.5	24	1.458	8	1.25
	Afternoon	15	2.267	10	0.3	30	1.033	10	0

Table I.8 Juvenile giraffe activities: back transformed means

	Time		**Season**			**Season x Time**				
Lying down			Summer	6.136			**Summer**	**Autumn**	**Winter**	**Spring**
	Morning	1.554	Autumn	1.301		Morning	5.833	1	1	1
	Midday	3.65	Winter	2.023		Midday	7.333	2	4.208	2.875
	Afternoon	1.893	Spring	1.468		Afternoon	5.4	1.1	1.967	1.1
S/R			Summer	3.698						
	Morning	1.672	Autumn	1.281		Morning	3.333	1	1.875	1.25
	Midday	2.449	Winter	2.381		Midday	5.417	1.5	3.542	1.25
	Afternoon	1.68	Spring	1.16		Afternoon	2.8	1.4	2.033	1
L/R			Summer	1.518						
	Morning	1.05	Autumn	1		Morning	1.167	1	1.042	1
	Midday	1.607	Winter	1.436		Midday	2.5	1	2.667	1
	Afternoon	1.064	Spring	1		Afternoon	1.2	1	1.067	1
Groom			Summer	4.078						
	Morning	2.052	Autumn	1.299		Morning	5.083	1.125	1.458	2.125
	Midday	2.413	Winter	1.939		Midday	4.083	1.5	2.458	2.25
	Afternoon	1.714	Spring	1.685		Afternoon	3.267	1.3	2.033	1
Stand			Summer	3.49						
	Morning	2.097	Autumn	1.273		Morning	5	1.375	1.5	1.875
	Midday	2.099	Winter	1.977		Midday	3.75	1.25	2.208	1.875
	Afternoon	1.863	Spring	1.883		Afternoon	2.267	1.2	2.333	1.9

Walk			Summer	6.071						
	Morning	4.662	Autumn	3.357		Morning	6.667	2.875	7.042	3.5
	Midday	4.789	Winter	8.543		Midday	4.417	3.375	12.833	2.75
	Afternoon	4.185	Spring	2.435		Afternoon	7.6	3.9	6.9	1.5
Browse			Summer	12.372						
	Morning	3.989	Autumn	1.032		Morning	11.25	1	18	1.25
	Midday	6.44	Winter	22.293		Midday	16.083	1	32.917	3.25
	Afternoon	3.923	Spring	1.647		Afternoon	10.467	1.1	18.7	1.1
W/R			Summer	1.587						
	Morning	1.341	Autumn	1.04		Morning	1.5	1	1.917	1.125
	Midday	1.392	Winter	1.708		Midday	1.333	1.125	2	1.25
	Afternoon	1.27	Spring	1.12		Afternoon	2	1	1.3	1
Looking around			Summer	5.851						
	Morning	4.54	Autumn	3.147		Morning	8.417	2.375	3.333	6.375
	Midday	4.378	Winter	5.959		Midday	3	4.375	9.333	3
	Afternoon	4.614	Spring	3.769		Afternoon	7.933	3	6.8	2.8
Other			Summer	1.542						
	Morning	1.205	Autumn	1.074		Morning	1.5	1	1.25	1.125
	Midday	1.383	Winter	1.312		Midday	1.833	1.125	1.292	1.375
	Afternoon	1.197	Spring	1.157		Afternoon	1.333	1.1	1.4	1

Appendix J Farm Evaluation for Keeping Giraffes

PROPERTY DETAILS					
Property name					
District					
Coordinates					
Surface area					
OWNER DETAILS					
Name					
ID / Passport number					
Telephone number					
E-mail					
Postal Address					
PROJECT DESCRIPTION					
Type and purpose		Extensive		Intensive	
Giraffe details		Existing		New	
Number of giraffe					
Sex	Male				
	Female				
Subspecies (giraffe)					
Origin of animals					

Contact person		
Contact number		
HABITAT DESCRIPTION		
Climate	Temperature	Rainfall
Bioregion		
Veld type / types		
Vegetation description		
Veld condition (Tree species available and tree quality determined by habitat assessment)		
Water provision		

Fence	
Security measures	

OTHER GAME SPECIES AND NUMBERS			
Species	Number	Species	Number

DOCUMENTATION SUPPLIED	
Evaluation and recommendation	
Permit requirements	
Management plan guidelines	
DNA Testing	

Capture and Translocation Code of Practice	

REQUIREMENTS

REQUIREMENT	DESCRIPTION	EVALUATION
Vegetation structure: Flat savannas with medium to tall *Acacia* trees Adequate shrubs and thicket (≥ 2.0 m) Adequate shade and shelter		
Food source: Abundant tree cover Adequate supply of palatable broad-leaved trees Average leaf height ≤ 5.0 m		
Water: Annual rainfall more than 300 mm Permanent supply of clean water More than one waterhole distributed evenly		
Size: Areas of 2 000 ha and larger preferable. > 1 000 ha per giraffe herd (6 individuals) required in rainfall >		

500 mm > 2 000 ha per giraffe herd (6 individuals) required in rainfall < 500 mm Camp may not be smaller than 1 000 ha		
Fence: Preferably electrified, especially small properties		

Appendix K Rhino Horn damage & KKNR Fencing

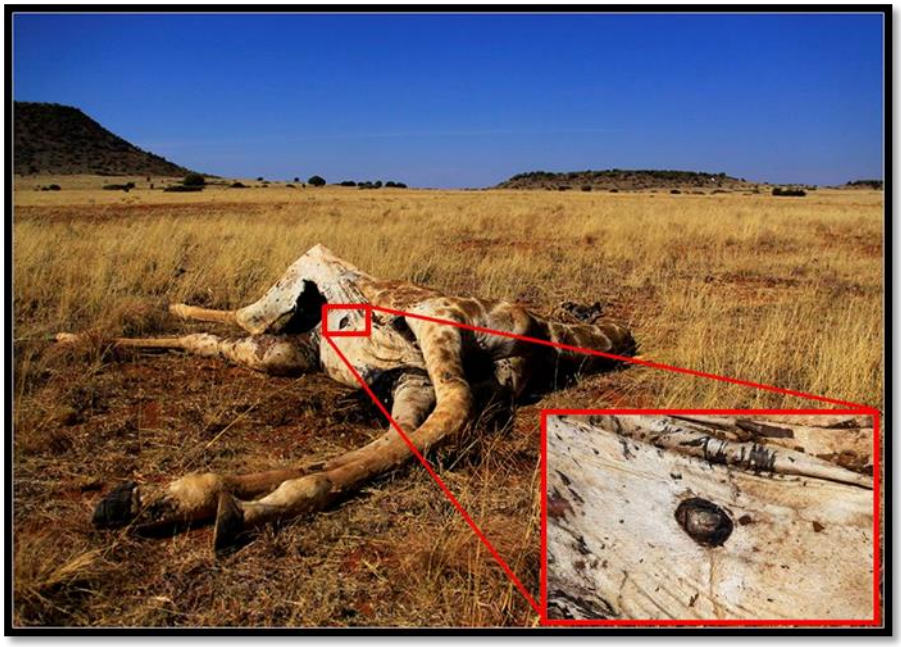


Figure K.1 Illustrating rhino horn damage and markings on killed sub-adult male giraffe (Kwaggafontein Nature Reserve, Free State, South Africa)

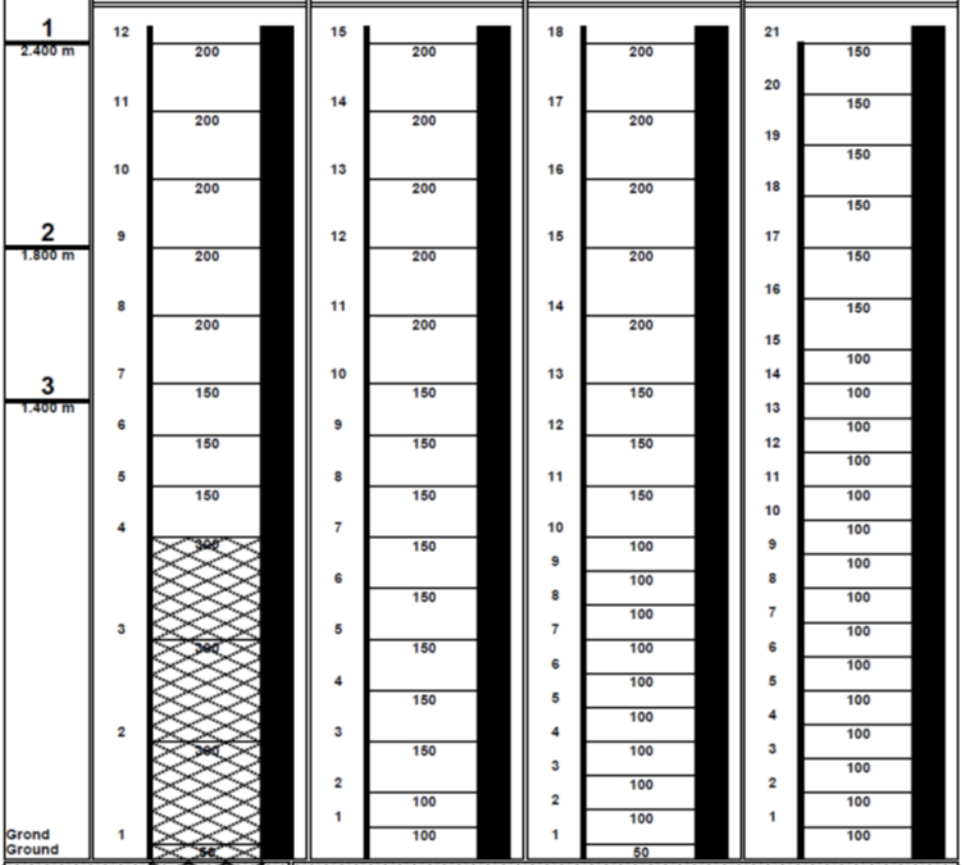
Figure K.2 Rhino damage and broken leg on adult female giraffe (Kwaggafontein Nature Reserve, Free State, South Africa)

Figure K.3 Illustrating the KKNR fence that keeps giraffes successfully within the boundaries

Appendix L NCNCA

NCNCA (ACT NO.9 of 2009) regulations on game fences

FENCE SPECIFICATIONS FOR HERBIVORE SPECIES
HEININGSPESIFIKASIES VIR HERBIVOOR SPESIES



TIPE PAAL / POST TYPE	MINIMUM VEREISTE / MINIMUM REQUIREMENT				
	YSTERPAAL IRON POST	HOUTPAAL WOODEN POST	SPASIERING / SPACING Maks./ Max.	Min.	BYKOMSTIG / ADDITIONAL
TREKPAAL / STRAIN-POST	74 mm	125-150 mm	300 m	200 m	In beton / in concrete
LYNPAAL / FENCE-POST	Y-Tipe / Type	100-125 mm	15 m	10 m	0.75 m in grond / in ground
SPAR / DROPPER	10 mm	35 mm	2.4 m	2 m	Vasgemaak / Tied

Maas Mesh	Diamantmaas / Jakkalsdraad / "Bonnox" / "Veldspan" waarvan die maksimum opening minder as 100 mm is. Diamond mesh / Jackal mesh / "Bonnox" / "Veldspan" of which the maximum opening is less than 100 mm.
Sif Netting	Begrawe die sifdraad of pak dit met klippe vir minstens 250 mm aan die binnekant van die heining. Bury netting or secure it with rocks for at least 250 mm to the inside of the fence.
Draad Wire	12 x 14 "S.D.D" gladde staaldraad en gegalvaniseerde binddraad. 12 x 14 "S.D.D" smooth steelwire and galvanised binding wire.
Nota Note	Die Direkteur kan redelike verslapping toestaan ten opsigte van die spasiëring van drade. The Director may grant reasonable relaxation regarding the spacing of strands.

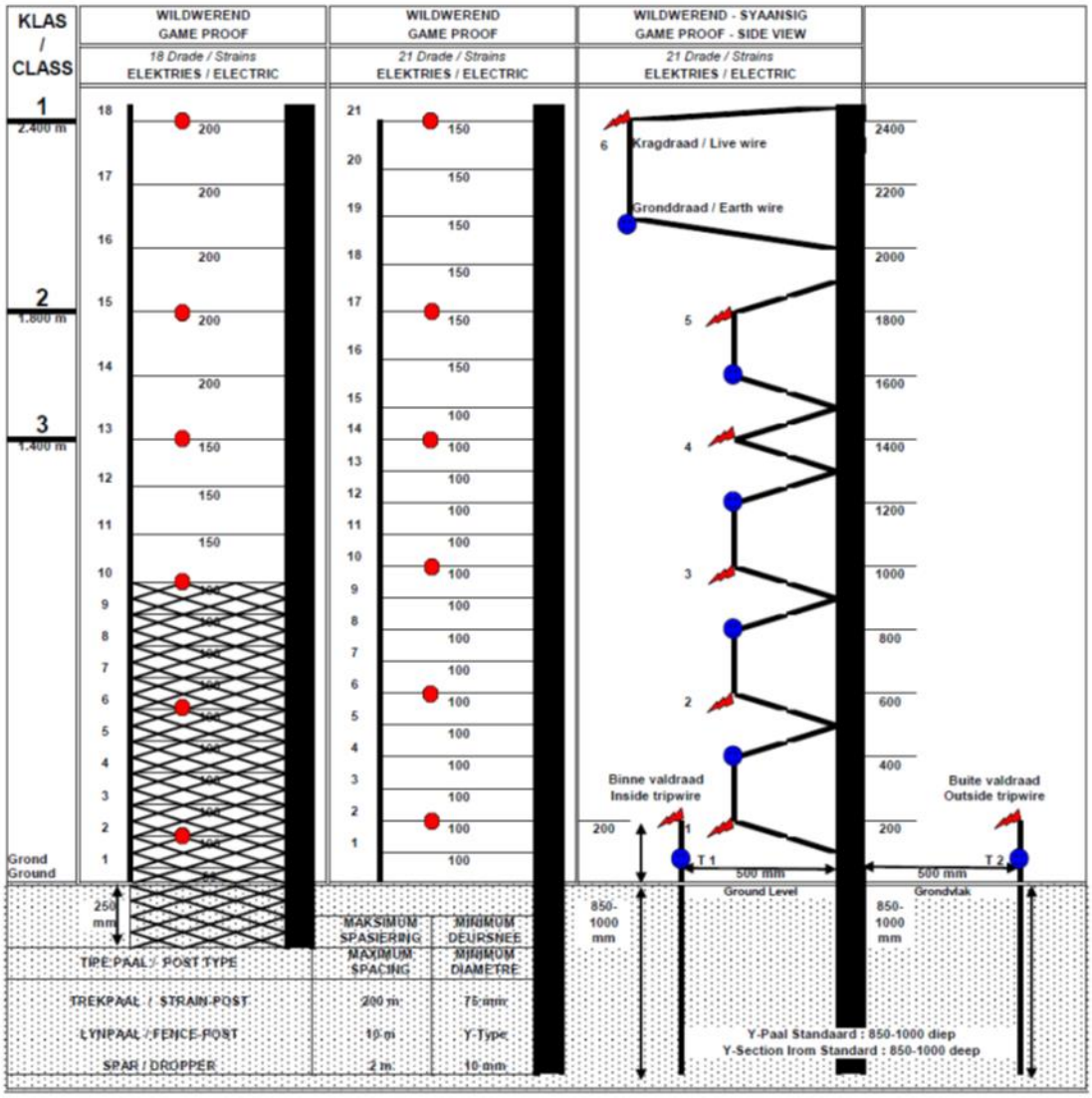
FENCE CATEGORIES FOR HERBIVORE SPECIES
HEININGKATEGORIEË VIR HERBIVOORSPESIES

KLAS / CLASS	PROBLEEMDIERWEREND PROBLEM ANIMAL PROOF	SEMI-WILDWEREND SEMI-GAME PROOF	WILDWEREND GAME PROOF	WILDWEREND GAME PROOF
	12 Drade / Strains	*15 Drade / Strains*	*18 Drade / Strains*	*21 Drade / Strains*
	A	**B**	**C**	**D**
1	12	15	18	21
2.400 m	Njala / Nyala Eland Koedoe / Greater kudu Rooibok / Impala Rietbok / Southern reedbuck Waterbok / Waterbuck Alle uitheemse spesies All exotic species	Eland Koedoe / Greater kudu Rooibok / Impala	Njala / Nyala Eland Koedoe / Greater kudu Rooibok / Impala Rietbok / Southern reedbuck Waterbok / Waterbuck Alle uitheemse spesies All exotic species	Njala / Nyala Eland Koedoe / Greater kudu Rooibok / Impala Rietbok / Southern reedbuck Waterbok / Waterbuck Alle uitheemse spesies All exotic species
2	9	12	15	17
1.800 m	Bosbok / Bushbuck Rooiribbok / Mountain reedbuck Hartbees spesies / Hartebeest species Vaalribbok / Vaal rhebok Kameelperd / Giraffe	Rooiribbok / Mountain reedbuck Vaalribbok / Vaal rhebok	Bosbok / Bushbuck Rooiribbok / Mountain reedbuck Hartbees spesies / Hartebeest species Vaalribbok / Vaal rhebok Kameelperd / Giraffe	Bosbok / Bushbuck Rooiribbok / Mountain reedbuck Hartbees spesies / Hartebeest species Vaalribbok / Vaal rhebok Kameelperd / Giraffe
3	7	10	13	14
1.400 m	Bontebok Steenbok Klipspringer Soeni / Suni Oorbietjie / Oribi Duiker spesies / Duiker species Gemsbok / Oryx Grysbok spesies / Grysbok species Swartwitpens / Sable Bastergemsbok / Roan Basterhartebees / Tsessebe Vlakvark / Warthog Bosvark / Bush pig - en alle spesies in kolom "B" van dieselfde klas. - and all species in column "B" from the same class.	Blesbok Springbok Volstruis Blouwildebees / Blue wildebeest Swartwildebees / Black wildebeest Vlaktesebra / Plains sebra - maar nie enige spesies in kolom "A,C of D" van dieselde klas nie. - but not any species in column "A, C or D" from the same class.	Bontebok Steenbok Klipspringer Soeni / Suni Oorbietjie / Oribi Duiker spesies / Duiker species Gemsbok / Oryx Grysbok spesies / Grysbok species Swartwitpens / Sable Bastergemsbok / Roan Basterhartebees / Tsessebe Vlakvark / Warthog Bosvark / Bush pig - en alle spesies in kolom "B" van dieselfde klas. - and all species in column "B" from the same class.	Bontebok Steenbok Klipspringer Soeni / Suni Oorbietjie / Oribi Duiker spesies / Duiker species Gemsbok / Oryx Grysbok spesies / Grysbok species Swartwitpens / Sable Bastergemsbok / Roan Basterhartebees / Tsessebe Vlakvark / Warthog Bosvark / Bush pig - en alle spesies in kolom "B" van dieselfde klas. - and all species in column "B" from the same class.
Grond Ground				

SPESIALE SPESIFIKASIES VIR / SPECIAL SPECIFICATION FOR :

Olifant / Elephant
Groot roofdiere / Large predators
Renoster / Rhinoceros
Seekoei / Hippopotamus
Buffel / Buffalo
Alle uitheemse spesies ten minste - klas 1 A / 1 C / 1 D
All exotic species at least - class 1 A / 1 C / 1 D

FENCE SPECIFICATIONS FOR DANGEROUS GAME SPECIES
HEININGSPESIFIKASIES VIR GEVAARLIKE WILDSPESIES



Maas Diamantmaas / Jakkalsdraad / "Bonnox" / "Veldspan" maksimum maas waarvan die maksimum opening minder as 100 mm is.
Mesh Diamond mesh / Jackal mesh / "Bonnox" / "Veldspan" of which the maximum opening is less than 100 mm.

Sif Begrawe die sifdraad of pak dit met klippe vir minstens 250 mm aan die binnekant van die heining.
Netting Bury netting or secure it with rocks for at least 250 mm to the inside of the fence.

Draad 12 x 14 "S.D.D" gladde staaldraad en gegalvaniseerde binddraad.
Wire 12 x 14 "S.D.D" smooth steelwire and galvanised binding wire.

Nota 1. Die Direkteur kan redelike verslapping toestaan ten opsigte van die spasiëring van drade.
Note 1. The Director may grant reasonable relaxation regarding the spacing of strands.

2. In die geval van 'n luiperd, moet elke hoekpaal beskerm word met 'n vertikale lewendige elekriese draad.
2. In the case of a leopard, each corner post must be protected with a vertical live electric wire.

Appendix M South African Giraffe Population Status

The following draft status report (SA National Red List Assessment) indicated that *G. c. giraffa* as a subspecies remains widespread across South Africa with a total estimated population of 22 710-29 310 individuals, numbering well over 10 000 mature individuals. Numbers are increasing due in part to the game ranching industry in South Africa. Giraffes are highly favoured by most game ranches to add to the tourism and economic value of the ranch. Private subpopulations of giraffes have been expanding and increasing within South Africa and this status report estimates there are between 11 299-13 850 giraffes across 10 000 private farms .

One of the reasons why giraffe numbers are increasing in SA can be attributed to private ownership. Ownership creates opportunities for demand; when there is a demand there is a market. If there is a market for giraffes, there is economic value added to them. When there is value added to them, they will stay in demand. Saving rhinos from extinction can be used as an example (Appendix O) published in the Government Gazette (2013). It contains valuable information on rhinos and also why other wildlife species like giraffes are so successful and why the population sizes are increasing in South Africa.

South African National Red List Assessment – Draft Status Report

Regional Red List status (2014):	**Least Concern**
National Red List status (2004):	Least Concern
Global Red List status (2008):	Least Concern
TOPS listing (NEMBA):	Protected
CITES listing:	None
Endemism:	Southern Africa
Wildness Status:	Lightly managed

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† Giraffe Specialist Group

Contributor(s)*:* Fennessy and Brown 2008

Species Champion: None

Taxonomy

Giraffa camelopardalis giraffa - (Linnaeus, 1758)

ANIMALIA - CHORDATA - MAMMALIA - CETARTIODACTYLA - GIRAFFIDAE - Giraffa – camelopardalis - giraffa

Common Names: Giraffe (English), Kameelperd (Afrikaans), Indlulamithi (Xhosa and Zulu), Thuhlo (Sotho), Thutlwa (Tswana).

Synonyms: No Synonyms

Taxonomic Level: Subspecies

Taxonomic Note:
A number of subspecies classifications have been proposed for giraffes (Ansell 1972, Dagg and Foster 1982, Kingdon 1997, East 1999, Grubb 2005, Ciofolo and Le Pendu 2013). There is considerable uncertainty surrounding the geographic and taxonomic limits of all described subspecies (Fennessy *et al.,* 2013). Furthermore, recent genetic work suggests that several subspecies may even represent distinct species (Brown *et al.* 2007). The Giraffe Conservation Foundation (GCF) are in the process of finalising DNA sampling to help unravel this mystery and hopefully provide a solid assessment using mitochondrial and nuclear DNA by the end of 2015.

Globally, only the forms *G. c. peralta* from West Africa, which recent genetic evidence has confirmed is indeed distinct (Hassanin *et al*. 2007), and *G. c. rothschildi* are assessed at the subspecies level – both now listed by the IUCN as Endangered.

Giraffe taxonomy of the various populations in Africa has largely been reliant on the variation of pelage pattern and geographic range. However, this has long been inconclusive. Even advances in molecular methods have left many aspects uncertain, often because of limited sampling (Fennessy et al. 2013). A good knowledge of giraffe genetics, however, is critical for their long-term sustainable management with an estimated population of less than 80,000 remaining in the wild. In particular, the taxonomic assignment and phylogeography of two populations in southern Africa, the South African giraffe (*Giraffa camelopardalis giraffa*) and the Namibian giraffe (*G. c. angolensis*), remains uncertain. To resolve this and estimate the divergence times among giraffe populations, an increase in sampling effort across this region as well as more broadly across Africa is very important (Bock *et al*., in review).

In this assessment, we treat *G. c. camelopardalis* as a subspecies in southern Africa.

Red List Assessment

Assessment Rationale
This subspecies remains widespread across the assessment region with a total estimated population of 22,000-29,000 individuals, numbering well over 10,000 mature individuals. There are giraffes on more than 10,000 game farms and ranches across the country. Numbers are increasing due in part to the game ranching industry in South Africa. Giraffes are highly favoured by most game ranches to add tourism value for the ranch. However, many exist outside the natural distribution range (extra-limital introductions) and may be intensively

managed on properties that are too small for self-sustaining subpopulations. If we exclude the private subpopulations and include only the subpopulations on national parks within the natural distribution range (Kruger, Augrabies Falls, Mapungubwe, Marakele and Mokala National Parks) there are still between 4,800 and 7,500 mature individuals (assuming a 63-68% mature herd structure).

With no immediate threats severe enough to cause population decline in the foreseeable future, we continue to list this species as Least Concern.

Across the rest of this subspecies' range, although some populations remain stable or are even increasing, others may be threatened and thus there may be future population declines, highlighting the importance of South Africa as a stronghold for *G. c. camelopardalis*.

- As many private subpopulations are kept on small reserves or game farms often outside of the species natural distribution range where they can cause habitat damage, conservationists and private landowners should work together to ensure giraffe are stocked sustainably and do not impact on natural resources.

Rescue Effect

There is dispersal across regional boundaries in the transfrontier parks (Kgalagadi, Greater Limpopo and Greater Mapungubwe). Both Kgalagadi and Mapungubwe, however, originate from introductions from Namibia. For the latter, approximately 22 giraffes were introduced to the Northern Tuli Game Reserve in the late 1980s and originated from two populations – about half were sourced from Langjan South Africa and the others from Namibia.

Reasons for Change

No change: Same category and criteria

Data Deficiencies

- A better estimate of giraffe numbers on private land (for example, only 2,000 owners belong to the Wildlife Ranching South Africa Association) and the effects of this species being extra-limitally introduced outside the natural distribution range.
- Subspecies clarification.

Data quality (max):	Observed
Data quality (min):	Estimated
Data sources:	Field Study, Literature, Expert Experience
Uncertainty resolution:	Author consensus
Risk tolerance:	Evidentiary

DISTRIBUTION

Geographic Range

The giraffe formerly occurred in arid and dry-savannah zones within sub-Saharan Africa, wherever trees (especially *Acacia* spp.) occurred. In southern Africa, having been reintroduced to many parts of the range from which they were eliminated, giraffes are currently common both inside and outside a number of protected areas in South Africa, as well as across the sub-region.
Within the assessment region of South Africa, the species naturally occurs in the Mpumalanga lowveld and north into the Limpopo Province, as well as westwards into the Northern Cape (Figure 1). It has been reintroduced into the North West and KwaZulu-Natal provinces. Additionally, it has been introduced into all other provinces, where it remains extra-limital (Figure 2). The natural distribution map for the subspecies, as compiled by the Department of Environmental Affairs, is shown in Figure 3.

The most current information obtained from the Giraffe Conservation Foundation (GCF) indicates the South African giraffe ranges east to west through northern South Africa, southeastern and northern Botswana, northeastern Namibia and southern Zimbabwe. Analyses of maternally inherited mitochondrial DNA loci (cytochrome b and the control region) reveal a fundamental divergence between northern and southern giraffe populations in Africa. In addition, the distribution of two currently classified subspecies, *G. c. angolensis* and *G. c. giraffa*, and the taxonomic status of Botswana and Namibian populations may need to be redefined. It appears that a cryptic rift valley in Botswana's Kalahari basin area during the Pleistocene acted as a strong barrier to gene flow between the central and northern giraffe Botswanan populations. The separation of these populations shown for maternally inherited loci may need to be taken into account for future conservation efforts and in the development of appropriate management strategies, as well as for the assessment of the taxonomic status of many giraffe populations in Africa (Bock *et al*., 2014). However, these findings are yet to be corroborated with nuclear DNA.

Though Lynch (1983) mentioned the possibility of giraffes occurring naturally in the eastern and western Free State (Harrismith and Hoopstad districts, respectively), there is no reliable historical evidence of giraffe presence in the Free State (Anon, 1972; Anseli, 1968). This province was not included in the current distribution area of giraffe (Dagg, 1962; Sydney, 1965). However, the Free State Provincial Authority initially imported five individuals in 1961 to the central Free State (Griesel, 1961). Since then, many giraffes have been brought into the Free State, regardless of their natural habitat preferences, namely the savanna biome in the lowveld with scattered sweet thorns (*A. karroo*). The reintroduction of giraffes by Transvaal Nature Conservation (Hirst, 1966; Lambrechts, 1974) in the 1970s (and beyond) was due to their demand within public and private reserves. Currently, giraffes continue to be requested by private owners based on aesthetic reasons, rather than natural management concerns.

Giraffe introductions into the Kalahari-thorn veld of the western Free State were unsuccessful because most of the animals died within two years of relocation. At the time, reasons for the mortalities could not be determined (Terblanche & Kok, op. cit.). However, according to Terblanche & Kok (1995), the giraffe population of the Willem Pretorius Game Reserve is doing fairly well, as measured by continued population growth. Skead (1987b) contends that the Eastern Cape vegetation flourished in the absence of browsers like giraffes and that browsing by them could negatively influence the indigenous flora. The composition and distribution of plant types in the Ithala Game Reserve, KwaZulu-Natal, according to Bond & Loffell (2001) were changed by the presence of giraffes. A few authors (Boshoff & Kerley, 2004; Parker, Bernard &

Colvin, 2003) viewed giraffes as a limited game type in suboptimal habitats: limited game types are generally viewed as indigenous to South Africa, but not necessarily common to all regions.

Range shifts are ongoing in South Africa because of the expanding game industry, with more and more game owners wanting giraffes on their farms with little or no consideration as to whether they would have naturally occurred there.

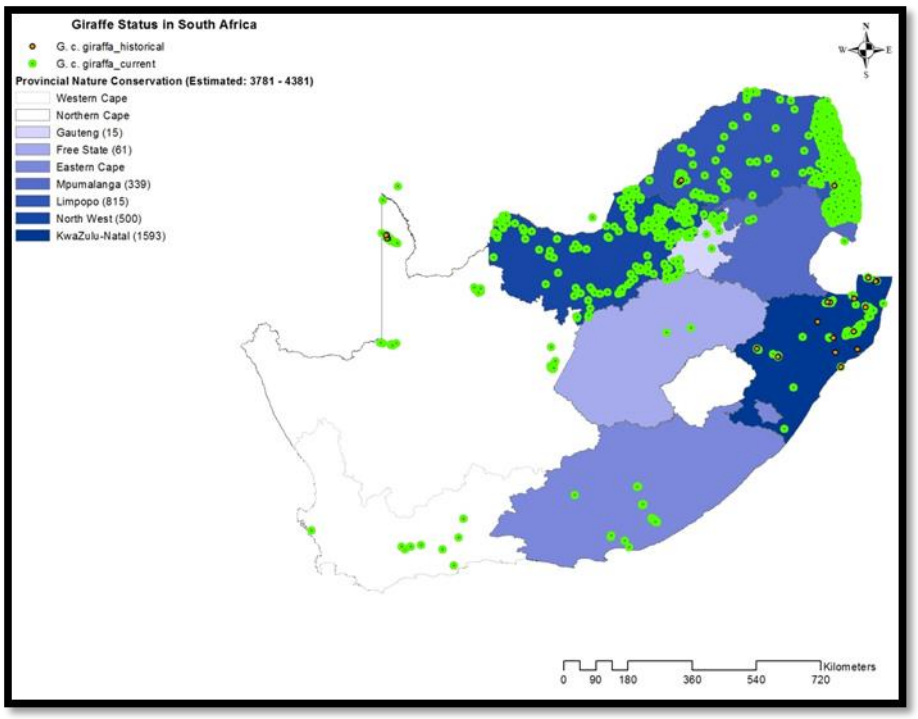

Figure M.1 Distribution map and density of giraffes in national and provincial protected areas (Deacon, 2014).

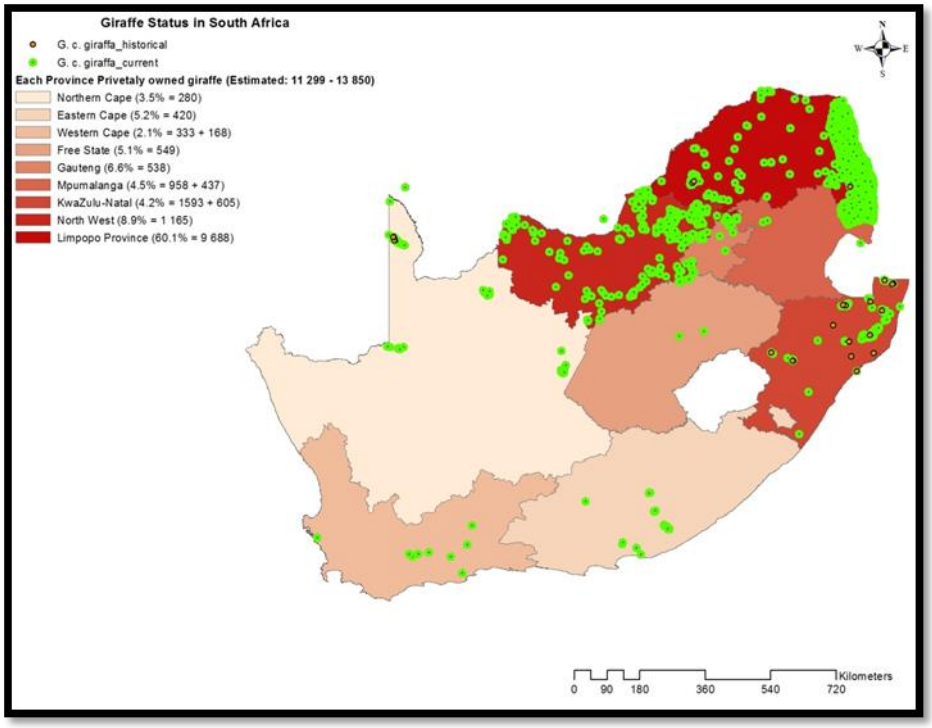

Figure M.2 Estimated distribution map and density of privately owned giraffe subpopulations (Deacon, 2014).

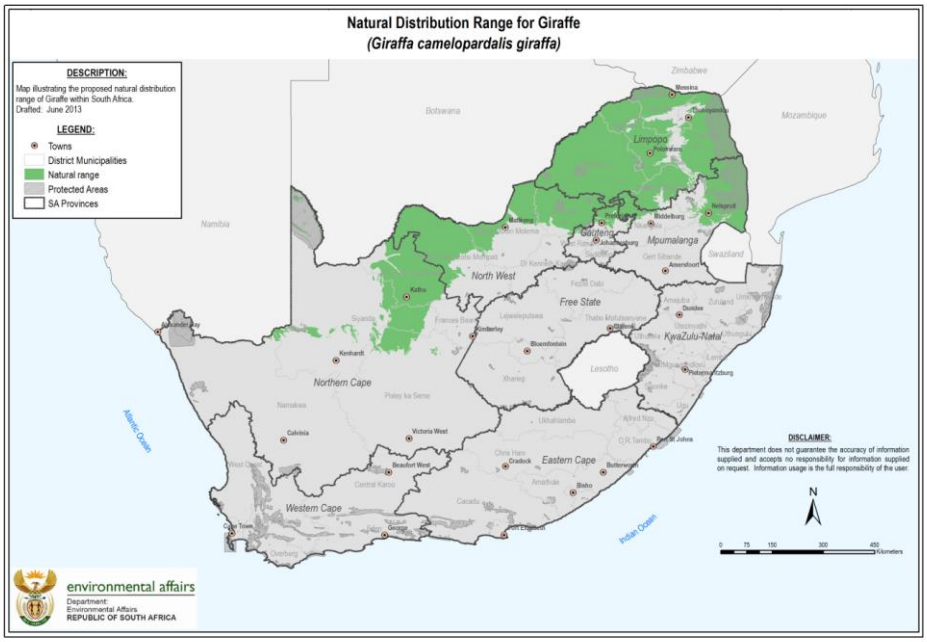

Figure M.3 The natural distribution map of G. c. giraffa as compiled by the department of Environmental Affairs.

Population

East (1999) estimated the total African population of giraffe at about 140,000 animals, predominantly in areas dominated by *Acacia* woodlands and shrublands. More recent estimates put the total population at less than 80,000 animals (Giraffe Conservation Foundation, 2013).

Within the assessment region of South Africa, there are estimated to be 22,710-29,310 individuals of which there are between 14,000-19,000 mature individuals (assuming a 63-68% mature herd structure). Within SANParks alone, there are an estimated 7,630-11,079 individuals (4,896 – 7,533 mature, Table 1). Provincial reserves around the country add another 3,781-4,381 individuals (2,571 – 2,760 mature). Thus, giraffe subpopulations within national and provincial protected areas alone exceed the threshold for both Criteria C and D (>1,000 and 10,000 mature individuals, respectively).

Private subpopulations of giraffes have been expanding and increasing within the assessment region and F. Deacon (unpubl. data, Table 2) estimates there are between 11,299-13,850 across 10,000 private farms. Although most will be wild and free-roaming individuals (i.e. not captive bred or kept in enclosures, not supplementary fed and kept on adequately sized properties), some game ranches as small as 20 ha keep and breed giraffes (F. Deacon, pers. comm.). Many of the giraffes have been introduced into areas that historically may not have been part of the giraffe's natural range (extra-limital introduction). Whilst important to obtain these numbers, they are not considered within this assessment, as these subpopulations fall outside of the species natural distribution range. For example, giraffes have been introduced throughout South Africa's Eastern Cape, but this is believed to be outside of their original range and therefore not part of the assessment.

According to Deacon's (2014) findings in the Kalahari, the average home range (206.02 km², calculated from eight-collared females; highest, 437.71 km², lowest 65.16 km²) is larger than any average giraffe home ranges previously reported: 24.6 km² (Langman, 1973), 68 km² in Zambia (Berry, 1978) and 199.51 km² Namibia (Fennessy, 2009).

Van der Jeugd & Prins (2000) reported mean home ranges of giraffes in Lake Manyara National Park, Tanzania to be between 5.2 km² (males) and 8.6 km² (females), but with much variation: 0.1 – 21.5 km² (for males) and 0.5 – 27.0 km² (for females). Berry (1978) observed that average male home range (82 km²) was greater than female home range (68 km²), and the largest for a male was 145 km² in the Luangwa valley, Zambia.

Fennessy (2009) estimated one bull's home range (in the Namib desert in northern Namibia) to be 1,950 km² and for one female 1,098 km². In the same study, the female's mean annual home ranges varied from 199.5 km² to 219.7 km² (using the 100% minimum convex polygon) and from 23.6 km to 119.1 km² (using the 95% minimum convex polygon).

If the giraffes are relying only on the natural resources and no supplementary feeding, then a typical property size to sustain an average giraffe herd should be > 3 000 ha in size, taking into account the critical period when giraffes experience feeding stress (July – September). This will limit the destruction of vegetation and possible mortalities. Prior to the introduction of giraffes into an area outside of their natural distribution range, a proper habitat risk assessment (Appendix 1) should be conducted and a management plan which includes feeding and disease monitoring should be submitted.

Table M.1 Giraffe subpopulation sizes in SANParks reserves from 2013.

Provincial and Private Giraffe	**Park name**	**Giraffe count**
Northern Cape	Augrabies Fall National Park Mokala National Park	36 57
Mpumalanga	Kruger National Park	7,427 -10,876
Limpopo	Mapungubwe National Park* Marakele National Park	60 50
	Total	**7630 -11,079**

* Please note that this is a transboundary population and that numbers will fluctuate between the three countries. Total population for GMTFCA is estimated at approx. 240 based on 2012 count.

Table M.2 Numbers of giraffes on 288 out of 10,000 privately owned game farms

Province	**Completed Requests**	**Total Registered Farms (WRSA)**	**Average giraffe Count on each**	**Average animals on 15% of 1,826 WRSA farms**

			farm	
Gauteng	19 (21.1%)	90	5	538
KZN	12 (17.9%)	67	9	605
Limpopo	173 (19.9%)	870	10	9,688
Mpumalanga	13 (16.3%)	80	6	437
Northern Cape	10 (9.5%)	105	5	280
Northwest	26 (10.9%)	238	8	1,165
Eastern Cape	15 (11.5%)	131	5	420
Free State	14 (9.9%)	142	7	549
Western Cape	6 (11.8%)	51	6	168
Total	**288 (15%)**	**1,826**	**60**	**13,850**

The subpopulation appears to be stable in the Kruger National Park but is increasing elsewhere in South Africa and continues to be reintroduced to areas within its natural range. There is also differentiation in the arid western ecotype and the lowveld giraffe, which may require management attention and metapopulation modelling.

Generation length is 10 years.

Population Information

Current Population Trend: Increasing

Severely fragmented?	Justification
Yes	In all areas besides the transfrontier parks

HABITATS and ECOLOGY

Giraffes spend most of their time feeding and according to Furstenburg (2003), up to 70% of their day is spent browsing. Similarly, in the study of Theron (2005) undertaken in the Free State, active browsing was responsible for more than half (53%) of the daily activities of the animals. During the day, browsing activities mostly took place in direct sunlight. Minimal time was spent in full or partial shade. During light rain showers, their ears were only flattened and browsing continued undisturbed, but a hard rain shower usually caused a temporary cessation of browsing. Though individuals sometimes smelled the leaves of trees before browsing, especially in the Franklin Nature Reserve in South Africa with its unusual composition of potential feeding plants, no relation was found between wind and browsing direction (Theron, 2005). The simultaneous browsing of the same plant by more than one giraffe was observed regularly by most authors. In contrast to the assumption of Dagg (1960) and Spinage (1968) that feeding activity also dominated the night-time activities, browsing was responsible for less

than a third (31%) of the total time budget during the night. In the early evening (17:00 - 20:00) and the early morning hours (01:00 - 05:00), the browsing frequency was high (84%), but the middle of the night it dropped to a low frequency (16%). In contrast, throughout the day, browsing took place at a relatively constant rate with an initial increase of 20% in the early morning and again in the late afternoon.

Theron (2005) observed that mature bulls browsed significantly less than cows ($\chi^2 = 28$; $p < 0.01$), supported by the findings of Du Toit (1990) and Pellew (1984). Young calves normally spend less time browsing, as mothers' milk largely fulfils their nutritive requirements. Browsing represents the dominant activity of adult giraffes in both the wet and dry seasons. In both sexes, browsing time increased slightly during periods of food scarcity.

Continuing Decline in Habitat

Is there decline in habitat quantity or quality?

Continuing decline in area, extent and/or quality of habitat?	Qualifier	Justification
Yes	Suspected	-

The giraffe's habitat is increasingly fragmented through development, urban sprawl and agricultural intensification.

Poorly managed game ranching is reducing habitat quality for this species. Currently, the game ranching industry is driven by economic value and little attention is given to the vegetation and the resources. Because few of these game ranches ever undertook a full habitat analysis looking at the sustainability of the resource and the animal, it is proposed that before any game ranch can own giraffes, they should undertake a habitat analysis (see Appendix 2). The habitat assessment should provide recommendations regarding the viability of the ranch (or similar) and/or the introduction of the species. Many giraffes have died because they could not adapt to the environment and the manager/owner did not realise it soon enough. With proper regulations we can limit these deaths and at the same time better protect the habitat.

Ecosystem and cultural services

- Giraffe are a flagship species of the African savanna. Giraffes are widely loved symbols of wildness and the beauty of nature.

- **Key Vegetation Types**

Acacia savanna/woodland and open woodland landscape, in which trees bigger than 3 m are common.

- **IUCN Habitats Classification Scheme**

Habitat	Season	Suitability	Major Importance?
1.5. Forest -> Forest - Subtropical/Tropical Dry	-	Suitable	-
2.1. Savanna -> Savanna - Dry	-	Suitable	-

2.2. Savanna -> Savanna - Moist	-	Suitable	-
3.5. Shrubland -> Shrubland - Subtropical/Tropical Dry	-	Suitable	-

USES and TRADE

- **General Use and Trade Information**

Non consumptive: Mostly eco-tourism.

Consumptive: hunting and bush meat. The tails are also used by traditional leaders and tribesmen for pride and status.

- Live animals are also traded privately and at government sanctioned at game auctions and distributed across South Africa.

Subsistence:	Rationale:	Local Commercial:	Further detail including information on economic value if available:
Yes	-	-	-

National Commercial Value: Yes

International Commercial Value: Yes

Trend in level of total offtake from wild sources: Unknown

Trend in level of total offtake from domesticated sources: Unknown

- **Effects of wildlife ranching**

Although the private sector has been largely responsible for restoring this species to many parts of its former natural range in South Africa, ranchers and private nature reserves are also introducing this species widely outside of its natural range (Parker and Bernard 2005).

Deacon *et al.* (2012) document the damage giraffes can cause within small, fenced game farms, and they are especially destructive towards certain *Acacia* species (Bond and Loffel 2001, Parker and Bernard 2005). However, there is no real evidence of negative effects caused by giraffes in the Eastern Cape. Anecdotal reports from parts of the Karoo (Asante Sane near Graaff-Reinet) indicate that there is insufficient food for them during the winter and they require supplemental feeding. Unpublished work by Jacobs (2008) showed very little impact of giraffes browsing on two species of *Schotia* in the Eastern Cape. Parker (unpubl. data) indicated that certain tree species may be targeted (depending on location) but that giraffe numbers were not high enough to result in the same sort of effects that Bond & Loffell (2001) observed in KwaZulu-Natal if overstocked. Thus, a nuanced management approach is required for giraffes in different habitat types and depending on giraffe density.

Regulation of translocations is required to enhance the conservation value of current extra-limital movements. Permits should be issued on a case-by-case basis following appropriate assessment and used to restore giraffes to their historical range (Bernard and Parker 2006). The following provinces provided current legislation regarding the keeping of giraffes, unfortunately other provinces did not reply.

Western Cape: Provision for the settling of giraffes in the Western Province is made in the Cape Nature Game Translocation and Utility Policy where private game farm owners with sufficient fencing may apply. The Western Cape is outside the natural giraffe range as per the IUCN definition (Coral Birss, Scientist: Mammal Ecologist of Scientific Services of Cape Nature, Figure 3).

Northern Cape: In the Northern Cape an impact assessment must be undertaken on the reserve or farm before giraffes can be introduced. According to the Northern Cape, they are not endangered nor indigenous to the region (Johan Kriek, Northern Cape Nature Conservation).

Free State: In the Free State, giraffes are regarded as normal wildlife and only a transfer permit is required. However, all giraffes coming into or leaving the Free State require a permit. The Nature Conservation of the Free State is currently working on developing this law to control the giraffe numbers more effectively (Johan Watson, Free State Nature Conservation).

Wildlife ranches may also be hybridising this species with exotic ESUs/ subspecies/ecotypes to increase sale or hunting value. This should be legislated against. However there is currently, no evidence that private landowners engage in this practice.

Net effect:	Positive
Wildness status:	Lightly managed
Data Quality:	Observed
Rationale:	Economic gains have largely driven the increase in giraffe numbers and large property sizes are required to reintroduce this species, plus the lack of intensive management practices for this species mean that they are self-sustaining or lightly managed in the long term.
Management recommendation:	If the giraffes are relying only on the natural resources and no supplementary feeding, then a typical property size to sustain an average giraffe herd should be bigger than 2 – 3 000 ha in size, taking into account the critical period when giraffes experience feeding stress (July – September). Do not overstock giraffes on small properties as this can cause habitat degradation. A habitat evaluation / risk assessment should be performed before introducing giraffes onto a farm.

- **Commercial utilisation**

Population	**Proportion of harvest (%)**	**Harvest trend**
Wild: individuals taken from natural habitat, with no human intervention in terms of enhancing individual survival or production (this includes any	Minority (c. 5%)	Stable

protected area that doesn't regularly manage specific species).		
Captive breeding: production of offspring in a controlled environment (ex situ) either from parents produced in captivity (F1) or from parents taken from the wild but maintained in captivity, where there is little further input from the wild, e.g. essentially a closed cycle production system.	Minority	Increasing
Ranching: (includes game farms, wildlife ranches, conservancies) Individuals maintained within confined areas of wild habitat, with or without other forms of manipulation, e.g. habitat manipulation	Majority (10-20%)	Increasing

THREATS

While some populations of giraffes in southern African are increasing – although those in Botswana are not and little is known of Zimbabwe currently, populations of giraffes in East, Central and West Africa have been decreasing, or low in numbers, due to habitat degradation, habitat loss and poaching. For example, poaching and armed conflict across the range of the reticulated giraffe in southwestern Somalia, southern Ethiopia and northern Kenya has reduced by more than 80% to fewer than 5,000 individuals in the last 15 years (GCF*,* 2013).

Within the assessment region of South Africa, the main threat is habitat fragmentation and degradation. This can cause inbreeding and a weakening of the species as a whole. The latest DNA results indicate that genetic diversity within South African giraffes might be very low because of these small islands of conservation areas and little effort made to conserve pure genetic material within the game ranches and conservation islands (P. Grobler, University of the Free State, pers. comm.).

Another potential threat is through hybridization of different subspecies (Namibian animals mixing with lowveld animals), which may threatens the genetic integrity of the southern ESU / ecotype.

- **Threats ranked in order of decreasing severity**

Rank	**Threat description**	**Scale** (local, regional, national)	**Data type** (observed, estimated, projected, inferred, suspected)	**Time Period** (past, present, future)	**Trend** (stable, increasing, decreasing)	**Severity**
1	Habitat fragmentation	National	Estimated	Present, future	Increasing	Unmanageable

2	Hybridisation with exotic ESUs / ecotypes / subspecies	National	Suspected	Present / Future	Stable	Manageable
3	Inbreeding	National	Suspected	Present / Future	Stable	Manageable
4						
5						

- **Threats Classification Scheme**

Threat	Timing	Scope	Severity	Impact Score
5.1.1. Biological resource use -> Hunting & trapping terrestrial animals -> Intentional use (species is the target)	Ongoing	-	-	Low Impact: 3
6.2. Human intrusions & disturbance -> War, civil unrest & military exercises	Ongoing	-	-	Low Impact: 3

CONSERVATION

This species occurs in many protected areas within the assessment region of South Africa and, given that it is an attractive ecotourism and trophy-hunting animal, the private sector will continue to stock, trade and increase their numbers. Private landowners should be encouraged to form conservancies to reduce the effects of habitat fragmentation and reduce habitat degradation from overstocking this species.

Regulations should be put in place to prevent the importation and exportation of incongruent ESUs / ecotypes or subspecies if such subspecies can be confirmed.

Similarly, a large scale ‘Stud Book’ for giraffes in South Africa could be established that would help to prevent inbreeding. These interventions could be tied together by the drafting and adoption of a Biodiversity Management Plan for giraffes.

Little is known regarding the minimum resource (and space range) requirements for giraffe populations to function sufficiently without support. This is a concern to wildlife and nature conservation officials, as these minimum standards have never been determined for management purposes. Currently, law officials cannot enforce regulations regarding minimum giraffe requirements for prospective owners of giraffes for game ranching purposes. Defining the home range requirements of giraffes within conservation areas might provide the necessary information regarding the requirements for giraffes to be self-sustained. Determination of seasonal variation in home range can assist game managers and nature conservation officials to make informed decisions regarding the well-being of giraffes during critical periods. Little exists in the literature on giraffe spatial ecology (in fenced game reserves and game ranches)

such as daily distances, home ranges and the influence temperature, rainfall and altitude might have on giraffes. For this reason more research is required on these topics.

- **Conservation interventions ranked in order of effectiveness**

Rank	**Intervention description**	**Scale** (local, regional, national)	**Data type** (observed, estimated, projected, inferred, suspected)	**In place, planned or future potential?**	**Success rate** (% target achievement)
1	Conservancy formation	National	Inferred	Both	High
2	Regulate and enforce exotic ESU trading	National	Observed	Both	Medium
3	Develop a Biodiversity Management Plan	National	Suspected	Future potential	Unknown
4					
5					

- **Key Protected Areas**

Giraffes occur in many protected areas within the assessment region (Figure 1,2).

- **Management Recommendations**

- Management guidelines are currently being drafted by Deacon (2014) to advise reserves and private giraffe owners on how best to manage the giraffe within natural habitats without degrading or affecting other species negatively.
- Mixing Giraffe ESUs through hybridisation should be avoided. Legislation should be in place to prevent the importation or exportation of incongruent giraffe populations.
- Properties with deciduous trees should provide supplementary feeding.

Research Priorities

- Continued introduction of giraffes into parts of the region that are considered extra-limital necessitates robust assessments of their impact on vegetation and other ecosystem processes. While some small, unpublished, and largely descriptive, studies have been carried out in the Eastern Cape (Parker 2004; Jacobs 2008; Marais 2010), further research is required (particularly in the Western Cape).
- Collecting DNA and genetic material.
- Supporting the development of appropriate management and legislation for the wildlife sector with respect to giraffes. The economic value should be excluded, as many game farms are driven by economic value rather than ecological value.

- **How can citizens contribute?**

- Upload sightings of giraffes outside protected areas to GiraffeSpotter (www.giraffespotter.org): a citizen scientist tool of the Giraffe Conservation Foundation

which seeks to engage people as a giraffe network to build a greater awareness about giraffe distribution and status across Africa. Uploading of sightings will be important to obtaining current information on the distribution of giraffes. These data also help the IUCN Giraffe and Okapi Specialist Group and the Giraffe Conservation Foundation to perform Red List assessments.

- Get information regarding giraffes
- at Universities and not from websites
- Participate in the World Giraffe Day – 21 June – by creating awareness and raising support for giraffe conservation.
- Invite lecturers and researchers working on giraffe projects to survey private land.
- Drop fences to form conservancies.

- **Conservation Actions In- Place**

Conservation sites identified	Note
Yes, over entire range	Migrated from Conservation Measures 4.4.2 Habitat and Site-based actions -> Protected Areas->Establishment: in-place

Harvest management plan	Note
Yes	Migrated from Conservation Measures 5.3.1 Species-based actions->Sustainable use->Harvest management: in-place

Successfully reintroduced or introduced benignly	Note
Yes	Migrated from Conservation Measures 5.1 Species-based actions->Re-introductions: in-place

- **Important Conservation Actions Needed**

Conservation Actions	Note
1.2. Land/water protection -> Resource & habitat protection	-
2.1. Land/water management -> Site/area management	-
3.1.1. Species management -> Species management -> Harvest management	-
3.1.2. Species management -> Species management -> Trade management	-
6.1. Livelihood, economic & other incentives -> Linked enterprises & livelihood alternatives	-

- **Research Needed**

Research	Note
1.1. Research -> Taxonomy	-
1.2. Research -> Population size, distribution & trends	-
3.1. Monitoring -> Population trends	-

Appendix N Government Gazette (2013)

In South Africa, private landowners who had already begun game ranching were identified and they were offered rhinos in the 1960s.The former Natal Parks Board began issuing permits for rhinos to be hunted on private land, sustainably. This instantly created a financial incentive for the private ownership of rhinos, which immediately created a demand for rhinos. Natal Parks Board began selling off surplus rhinos to private ranchers and the game ranching boom had begun! Surplus rhinos were sold to the private sector just like the antelope species. An important point to note is that initially many land owners did not want rhinos because they held no value, meaning they could not be hunted, and they couldn't trade with them. Rhinos were initially NOT a worthwhile investment for game ranchers. This alone was a threat to rhinos. Only when permits were issued that allowed rhinos to be sustainably hunted, did the demand for rhinos grow, and with this their value was enhanced dramatically. The professional hunting industry, focusing on international hunting tourists also grew and that promoted the value of rhinos and hunting was a major factor in this brilliant concept. This led to the successful conservation and widespread growth of rhino populations through the wise concept of sustainable utilization. The same principles applied to other wildlife species.

In 1976, Kenya stopped all hunting as a result of pressure from fanatical anti-hunting/utilization groups. Two things happened. The first was that South Africa became a more desirable destination for foreign hunters; the main attraction at that time was rhinos along with some plains game antelope species. The second thing that happened was that Kenya's wildlife began disappearing in the wilderness areas around the parks, because nobody was benefiting from the wildlife and nobody had any incentive to protect the wildlife in the "wilderness areas". Today Kenya's wildlife is nothing close to what it once was; in fact their wildlife is limited to a few parks such as the Masai Mara and a few game ranches. Their rhino populations today, are miniscule in comparison with what we have in South Africa. They only have a few hundred left and many of these were re-introduced to Kenya from South Africa and many of these have already been poached. It's ironic that Kenya is the country that has submitted a proposal to CITES to ban all trade in rhinos, including legitimate trophy hunted rhinos in South Africa and Swaziland, the world's two strongholds for rhinos. Despite their failed conservation of rhinos, they are determined to impose restrictions on the two countries which are renowned for rhino conservation successes.

Today we have 10 000+ privately owned game ranches in South Africa covering an area of 20 500 000 million hectares. This is land that supports wildlife and is mostly marginal agricultural land. In contrast, the Government Reserves collectively cover a mere 7 500 000 million hectares. A huge portion of the privately owned land entertains hunting, and a lesser portion entertains photographic tourism and many landowners and reserves (state and private) do both. South Africa has approximately 6 000 foreign hunter tourists visiting our country each year, and the game ranching and hunting industry accounts for approximately R8 billion to the GDP each year, and it's growing and so is the "space" that is home to wildlife. Employment is created to well over 100 000 people directly, the domino benefit to families of the employed is exponential. Privately owned game ranches account for approximately 2,5 million head of game, which is approximately four times more than can be found in our state parks. This huge conservation success story, which began in the late 1960s, is all a result of the value that was and is placed

on wildlife, including rhinos. Today there are ± 20 000 rhinos in South Africa, of which 5 000+ live on privately owned game ranches.

No form of tourism or wildlife industry places more value on a wild animal than hunting does, including rhinos. The minute the value of rhinos decreases or is lost, is the day that the rhino numbers will begin to decline. At the moment the vast majority of rhinos poached are in state parks, far fewer are poached on private land, because the incentive to protect their private investment is paramount.

The national population was estimated to number 18 800 individuals in 2010, a significant increase from the approximately 6,000 white rhinos in 1991. Analysis undertaken by the IUCN African Rhino Specialist Group indicates that the national average growth rate of the white rhino population was just over 7% from 1991 to 2010. A number of key events apparently contributed to the exponential increase in the national population of white rhino since the late 1800s, such as the advent of translocations and policy changes, both locally and internationally, that created economic incentives for the private ownership and protection of rhinos.