The behaviour and feeding ecology of extralimital giraffe within Albany Thicket vegetation in the Little Karoo, South Africa

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DECLARATION

I declare that *The behaviour and feeding ecology of extralimital giraffe within Albany Thicket vegetation in the Little Karoo, South Africa* is my own work, that it has not been submitted for any degree or examination in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by complete references.

Full name: ..Jamie Paulse..... **Date:** ...27/02/2018.....

Signed:  .....

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ABSTRACT

Due to their popularity for tourism, giraffes are being introduced into Thicket areas within the Little Karoo region of the Western Cape. However, information regarding the activity budgets and diet selection of these giraffes is lacking. Therefore, this study aimed to achieve three objectives; to determine the diurnal activity budget, diet composition and browsing levels, and the estimated browsing capacities of extralimital giraffe. The study was conducted on two privately owned farms, namely Kareesbos Private Game Reserve and Tsumkwe Private Game Reserves. Observations were completed on both study sites using the interval scan method, whereby observations were conducted on all visible individuals from 6 am – 6 pm for four days every 3 months (winter, spring, summer and autumn). Observations found browsing to be the most dominant activity displayed by both populations, with walking and rumination being the second and third most dominant activity. Females browsed more than males in both study sites.

Dietary observations showed four species (*Pappea capensis*, *Portulacaria afra*, *Euclea undulata* and *Searsia longispina*) and five species (*Searsia longispina*, *Euclea undulata*, *Pappea capensis*, *Vachellia karroo* and *Grewia robusta*) to comprise approximately 90% and 80% of their diet in Kareesbos and Tsumkwe respectively. The importance of flower bearing species (*Lycium spp*. and *Rhigozhum obovatum*) increased during the spring and summer seasons in both study sites. In addition to the diet selection, browsing by both giraffe populations was shown to occur mostly below 2 m.

Estimated browsing capacities for Kareesbos and Tsumkwe were 25 and 21, and 107 and 88 ha per giraffe, respectively, for the respective browse height strata of less than two metres and five metres. It is suggested that browsing capacities of less than two metres be considered when stocking giraffe and the number of individuals adjusted accordingly on each farm, due to the continuous low browsing of giraffe at less than two metres. Furthermore, results indicate that these giraffes have adapted to take advantage of forage available in ecosystems outside their natural ranges. Low foraging heights suggests possible niche overlap with other browsers, which may result in increased competition for food when it becomes limited. Long term ecological monitoring of extralimital populations and appropriate management procedures are therefore required to avoid the displacement and degradation of indigenous fauna and flora within the Little Karoo, and possible mortalities amongst the giraffe populations.

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CHAPTER 1 : LITERATURE REVIEW

1.1. Description

Although giraffes are traditionally classified as belonging to a mono-specific genus (*Giraffa camelopardalis*) with several subspecies. Fennessy *et al.*, (2016) have recently suggested that they should be split into four distinct species, based on genetic evidence. However, there is a lack of consensus amongst researchers regarding these proposed changes to the classification system (Bercovitch *et al.*, 2017). Regardless, giraffes are the tallest even-toed ungulate in the world, reaching of heights between 4.3 and 5.2 metres, with the tallest recorded giraffe reaching a height of six metres (Dagg, 1971; Skinner and Smithers, 1990; Parker, 2004). With females generally being smaller than males, the average mass for females has been recorded to vary between 800 and 900 kg, with the average mass of males approximating 1200 kg (Dagg, 1971; Skinner and Smithers, 1990; Parker, 2004). Giraffe are therefore classified as megaherbivores due to their large size exceeding 1000 kg (Owen-Smith, 1988; Jacobs, 2008). The height of giraffe allows these animals to take advantage of browse higher up in the canopy of trees, thus avoiding potential competition with other ungulates. However, although this feature is beneficial, particularly in drier periods when browse is scare, it has been shown that giraffe do not always take advantage of this opportunity (Blomqvist and Renberg, 2007). The marginally longer forelegs and shorter hind legs compliment the sloped back.

The giraffe skull, approximately 73 mm long, is structurally different for males and females. At birth, the horns present on the skulls of both males and females are soft and cartilaginous, fusing with the skull as it ossifies with age (Skinner and Smithers, 1990; Parker, 2004). Once giraffes reach adulthood, the horns are more protuberant in males as they are thicker and lack the hair present on the tip of female horns (Parker, 2004). Males are also distinguished from females by the presence of irregular bony growths on the facial region (Dagg, 1971). The hide colour differs between subspecies, being usually of a buff colour varying between chestnut-brown and black spots or patches separated by off-white, white or yellowish-white bands (Dagg, 1971; Skinner and Smithers, 1990; Parker, 2004). The spots or patches, serving as a thermoregulatory function or for camouflage, vary in size from irregular jagged blotches to smooth polygons spread throughout the body (Kingdon, 1979; Skinner and Smithers, 1990; Parker, 2004). These differ throughout the body, with spots and patches being smaller on the head and upper legs, and larger on the rest of the body (Dagg, 1971; Skinner and Smithers, 1990; Parker, 2004). The hairs of the tail and neck differ, with the tail consisting of long, black, coarse terminal hair, and the neck consisting of short, brown, stiff hair (Dagg, 1971).

1.2. Diurnal behaviour (activity budget)

To ensure long term survival, herbivores are required to maximise their fitness by maintaining a positive energy balance, which is achieved by distributing their time and energy budget (Adolfsson, 2009). This energy balance is regulated through forage intake or feeding, which is achieved through the involvement of several behavioural factors (Pellew, 1983; Adolfsson, 2009). These factors include forage habitat choices, the selection or rejection of particular plant species, as well as the time allocated to foraging and other energy consuming activities (Pellew, 1983; Fennessy, 2004; Adolfsson, 2009; Deacon, 2015).

Time allocated to activities, otherwise known as activity budget, has been shown to differ between the different giraffe subspecies in different habitats, between giraffe sex and age categories, as well as between seasons and different daily time periods (Kok and Opperman, 1980; Pellew, 1984a; Kok and Opperman, 1985; Fennessy, 2004; Blomqvist and Renberg, 2007; O'Connor, 2013; Deacon, 2015). Their capability to exploit different habitats successfully is through their combined physiological and behavioural adaptations (Fennessy, 2004; Dagg, 2014). For example, nasal cooling, a physiological feature, is an evolutionary adaptation enabling giraffe to cope in arid areas (Fennessy, 2004; Dagg, 2014). In order to keep cool, the lungs of most mammals heat up to body temperature and become saturated with water vapour. However, incoming air cools down the nasal passages of giraffes through the process of evaporation, thus cooling down the warm air from the lungs during exhalation. This process produces and retains water, reducing water loss of up to 1.5 – 3 litres per day (Dagg, 2014).

An example of a behavioural adaptation by mammals is changing their behaviour during different times of the day. This behaviour, also known as biphasic behaviour, helps large mammals cope in arid areas (Fennessy, 2004), and entails the increase of energy consuming activities (i.e. walking and browsing) during the cooler periods of the day (early morning and late afternoon), and the increase of energy conserving activities (i.e. resting and ruminating) during the hotter periods (midday) (Fennessy, 2004). This behaviour has been documented for giraffes (Dagg and Foster, 1976; Pellew, 1983; Fennessy, 2004; Adolfsson, 2009; Deacon, 2015). Within the Serengeti National Park, Tanzania, browsing by giraffes was observed to be strongly biphasic, occurring more three hours post-dawn and pre-dusk than during midday (Pellew, 1983). The decline in browsing around midday, when ambient temperatures were the highest, was evident, and inversely correlated with rumination (energy conserving) (Pellew, 1983). Similar results were observed in the Masai Mara National Reserve, Tanzania (Adolfsson, 2009), Namib Desert, Namibia (Fennessy, 2004), Kalahari (Deacon, 2015) and in

the Eastern Transvaal (Mpumalanga), South Africa and Nairobi National Park, Kenya (Dagg and Foster, 1976).

Although few studies have documented the activity budgets of giraffes (Pellew, 1983; Fennessy, 2004; Blomqvist and Renberg, 2007; Adolfsson, 2009; Deacon, 2015), browsing tends to be the dominant activity observed in most of these studies. Within the Molokodi Nature Reserve, Botswana (Blomqvist and Renberg, 2007), giraffes spent 36% of their time browsing, 20% walking, 16% standing and ruminating and 10% on vigilance. Sexual differences were observed for browsing, vigilance and rumination, with females spending more time than males on browsing and vigilance, and males spending more time than females on rumination.

Browsing was also found to be the dominant activity displayed by giraffe in the Serengeti National Park, Tanzania (Pellew, 1983). Time spent browsing differed both seasonally and between sexes, with females spending more daylight hours browsing than males (72.4% vs 55.4%), with an increase in browsing from the wet to the dry season for both males (39.7% to 48%) and females (51.8% to 55.1%). Rumination, too, differed between sexes, with males ruminating more than females (30.2% vs 26.9%). A similar dominance of browsing was observed in the Masai Mara National Reserve, with males and females spending 39% and 36% of their time browsing respectively (Adolfsson, 2009).

In the Namib Desert, Namibia, browsing, walking, ruminating and resting constituted 95% of the giraffes' activity budget, with sex and seasonal differences evident (Fennessy, 2004). Females were observed to spend more time browsing (59% vs 51.1%) and resting (14.2% vs 13%) than males, whilst males spent more time ruminating (13.1% vs 9.1%) and walking (17.4% vs 15%) than females. Browsing by both males and females increased from the wet to the dry season, while rumination by males and females decreased in the dry and wet season respectively. Resting by males predominated in the wet season.

In the Khamab Kalahari Nature Reserve, South Africa, browsing was the dominant activity amongst giraffes, with adult (48%) and sub-adult (57%) females browsing more than adult (41%) and sub-adult (38%) males as well as juveniles (42%) (Deacon, 2015). Other dominant activities included walking, standing and ruminating, and vigilance. Adult females spent 18%, 11% and 9% of their time on walking, standing and ruminating, and vigilance respectively, whilst adult males spent 20%, 10% and 9% on these activities respectively. The dominant activities of sub-adults, however included lying down, with 18%, 10% and 9% of sub-adult males time spent on walking, lying down and both standing and vigilance respectively. Sub-

adult females spent 11%, 11% and 8% on walking, lying down and vigilance respectively, whilst juveniles spent 18%, 15% and 7% on walking, vigilance and lying down respectively (Deacon, 2015).

Various explanations have been given as to why certain giraffe behaviours differ between sexes. Females spending more time browsing has been attributed to sexual dimorphism, with females being smaller in body size than males, thus having different nutritional and energetic requirements, with males requiring more total energy per unit body mass per unit time (Ginnett and Demment, 1997). Males, therefore, spend more time on forage ingestion, by consuming larger and more bites than females (Ginnett and Demment, 1997; Deacon, 2015). In addition, males spend more time ruminating than females, thus extracting more nutrients (Fennessy, 2004)

Vigilance serves many purposes. Firstly, vigilance may function as anti-predator protection (Ginnett and Demment, 1997). For example, males have been observed to increase their vigilance with the corresponding shift in predators during the wet season (Ginnett and Demment, 1997). This increase is coupled with the increase in forage intake due to new plant growth during this season (Ginnett and Demment, 1997).

Vigilance has also been studied in accordance with group dynamics (Ginnett and Demment, 1997; Cameron and Du Toit, 2007). Therefore, vigilance does not only act as an anti-predator function, but may serve as protection against competitors (conspecifics) (Renouf and Lawson, 1986; Yaber and Herrera, 1994; Cameron and Du Toit, 2007). Males may be more vigilant than females when they are within a group in order to compete for females, or other socially related vigilance in larger groups (Ginnett and Demment, 1997). Smaller males may also be more vigilant than larger males in order to avoid aggression from dominant males (Pellew, 1984a; Artiss and Martin, 1995; Cameron and Du Toit, 2007). In addition, the increase in vigilance has also been associated with higher browsing levels. In other words, when browsing occurs with the eyes directed at the sky, individuals may interrupt foraging more often to scan (Cameron and Du Toit, 2007).

Behavioural seasonal differences are commonly found in browsing and are explained in detail in section 1.3. However, numerous studies have shown a seasonal increase in browsing from the wet to the dry season (Pellew, 1983; Fennessy, 2004; Smit, 2006; Deacon, 2015). This is attributed to the phenological change of preferred forage plants in giraffe habitats. Deciduous trees tend to lose their leaves during the dry season, causing a reduction in the availability and

nutrient quality of forage and the subsequent increase in time spent foraging. The reduction in forage during the dry season may also lead to an increase in mobility (walking) in order to seek out food (Cilliers and Kok, 1994).

1.3. Diet

Herbivores often select forage with a high moisture and nutrient (e.g. protein and fibre) content in order to meet their daily energy and nutritional requirements (Fennessy, 2004; Blomqvist and Renberg, 2007; Zinn *et al.*, 2007; Cornelius, 2010). However, to achieve this, herbivores continuously modify their diets according to certain intrinsic and extrinsic factors (Fennessy, 2004; Cornelius, 2010). Plant factors include the variation in plant availability and nutritional quality between seasons, plant composition and density, palatability, chemical composition and growth potential (Pellew, 1984b; Fennessy, 2004); whereas animal factors include body size, digestibility and experience (Cornelius, 2010).

Giraffes are browsers, predominantly feeding on trees and shrubs, with grasses being consumed on the rare occasion (Oates, 1970; Hall-Martin and Basson, 1975; Baer *et al.*, 1985; Adolfsson, 2009; Cornelius, 2010; Seeber *et al.*, 2012). Giraffes are considered to be selective browsers (Baer *et al.*, 1985; Adolfsson, 2009), selecting not only certain individual forage species within a habitat, but also selecting specific plant parts of a higher nutritional quality (Adolfsson, 2009; Deacon, 2015). Consumed plant parts include leaves and shoots (Cornelius, 2009), with giraffes preferring flowers and pods, as well as younger shoots and leaves due to a higher protein, mineral and carbohydrate content and digestibility compared to mature leaves (Fennessy, 2004). However, the plant, and plant part, selection is based on availability and accessibility (Spinage, 1968). For example, selectivity is highest during the wet season when the quantity of fruits and flowers, as well as new leaf and shoot growth, is at its greatest (Cornelius, 2010).

The diet of giraffes has been documented to constitute a wide variety of plant genera, varying between a total of 10 and 80 plant species throughout and beyond their range (Evans, 1970; Oates, 1970; Sauer *et al.*, 1977; Leuthold and Leuthold, 1978; Kok and Opperman, 1980; Pellew, 1983; Parker *et al.*, 2003; Fennessy, 2004; Blomqvist and Renberg, 2007; Cornelius, 2010; Caroline and Adhiambo, 2012; Deacon, 2015). However, this diversity does not only differ between ranges, but between habitat types within the same area. For example, within the Ruma National Park, Kenya, the food selection of giraffes differed between habitat types (Caroline and Adhiambo, 2012). Although 42 species were consumed in total throughout the

whole park, 19 species were browsed within the *Balanites aegyptiaca* wooded grassland. However, the number of species increased with an increase in the availability of the preferred *Vachellia* species in the *Vachellia* habitats, with 36 species being browsed in the *Vachellia seyal* woodland, 29 species in the *Vachellia drepanolobium* habitat, and 35 species within the riverine vegetation community (Caroline and Adhiambo, 2012).

1.4. Diet composition

Giraffes have been shown to have strong preferences for *Vachellia* species throughout their natural range, and this is dependent on their availability within different habitats (Dagg and Foster, 1976). In Niger, giraffes showed strong preferences to *Vachellia nilotica, V. seyal* and *Combretum glutinosum* in habitats they occupied during the dry season (Caister *et al.*, 2003). In *Vachellia* habitats in the Ruma National Park, Kenya, *Vachellia* species available in each corresponding *Vachellia* habitat contributed significantly to the diet of giraffes (Caroline and Adhiambo, 2012). For example, in the *V. seyal* woodlands, *V. seyal* had the highest representation in the diet of giraffes, with other *Vachellia* species, namely *Senegalia polyacantha* and *Vachellia abyssinica* being preferred as well. In the *V. drepanolobium* wooded grassland, *V. drepanolobium* had the highest representation in the diet, with other important *Vachellia* species including, *Vachellia kirkii*, *V. seyal*, *Vachellia gerardii* and *S. polyacantha* also being consumed.

Seasonality has been documented to have an effect on plant selection due to the change in phenology of browse species (Janecke and Smit, 2011). In the Serengeti National Park, Tanzania, *Vachellia tortilis*, the dominant species found in the diet of both females and males, as well as *Senegalia senegal*, *Vachellia hockii* and *Commiphora trothae*, were selected more during the wet season (Pellew, 1983). However, due to the decrease in biomass of these species during the dry season, *Grewia bicolor*, *Grewia fallax* and *B. aegyptiaca* were selected more (Pellew, 1983).

In the Timbavati Private Nature Reserve, South Africa, preferred species, mostly deciduous, such as *Combretum apiculatum*, *Terminalia prunioides*, *Senegalia nigrescens*, *Ziziphus mucronata* and *Combretum zeyheri*, were utilised to the maximum during the hot wet season (Hall-Martin, 1974). However, the onset of leaf shedding of most of these species during the cool dry season caused a shift in species utilisation, to species such as *Bolusanthus speciosus*, *Combretum hereroense*, *Grewia subspathulata*, *Combretum imberbe* and *Colophospermum mopane*. Further drastic reduction in leaf availability during the hot dry season caused another

shift, to more semi-deciduous and evergreen species being utilized. These species included *Euclea undulata*, *Maytenus senegalensis*, *Schotia brachypetala* and *Diospyros mespiliformis*. Shortage of food during this season also resulted in increased consumption of woody material such as twigs (Hall-Martin, 1974).

The phenology of principal species also caused seasonal variations in the diet composition of giraffes in the Koos Meintjies Nature Reserve, South Africa (Sauer *et al.*, 1977). Important deciduous browse species, such as *Z. mucronata* (14.65% vs 0.65%) and *Peltophorum africanum* (13.5% vs 0.99%) were consumed more during the wet season than during the dry season. The semi-deciduous species, namely *C. hereroense* (9.4% in the wet season vs 19.23% in the dry season), was utilized more during the dry season when leaf availability was reduced. *Vachellia tortilis* (10.05% during wet seasons vs 19.8% during dry season), although deciduous, retained some of its leaves during the dry season, providing further support during this period of nutritional stress (Sauer *et al.*, 1977).

The diet composition of extralimital giraffe was determined within the Eastern (Parker *et al.*, 2003) and Western Cape (Cornelius, 2010) of South Africa. In the Eastern Cape, *Searsia undulata* (47.9%), *Vachellia karroo* (25.7%) and *E. undulata* (17.6%) formed the bulk of the giraffes' diet in Shamwari Game Reserve. Seasonal variation in diet composition was evident, with the evergreen *S. undulata* more important in winter (61.1%) than summer (34.7%) and the deciduous *V. karroo* being more important in summer (39.6%) than in winter (12.9%) (Parker *et al.*, 2003). *Vachellia karroo* (60.5%) and *Acacia cyclops* (27.7%) formed the bulk of the diet of extralimital giraffe within the Western Cape (Cornelius, 2009). Seasonal shifts, too, were evident, with the importance of *V. karroo* decreasing (27%) and the consequent increase in the evergreen *A. cyclops* (48.2%) in winter.

1.5. Browsing levels

Browsing levels, otherwise known as browsing heights, refer to the level/height at which browsers forage within the canopy. The giraffes' elongated neck is considered advantageous, as it allows it to forage out of reach of other browsers, thus avoiding competition (Blomqvist and Renberg, 2007). In addition to avoiding competition, it is suggested that giraffes receive more biomass per bite higher up in the canopy, due to the combined browsing of smaller browsers lower in the canopy (Woolnough and Du Toit, 2001). However, giraffes do not always make use of this advantage, and have been documented to browse throughout the canopy (Blomqvist and Renberg, 2007).

Cilliers and Kok (1994) determined browsing height using six levels. The browsing levels included stretch height (mouth stretched higher than the base of the horns), head height (upright position with neck angle 45° to the horizontal), neck height (neck bent less than 45° from the horizontal), chest height (neck horizontal or lower, but above the underside of the belly), knee height (head lower than the underside of the belly with the exception of knee bending), and ground height (grazing at ground height, including knee bending position). Approximately 40% of the giraffes' browsing time occurred below two metres (below chest height). However, lower forage availability and quality during the dry season influenced browsing levels, with browsing occurring more at ground, knee and head height during this time.

Seasonal change and forage availability also influenced the browsing levels of giraffes in Tsavo National Park, Kenya (Leuthold and Leuthold, 1978). Two browsing levels were used to determine browsing height, namely low (less than 2 m above the ground) and high (more than 2 m above the ground). Giraffes in Tsavo spent 50% of their browsing time foraging lower than two metres above the ground, which are heights within reach of gerenuk and lesser kudu. During the dry season, giraffe browsed more at higher levels, spending 8% and 5% of their browsing time foraging lower than 1 m, 55% and 28% between 1 and 2 m, and 37% and 67% higher than 2 m during the green and dry seasons respectively.

However, using the same browsing levels as Leuthold and Leuthold (1978), Van Aarde and Skinner (1975) found giraffes to spend approximately 17.2% of their browsing time foraging below 2 m in Jack Scott Nature Reserve, South Africa, within reach of smaller browsers. Not only was an overlap in browsing levels with other browsers such as eland and kudu evident, but an overlap in diet was observed, with four of the five important giraffe browse species being incorporated in the diet of eland, kudu and impala as well. This heightens the intensity of competition within the area.

In Koos Meintjies Nature Reserve, South Africa, 32.6% of browsing occurred below 2 m, particularly between 0.5 and 2 m (Sauer *et al.*, 1977). The remaining 67.4% of browsing occurred within the tree stratum, above 2 m. This difference is explained by the difference in vegetation in Tsavo (Leuthold and Leuthold, 1972) and Koos Meintjies, with species being taller in height in the latter area (Sauer *et al.*, 1977).

Within the Khamab Kalahari Nature Reserve, browsing levels differed between sex and different tree species (Deacon, 2015). Females browsed 99% of the time at 3 m and higher, with 89%, 70%, 90% and 94% of browsing on *Vachellia erioloba*, *Senegalia mellifera*, *Z.*

mucronata and Boscia albitrunca occurring at 3 m and higher. The majority of browsing by males occurred at 4 m and higher, with 90%, 92% and 95% of browsing on *V. erioloba*, *S. mellifera* and *Z. mucronata* occurring at 4 m and above. Direct competition in Khamab with smaller browsers is therefore avoided, with only 7% of female browsing occurring below 3 m, and 19% of male browsing occurring below 4 m (Deacon, 2015).

Within the Molokodi Nature Reserve, Botswana, giraffes spent more than 80% of their time browsing between 2 and 5 m (between neck and stretch height) (Blomqvist and Renberg, 2007). Males browsed more at head height (49% of browsing time), whilst females browsed more at neck height (40.4% of browsing time). These browsing levels by both males and females were supported by the heights of preferred browse species, with trees between 3 and 4 m being preferred by males, and trees between 2 and 3 m being preferred by females. In addition to the heights of preferred browse species driving giraffe browsing levels, it is suggested that giraffes may be forced to forage higher up due to browsing pressure lower down in the canopy by smaller browsers.

A determination of browsing levels in accordance with the height of particular species was conducted by Woolnough and Du Toit (2001) in South Africa. Browsing levels were determined using two principal species, namely *S. nigrescens* and *B. albitrunca*. Browsing of both species occurred mostly at a height of 2.5 m, out of reach of smaller browsers and, thus, avoiding competition. In addition, a higher amount of leaf per shoot is available higher in the canopy, therefore giraffes make full use of this advantage.

To confirm whether there is more browse available higher in tree canopies, Cameron and Du Toit (2007) tested the influences of foraging pressure of smaller browsers, as well as the differential resource allocation throughout the tree stratum. Combined browsing by smaller herbivores resulted in differences in forage availability at different heights due to their selectivity of young leaves and shoots. This selectivity therefore results in the depletion of biomass and quality of forage lower down in the canopy, with more available at heights only accessible to giraffes. This depletion “forces” giraffes to forage at higher levels, therefore gaining a nutritional advantage (Cameron and Du Toit, 2007).

The browsing levels of giraffes based on the height of particular browse species were also determined in Northern Kenya, and were quantified based on the angle between the neck and forelegs (O’Connor, 2013) and the corresponding height above ground level at which the giraffes browsed. This was done by measuring the height above the ground at a focal adult

male and female browsing at a specific neck angle. Four levels were identified; feed high (180°), feed medium (135°), feed level (90°) and feed below (45°). Males browsed higher than females at an average height of 3.7 m compared to 2.5 m respectively. The height of preferred browse species supported sex differences. Regarding *A. drepanolobium*, males browsed above the median height, whereas females browsed lower than the median height. This was the same in the case of *Acacia etbaica*. It is suggested that the lower browsing of females is an indicator of intraspecific competition avoidance, or out of habit due to the stunted form of particular preferred species in certain habitats (O'Connor, 2013).

1.6. Browsing capacity

An understanding of the behaviour and diet selection of herbivores is required for the determination of carrying capacities. Carrying capacity is defined as the potential of an area to support animals through the grazing and/or browsing and/or fodder production over an extended number of years without deterioration to the overall ecosystem (Danckwerts, 1981; Trollope and Trollope, 1990). However, due to the complexity and continuous change of ecosystems, browsing capacity is more appropriate to determine production on a short term basis. Animal and area specific browsing capacity, too, can be determined (Cornelius, 2010). Browsing capacity, defined as the productivity of the grazeable/browseable portion of a homogeneous unit of vegetation expressed as the area of land required to maintain a single animal unit over an extended number of years without deterioration to vegetation or soil (Booysen, 1967; Trollope and Trollope, 1990), is discussed in detail in Chapter 4.

1.7. Distribution

Although beginning to dwindle in numbers, the distribution of giraffe populations is widespread throughout the African continent, where they are currently discontinuous from South Africa to West Africa (Parker, 2004; Skinner and Chimimba, 2005; Cornelius, 2010). Populations, however, do not occupy deserts, rainforests or mountains, with occurrences in open plains being rare (Skinner and Chimimba, 2005; Cornelius, 2010). Occurring historically throughout the grassland and savannah areas of Africa where there is tree and shrub browse (Jacobs, 2008), the distribution of giraffe has reduced and become discontinuous due to the increase in aridity, urban expansion and consequently habitat removal, hunting, farming, and occasional epidemics of rinderpest (Dagg, 1971; Dagg & Foster 1976; Jacobs, 2008; Cornelius, 2010). Within southern Africa, most giraffe populations tend to be found north of the Orange River, with other populations scattered widely, mostly in dry savannah areas, throughout the northern parts of South Africa, Namibia, Botswana, Mozambique and Angola (Dagg and

Foster, 1976; Skead, 1987; Skinner and Chimimba, 2006; Jacobs, 2008; Cornelius, 2010). These areas are favoured due to the seasonal availability of food and good visibility of predators (Skinner and Chimimba 2005; Cornelius, 2010).

Giraffes are commonly found within savannah and open grassland areas. However, with reintroductions taking place (Owen-Smith 1988), no recorded occurrence of giraffe has been observed within the Eastern Cape and east of the Pongola River (Skead, 1987; Jacobs 2008). Skead (1987). It has been documented that the southernmost district known for the natural occurrence of giraffe is Namaqualand, positioned in the northwestern Cape of South Africa. However, this has been countered by Skinner and Chimimba (2005), arguing that geographical barriers, such as the Komati River, possibly restricted giraffe populations in the north (Skinner and Chimimba, 2005; Cornelius, 2010). Despite the uncertainty on historic giraffe occurrences, the introduction of giraffes into areas in which they have not previously been found, such as the Free State (Griesel, 1961), KwaZulu-Natal and Swaziland (Kirk, 1966) have increased rapidly within recent decades (Dagg, 1971). Thus, these giraffe populations have been regarded as extralimital.

1.8. Giraffe as an extralimital species

The sole purpose being for ecotourism, giraffe introductions have increased within a variety of habitats throughout South Africa. However, while these introductions bring short term benefits in potentially increasing local income, they should also be viewed in terms of long termecological sustainability (Castley *et al.*, 2001; Cornelius 2010). Although numerous introductions have taken place, the only known research conducted on these extralimital introductions was in the Eastern Cape, Free State, KwaZulu-Natal and Swaziland (Cornelius, 2010).

It is the policy of South African National Parks to only reintroduce species that have been proven to historically occur within the parks. The reason for this stance is to maintain the natural state of the parks, as extralimital species are regarded as species that negatively impact areas into which they are introduced (Parker and Bernard, 2005; Jacobs, 2008). However, extralimital species are also introduced for ecological reasons. Introduced to artificially increase faunal diversity, this has been found to be unsuccessful, as introduced species compete with indigenous species, resulting in the displacement and extinction of local populations. In turn, these species losses result in less biological complexity, leading to the possible further

loss of biodiversity (Naeem *et al.*, 1994; Castley *et al.*, 2001, Clavero and Garcia-Berthou, 2005; Cornelius, 2010).

Within in the southern Cape, there has been a rapid transition from agriculture and livestock farming to conservation and game farming. While the expansion of existing reserves for conservation and the establishment of game farms may potentially increase the natural diversity of the regions with high plant diversity, private game farm and wildlife owners, many for tourism and hunting purposes, continue to introduce extralimital species to satisfy the expectations of potential clients (Castley *et al.*, 2001; Parker, 2004).

The natural distribution and southernmost occurrences of giraffe are controversial, without convincing evidence either way to support the extralimital status of giraffe in southern locations. However, with the scant amount of information available on these distributions, historical records have suggested that the southernmost occurrence of extant giraffe in Africa was the northern border between Swaziland and South Africa (Skinner and Smithers, 1990; Parker, 2004). On the other hand, fossil records of *Giraffa camelopardalis* and its extinct relatives have been distributed further south. Found within the south-western (Darling district of the Western Cape Province) and central part (Free State Province) of South Africa, these records suggest that the distribution of giraffe within southern Africa is wider than originally thought (Singer and Bone, 1960; Cooke, 1974; Parker, 2004). While it is generally accepted that the distribution of giraffe have been reduced due to excessive hunting, disease and climate change (Kingdon, 1979; Nowak and Paradiso, 1983; Parker, 2004), giraffe continue to be regarded as extralimital within areas in which historic San paintings of giraffes have been reported. Therefore, the debate on the natural distribution of giraffe continues to be problematic both in the conservation of giraffe subspecies and in the management of giraffe outside what are considered natural ranges. Thus, for the purpose of this study, giraffe are regarded as extralimital within the Western Cape.

1.9. Giraffe impacts

Giraffes have been documented to negatively impact the vegetation of areas they inhabit within their natural range (Foster and Dagg, 1972; Hall-Martin, 1974; Van Aarde and Skinner, 1975; Sauer *et al.*, 1977; Pellew, 1983; Augustine and McNaughton, 1998; Birkett, 2002; Brenneman *et al.*, 2009). Browse lines are a common indication of browser impacts and have been observed to occur through giraffe browsing at approximate heights of 5 m and above, through the intense utilisation of flowers and pods (Foster and Dagg, 1972; Hall-Martin, 1974; Van Aarde and

Skinner, 1975; Sauer *et al.*, 1977; Leuthold and Leuthold, 1978). In the Western Transvaal (North West Province), South Africa, browse lines were found on preferred species, such as *Spirostachys africana*, *Z. mucronata* and *S. caffra* (Sauer *et al.*, 1977). Younger trees were overbrowsed to the extent of death, whilst the remaining trees grew abnormally and were kept at heights of between 0.5 and 1.2 m (Sauer *et al.*, 1977). Heavy hedge cropping by giraffes, too, have been observed to affect the growth and form of plants (Foster, 1966; Van Aarde and Skinner, 1975).

Structural damage to trees by giraffes has been documented by Van Aarde and Skinner (1975) and Brenneman *et al.* (2009). In South Africa, giraffes tend to tear down branches in order to access leaves and pods out of reach due to the reduction in browse availability during the dry season (Van Aarde and Skinner, 1975). In Kenya, an increase in the intensity of debarking of *Vachellia xanthophloea* trees by giraffes has been observed (Brenneman *et al.*, 2009). It is predicted that the continuous debarking of these trees will result in increased pressure on *Vachellia* woodlands, as well as browse reduction and shortage (Brenneman *et al.*, 2009).

Giraffes are capable of preventing tree growth (Foster and Dagg, 1972; Sauer *et al.*, 1977), causing a decline in tree density (Foster and Dagg, 1972; Augustine and McNaughton, 1998; Birkett, 2002) and productivity (Pellew, 1983), eventually leading to plant death (Sauer *et al.*, 1977). In Nairobi National Park, Kenya, giraffe browsing, together with other herbivores, negatively affected *Vachellia* species (Foster and Dagg, 1972). Regarding *V. drepanolobium*, due to this species being abundant, highly palatable and always accessible, giraffes have utilised this species more than it can recover, thus preventing growth and causing a decrease in average height (Foster and Dagg, 1972; Wyatt, 1969). This growth prevention has resulted in trees within the park being half the height of trees found outside the park (Foster and Dagg, 1972). Augustine and McNaughton (1998) found plant selectivity by giraffes and other herbivores to be responsible for the decline in tree densities. Giraffes are highly selective, therefore they consume preferred plants to the point at which the availability of preferred species declines. This results in the reduction of browse selectivity and availability of preferred plant species per animal, and the subsequent increase in consumption of other available plant species (Augustine and McNaughton, 1998).

The combined browsing impact of giraffes, elephants and black rhino was documented in the Sweetwaters Game Reserve, Kenya (Birkett, 2002). Combined impacts included the loss of 52% of seedlings in one year, 36% mortality of trees in the 0.5 – 1 m height class, as well as a

2% decline in tree density per annum. Giraffe impacts in particular were greatest in the 3 – 5 m height class, as the mean annual growth rate of trees in the *Vachellia* woodlands was significantly lower in the 3 – 5 m class compared to the < 1 m class. Removal of giraffes from the area would cause a predicted 2% increase in tree density per annum (Birkett, 2002).

Bond and Loffell (2001) determined the impacts of extralimital giraffe within the Ithala Game Reserve, KwaZulu-Natal province, South Africa. Higher browse lines, less pods and pod bearing trees and more twig tip damage was found within the high giraffe density areas. Mortality between different *Vachellia* species, too, was evident. Regarding *Vachellia davyi,* all individuals within the high giraffe density areas were dead, whilst the live individuals were either inaccessible, or within the low giraffe density areas. This was the case for *S. caffra* and *V. karroo* as well. Mortality stood at >50% and 21.2% in the high density areas, compared to <5% and 2% in the low density areas for *S. caffra* and *V. karroo* respectively. This mortality was further illustrated by fence line contrasts. Most trees with foliage accessible to giraffes were found dead within the reserve, compared to live ones found across the fence (Bond and Loffell, 2001).

1.10. Gap in literature

As seen by the literature, numerous studies have been conducted on the diurnal and foraging behaviour of giraffes throughout their natural range. However, behavioural and diet information in areas where they are considered extralimital is lacking, especially in the Western Cape, South Africa. In the Western Cape, no behavioural studies have been conducted, with only two documented studies on the diet of extralimital giraffe in Mosaic Thicket vegetation in the southern Cape (Cornelius, 2010; Gordon *et al.*, 2016).

Within the Western Cape, particularly within the Little Karoo, viable populations of giraffes are continuously being introduced into game farms to improve tourist attractions and for recreation. Two decades ago, the amount of game farms only made up a small portion of the region, therefore the significant effect these individuals had on the environment was considered negligible. However, the number of game farms has increased considerably since then.

Extralimital species may have negative impacts on indigenous fauna and flora. However, in order to determine impacts, as well as to determine adaptability and to initiate long term monitoring, the ecology of these species needs to be fully understood. The general daily behaviour of an organism is dictated by its feeding behaviour, this being the primary driving force for survival (Dagg and Foster, 1976). Therefore, the understanding of an organism's

nutritional requirements, which, in turn, dictate the behaviour of an organism, is crucial for the formulation and implementation of effective management decisions. This ecological information will, therefore, serve as the baseline for long term monitoring of extralimital species, and for the initiation of impact assessments of extralimital species to assist in protecting natural ecosystems.

1.11. Thesis description

The general aim of this study was therefore to determine the diurnal activities and foraging behaviour of extralimital giraffe within the Little Karoo in the Western Cape. The aim was achieved through the following objectives:

1. To determine the diurnal activity budgets,
2. the diet composition and browsing levels, and
3. the availability of browse and estimated site specific browsing capacities of extralimital giraffe.

The remainder of the thesis is set out as follows:

Chapter 2: Description of study sites

This chapter describes the locality and climate of the Little Karoo, thereafter focussing on the location, history, geology, vegetation and fauna of the two study sites (Kareesbos Private Game Reserve and Tsumkwe Private Game Reserve). The study populations of each study site are given and further discussed in terms of size and length of time present.

Chapter 3: Behavioural ecology of introduced giraffe

Determination of the behaviour of giraffe within the two study sites. The activity budgets of giraffe of different sexes and for the seasons of summer, autumn, winter and spring are provided and explained.

Chapter 4: Diet composition and preference of introduced giraffe

Determination of the diet composition of giraffes within each study site. The diet of the giraffes between different sexes and seasons are compared. The level of feeding, too, is observed and compared.

Chapter 5: Determination of browsing capacities

Determination of the amount of browse available in each of the study sites, quantified by means of the Biomass Estimates of Canopy Volume (BECVOL) method. This attempts to provide an estimate on whether or not sufficient browse is available for giraffe, and whether the study sites will be able to sustain them in the long term. Site-specific browsing capacities for giraffe based on biomass estimates are also described within this chapter.

Chapter 6: General conclusions and management implications

This is the concluding chapter in which all important aspects of each of the main themes are highlighted and commented on. Management implications based on the main results are given, and suggestions for future research are provided.

CHAPTER 2 : GENERAL DESCRIPTION OF STUDY SITES

2.1. Location

Situated in the Western Cape of South Africa, the boundaries to which the Little Karoo extends have been debated for numerous years as these boundaries have been defined either geographically, biogeographically or hydrologically (Maitre *et al.*, 2009). However, the typical boundaries used to describe the Little Karoo are generally according to Vlok *et al.* (2005) based on the combination of municipal administrative and water catchment boundaries encompassing the vegetation of the area (Thompson *et al.*, 2005). It is defined as a broad east-west orientated valley, bordered by the coastal Langeberg and Outeniqua mountain ranges in the south and the inland Witteberg and Swartberg mountain ranges in the north, being geographically isolated from the Great Karoo (Thompson *et al.*, 2005; Maitre *et al.*, 2009; Mann, 2014) (Figure 2.1).

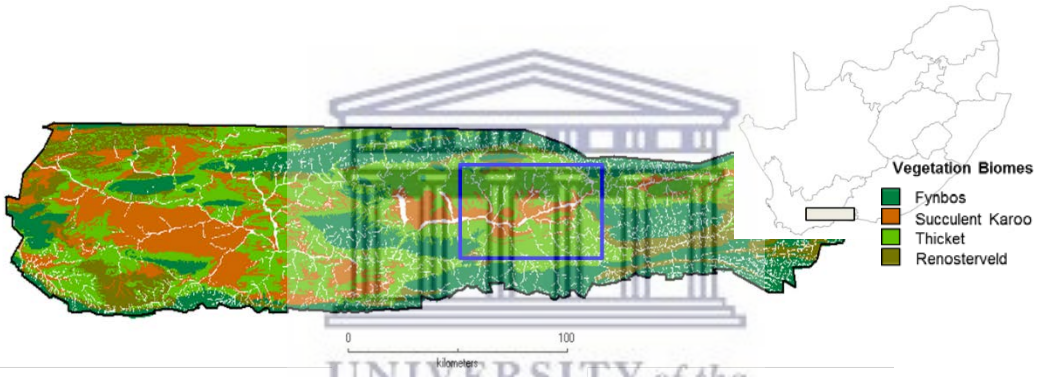

Figure 2.1: Map of the Little Karoo (Blue square illustrates the area in which the two study sites are positioned)

The study was conducted on two privately owned farms, namely Kareesbos Private Game Reserve (KPGR) and Tsumkwe Private Game Reserve (TPGR), within the Oudtshoorn area of the Little Karoo. With numerous game farms present within and around Oudtshoorn, sites were selected based on the presence of giraffe on privately owned land and the positioning of the farms within the Thicket biome.

2.2. Climate

2.2.1. Rainfall

Whilst the Witteberg and Swartberg mountain ranges in the north separate the Little Karoo from the arid and summer rainfall of the Greater Karoo, the Langeberg and Outeniqua mountain ranges in the south have a larger influence on the climatic conditions of the sub-region (Potts *et al.*, 2013). Not only do these south bordering mountain ranges separate the region from the

mesic and winter rainfall of the coastal region of the Greater Cape Floristic Region (GCFR), they block the winter rainfall frontal systems from the Atlantic and the moist rain-bearing air from the Indian Ocean (Potts *et al.*, 2013, Vlok *et al.*, 2005). The physical barriers, thus, allow the Little Karoo to have an aseasonal rainfall regime, experiencing rainfall throughout the year (Potts *et al.*, 2013).

Rainfall varies with altitude and latitude, with the Langeberg-Outeniqua mountain ranges receiving the highest amount of rainfall of up to 1650 mm per annum, compared to the 1000 mm received by the Witteberg-Swartberg mountain ranges and the 100-300 mm received by the low lying central valleys (Figure 3.2) (Maitre *et al.*, 2009). Differing pressure systems and orographic gradients distribute the seasonal rainfall experienced in the west and in the east. In the far west (Montagu), rainfall is winter dominated and more reliable due to less variability in rainfall events. Rainfall events in the west are brought about by cold fronts, together with low pressure systems and westerly winds. In contrast, in the east (Willomore), summer rainfall is experienced, dominated by moisture received from the east, and convective systems are less influenced by orographic gradients. Areas centrally positioned (Ladismith) between the far west and east borders experience bimodal rainfall (Maitre *et al.*, 2009).

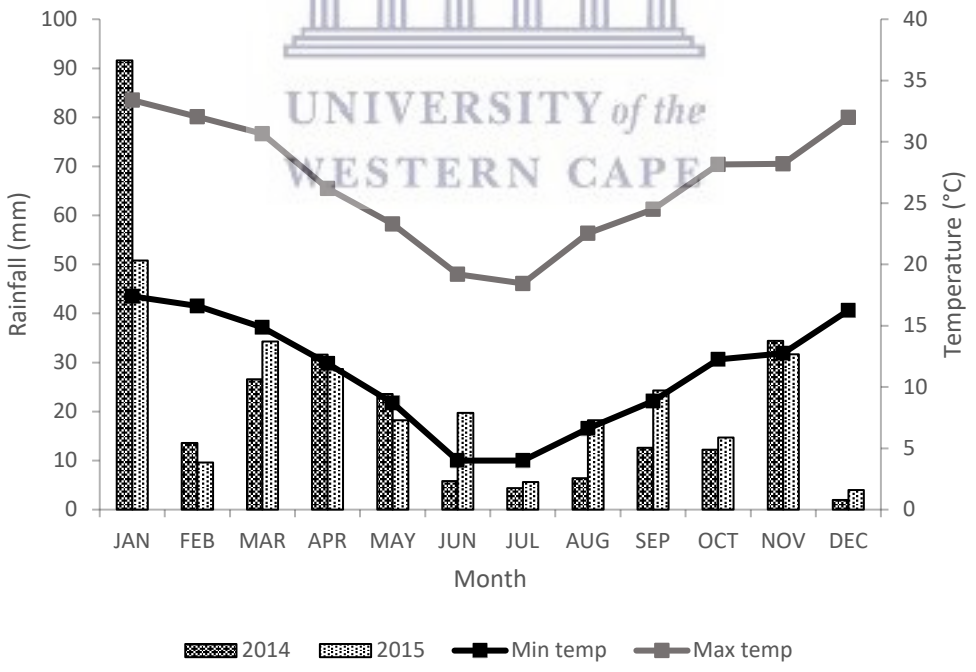

Figure 2.2: Average rainfall (mm), minimum and maximum temperatures (°C) in the Oudtshoorn area throughout the study period (2014-2015)

2.2.2. Temperature

The mean daily temperatures in the Little Karoo vary tremendously, largely due to high temperatures, low relative humidity, and little or no cloud cover (Desmet and Cowling, 1999). The highest temperatures are experienced between the months of December and February (summer), with the lowest temperatures occurring between the months of June and August (winter) (Nongwe, 2008). Mean daily maximum and minimum temperatures vary between lowland, mountain and coastal areas, with mountain and coastal areas experiencing similar temperatures, while differing to those experienced in the lowlands (Maitre *et al.*, 2009). In summer months, the lowlands experience mean daily maximum temperatures greater than 30°C and mean daily minimum temperatures ranging between 14 and 16°C. In winter, lowland areas experience mean daily maxima and minima temperatures ranging between 20 and 22°C and 4 and 8°C respectively (Figure 2.2). In summer, mountain and coastal areas experience mean daily maximum temperatures in the upper 20s, and mean daily minimum temperatures ranging between 10 and 12°C. In winter, the temperatures drop dramatically, with mean daily maxima and minima ranging between 10 and 12°C and -2 and 2°C respectively (Maitre *et al.*, 2009).

2.3. Vegetation

The aseasonal rainfall regime and geographical positioning of the Little Karoo has resulted in astonishingly high levels of plant diversity and endemism despite its aridity (Cupido, 2005; Nongwe, 2008). Four of the seven vegetation biomes within southern Africa are present within its boundaries, namely the Afromontane Forest, Fynbos, Succulent Karoo and Subtropical Thicket biome (Cupido, 2005; Vlok *et al.*, 2005; Nongwe, 2008). Of these four biomes, the Succulent Karoo and the Fynbos contribute considerably to the rich diversity and are recognised as two of the 25 global biodiversity hotspots (Maitre *et al.*, 2009). Vegetation present within the study farms is described in greater detail in sections 2.4.3 and 2.5.3.

2.4. KAREESBOS PRIVATE GAME RESERVE (KPGR)

2.4.1. Location and description

KPGR (33°32’34”S; 22°01’58”E) is approximately 900 ha in size and is separated from farmlands by means of fences in the north, south and west. The entrance is located on the northeast end of the farm, bordered by an unnamed gravel road running parallel to the perennial Wynands River. The farm is used for private recreational use, with occasion hunts occurring throughout the year. Minimal human interaction is made with animal species present, with the provision of water being in the form of one large manmade dam and several smaller water

points present throughout the area, as well as supplementary feed only being provided during times of extreme dry periods, which is not often.

Several antelope species are present, including plains zebra (*Equus quagga*), eland (*Taurotragus oryx*), greater kudu (*Tragelaphus stepsiceros*), gemsbok (*Oryx gazella*), common duiker (*Sylvicapra grimmia*) and impala (*Aepyceros melampus*). A total of 10 giraffes were present at the commencement of the study, with the unknown removal of one adult male during mid-2014 and a birth occurring at the end of 2014. Evidence shows the occasional occurrence of the predatory black backed jackal (*Canis mesomelas*) and leopard (*Panthera pardus*).

2.4.2. Soil and geology

The dominant geological formations on KPGR are calcrete, hardpan, conglomerate, sandstone, siltstone and mudstone, all typical of the Enon Formation of the Uitenhage Group (ENPAT, 1995). The soils are red-brown in colour (ENPAT, 1995), characteristic of the dominant coarse-grained conglomerate, with size varying between pebbles, cobbles and boulders formed with other hard rocks (Lubke and De Moor, 1998). Soils are red-yellow apedal (structureless) and approximately < 300 mm deep, allowing water to drain freely (ENPAT, 1995). However, these characteristics make this kind of geology an ineffective/poor aquifer, offering poor borehole yields with water being of a brackish and salty nature (Lubke and De Moor, 1998).

2.4.3. Vegetation

Vegetation is described at different scales according to Mucina and Rutherford (2006) and Vlok *et al.* (2005). Vegetation units are described at a broad scale of 1:1 000 000 according to Mucina and Rutherford (2006), and thereafter described in greater detail at a scale of 1:50 000, making reference to the six-tier vegetation classification system developed by Vlok *et al.* (2005).

According to Vlok *et al.* (2005), three vegetation units are present in KPGR (Table 2.1) (Figure 2.3).

Table 2.1: Vegetation units present on KPGR

	Vegetation unit		
Category	Oudtshoorn Scholtzbosveld	Grootkop Arid Spekboomveld	Volmoed Gannaveld
Biome	Succulent Karoo	Thicket	Succulent Karoo

Habitat	Scholtzbosveld	Arid + Spekboom + Succulent Karoo	Gannaveld
Region	Gamka	Gamka	Gamka
Sector	Oudtshoorn Scholtzbosveld	Grootkop	Volmoed
Unit	Solid	Mosaic	Solid

2.4.3.1. Scholtzbosveld

Scholtzbosveld is typical of flat areas, usually on the top of hills, dominated by a single shrub species, *Pteronia pallens*, accompanied by various other shrub and succulent plant species. This single species dominance is often said to have been due to heavy grazing, and although unpalatable, occupant species are palatable and favoured by many animal species.

In KPGR particularly, the habitat type Oudtshoorn Scholtzbosveld is present. Differing from other Scholtzbosveld units due to heuweltjies often being present, prominent species include *Mesembryanthemum crystallinum, Lycium cinereum, Oncosiphon suffruticosum, Phyllobolus splendens* and *Psilocaulon junceum*.

2.4.3.2. Gannaveld

Located on valley bottoms, Gannaveld is often described as open plains devoid of trees, with the presence of succulent and grass plant species being uncommon. Numerous tall and small shrubs are present within this vegetation type, with the appearance of an abundance of endemic annual species after rains.

Volmoed Gannaveld is present on KPGR. Shrub species are usually short (< 1 m) and infrequent, with the abundance of shrub species differing between the higher and lower lying areas. Fewer shrub species are found in the higher lying areas with *Eriocephalus spp.*, *Euryops subcarnosus*, *Justicia orchiodes*, *Pteronia pallens*, *Tripteris sinuate* and *Zygophyllum retrofractum* being the dominant species present. The lower lying areas are more established in terms of shrubs, with *Atriplex vestita, Salsola spp., Suaeda fruticose* and *Zygophyllum microcarpum* being the dominant species present. Although the presence of grasses and succulents are uncommon, typical of Gannaveld vegetation, *Cenchrus ciliaris* and *Fingerhuthia africana* and *Malephora spp.* and *Phyllobolus splendens* respectively, can be found. If present, heuweltjies are dominated by the invasive *Augea capensis*.

2.4.3.3. Valley Thicket with Spekboom

Located on moderate to steep hill slopes, this vegetation type is characterised by the abundance of *Portulacaria afra*, forming fairly dense and closed stands or bush clumps (Vlok *et al.*, 2005). Other trees and shrubs that may be present do not form clumps, but rather occur as single plants.

Grootkop Arid Spekboomveld is present on KPGR. *Portulacaria afra*, the indicator species for this vegetation unit, together with other woody trees and tall shrubs, are locally dominant on north facing slopes, namely *Euclea undulata*, *Lycium cinereum*, *Grewia robusta*, *Nymannia capensis*, *Searsia undulata*, *Rhigozhum obovatum*, *Carissa haematocarpa* and *Gloveria intergrifolia*. *Pappea capensis* and *Dodonaea augustifolia* are sparsely present (Vlok and Euston-Brown, 2002; Vlok *et al.*, 2005). Succulent Karoo vegetation patches are common, with *Pteronia spp.* and the succulent *Aloe*, *Cotyledon* and *Tylecolon spp.* species being abundant. The annual grass species *Aristida congesta* and *Enneapogan desvauzii* are occasionally present (Vlok and Euston-Brown, 2002; Vlok *et al.*, 2005).

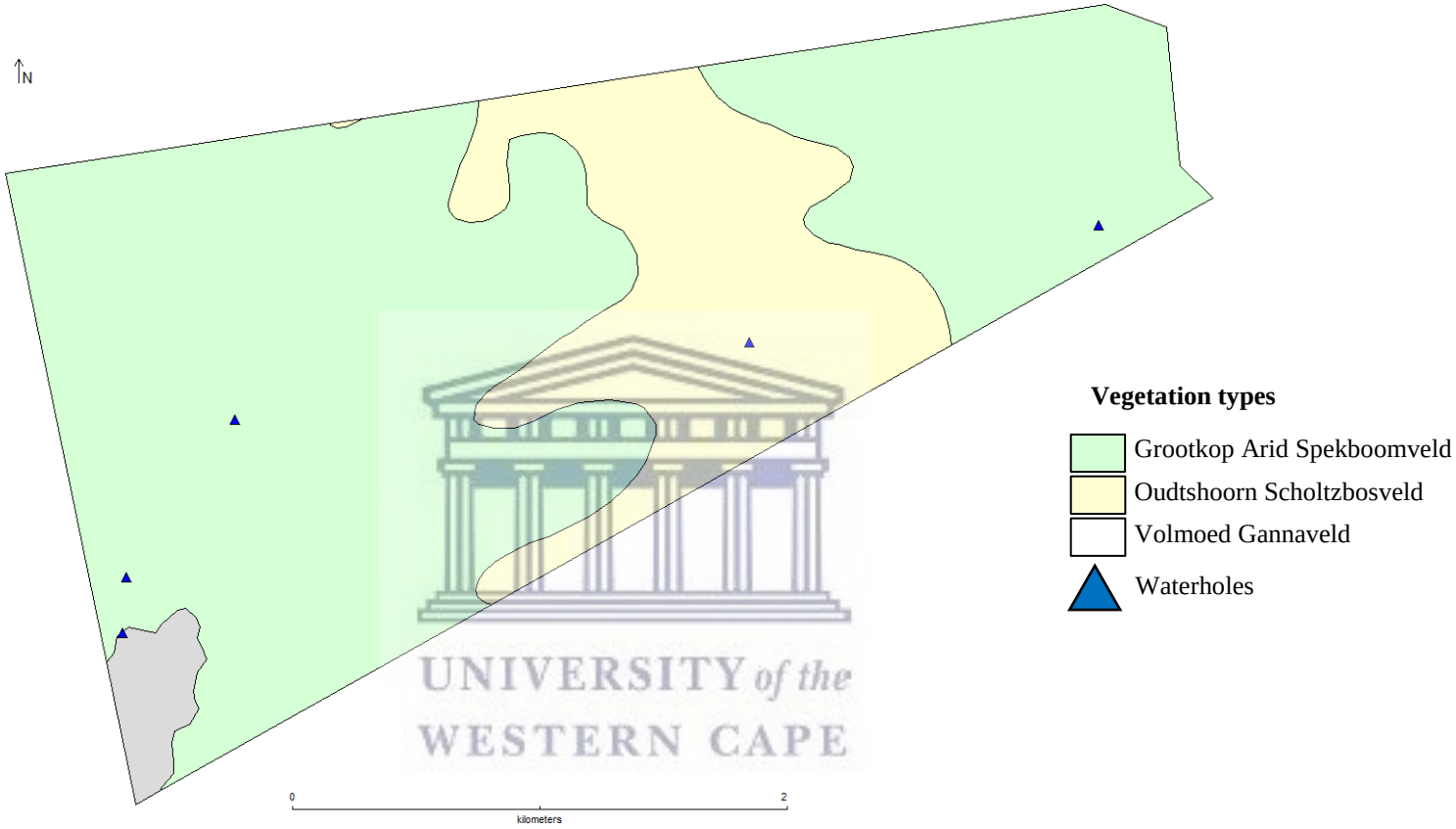

Figure 2.3: Vegetation map of KPGR

2.5. TSUMKWE PRIVATE GAME RESERVE (TPGR)

2.5.1. Location and description

TPGR (33°33'41" S; 22°21'51" E) is approximately 1500 ha in size, bordered by the N12 in the south and by farmland fences in the west, east and northeast. Used for educational and tourism purposes, several animal species are present, including springbok (*Antidorcas marsupialis*), eland (*Taurotragus oryx*), greater kudu (*Tragelaphus strepsiceros*), gemsbok (*Oryx gazella*), wildebeest (*Connochaetes gnou*), impala (*Aepyceros melamphus*) and giraffe (*Giraffa camelopardalis giraffa*). Water is supplied by several small waterholes throughout the farm and supplementary feed is provided for smaller antelope species, particularly springbok. Six giraffe were present at the start of the study period, but reduced to five at the end. One giraffe was killed due to an unknown medical condition at the beginning of 2014, one translocated to avoid inbreeding in August 2014, and one birth occurred in May 2015. Predator species present include the black backed jackal (*Canis mesomelas*) and leopard (*Panthera pardus*).

2.5.2. Soil and geology

Similar soil and geological formations are present on TPGR, as described in KPGR. See section 2.4.2.

2.5.3. Vegetation

According to Mucina and Rutherford (2006), TPGR encompasses vegetation that is positioned within the Albany Thicket, Fynbos and Succulent Karoo biomes. The Albany Thicket biome is the smallest compared to the Fynbos and Succulent Karoo biomes, making up only 2.2% of the area of South Africa, with the majority positioned within the Eastern Cape (Strydom and King, 2009). With approximately 1600 plant species, of which 20% are endemic to South Africa, overstocking has said to have severely degraded approximately 60% of the biome. TPGR is located in the Gamka Thicket (AT 2) vegetation unit (Mucina and Rutherford, 2006), occurring on the lower mountain slopes and river valleys between the Swartberg and Outeniqua mountain ranges bordering the Little Karoo centering around the Oudtshoorn area. Classified as least threatened, the main impact on this vegetation is fire, causing fragmentation.

Although the Fynbos biome only encompasses approximately 6.7% of South Africa, this biome possesses a higher number of plant species (approximately 7 500 vascular plant species) than any other biome occurring in the region, of which 70% are endemic (Mucina and Rutherford,

2006). Located in the Limestone Renosterveld Bioregion, particularly the Kango Limestone Renosterveld (FRI 1) vegetation unit (Mucina and Rutherford, 2006), it extends from Calitzdorp in the north to the Cango Caves region in the east, including the De Rust area (Mucina and Rutherford, 2006). Classified as least threatened, the main risk to this vegetation unit is cultivation, with approximately 14% already transformed (Mucina and Rutherford, 2006).

According to Vlok *et al.* (2005), three vegetation units are present in TPGR (Table 2.2) (Figure 2.4).

Table 2.2: Vegetation units present on TPGR

	Vegetation units			
Category	Mons Ruber Waboom-Thicket	Kruisrivier Spekboom-Pruimveld	Grootkop Apronveld	Olifants River and floodplain
Biome	Thicket	Thicket	Succulent Karoo	Drain
Habitat	Mosaic Waboomveld	Valley + Spekboom + Succulent Karoo	Gravel Apronveld	River
Region	Gamka	Gamka	Gamka	Gamka
Sector	Mons Ruber	Kruisrivier	Grootkop	Olifants
Unit	Mosaic	Mosaic	Solid	Brack

2.5.3.1. Mons Ruber Waboom-Thicket

Located on moderate to steep hill slopes, this habitat type is characterised by the dominance of Albany Thicket elements on north facing slopes and in fire protected areas on south facing slopes where soils are deep and/or nutrient rich, and the dominance of Fynbos elements in shallow soils low in clay content on south facing slopes (Vlok and Euston-Brown, 2002, Vlok *et al.*, 2005). Albany Thicket elements include *Carissa haematocarpa*, *Euclea undulata*, *Gloveria integrifolia*, *Searsia undulata* and *Portulacaria afra* on the north facing slopes, as well as *Cassine euclaeformis*, *Gymnosporia buxifolia*, *Maytenus acuminate*, *Maytenus oleoides, Nymannia capensis, Olea europaea subsp. africana* and *Pterocelastrus tricuspidat*us

on the south facing slopes, whereas the Fynbos elements include *Agathosma recurvifolia, Erica karooica*, *Ishyrolepis gaudichaudiarius*, *Passerina obtusifolia*, *Protea nitida*, *Rhodocoma arida* and *Rhodocoma gracilis* (Vlok and Euston-Brown, 2002, Vlok *et al.*, 2005).

2.5.3.2. Grootkop Apronveld

Located in flat lying areas, these habitat types are patchy, however they have a large variety of species, with a dominance of asteraceous and succulent shrubs, aloes and geophytes, and with trees and tall shrubs being less prominent (Vlok *et al.*, 2005).

Dominant asteraceous shrubs include *Elytropappus rhinocerotis*, *Eriocephalus ericoides*, *Euryops lateriflorus*, *Euryops oligoglossus*, *Euryops subcarnosus*, *Hertia cf. pallens*, *Hirpicium alienatum*, *Pteronia incana*, *Pteronia pallens*, *Pteronia paniculata*, *Rosenia humilis* and *Tripteris sinuata*. Succulent species include prominent leaf succulent shrubs, namely *Cotyledon orbiculata*, *Drosanthemum giffenii*, *Lampranthus haworthii*, *Ruschia cf. ceresiana* and *Tylecolon wallichii*, and smaller succulent species, namely *Adromischus triflorus*, *Conophytum truncatum* and *Glottiphyllum depressum*. Locally dominant grasses, *Digitaria argyrograpta* and *Fingerhuthia africana*, dominate these flat areas, whereas geophyte species, namely *Babiana sambucina*, *Freesia refracta*, *Gladiolus permeabilis*, *Lapeirousia pyramidalis*, *Moraea polyanthos*, *Moraea polystachya*, *Ornithogalum dubium*, *Ornithogalum juncifolium* and *Tritonia securigera*, dominate the patchy gravel areas. The less prominent tree and tall shrub species include *Carissa haematorcarpa*, *Euclea undulata*, *Searsia undulata*, *Lycium cinereum* and *Nymannia capensis*.

2.5.3.3. Kruisrivier Spekboom-Pruimveld

Located on flat lying areas and on the bottom of slopes, this vegetation unit is characterised by the dominance of *Portulacaria afra* and other woody trees and shrubs in a matrix of Succulent Karoo, on sandy and gravel soils.

Dominant woody trees and shrubs include *Carissa haematocarpa*, *Euclea undulata*, *Gloveria integrifolia*, *Nymannia capensis*, *Pappea capensis*, *Grewia robusta*, *Searsia longispina*, *Rhigozhum obovatum*, *Pteronia incana*, *Ericephalus africana*, *Eriocephalus ericoides* and *Eriocephalus punctulatus*. Stem and leaf succulent and geophyte species are also abundant in this vegetation unit and include *Aloe microstigma*, *Aloe ferox*, *Cotyledon orbiculare*, *Gasteria brachyphylla*, *Pelargonium peltatum*, *Pelargonium tetragonum*, *Quaqa pillansii*, *Ruschia ceresiana*, *Sarcostemma viminale*, *Tylecolon cacalioides*, *Tylecolon paniculata*, *Chlorophytum*

comosum, *Dipcadi viride*, *Drimia capenis*, *Hessea stellaris*, *Nerine humilis* and *Ornithogalum graminifolium*. Grass species are usually abundant after heavy rains, with species including *Cenchrus ciliaris*, *Erharta calycina*, *Panicum deustum*, *Sporobolus africanus* and *Stipa dregeana*.

2.5.3.4. Olifant's River and floodplain

Classified as a riverine unit, the indicator of this vegetation type is *Vachellia karroo*, with the distinctive prominence of *Salsola aphylla*. Herb species, such as *Ballota africana*, occur together with *Vachellia karroo*, with *Senegalia caffra*, *Chrysocoma oblongifolia* and *Cyperus congestus* occasionally present. These areas are highly subjected to soil erosion in the long term.

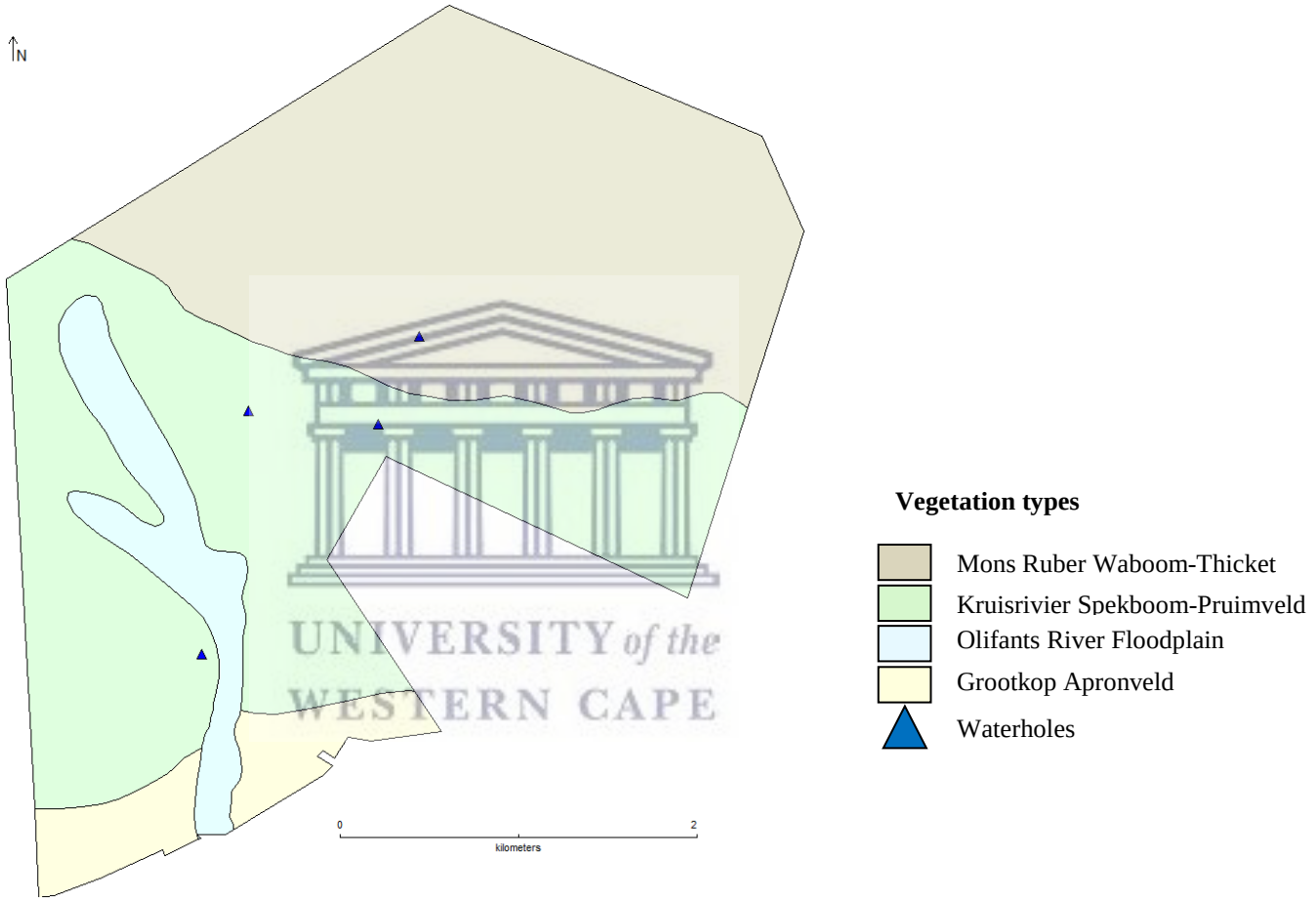

Figure 2.4: Vegetation map of TPGR

CHAPTER 3 : DIURNAL ACTIVITY BUDGETS OF EXTRALIMITAL GIRAFFE

3.1. INTRODUCTION

Understanding the social and non-feeding related behaviour of animals is of a great importance to understanding the way in which individuals not only interact with one another, but with the environment. For extralimital species within game farms, this knowledge is extremely beneficial, as animal behaviour may be altered and restricted in confined spaces, compared to open areas. In addition, it may help in providing information about the welfare of the populations, as well as the facilitation of managerial decisions regarding the maintenance of populations and habitats.

Giraffes have been able to successfully exploit different habitats through their physiological and behavioural adaptations (Fennessy, 2004). Physiologically, the nasal cooling of the brain enables giraffes to cope in arid environments (Fennessy, 2004; Dagg, 2014). On the other hand, giraffe are able to adjust their behaviour, such as the time spent on different activities (activity budgets), depending on various factors, such as the time of day, season, habitat type, foraging and social strategies (Dagg, 2014; Deacon, 2015). Activity budgets are discussed in greater detail in Chapter 1. However, in short, activity budgets have been documented by a few studies. Browsing is a dominant activity, comprising approximately 30-80% of giraffes' activity budgets (Pellew, 1983; Fennessy, 2004; Blomqvist and Renberg, 2007; Adolfsson, 2009; Deacon, 2015). Furthermore, activity budgets are shown to differ between sex and season (Pellew, 1983; Fennessy, 2004; Blomqvist and Renberg, 2007; Adolfsson, 2009; Deacon, 2015). For example, males are known to spend more time travelling, whereas females tend to spend more time foraging than males (Pellew, 1983; Fennessy, 2004; Blomqvist and Renberg, 2007; Adolfsson, 2009; Deacon, 2015). Seasonally, giraffes are shown to spend more time on energy conserving activities, such as resting, ruminating and vigilance during hotter seasons, and more time on energy consuming activities, such as walking and browsing during the cooler seasons (Fennessy, 2004; Deacon, 2015).

With only a few studies documenting the activity budgets of giraffes, information on the behaviour of extralimital giraffe in South Africa is limited, with no literature available on the behaviour of extralimital giraffe in Albany Thicket vegetated areas. Therefore, the results reported in this chapter are the first to be documented on extralimital giraffe within the Albany Thicket biome within South Africa.

The objectives and hypotheses of this chapter are as follows:

1. To describe the diurnal activity budgets of giraffes in Kareesbos Private Game Reserve (KPGR) and Tsumke Private Game Reserve (TPGR)
    - Hypothesis 1: Browsing will be the dominant activity displayed by giraffes
2. To compare the activity budgets of giraffes of differing sex
    - Hypothesis 2: Activity budgets will differ between males, females and juveniles
3. To compare activities of giraffes between different seasons
    - Hypothesis 3: Activity budgets will differ between the different seasons, with giraffes spending more time on energy consuming activities during cooler seasons and spending more time on energy conserving activities during the warmer seasons

3.2. METHODS

3.2.1. Field observations

Prior to the commencement of field observations, familiarization with individuals was done using photo identification (Appendix A and B). Field observations were conducted from a vehicle and occasionally on foot, at an approximate distance of 100-400 m where animals were observed to continue with 'natural' behaviour such as browsing. No absolute distance was decided upon due to the distance varying depending on the study area in terms of vegetation cover and height, the presence of other animals and environmental variables such as rain or fog. The herd was followed, either by foot or vehicle, with the number of individuals, estimated age and gender being noted. Observations, completed using binoculars if individuals were too far to observe with the naked eye, were conducted using a modified version of the interval scan sampling method (Altmann, 1974). The method involved observations being conducted on the same herd every five minutes from 06:00-18:00 on all visible individuals, with night observations being excluded from the study. This results in approximately 1 200 (maximum) observations per day depending on farm, herd size, and limiting factors such as climatic conditions and accessibility (terrain, slope, etc.). An observation was defined as one activity being conducted by one individual during one scan (Parker and Bernard, 2005; Deacon, 2015). To avoid observer bias and subjectivity, the first observed activity displayed by an individual

during a scan was recorded, with the next observation taken after five minutes. Observations were completed for each farm per season (winter, spring, summer and autumn).

Activity budgets were based on the following displayed behaviours (Fennessy, 2004; Deacon, 2015):

- Browsing: Defined as an individual foraging on a plant. Foraging to the point of chewing (not ruminating) and swallowing was included.
- Vigilance: Defined as an individual focussing on external stimuli such as predators or other animals. Individuals are seen as vigilant when eyes and ears are focused in the direction of the stimulus.
- Standing: Different to vigilance and can be defined as an individual resting in a standing position without doing any specific activity.
- Walking: Defined as an individual walking without foraging or ruminating.
- Rumination: Defined as an individual standing or walking and ruminating simultaneously. Ruminating should not be confused with chewing.
- Galloping: Defined as an individual running.

Activities observed at a lesser extent were:

- Defecation.
- Urination.
- Grooming: Defined as an individual licking itself or scratching against plants or other objects.
- Sexual behaviour: Includes flehmen response, sniffing or mounting displayed by males.
- Suckling: Whereby juvenile individuals nurse from any female.
- Oesteophagia: Defined as an individual feeding on the bones of carcasses found within the study area.

3.2.2. Statistical analysis

The frequency of each activity was determined by expressing the number of each record for each activity as a percentage of the frequency of occurrence per season. All descriptive statistics and graphs calculated and displayed respectively were generated in Microsoft Excel 2015.

To evaluate seasonal differences in giraffe activities, proportion (percentage) data was used and checked for normality using the Shapiro-Wilk normality tests. The majority of the data was shown not to be normally distributed; hence, results were further tested using generalized linear mixed models (GLMM) to cater for non-normal distributions (IBM Corporation, 2012). The Poisson loglink model was applied for count data. The analysis was used to test for differences between behaviours displayed by giraffes of differing sex, as well as how behaviour differed between different seasons. Pairwise comparisons were tested at a 5% significance level.

3.3. RESULTS

3.3.1. Kareesbos Private Game Reserve

3.3.1.1. Activity budgets

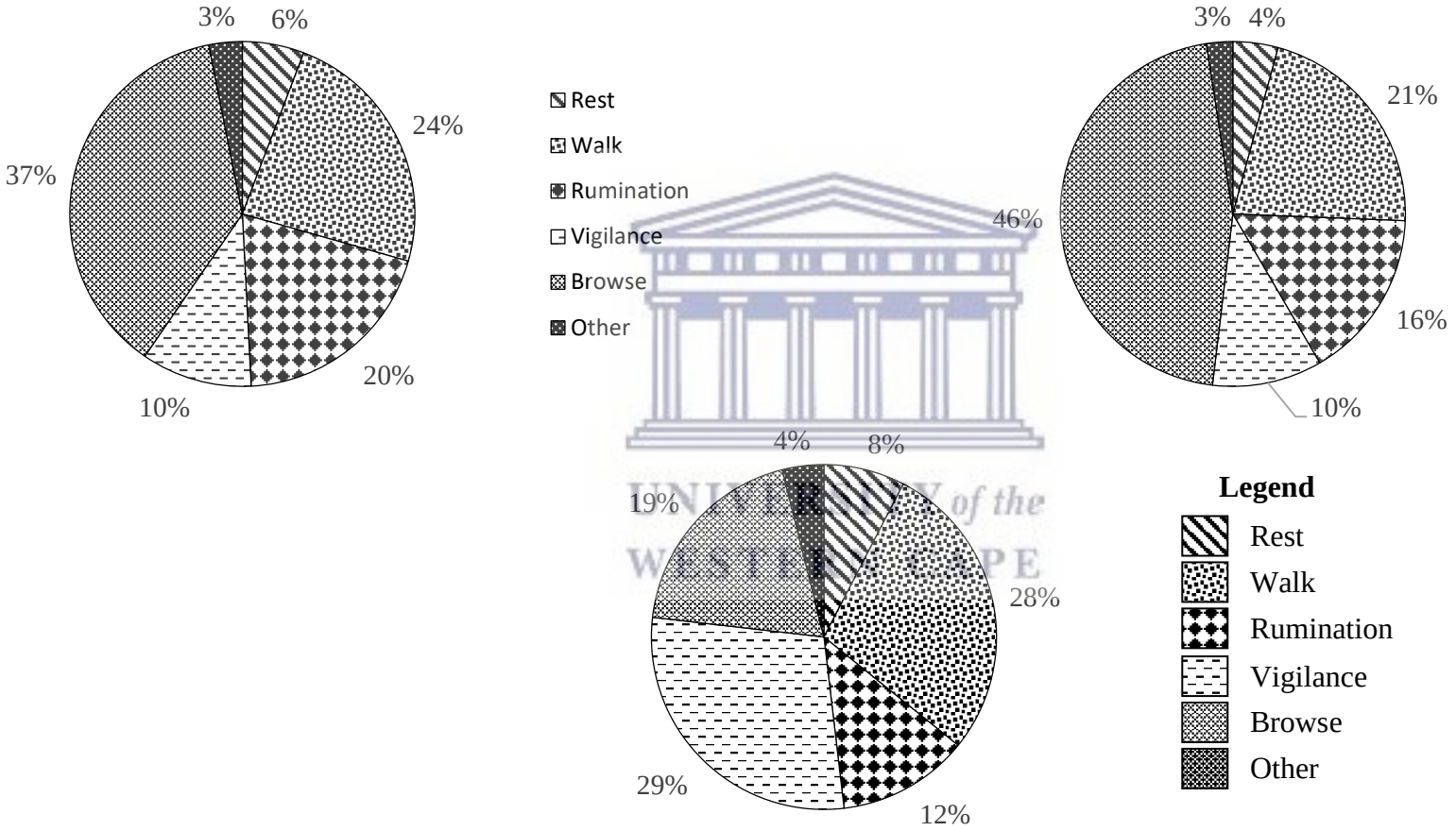

Figure 3.1: Diurnal activity budgets of males (n = 3006) (top left), females (n = 2346) (top right) and juveniles (n = 725) (bottom) in Kareesbos Private Game Reserve during the entire study period

Hypothesis 1: Browsing will be the dominant activity displayed by giraffes

The overall activity budgets for males, females and juveniles in KPGR are shown in Figure 3.1. The most common activity displayed by males was browsing (37%), followed by walking (24%), rumination (20%) and vigilance (10%). However, resting (6%) accounted for a small portion of the activity budget.

Browsing (46%), too, was the most common activity displayed by females in KPGR. This was followed by walking (21%), rumination (16%) and vigilance (10%). Resting (4%) by females comprised a small portion of the diurnal activity budgets.

Juveniles, however, spent most of their time on vigilance (29%) throughout the study period. Walking (28%), browsing (19%) and rumination (12%) were observed to be the second, third and fourth most displayed activities, with resting (8%) occurring to a lesser extent.

3.3.1.2. Sex differences in activity budgets

Hypothesis 2: Activity budgets will differ between males, females and juveniles

Certain activities were shown to differ between sexes. Males (6% vs. 4%) were shown to rest ($F_{2,199} = 3.3346$, $p = 0.031$), walk (24% vs. 21%) ($F_{2,199} = 14.598$, $p < 0.001$) and ruminate (20% vs. 16%) ($F_{2,199} = 28.119$, $p < 0.001$) more than females. Males, too, ruminated (20% vs. 12%) ($p < 0.001$) and browsed (37% vs. 19%) ($F_{2,199} = 25.443$, $p < 0.001$) more than juveniles. Females, however, were shown to browse more than males (46% vs. 37%) ($p < 0.001$) and juveniles (46% vs. 19%) ($p < 0.001$), as well as ruminate (16% vs. 12%) more than juveniles ($p < 0.001$).

Although males and females spent relatively the same amount of time on vigilance ($p > 0.05$), juveniles were shown to be more vigilant than both males ($p < 0.001$) and females ($p < 0.001$). Juveniles, too, walked more than males ($p < 0.001$) and females ($p = 0.004$).

3.3.1.3. Seasonal differences in activity budgets

Hypothesis 3: Activity budgets will differ between the different seasons, with giraffes spending more time on energy consuming activities during cooler seasons and spending more time on energy conserving activities during the warmer seasons.

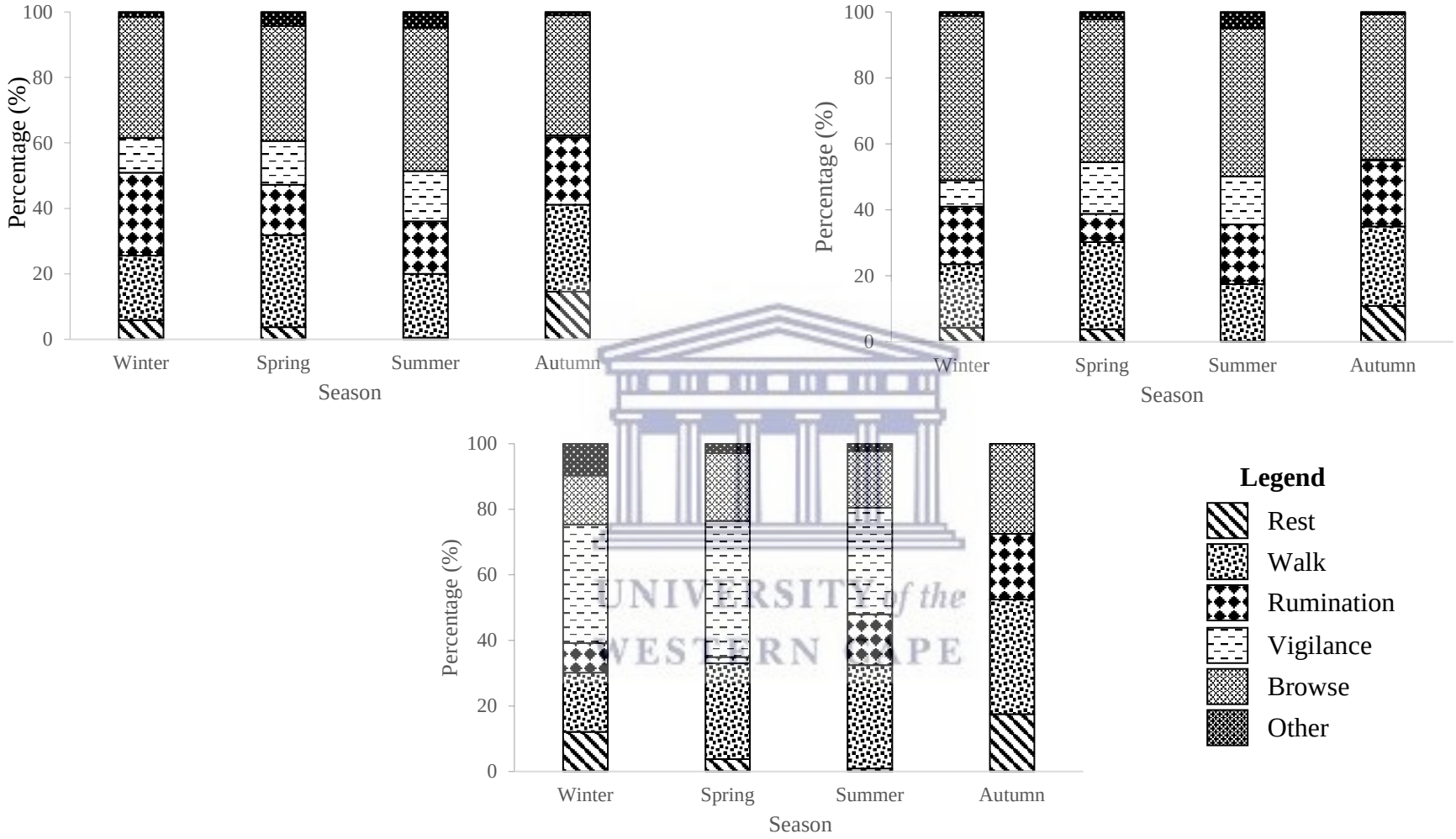

Figure 3.2: Behaviour of males (top left), females (top right) and juveniles (bottom) during winter, spring, summer and autumn in Kareesbos Private Game Reserve

3.3.1.3.1. Energy conserving activities

Females rested ($F_{3,199} = 14.461$, $p < 0.001$) and ruminated ($F_{3,199} = 5.0384$, $p = 0.001$) more during the cooler seasons than the warmer seasons. Females rested less during summer than winter ($p < 0.001$), autumn ($p < 0.001$) and spring ($p = 0.002$). Rumination occurred the most during autumn, decreasing in winter ($p = 0.043$) and spring ($p = 0.022$), where rumination occurred the least. Females, however, were more vigilant ($F_{3,199} = 28.965$, $p < 0.001$) during the warmer seasons, with vigilance occurring less frequently during autumn than the remaining seasons ($p < 0.001$).

Males, too, rested ($F_{3,199} = 24.91$, $p < 0.001$) and ruminated ($F_{3,199} = 5.146$, $p = 0.002$) more during the cooler seasons than the warmer seasons. Males rested more during autumn than spring ($p < 0.001$) and summer ($p < 0.001$) and ruminated more during winter than spring ($p < 0.001$) and summer ($p = 0.017$). Males, however, were more vigilant during the warmer seasons ($F_{3,199} = 35.8442$, $p < 0.001$), with males being less vigilant in autumn than the remaining seasons ($p < 0.001$).

Juveniles rested ($F_{3,199} = 6.331$, $p < 0.001$) and ruminated ($F_{3,199} = 8.62$, $p < 0.001$) more during the cooler seasons than warmer seasons. More specifically, juveniles rested more during winter and autumn than during summer and spring ($p < 0.05$). In addition, juveniles ruminated more during winter than during spring ($p < 0.001$) and summer ($p = 0.001$) and ruminated the most in autumn ($p = 0.006$). Vigilance however, occurred more during the warmer seasons ($F_{3,199} = 42.22$, $p < 0.001$), with juveniles being less vigilant in autumn than the remaining seasons ($p < 0.001$).

3.3.1.3.2. Energy consuming activities

No seasonal differences were shown for walking by females ($F_{3,199} = 2.521$, $p = 0.059$), males ($F_{3,199} = 0.432$, $p = 0.73$) and juveniles ($F_{3,199} = 0.83$, $p = 0.479$). However, females ($F_{3,199} = 4.335$, $p = 0.006$) browsed more during the cooler seasons, with more browsing occurring during winter and spring and autumn ($p < 0.001$). Males, however, browsed more during warmer seasons ($F_{3,199} = 3.211$, $p = 0.024$), with more browsing occurring during summer than during winter ($p = 0.025$) and autumn ($p = 0.003$). No seasonal variation in browsing was shown for juveniles ($F_{3,199} = 0.016$, $p = 0.997$).

3.3.2. Tsumkwe Private Game Reserve

3.3.2.1. Activity budgets

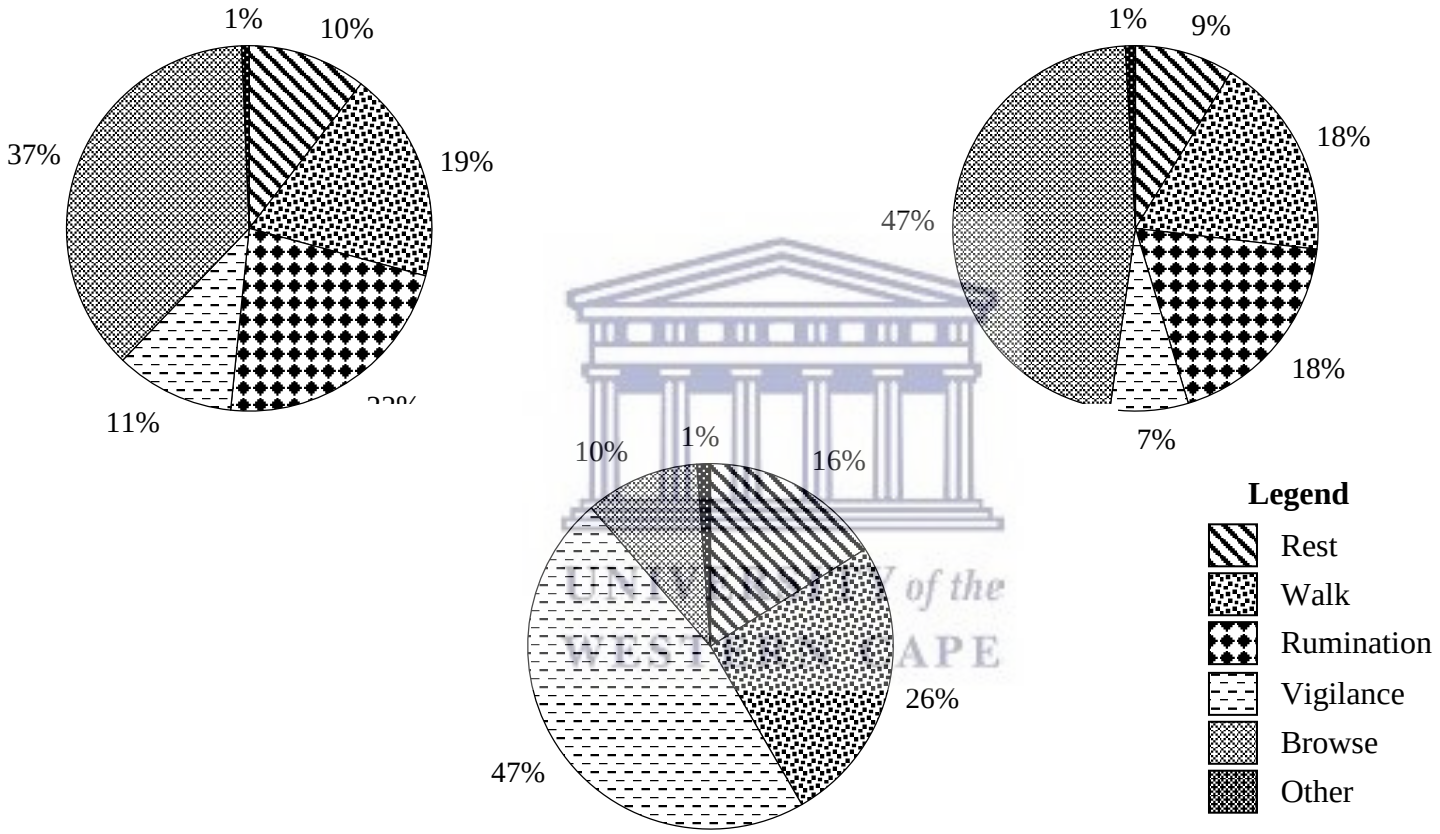

Figure 3.3: Diurnal activity budgets of males (n = 3101) (top left), females (n = 2090) (top right) and juveniles (n = 160) (bottom) in Tsumkwe Private Game Reserve during entire study period

Hypothesis 1: Browsing will be the dominant activity displayed by giraffes

The overall activity budgets for males, females and juveniles in TPGR are shown in Figure 3.3. The most common activity displayed by males was browsing (37%), followed by rumination (22%), walking (19%) and vigilance (11%). Resting accounted for 10% of the activity budget.

Browsing (47%), too, was the most common activity displayed by females in TPGR. This was followed by walking (18%), rumination (18%) and resting (9%). Vigilance (7%) by females comprised a small portion of the diurnal activity budget.

The activity budgets of juveniles were only determined during autumn. Vigilance was the most common activity (47%), followed by walking (26%), resting (16%) and browsing (10%). Juveniles were shown not to ruminate.

3.3.2.2. Sex differences in activity budgets

Hypothesis 2: Activity budgets will differ between males and females

Certain activities were shown to differ between sexes. Males were shown to walk more than females (19% vs. 18%) ($F_{1,127} = 11.174$, $p = 0.001$), with females spending more time browsing than males (47% vs. 37%) ($F_{1,127} = 78.314$, $p < 0.001$). Males and females spent relatively the same amount of time on resting ($F_{1,127} = 2.088$, $p = 0.151$), rumination ($F_{1,127} = 0.41$, $p = 0.523$) and vigilance ($F_{1,127} = 0.915$, $p = 0.341$) throughout the study period.

3.3.2.3. Seasonal differences in activity budgets

Hypothesis 3: Activity budgets will differ between the different seasons, with giraffes spending more time on energy consuming activities during cooler seasons and spending more time on energy conserving activities during the warmer seasons

3.3.2.3.1. Energy conserving activities

Females rested ($F_{3,127} = 2.615$, $p = 0.049$) and ruminated ($F_{3,127} = 9.421$, $p < 0.001$) more during the warmer seasons than during the cooler seasons. Females rested more during summer than during winter ($p = 0.01$), spring ($p = 0.008$) and autumn ($p = 0.014$). Rumination occurred more during summer than during winter ($p < 0.001$) and autumn ($p < 0.001$). No seasonal variation in vigilance was shown for females ($F_{3,127} = 2.233$, $p = 0.088$).

Males, too, rested ($F_{3,127} = 13.935$, $p < 0.001$) more during the warmer seasons compared to the cooler seasons. Males rested more during summer than during spring ($p < 0.001$) and autumn

(p < 0.001). Males, however, ruminated ($F_{3,127}$ = 6.02, p = 0.001) more during winter than during autumn (p < 0.001) and spring (p = 0.042) and more during summer than autumn (p = 0.001). Males were also shown to be more vigilant ($F_{3,127}$ = 5.986, p = 0.001) during autumn than during winter (p = 0.001) and summer (p = 0.002).

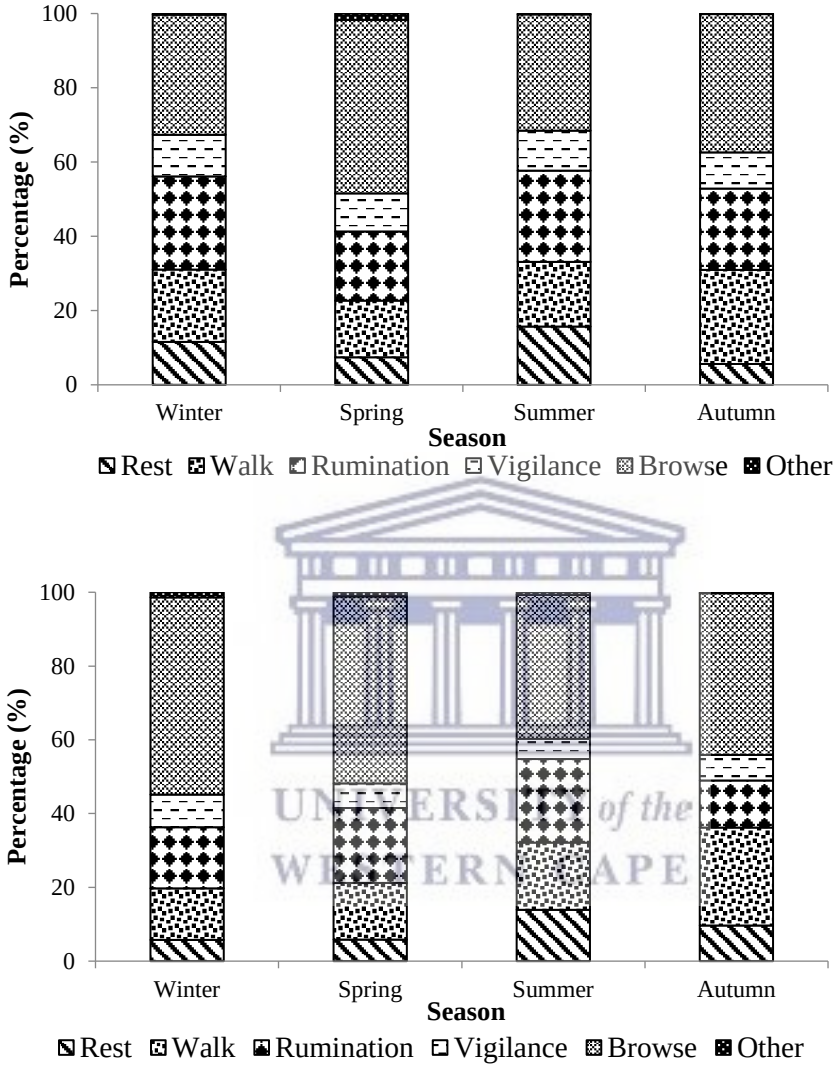

Figure 3.4: Behaviour of males (top) and females (bottom) during winter, spring, summer and autumn in Tsumkwe Private Game Reserve

3.3.2.3.2. Energy consuming activities

No differences were shown in walking by females ($F_{3,127}$ = 9.421, p < 0.001) and males ($F_{3,127}$ = 6.02, p = 0.001). Browsing by females ($F_{3,127}$ = 14.685, p < 0.001) decreased from the cooler to the warmer seasons, with females browsing more in winter than during summer (p < 0.001) and autumn (p < 0.001) and more during spring than summer (p < 0.001) and autumn (p < 0.001). Browsing by males ($F_{3,127}$ = 10.705, p < 0.001), however, increased dramatically from

winter to spring (p = 0.005) and decreased from spring to autumn, with more browsing occurring in spring than in summer (p = 0.001) and autumn (p < 0.001).

3.4. DISCUSSION

Browsing will be the dominant activity displayed by giraffes

Activity budgets of giraffes have been documented by a few studies (Pellew, 1983; Fennessy, 2004; Blomqvist and Renberg, 2007; Adolfsson, 2009; Deacon, 2015). In all these documented cases, browsing was shown to be the dominant diurnal behaviour. In Mokolodi Nature Reserve, Botswana, giraffes spent approximately 36% of their time browsing (Blomqvist and Renberg, 2007). In Serengeti National Park, Tanzania (Pellew, 1983), females and males were shown to browse 72.4% and 55.34% of their time respectively. Similar dominance was shown in the Namib Desert, Nambia and Masai Mara National Reserve, with females and males spending 59% and 51% and 39% and 36% of their time browsing, respectively. As shown, the dominance of browsing is a norm for giraffes.

Activity budgets will differ between males and females

Cows spending more time browsing than males is considered as the norm in numerous studies conducted within natural ranges (Pellew, 1984a; Du Toit, 1990; Blomqvist, 2007; Fennessy, 2004; Deacon, 2015), as well as on other African herbivores (Spinage, 1968, Leuthold and Leuthold, 1978; Ben-Shahar and Fairall, 1987). According to Ginnett (1997), sexual dimorphism and reproductive concerns are two main factors influencing foraging differences in males and females. In terms of sexual dimorphism, Ginnett and Demment (1997) explain that total basal metabolism increases as a fractional exponent of body mass, therefore males, who tend to be larger than females, require more energy per unit time. In addition, a linear function exists between the gut capacity of herbivores and body mass. Herbivores with a greater body mass will have a higher gut volume to metabolic requirement ratio ("food processing capacity"), thus having the capability to retain food in the gut for longer periods of time, and in turn increasing the efficiency of nutrient extraction per unit of intake (Ginnett and Demment, 1997). Therefore, males have the ability to incorporate low quality forage within their diet, and meet metabolic and energy requirements in shorter time periods than females by increasing feeding rates (Ginnett and Demment, 1997). Reproductive requirements of either sex may also play a role in foraging differences (Parker, 2004).

Males were also shown to rest, walk and ruminate more than females. Males browsing less than females, thus allowing more time for other activities, may explain this. Fennessy (2004)

indicated that increased vigilance comes at a cost to foraging and reduces the risk of predation. However, predators are at no risk to giraffes in KPGR and TPGR, due to their absence. Therefore, increased vigilance by males may be socially related (Ginnett and Demment, 1997). For example, older males may be more vigilant in order to compete for females, whereas smaller males may be more vigilant to avoid aggression (Pellew, 1984; Artiss and Martin, 1995; Cameron and Du Toit, 2005). Furthermore, males tend to ruminate more than females due to their increased feeding rates and their need to extract more nutrients (Leuthold and Leuthold, 1978; Pellew, 1984).

Activity budgets will differ between the different seasons, with giraffes spending more time on energy consuming activities during cooler seasons and spending more time on energy conserving activities during the warmer seasons

Foraging time is dependent on numerous factors, such as body size, metabolic and energetic requirements of species and individuals, the availability of digestible food, food intake rates, habitat, as well as abiotic factors such as ambient temperatures and wind (Knight, 1991). The amount of digestible food plays a huge role in the proportion of time herbivores invest in browsing, with seasonal variations usually as a result of the change in food quantity and quality (Beckman and Prins, 1989; Knight, 1991). Seasonal variation in giraffe browsing has been frequently documented (Parker, 2004; Theron, 2005; Cornelius, 2010; Deacon, 2015). These variations have been associated with the change of the phenology of deciduous plant species that dominate these regions, with food quantity and quality decreasing during the drier seasons and foraging time increasing (Janecke and Smit, 2011). However, in this study, browsing by males increased from the cooler to the warmer seasons (winter to summer), whereas female browsing decreased from the cooler to the warmer seasons. This trend may be explained not by the quantity of available forage, but the quality. In both study sites, the majority of available forage species are evergreen, except for small patches of *Vachellia karroo* and *Lycium cinereum* (Chapter 3). However, since quality was not investigated within this study, it is suggested that differences in food quantity may be minimal between the different seasons, but changes in the quality of these plant species may cause the change in browsing frequency between seasons.

Females in TPGR were shown to rest more during the warmer seasons (summer) than the cooler seasons. This may be explained by ambient temperatures, with giraffes often resting more when ambient temperatures are high (Fennessy, 2004; Deacon, 2015). In addition, males ruminated

more during winter than the rest of the seasons in TPGR. This increase in rumination may be due to their browsing patterns and possible lower quality of browse during the winter seasons, thus compensating for their need to extract more nutrients.

3.5. CONCLUSION

Browsing was shown to be the dominant diurnal activity of males, females and juveniles in both study sites. Marked differences were observed in activity budgets of different sexes, with females browsing more than males, and males ruminating, walking and allocating more time to vigilance than females. Females likely browse more than males due to males requiring more energy per unit time, thus increasing feeding rates and incorporating lower quality forage in their diet to meet metabolic requirements in a shorter time. Males therefore ruminate more than females, due to this increase in feeding rates and low quality forage and the need to extract more nutrients. Furthermore, males spending less time browsing allows them to allocate more time to other activities, such as walking and vigilance, than females.

Season did not have as great an effect on all diurnal activities as within their natural ranges, possibly due to the differences in factors such as rainfall, temperature and other environmental factors. These factors need to be studied in greater depth to understand why the behaviour of giraffe in different localities differs according to season. Browsing is of great importance, particularly due to the extralimital status of giraffe within the area, therefore the identification and understanding of forage species, browsing behaviour and forage availability is essential and will be explored in Chapter 4 and Chapter 5 respectively.

CHAPTER 4 : DIET AND BROWSING LEVELS OF EXTRALIMITAL GIRAFFE

4.1. INTRODUCTION

The relationship between herbivores and plant communities is best described by a herbivore's foraging behaviour (Cornelius, 2010), and is essential for and influenced by, various reasons and factors respectively. Foraging behaviour is influenced by both plant and animal factors, such as plant availability, chemical composition and defence, and animal digestibility and body size (Owen-Smith, 1982; Pellew, 1984a; Bryant *et al.*, 1991; Cornelius, 2010). These factors result in herbivores continuously modifying their foraging behaviour according to seasonal variation in plant species availability and quality.

Giraffes are considered megaherbivores, with an adult female having to consume approximately 2.1% of their live weight per day, which approximates to 16 kg of digestible dry matter (DM^{-1}) (Dagg and Foster, 1976; Deacon, 2015). Regarded as browsers, giraffes feed on the leaves and shoots of trees and shrubs (Hofmann, 1989; Du Toit, 1988, Parker *et al.*, 2003). *Vachellia* species dominate the diet of giraffes within their natural ranges, resulting in an observed dietary shift from a deciduous dominated diet within the wet season, to a semi-deciduous, evergreen diet during the dry season (Leuthold and Leuthold, 1972; van Aarde and Skinner, 1975; Sauer *et al.*, 1977; Parker, 2004; Theron, 2005). Preferences, however, differ between areas, with plant species of higher water and protein content, as well as those with more newly produced shoots and leaves, being favoured (Pellew, 1984a; Hall-Martin and Basson, 1975; Cornelius, 2010).

It is said that the neck of the giraffe has developed in such a way that browsing occurs higher than other browsers, thus reducing the risk of competition (Cameron and Du Toit, 2007). Males are larger than females (Deacon, 2015), documented to browse higher in plant canopies than females (Parker, 2004). However, numerous studies (Leuthold and Leuthold, 1972; Sauer *et al.*, 1977; Woolnough and Du Toit, 2001; Blomqvist and Renberg, 2007; O'Connor, 2013) have observed giraffe to browse lower than three metres (see Chapter 2). This promotes niche overlap with other herbivores, hence increasing the risk of interspecific competition. For example, kudus and eland have been documented to have a maximum browsing height of 2.5 m (Dayton, 1978; Watson, 1999; Smit, 2004; Deacon, 2015).

Giraffe diet assessments, therefore, are crucial for management decisions regarding natural rangelands, providing the basis for understanding resource and habitat requirements of species

(Deacon, 2015), maintaining and regulating animal populations (Cornelius, 2010), identifying potential competition with other herbivore species, as well highlighting potential impacts giraffes may have on the environment (Parker, 2004; Pienaar, 2013; Deacon, 2015). Only two studies has been conducted on the diet composition of giraffes within the Western Cape (Cornelius, 2010; Gordon *et al*., 2016), with no detailed studies being conducted on browsing levels within the area. Therefore, it is imperative to understand these ecological aspects of extralimital giraffe within the Western Cape, and to manage them accordingly to prevent negative impacts on thicket vegetation, and to ensure the welfare of giraffe populations.

Therefore, the aim of this chapter was to determine the diet composition and browsing postures of extralimital giraffe within the Western Cape. This chapter addresses the following objectives and hypotheses:

- To determine diet composition of giraffes
    - Hypothesis 1: Giraffes of differing sex will consume the same species
- To compare diet composition between different seasons
    - Hypothesis 2: Diet composition will not differ between different seasons due to the majority of the plant species being evergreen
- To determine the browsing levels of giraffes and compare between different seasons
    - Hypothesis 3: Giraffes will browse at low levels that will not differ seasonally

4.2. METHODS

4.2.1. Field observations

4.2.1.1. Diet observations

Giraffe observations were completed using the interval scan method, whereby observations were conducted every five minutes on each individual in a herd from sunrise to sunset for four days each season (winter, spring, summer and autumn) from August 2014 to May 2015. Observations, done by means of binoculars if individuals were too far to observe with the naked eye, were conducted mostly from a vehicle; however, observations were conducted occasionally on foot if obstacles such as vegetation cover or environmental factors such as mist or rain restricted views. When observed as browsing, sex of the individual, as well as the

browse species consumed and level of browsing was recorded. Before the commencement of the study, plant species were familiarised with.

4.2.1.2. Level of browsing

The general browsing level of giraffe was determined using methods by Theron (2005) and Deacon (2015). The level of browsing is generally categorised according to the height of browsing in relation to body posture, with six levels of feeding existing for giraffe. These levels of browsing range from ground height to head height, with each level and approximate heights illustrated in Figures 4.1and 4.2 respectively, and are defined as follows:

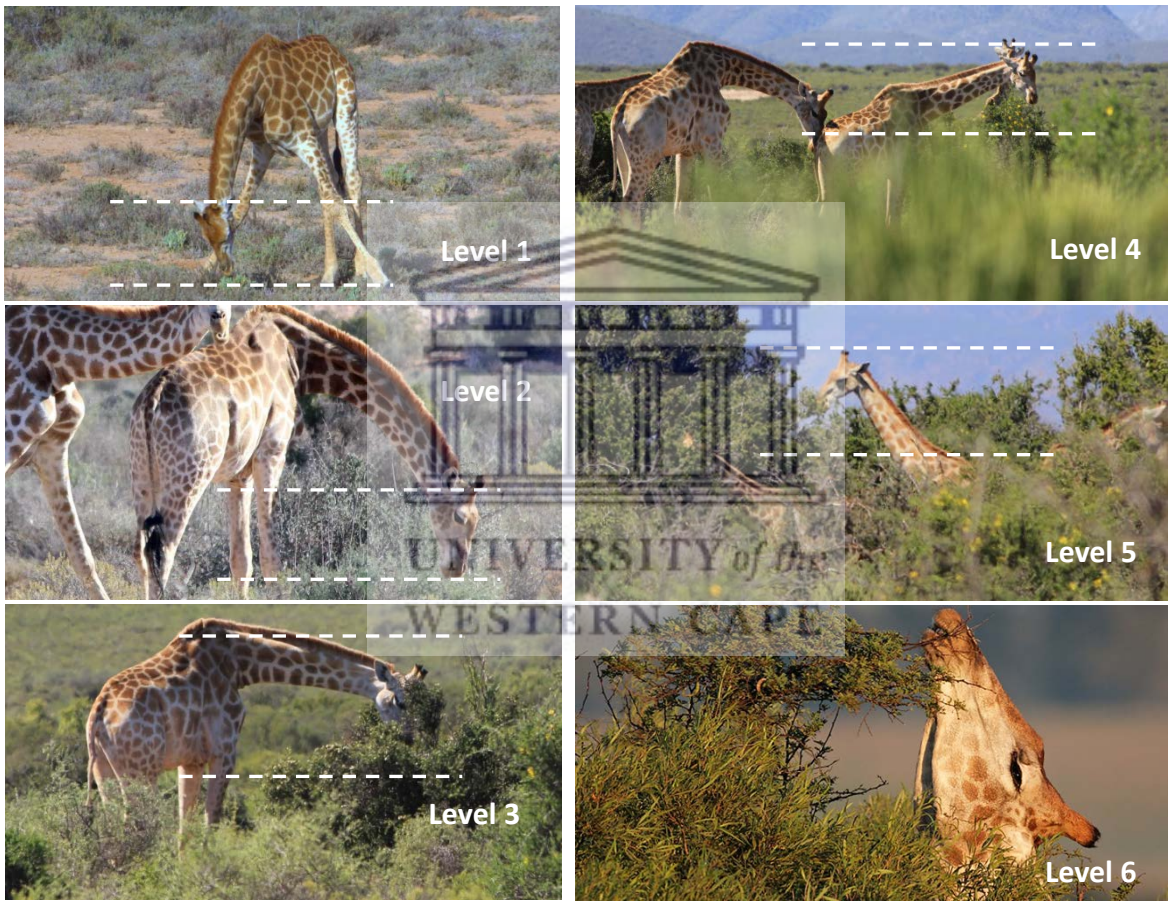

Figure 4.1: Pictures depicting the different browsing levels by giraffes (Pictures taken by: Clement Cupido and Nico Smit)

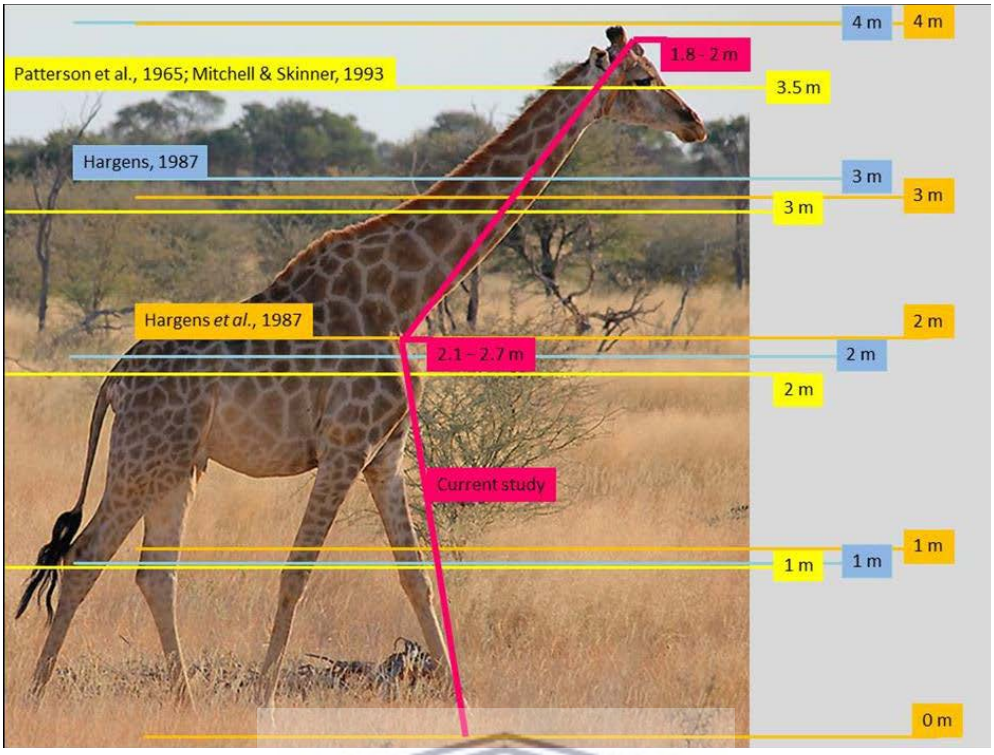

Figure 4.2: Picture illustrating the approximate height measurements of an adult female giraffe as reported in literature (Patterson *et al.*, 1965; Hargens *et al.*, 1987; Mitchell and Skinner, 1993; Deacon, 2015)

- Level 1 (ground height) is defined as browsing with the head positioned lower than the knees, with knees bent or stretched outwards (height less than 1 m).

- Level 2 (knee height) is defined as browsing with the head positioned lower than the underside of the abdomen, with the exception of feeding at ground height with knees bent (level 1) (height approximately 1 m).

- Level 3 (chest height), is defined as browsing with the neck positioned horizontally or lower, with the neck not being positioned lower than the underside of the abdomen (height approximately 2 m).

- Level 4 (neck height) is defined as browsing with the neck positioned lower than 45° from the horizontal neck position, with the neck not extended lower than the base of the neck (height approximately 3 m).

- Level 5 (head height) is defined as browsing at the normal upright standing position, with the neck positioned at least 45° from the horizontal neck position (height approximately 3.5 m).

- Level 6 (stretch height) is defined as browsing with mouth and head reaching upwards higher than the base of the horns (height approximately 4 m and higher).

4.2.1.3. Statistical analysis

The diet composition and browsing levels of giraffe categories during the study period and different seasons were considered as the frequency of each browsed species represented as a percentage (%). The comparisons of diet composition and browsing levels between seasons and sex were further analysed using generalized linear mixed models (GLMM) to cater for non-normal distributions (IBM Corporation, 2014). The Poisson with loglink model was applied for count data. Pairwise comparisons were tested at a 5% significance level using the Tukey least significant difference (LSD) method. All tests were conducted at a 0.05 significance level using IBM SPSS Statistics (IBM Corporation, 2014).

4.3. RESULTS

4.3.1. Kareesbos Private Game Reserve (KPGR)

4.3.1.1. Diet composition

Hypothesis 1: Giraffes of differing sex will consume the same species

Table 4.1: The diet composition of all categories of the giraffe herd in KPGR throughout the study period

		Proportion in diet (% ± 1 SD)		
Species	Plant family	Males	Females	Juveniles
Pappea capensis	Sapindaceae	44.95 ± 5.88	47.71 ± 8.59	54.40 ± 12.01
Portulacaria afra	Portulacaceae	16.06 ± 2.49	16.46 ± 4.41	16.00 ± 10.39
Euclea undulata	Ebenaceae	15.89 ± 5.17	15.23 ± 6.92	6.40 ± 5.21
Lycium spp.	Solanaceae	12.58 ± 6.61	11.88 ± 8.42	15.20 ± 10.02
Other				
Salsola glabrescens	Chenopodiaceae	2.73 ± 3.19	1.58 ± 0.79	1.60 ± 2.77
Searsia longispina	Anacardiaceae	2.24 ± 3.32	2.11 ± 2.07	-

Rhigozhum obovatum	Bignoniaceae	1.57 ± 3.54	2.20 ± 4.21	1.60 ± 4.16
Vachellia karroo	Fabaceae	0.99 ± 1.37	0.70 ± 1.25	4.00 ± 6.25
Leipoldtia schultzei	Aizoaceae	0.75 ± 0.92	0.62 ± 0.69	-
Augea capensis	Zygophyllaceae	0.91 ± 1.68	0.35 ± 0.88	-
Asparagus spp.	Asparagaceae	0.58 ± 1.24	0.62 ± 0.57	0.80 ± 1.38
Carissa haematocarpa	Apocynaceae	0.17 ± 0.18	0.35 ± 0.38	-
Euphorbia mauritanica	Euphorbiaceae	0.17 ± 0.35	0.18 ± 0.32	-
Schinus mollie	Anacardiaceae	0.33 ± 0.45	-	-
Malephora lutea	Mesembryanthemaceae	0.08 ± 0.18	-	-

A total of 15 species from 14 plant families were consumed by giraffes in KPGR throughout the study period (Table 4.1). However, only four species, namely *P. capensis*, *P. afra*, *E. undulata* and *Lycium spp*. were considered important species, contributing approximately 89%, 91% and 92% to the diet of male, female and juvenile giraffes respectively.

Hypothesis 2: Diet composition will not differ between different seasons due to the majority of the plant species being evergreen

Pappea capensis was the most important species consumed by males, with significantly more being consumed in spring and summer than during winter and autumn ($F_{3,87} = 2.864$, $p = 0.041$). *Portulacaria afra* was the second most important species, with consumption remaining relatively the same between the different seasons ($F_{3,87} = 0.871$, $p = 0.459$). *Euclea undulata* was the third most important species consumed, with consumption decreasing in spring compared to the other seasons ($F_{3,87} = 5.853$, $p = 0.001$). Although the fourth most important species, the consumption of *Lycium spp*. only increased from spring to autumn ($F_{3,87} = 6.604$, $p < 0.001$). Consumption of the remaining species remained low during the study period. *Rhigozhum obovatum* and *V. karroo* were only consumed by males during spring and summer respectively. The consumption of *S. longispina* ($F_{3,87} = 3.463$, $p = 0.02$) and *S. glabrescens* ($F_{3,87} = 3.417$, $p = 0.021$) was greatest during winter, with less being consumed during the remaining seasons. *Carissa haematocarpa* (other category) was only consumed in spring and

summer, with *S. mollie* and *M. lutea* consumed in summer and spring respectively. *Euphorbia mauritanica* and *Asparagus spp*, were only consumed in autumn, with *A. capensis* being only consumed in winter and autumn.

Pappea capensis was the most important species consumed by females, with consumption decreasing from winter to autumn ($F_{3,82} = 6.938$, $p < 0.001$). *Portulacaria afra* was the second most important species, with significantly less being consumed during spring than the remaining seasons ($F_{3,82} = 3.099$, $p = 0.031$). *Euclea undulata* was the third most important species consumed, with its importance decreasing in spring compared to the other seasons ($F_{3,82} = 5.145$, $p = 0.003$). The importance of *Lycium spp*., the fourth most important species consumed by females, increased from spring to autumn ($F_{3,82} = 13.668$, $p < 0.001$). The importance of the remaining species remained low during study period, with *R. obovatum* only being consumed in autumn and spring. *Vachellia karroo* was only consumed during summer. No seasonal differences in the consumption of *S. glabrescens* was observed ($F_{3,82} = 0.728$, $p = 0.538$). *Searsia longispina* was not consumed during summer ($F_{3,82} = 2.834$, $p = 0.043$). Species in the "other" category in Figure 5.3, namely *A. capensis* and *E. mauritanica* were only consumed in autumn and winter respectively. *Carissa haematocarpa* was consumed only in summer and spring, whereas *L. schultzei* was only consumed in winter and summer.

Pappea capensis was the most important species consumed by juveniles, with juveniles consuming less during summer than during the remaining seasons ($F_{3,33} = 4.198$, $p = 0.023$). *Portulacaria afra* was the second most important species, with consumption decreasing from winter to autumn ($F_{3,33} = 4.421$, $p = 0.009$). *Lycium spp*., the third most important species, was only consumed from spring, with consumption increasing till autumn ($F_{3,33} = 4.398$, $p = 0.01$). *Euclea undulata*, the fourth most important species, was consumed in winter. However, consumption of *E. undulata* ceased in spring, and increased in summer and autumn ($F_{3,33} = 2.909$, $p = 0.049$). Juveniles did not consume *S. longispina*. *Rhigozhum obovatum*, *V. karroo* and *S. glabrescens* were only consumed in spring, summer and autumn respectively.

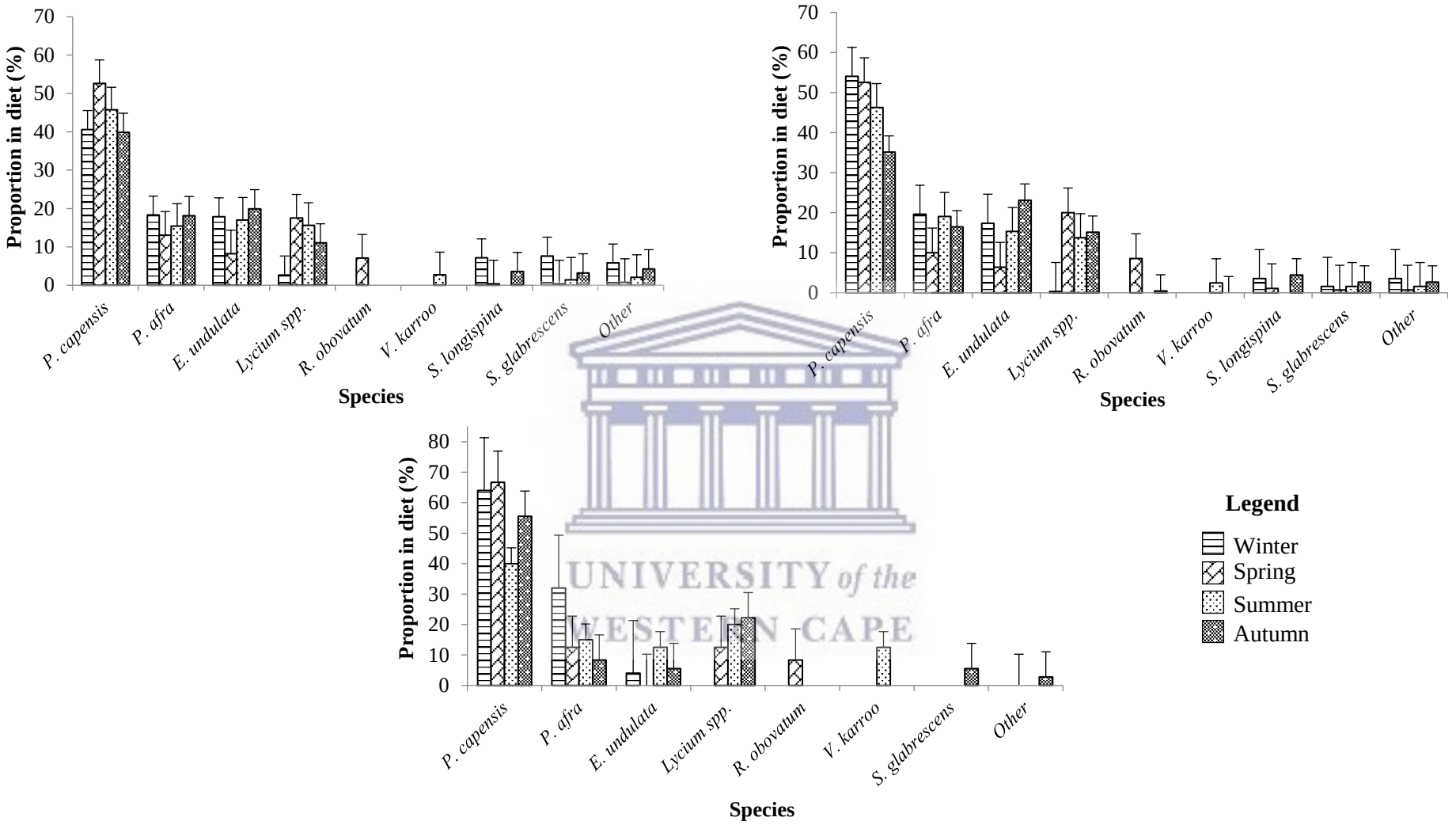

Figure 4.3: Diet composition of male (top left), female (top right) and juvenile (bottom) giraffes in KPGR during the different seasons (% + 1 SE)

4.3.1.2. Browsing levels

Hypothesis 3: Giraffes will browse at low levels that will not differ seasonally

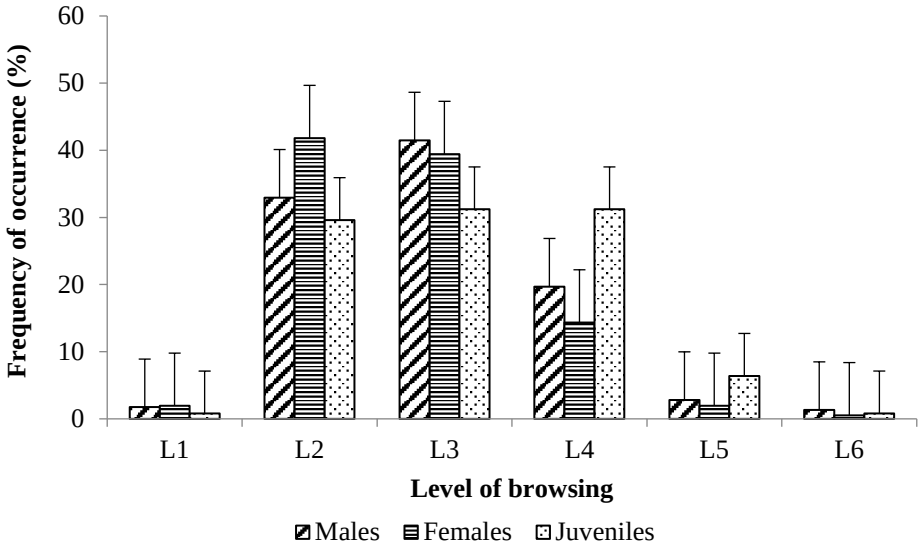

Figure 4.4: Browsing levels of males, females and juveniles in KPGR during the study period (% + 1 SE)

Males browsed more frequently at L3 (55%) (Figure 4.4) throughout the study period. Males decreased their browsing height levels from winter to autumn, with males browsing more at L2 ($F_{3,1316} = 7.843$, $p < 0.001$) than L3 ($F_{3,1316} = 4.925$, $p = 0.002$) during these seasons (Figure 4.5). In addition, males did not browse at L5 and L6 during winter (Figure 5.5).

Females browsed more frequently at L2 (41%) (Figure 4.4) throughout the study period. However, females increased their browsing height levels in winter, with females shown to browse significantly more at L3 ($F_{3,1286} = 5.057$, $p = 0.002$) during this season (Figure 4.5). Females, too, increased their browsing levels during spring, with females browsing more at L4 ($F_{3,1286} = 12.746$, $p < 0.001$) and L5 ($F_{3,1286} = 4.591$, $p = 0.003$). In addition, females only browsed at L6 during autumn (Figure 4.5).

Juveniles browsed more frequently at L3 and L4 (31.2%) (Figure 4.4) throughout the study period. Juveniles increased their browsing level during spring and summer, with juveniles shown to browse more at L4 ($F_{3,551} = 1.325$, $p = 0.026$) during these seasons (Figure 4.5). As the seasons moved into autumn, juveniles adjusted their browsing level, with juveniles browsing more at L2 ($F_{3,551} = 1.319$, $p = 0.049$) during this season (Figure 4.5). In addition, juveniles only browsed at L6 during autumn.

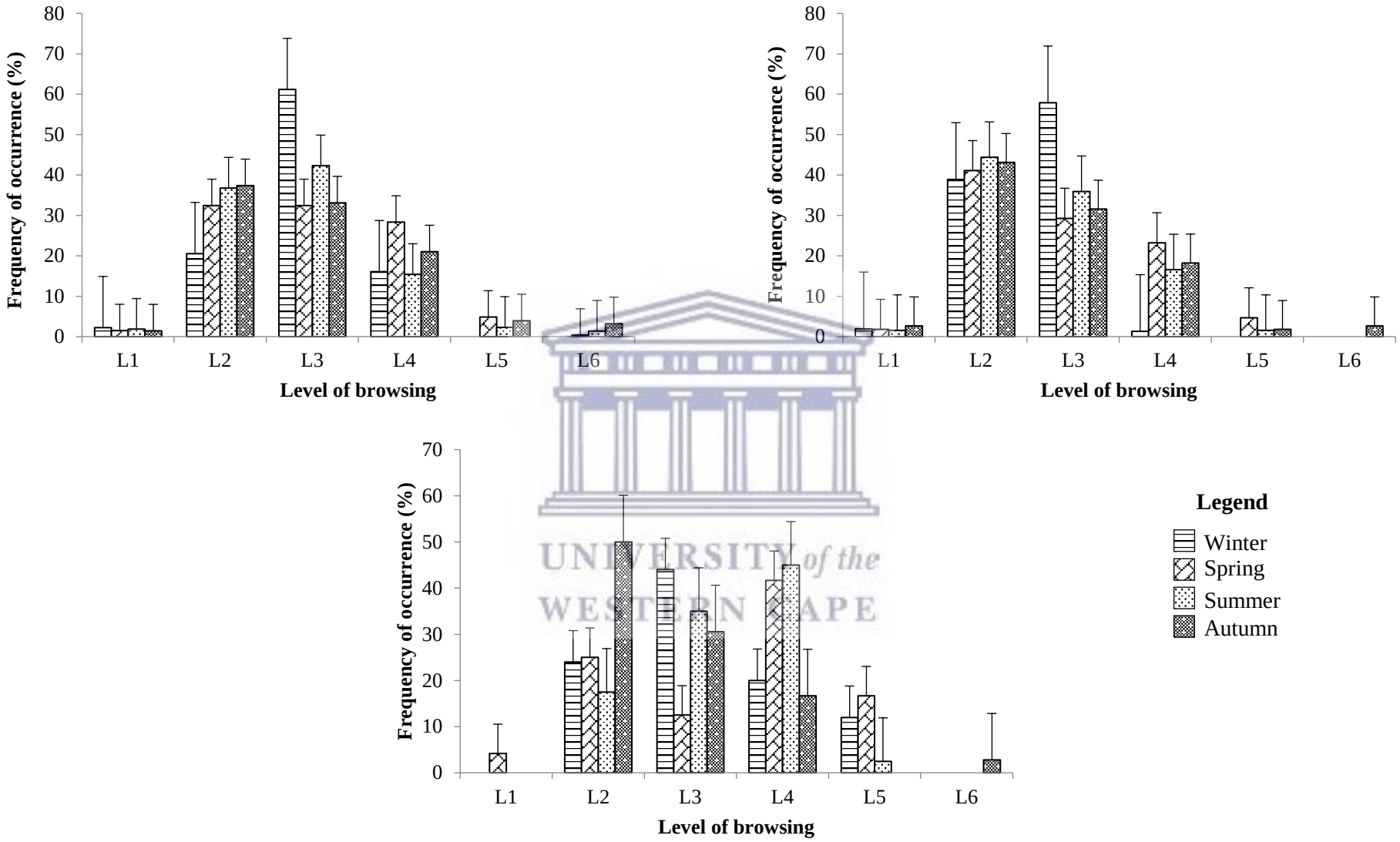

Figure 4.5: Browsing levels of male (top left), female (top right) and juvenile (bottom) giraffes in KPGR during the different seasons (% + 1 SE)

4.3.2. Tsumkwe Private Game Reserve (TPGR)

4.3.2.1. Diet composition

Hypothesis 1: Giraffes of differing sex will consume the same species

Table 4.2: The diet composition of all categories of the giraffe herd in TPGR throughout the study period

		Proportion in diet (% ± 1 SD)		
Species	Plant family	Males	Females	Juveniles
Searsia longispina	Anacardiaceae	25.95 ± 10.81	31.00 ± 10.62	80.00
Euclea undulata	Ebenaceae	18.67 ± 8.02	17.19 ± 5.39	15.64
Pappea capensis	Sapindaceae	8.94 ± 3.46	12.06 ± 4.11	4.36
Vachellia karroo	Fabaceae	18.51 ± 16.34	8.44 ± 8.41	-
Grewia robusta	Tiliaceae	8.09 ± 6.12	10.62 ± 7.53	-
Lycium spp.	Solanaceae	6.18 ± 3.48	9.42 ± 1.71	-
Nymannia capensis	Meliaceae	4.60 ± 1.31	4.67 ± 1.2	-
Rhigozhum obovatum	Bignoniaceae	3.81 ± 2.46	3.83 ± 3.51	-
Other				
Dodonaea viscosa	Sapindaceae	2.11 ± 0.84	1.30 ± 0.88	-
Euphorbia mauritanica	Euphorbiaceae	1.39 ± 2.02	1.21 ± 1.05	-
Salsola glabrescens	Chenopodiaceae	1.20 ± 1.76	1.89 ± 1.09	-
Zygophyllum spp.	Zygophyllaceae	0.56 ± 0.76	0.47 ± 0.39	-

A total of 12 species from 12 plant families were consumed by giraffes in TPGR throughout the study period (Table 4.2). However, five species, namely *S. longispina*, *E. undulata*, *P. capensis*, *V. karroo* and *G. robusta* were considered important species, contributing approximately 80% and 79% to the diet of male and female giraffes respectively. Juveniles only browsed on three species, namely *S. longispina*, *E. undulata* and *P. capensis*.

Hypothesis 2: Diet composition will not differ between different seasons due to majority of the plant species being evergreen

Searsia longispina ($F_{3,41}$ = 14.301; $p < 0.001$) and *E. undulata* ($F_{3,41}$ = 13.11; $p < 0.001$) were the first and second most important species consumed by males respectively, with consumption of both species decreasing significantly from winter to autumn. *Pappea capensis* was the third most important species during winter, with its importance decreasing from spring to autumn ($F_{3,41}$ = 6.493, p = 0.001) and the importance of *V. karroo* ($F_{3,41}$ = 68.705, p < 0.001) and *G. robusta* ($F_{3,41}$ = 35.362, $p < 0.001$) increasing during these seasons. *Lycium spp.* was the sixth most important species, with male consumption decreasing significantly from summer to autumn ($F_{3,41}$ = 18.652, $p < 0.001$).The importance of *N. capensis*, *R. obovatum*, *D. viscosa*, *E. mauritanica*, *S. glabrescens* and *Zygophyllum spp.* remained low during all seasons. The consumption of *N. capensis* ($F_{3,41}$ = 9.88, $p < 0.001$) differed seasonally, with males consuming *N. capensis* more during winter than the remaining seasons. The consumption of *D. viscosa* increased from winter to autumn ($F_{3,41}$ = 5.507, p = 0.003). The consumption of *R. obovatum* increased significantly during the spring and summer seasons compared to autumn and winter ($F_{3,41}$ = 3.702, p = 0.019). *Euphorbia mauritanica* ($F_{1,41}$ = 3.918, p = 0.028) and *Zygophyllum spp* were only consumed during summer and autumn, whereas *S. glabrescens* was only consumed during spring and autumn.

Similar results were observed for females, with *S. longispina* ($F_{3,41}$ = 30.605; $p < 0.05$) and *E. undulata* ($F_{3,41}$ = 12.197; $p < 0.001$) being the first and second most important species respectively, with consumption decreasing significantly from winter to autumn. *Pappea capensis* was the third most important species during winter, with its importance decreasing from spring to autumn ($F_{3,41}$ = 20.854, $p < 0.001$) and the importance of *V. karroo* ($F_{3,41}$ = 16.015, $p < 0.001$) and *G. robusta* ($F_{3,41}$ = 99.095, $p < 0.001$) increasing during these seasons. *Lycium spp.* was the sixth most important species, with females' consumption increasing significantly from summer to autumn ($F_{3,41}$ = 3.025, p = 0.04). The importance of *N. capensis*, *R. obovatum*, *D. viscosa*, *E. maurtianica*, *S. glabrescens* and *Zygophyllum spp.* remained low during all seasons. The consumption of *N. capensis* ($F_{3,41}$ = 1.528, p = 0.222) did not differ seasonally. However, the consumption of *R. obovatum* increased significantly during the spring and summer seasons compared to autumn and winter ($F_{3,41}$ = 14.33, $p < 0.001$). The consumption of *D. viscosa* ($F_{3,41}$ = 6.296, p = 0.001) and *S. glabrescens* ($F_{2,41}$ = 8.244; p = 0.001) increased during spring and autumn. *Euphorbia mauritanica* was only consumed in summer and autumn, with consumption increasing significantly in autumn. *Zygophyllum spp.* was only consumed in summer. Only one juvenile was present during the study period on TPGR during the season of autumn. However, since the individual was born in autumn, not

much browsing occurred. However, when browsing, the juvenile consumed only three species, namely *S. longispina*, *E. undulata* and *P. capensis* (Table 4.2).

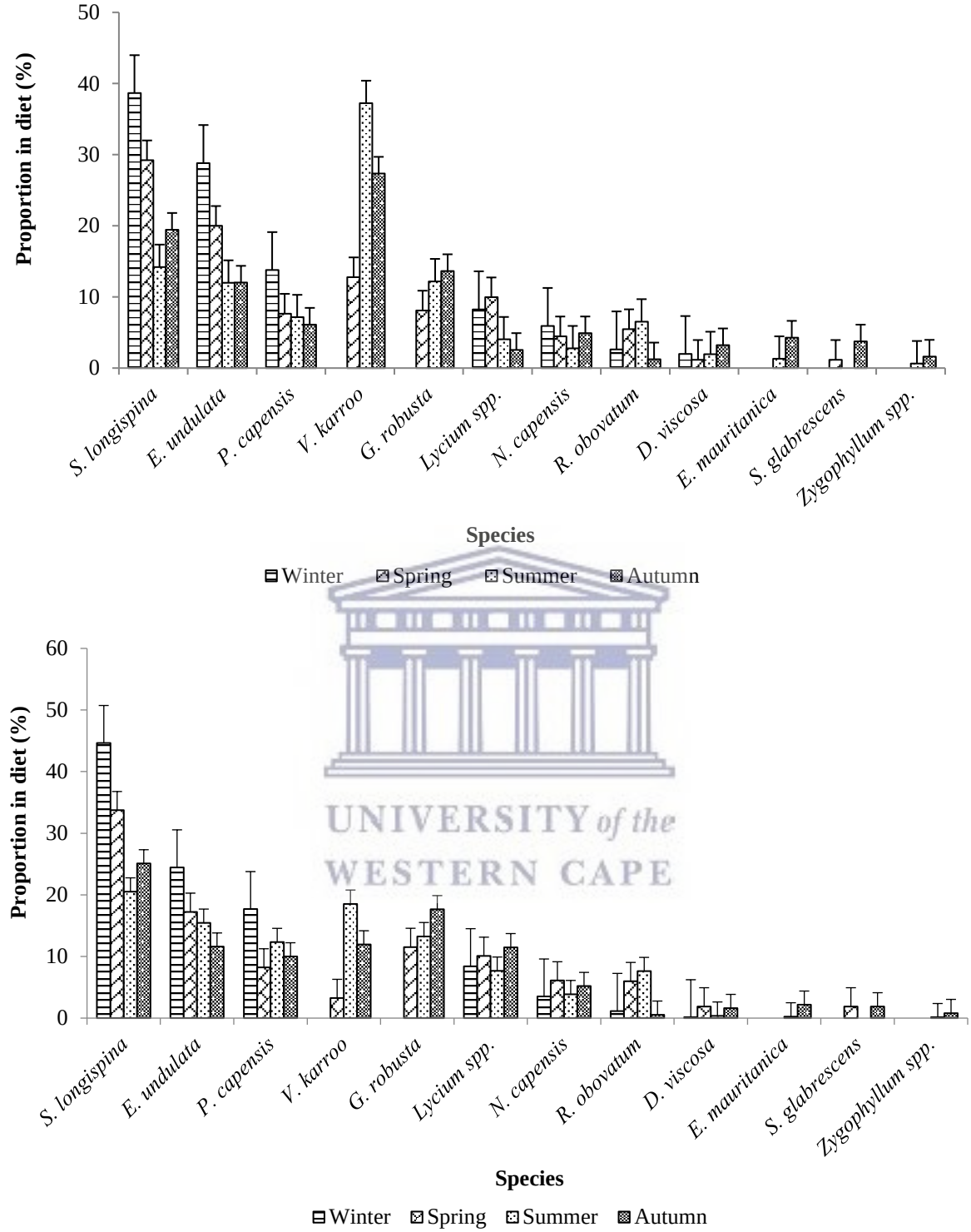

Figure 4.6: Diet composition of males (top) and females (bottom) in TPGR during the different seasons (% + 1 SE)

4.3.3.2. Browsing levels

Hypothesis 3: Giraffes will browse at low levels that will not differ seasonally

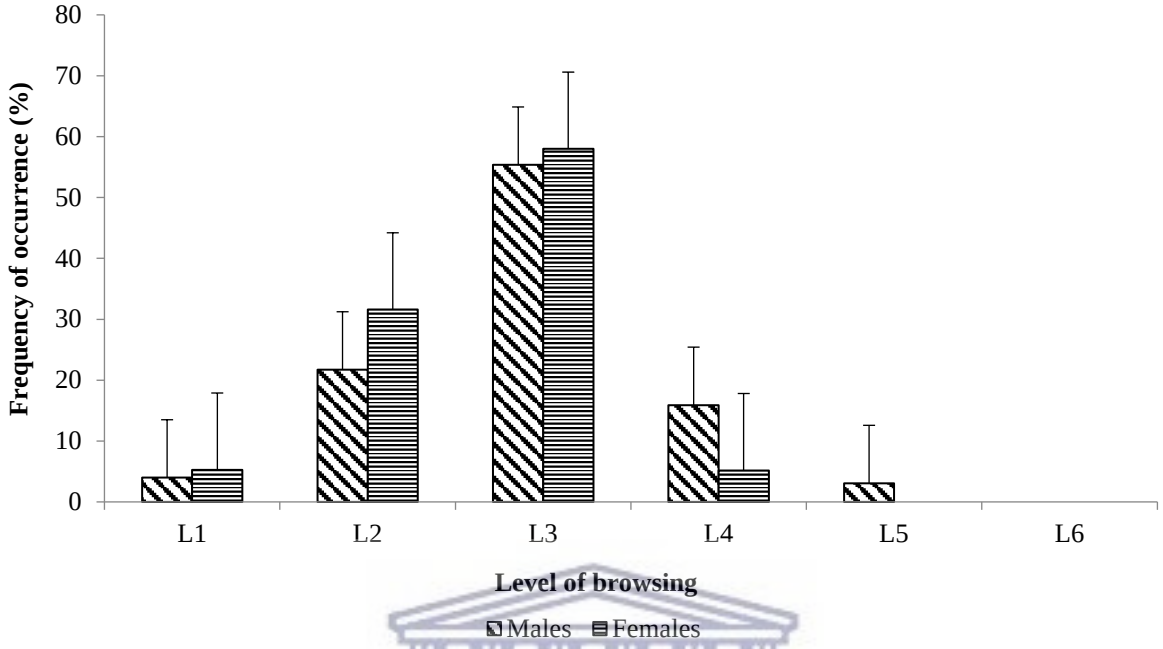

Figure 4.7: Browsing levels of males and females in TPGR during the study period (% + 1 SE)

Males browsed more frequently at L3 (55%) (Figure 5.7) throughout the study period. However, males adjusted their browsing level from winter to autumn, shown by the decrease in browsing at L3 ($F_{3,41} = 7.71$, $p < 0.001$) from winter to autumn, and the subsequent increase in browsing at L5 ($F_{3,41} = 6.16$, $p = 0.001$) from spring to autumn (Figure 4.8). Males were shown not to browse at L6 (Figure 4.7).

Females browsed more frequently at L3 (57%) (Figure 4.7) throughout the study period. However, females decreased their browsing levels during spring and autumn, with females browsing more at L2 ($F_{3,41} = 5.891$, $p = 0.002$) during these seasons (Figure 4.8). In addition, females were shown not to browse at L5 and L6 (Figure 4.7).

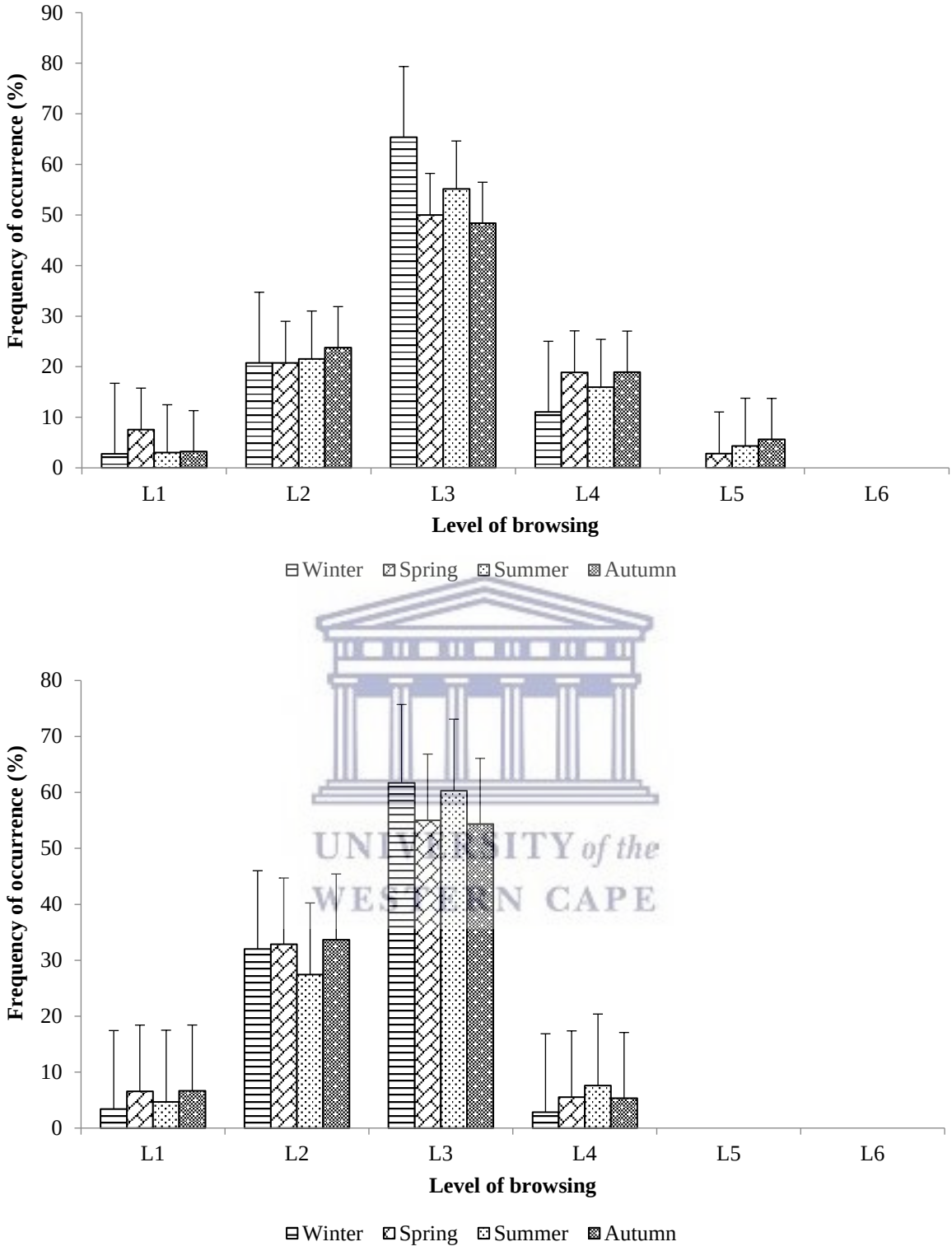

Figure 4.8: Browsing levels of males (top) and females (bottom) in TPGR during the different seasons (% + 1 SE)

4.4. DISCUSSION

Numerous studies have shown that giraffes tend to consume more than 20 species within their diet (Leuthold and Leuthold, 1972; Hall-Martin, 1974; van Aarde and Skinner, 1975; Sauer *et al.*, 1977, Sauer *et al.*, 1982, Parker, 2004). The only study conducted within Mosaic Thicket within the southern cape reported 20 species to have been consumed by giraffes (Cornelius, 2010). The wide variety of species consumed by giraffes in larger open areas is explained by the ability of giraffe to travel long distances and their high metabolic requirements (Parker, 2004). In addition, their high metabolic requirements allow less time for giraffes to be selective, thus including more plant species in their diet to compensate for their need to consume high quantities of food per day (Innis, 1958; Bell, 1971; Pellew, 1984a, b; Skinner and Smithers, 1990; Parker, 2004).

However, within the smaller, confined areas such as KPGR and TPGR, the number of species consumed was less than that reported in the literature, specifically 14 and 12 in KPGR and TPGR respectively. The vegetation types found within the two reserves may explain this. Discussed in greater detail in Chapter 2, the largest vegetation type taking up the majority of the area of KPGR is Grootkop Arid Spekboomveld (see Chapter 2), whereby the indicator species *P. afra* and a few other tall shrub and woody tree species, namely *E. undulata*, *L. cinereum*, *G. robusta*, *N. capensis*, *S. undulata*, *R. obovatum*, *C. haematocarpa*, *Gloveria intergrifolia*, *P. capensis* and *Dodonaea augustifolia* are present (Chapter 2). In addition, approximately half of TPGR lies within the Kruisrivier Spekboom-Pruimveld vegetation type, a mixture of Mosaic Thicket and Fynbos elements (Vlok *et al.*, 2005) (Chapter 2). Dominant species present are few, namely *C. haematocarpa*, *E. undulata*, *G. integrifolia*, *N. capensis*, *P. capensis*, *G. robusta*, *S. longispina*, *R. obovatum*, *Pteronia incana*, *Ericephalus africana*, *Eriocephalus ericoides* and *Eriocephalus punctulatus* (Chapter 2). Therefore, a single vegetation type occupying a large area may have resulted in this low diversity of species consumed compared to other studies due to a low diversity of species present within both reserves.

Although many species were present within the diet in both farms, only four and five species formed approximately 90% of the giraffes' diet in KPGR and TPGR respectively. Plants of the *Vachellia* genus are known to be principal diet species, and have been well documented within the literature (Innis, 1958; Oates, 1970; Leuthold and Leuthold, 1972; Hall-Martin, 1974; Stephens, 1975; van Aarde and Skinner, 1975; Field and Ross, 1976; Kok and Opperman, 1980; Parker, 2004; Cornelius, 2010). Cornelius (2010) showed giraffe to consume 60.5% of

V. karroo, which is much higher than that found within this study, even though being conducted within the same biome within the same region. Although less was consumed in both KPGR and TPGR, *V. karroo* was still consumed when present. *Vachellia karroo* is not a dominant species found within the vegetation types of both reserves (Chapter 2), which may explain the low proportion in the diet.

Seasonal differences in the importance of principal diet species were observed. In both reserves, the importance of *R. obovatum* and *Lycium spp.* in the case of KPGR, and the deciduous *V. karroo* and *G. robusta* in the case of TPGR, which all produce flowers after spring rains (Anderson, 2004) increased during spring and summer. Giraffes are known to adjust their diet during leaf bearing and flowering seasons, due to their preference for new shoots due to the higher water, protein, and mineral content (Fennessy, 2004), as well as their preference for flowers and pods (Sauer, 1983; Cooper *et al.*, 1988; Du Toit, 1990; Parker, 2004).

As seen in the results, the majority of browsing occurred at level 3 and below in both KPGR and TPGR. As seen in Figure 4.2, adults browsing at level 3, or chest height, occurs at an approximate height of 2 metres (Deacon, 2015). Therefore, younger adults or juveniles browsing at the same level will be browsing at a height lower than 2 m. Taking this into consideration, most of the browsing by giraffes on both reserves occurred below two metres. A possible reason for the low browsing can be due to the low height of vegetation present within the area (J Paulse, personal observation). This is lower than what has been documented in other studies (see Chapter 1), where browsing occurred mostly below three metres. Kudus and eland, present on both farms, have a maximum browsing height of 2.5 m (Dayton, 1978; Watson, 1999; Deacon, 2015). Therefore, with the continuous low levels of browsing by giraffe, as well as browsing by elands and kudus, niche overlaps occur with these three species, which are common (Leuthold and Leuthold, 1978; Deacon, 2015). This poses a risk of interspecific competition if there is a lack of browse available higher up in tree canopies.

4.5. CONCLUSION

Pappea capensis and *Searsia longispina* were the most important species forming the bulk of the giraffes' diet in KPGR and TPGR respectively. Although known as a highly preferred genus, *Vachellia* species formed a small proportion of giraffes' diet in KPGR due to its scarcity within the area. However, *V. karroo* was the third most important species consumed in TPGR, increasing in spring and summer due to its deciduous nature.

Giraffe browsing in both KPGR and TPGR occurred mostly below two metres, which may compete with other herbivores, such as kudu and eland present at both study sites. This may pose a risk to giraffe and other herbivore populations, as well as plant species, due to the possible increase in interspecific competition within the two reserves. It therefore has a management implication to keep numbers low and according to the browsing capacity to avoid losses of animals or the deterioration of vegetation.

CHAPTER 5 : QUANTIFICATION OF POTENTIAL BROWSE AND BROWSING CAPACITY

5.1. INTRODUCTION

Wildlife management requires proper management of both vegetation and soil (Bothma *et al.*, 2004). However, knowledge of various factors, such as the quantity and quality, growth processes and the grazing and browsing potential of plants, the causes and effects of overgrazing, fire and bush encroachment, soil dynamics, as well as seasonal variation, is required to achieve proper management (Bothma *et al.*, 2004). There are several measurable approaches to better understand these aspects and enforce proper management. Browsing capacity is one of these approaches, by managing vegetation through the regulation of large herbivore numbers.

It is important to distinguish between browse and available browse. The browse can be seen as the total plant material of the woody species that are potentially used as food by a specific group of animals (Rutherford, 1979). Seasonal changes such as the moisture content and palatability of species can also influence the definition of browse. The available browse is usually a more restricted quantity than browse. The availability of this browse is usually based on the maximum height above the ground which an animal can utilize. Some species like the giraffe and the black rhinoceros (*Diceros bicornis*) change their feeding height according to factors such as the time of year as well as social behaviour (Stuart-Hill, 1991).

Browsing capacity is a useful planning tool, providing guidelines as to how many large herbivores an area can sustain (Bothma *et al.*, 2004). It is defined as the productivity of the browsable portion of a homogeneous unit of vegetation expressed as the area of land required to maintain a single animal unit over an extended number of years without the deterioration of vegetation or soil (AU/ha) (Trollope and Trollope, 1990). Various factors may influence the browsing capacity of an area, such as the density, species composition, palatability, digestibility, growth potential and phenology of woody plants, as well as their chemical and structural defences (Bothma *et al.*, 2004; Cornelius, 2010; Janecke and Smit, 2011; Deacon, 2015). The combination of these factors, as well as the effect of predation and water availability, often leads to herbivores distributing themselves throughout the area, with certain areas being preferred and/or avoided (Deacon, 2015).

Although non-territorial, giraffes tend to travel within a specific home range, often overlapping with the home ranges of other giraffes and herbivores (Kok and Opperman, 1980). This,

together with giraffes having high metabolic requirements (Bell, 1971), may result in the overexploitation of resources if concentrated in certain areas, particularly within fenced areas (Deacon and Smit, 2012). The overexploitation of food resources, as well as the negative effects giraffes have on the ecosystem within their natural and extralimital ranges, is discussed in greater detail in Chapter 1.

Subtropical thicket is said to be resilient to indigenous herbivores (Stuart-Hill, 1992; Sigwela *et al.*, 2009). For example, in the Eastern Cape, South Africa, goats had a more detrimental effect on Kaffrarian Succulent Thicket, such as through the decline in plant species, even when stocked at similar stocking densities as elephants (Stuart-Hill, 1992). Elephants, on the other hand, kept the succulent thicket in a relatively uniform state (Stuart-Hill, 1992). However, it is not known how subtropical thicket is impacted by extralimital species. Due to this vegetation evolving in the absence of giraffes (Parker, 2004; Cornelius, 2010), Subtropical Thicket may be impacted by giraffe herbivory if not managed properly. In the Western Cape particularly, giraffes are being introduced for aesthetic and tourism reasons, despite their extralimital status, availability of preferred plant species, browsing capacities and giraffe impacts being unquantified. Considering these impacts, information on browsing capacities is imperative for the sustainable management of Thicket vegetation and giraffe populations alike. The following objectives and hypotheses for this study were thus as follows:

- Objective 1: To determine browsing capacity for each utilization area
    - Hypothesis 1: Browsing capacity will not differ between the different areas.
- Objective 2: To determine the browsing capacity for each height stratum
    - Hypothesis 2: Browsing capacity will decrease as the height stratum increases.
- Objective 3: To determine browsing capacity for the different seasons of the year
    - Hypothesis 3: Browsing capacity will remain the same between the different seasons.
- Objective 4: To determine the number of browsers that can be sustained by each farm

5.2. METHODS

5.2.1. Selection of habitats

Utilization areas were divided into four categories, namely no, low, medium and high utilization areas. The selection was based on the amount of time the giraffe herd spent within each area during the study period. GPS coordinates, with a coordinate taken once a giraffe was located and thereafter every time it moved to a different location, determined the amount of time spent within each area. GPS locations were taken for each of the four days per season, totalling 16 days. The vegetation type of each utilization area is described in Chapter 2.

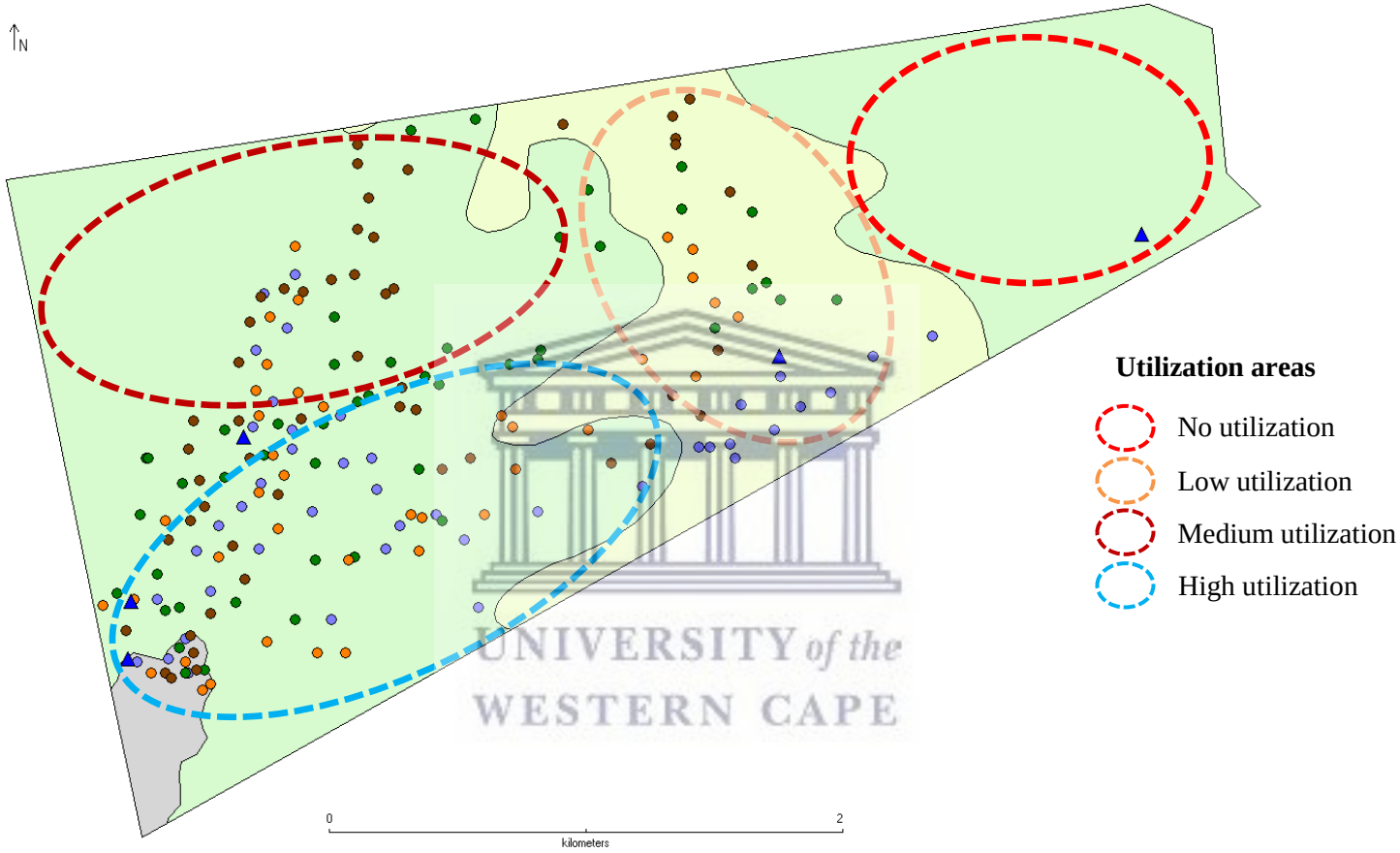

Figure 5.1: Habitat preferences determined by giraffe movement on KPGR throughout the study period

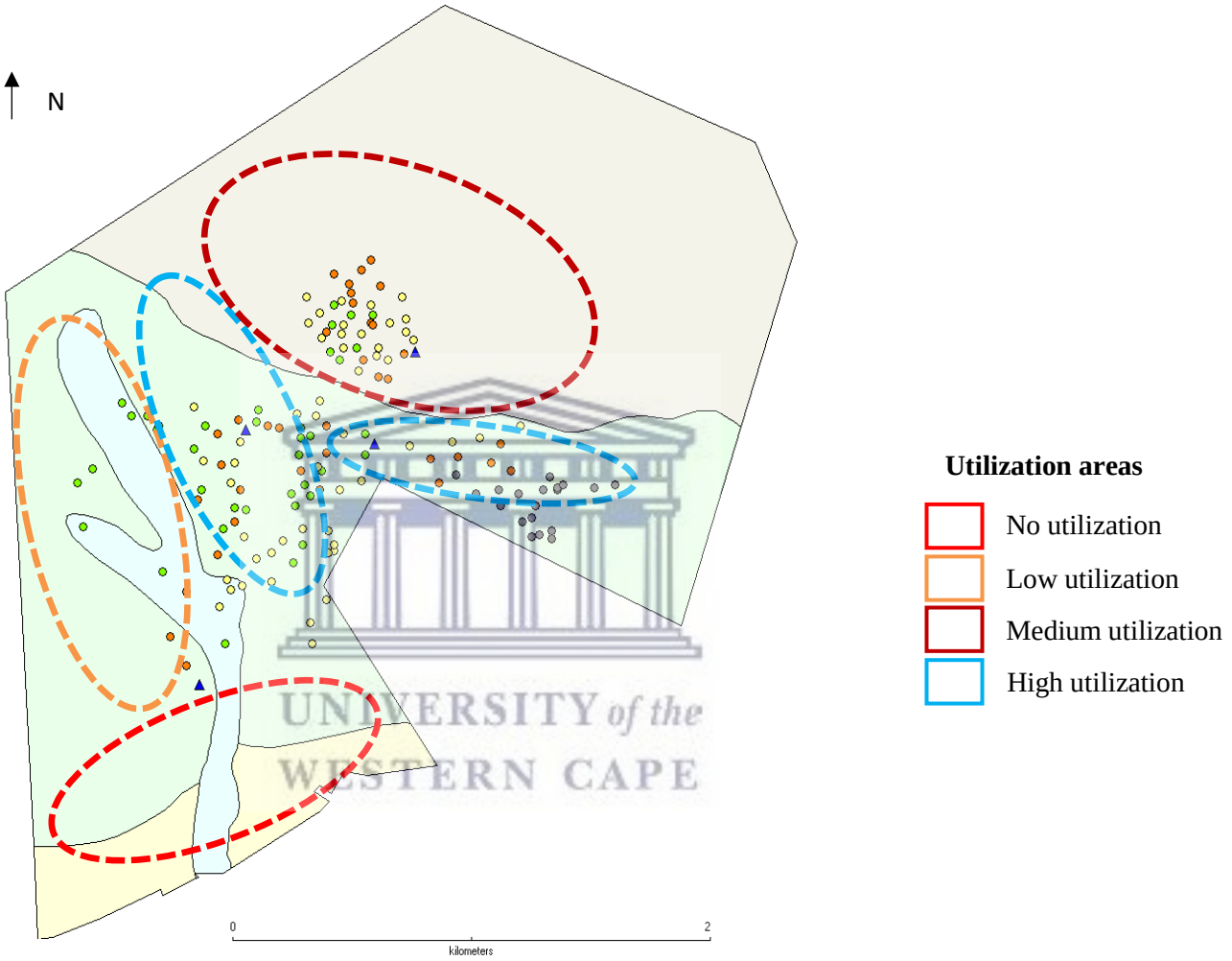

Figure 5.2: Habitat preferences determined by giraffe movement on TPGR throughout the study period

5.2.2. Quantification of potential browse

Potential browse was quantified using the BECVOL procedure (Smit, 1989). BECVOL allows for the quantification of available plant biomass between the different height strata of woody plants. Evaluating the strata illustrates that the browsing capacity for browser game species is far more complex than calculating the grazing capacity for grazing game species. The following may influence the calculation of the browsing capacity for a specific browser species:

- Accessibility of the plant species to browsers;
- Height distribution of the browse material;
- Phenology of the plant species (whether they are evergreen or deciduous);
- Seasonal presence of flowers and pods or seeds with a high nutrient content.

Three 100 x 2.5 m (250 m^2) transects were sampled within each utilization area within each farm, totalling 12 transects per farm (3 000 m^2). For each transect, the dimensions of all plants, above 0.5 m, were measured. Plants with a height less than 0.5 m were regarded as saplings, and included in the number of plants per hectare (plants ha^{-1}). The dimensions measured for each woody plant included the following: (A) maximum tree height; (B) height of maximum canopy diameter; (C) height of first leaves/leaf bearing shoots; (D) maximum canopy diameter (considering a theoretical canopy being circular, maximum canopy diameter was taken as the average of two measurements (D1 and D2) taken perpendicular to each other); (E) base diameter at height of first leaves (application of same principle used for maximum canopy diameter).

Figure 5.3 is schematic diagram illustrating a typical woody plant and measurements in the BECVOL procedure. Some Thicket species do not follow this growth form, but the program differentiates between various shapes and sizes. In addition, it is important to note that the regressions (see below) incorporated into the BECVOL do not include all the species from the thicket biome. However, since there are no alternative methods to quantify potential browse, general regressions were used (Professor Nico Smit, University of the Free State, personal communication).

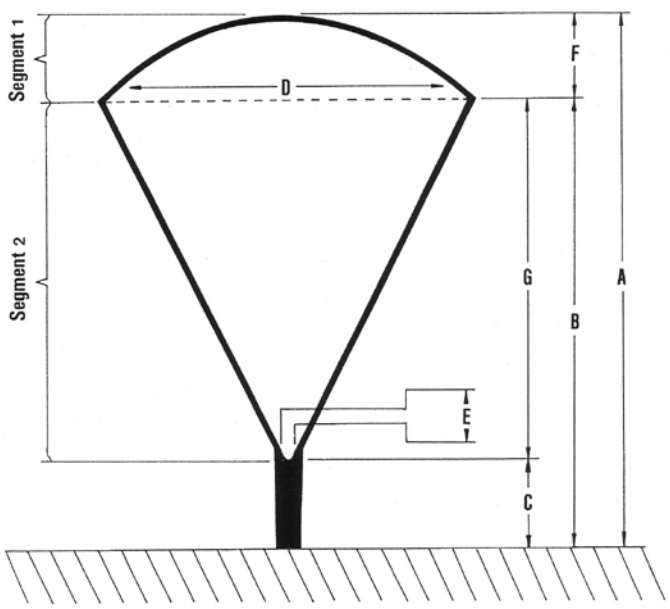

Figure 5.3: Schematic diagram of a typical tree and measurements involved in the BECVOL method (Smit, 2014)

The original BECVOL model was developed from harvested woody plants, which includes a regression equation that relates the spatial volume to the actual leaf volume and leaf dry mass (Smit, 1989; Smit, 1996). The BECVOL-3 model (Smit, 2014), the latest version, however, allows for the available browse to be calculated from the plant canopy volume. These estimates include those of leaves and young shoots (< 0.5 cm in diameter), an addition to the previous model (version 2) (Smit, 1996), which only allowed the estimates of the leaves (leaf volume and leaf dry mass) (Smit, 2014). The BECVOL-3 model, is therefore considered to be more accurate, as some browsers are selective feeders, browsing on leaves, as well as young shoot regrowth and fresh plant material (Penderis and Kirkman, 2014). More importantly, the BECVOL-3 model allows for the estimation of dry biomass in different height strata (Smit, 2014).

The BECVOL-3 model allows the following to be computed (described and detailed in Smit, 2014):

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

- Total leaf dry mass (DM ha^{-1})
- Leaf biomass below a browsing height of 1.5 m (DM ha^{-1})
- Leaf dry mass below a browsing height of 2.0 m (DM ha^{-1})
- Leaf dry mass below a browsing height of 5.0 m (DM ha^{-1})
- Shoot dry mass - shoots <0.5 cm below a browsing height of 1.5 m (DM ha^{-1}),
- Shoot dry mass - shoots <0.5 cm below a browsing height of 2.0 m (DM ha^{-1}),
- Shoot dry mass - shoots <0.5 cm below a browsing height of 5.0 m (DM ha^{-1}),
- Stem dry mass - stems >0.5-20 cm in diameter (DM ha^{-1}),
- Wood dry mass - wood >20 cm in diameter (DM ha^{-1}),
- Total wood dry mass (all fractions) (DM ha^{-1}),
- Total tree dry mass - leaves and wood combined (DM ha^{-1}).

Leaf and shoot DM ha^{-1} was additionally calculated at a stratified height of below 1.5, 2 and 5 m. These represent the mean heights of impala (*Aepyceros melampus*) and Boer goat (*Capra aegagrus hircus*), kudu (*Tragelaphus strepciseros*) and giraffe respectively (Dayton, 1978, Skinner and Smithers, 1990).

5.2.3. Browsing capacity calculations

The average browsing capacity for the year for each utilization area, as well as the total area for each study site, was calculated using the following formula (Smit, 2014):

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

Where:

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

d = number of days in year (365)

DM = total leaf dry mass yield ha^{-1}

f = utilization factor

p = phenology

r = daily leaf dry mass required per BU (2.5% of body mass)

The substitution for specific species in terms of their daily leaf dry mass per grazer or browser unit (GU/BU) can be seen in Table 5.1 below (Smit, 2006). A browser unit is defined as the metabolic equivalent of a kudu (mean mass of 140 kg) (Smit, 2006). A giraffe is equivalent to 5.2 BU's.

Table 5.1: Approximate substitution values of a few game species in terms of grazer units (GU) and browser units (BU)

Game species	**Aver. Mass (kg)**	**Intake (% of mass)**	**% grass**	**% leaves**	**GU**	**BU**
Gemsbok	210	2.7	100	0	1.3	0
Black wildebeest	140	2.5	100	0	0.8	0
Burchell's zebra	216	4.1	100	0	1.9	0
Roan antelope	235	2.8	100	0	1.5	0
Springbok	37	3.0	70	30	0.1	0.1
Impala	52	2.7	70	30	0.2	0.1
Eland	460	2.4	30	70	0.7	2.2
Kudu	140	2.5	0	100	0	1.0
Giraffe	**828**	**2.2**	**0**	**100**	**0**	**5.2**

Phenology values were allocated for each species measured. These values vary from 100% (p = 1.0) for evergreen species, to 0% (p = 0.0) for deciduous species. Phenology values of 1, therefore, were given to all plant species in this study due to their evergreen nature, except for *Lycium cinereum* and *Vachellia karroo* (Table 5.2).

The utilization factor was applied, and refers to the edible parts of the leaf and shoots material to avoid the assumption that browsers feed in the centre of the foliage. The actual consumption

of this material, however, is limited due to the browsing utilizations of the animals (Deacon, 2015).

The number of giraffe individuals that each study area can maintain was therefore calculated as follows:

$$BU = \frac{ha}{BC}$$

Where:

BU = browser unit

ha = total area of study site

BC = browsing capacity (ha/BU)

5.2.4. Statistical analysis

Results from the BECVOL-3 model were further tested using generalized linear models (GLMM) to cater for non-normal distributions (IBM Corporation, 2012). The gamma with loglink model was applied for continuous data produced by the BECVOL-3 model. The analysis was used to test for differences between browsing capacities between utilization areas, height strata, as well as between seasons. Pairwise comparisons were tested at a 5% significance level using the Sequential Bonferroni method to control for alpha rates.

5.3. RESULTS

5.3.1. Species list

A total of 23 and 27 plant species were measured using the BECVOL method on Kareesbos Private Game Reserve (KPGR) and Tsumkwe Private Game Reserve (TPGR) respectively (Table 5.1). Of these species, 877 and 947 individuals were measured on KPGR and TPGR respectively. As observed in Chapter 5 (diet chapter), of the 23 species sampled in KPGR, only 14 were present within the giraffe diet. For TPGR, only 12 of the 27 plant species sampled were present within the diet. The majority of the plant species were evergreen, with only two plant species, namely *Lycium cinereum* and *Vachellia karroo* being deciduous (Table 5.2).

Table 5.2: List of all plant species present within the BECVOL sampling plots in KPGR and TPGR

Species	Family	Growth form	Phenology	Study site
Galenia fruticosa	Aizoaceae	Shrub	Evergreen	Both
Tetragonia fruticosa	Aizoaceae	Shrub	Evergreen	Kareesbos
Searsia longispina	Anacardiaceae	Tree	Evergreen	Tsumkwe
Carissa haematocarpa	Apocynaceae	Shrub	Evergreen	Both
Asparagus spp.	Asparagaceae	Shrub	Evergreen	Both
Euryops spp.	Asteraceae	Shrub	Evergreen	Both
Pteronia pallens	Asteraceae	Shrub	Evergreen	Both
Pentzia incana	Asteraceae	Shrub	Evergreen	Kareesbos
Chrysocoma spp.	Asteraceae	Shrub	Evergreen	Tsumkwe
Elytropappus rhinocerotus	Asteraceae	Shrub	Evergreen	Tsumkwe
Eriocephalus africanus	Asteraceae	Shrub	Evergreen	Tsumkwe
Rhigozum obovatum	Bignoniaceae	Tree	Evergreen	Kareesbos
Salsola glabrescens	Chenopodiacea e	Shrub	Evergreen	Kareesbos
Cotyledon spp.	Crassulaceae	Shrub	Evergreen	Both
Crassula spp.	Crassulaceae	Shrub	Evergreen	Kareesbos
Tylecodon wallichii	Crassulaceae	Shrub	Evergreen	Tsumkwe
**Euclea undulata*	Ebenaceae	Tree	Evergreen	Both
Euphorbia mauritanica	Euphorbiaceae	Shrub	Evergreen	Both
Aspalathus spp.	Fabaceae	Shrub	Evergreen	Kareesbos
Calobota sericea	Fabaceae	Shrub	Evergreen	Tsumkwe
Nymmania capensis	Meliaceae	Tree	Evergreen	Tsumkwe
Drosanthemum spp.	Mesembryan-themaceae	Shrub	Evergreen	Both
Ruschia robusta	Mesembryan-themaceae	Shrub	Evergreen	Both
Psilocaulon spp.	Mesembryan-themaceae	Shrub	Evergreen	Kareesbos

Aridaria spp.	Mesembryan-themaceae	Shrub	Evergreen	Tsumkwe
**Portulacaria afra*	Portulacaceae	Shrub	Evergreen	Kareesbos
Thamnochortus spp.	Restionaceae	Restio	Evergreen	Tsumkwe
**Pappea capensis*	Sapindaceae	Tree	Evergreen	Both
Dodonaea viscosa	Sapindaceae	Tree	Evergreen	Tsumkwe
**Lycium cinereum*	Solanaceae	Shrub	Deciduous	Both
**Lycium ferocissimum*	Solanaceae	Shrub	Evergreen	Both
Hermannia amoena	Sterculiaceae	Shrub	Evergreen	Kareesbos
Struthiola ciliata	Thymelaeaceae	Shrub	Evergreen	Tsumkwe
**Grewia robusta*	Tiliaceae	Tree	Evergreen	Tsumkwe
Zygophyllum spp.	Zygophyllaceae	Shrub	Evergreen	Both

*indicates species forming the bulk of the diet composition of the two giraffe populations (see Chapter 4)

5.3.2. Kareesbos Private Game Reserve

5.3.2.1. Available browse

Table 5.3: Plant density (plants ha^{-1}), evapotranspiration tree equivalents per hectare (ETTE ha^{-1}) and total dry mass per hectare (kg DM ha^{-1}) for all species measured using the BECVOL method in the different utilization areas in KPGR

Utilization area	Plant density (Plants ha^{-1})	Evapotranspiration tree equivalents (ETTE ha^{-1})	Total browse mass (< 5 m) (kg DM ha^{-1})
No utilization	4 349	4 606	1 868
Low utilization	2 440	2 698	1 087
Medium utilization	2 401	3 456	1 417
High utilization	2 879	3 717	1 502

Table 5.4: Plant density (plants ha^{-1}), evapotranspiration tree equivalents per hectare (ETTE ha^{-1}) and total dry mass per hectare (kg DM ha^{-1}) for all important diet species measured using the BECVOL method in the different utilization areas in KPGR

	Plant density (Plants ha^{-1})				Evapotranspiration tree equivalents (ETTE ha^{-1})				Total browse mass (< 5 m) (kg DM ha^{-1})			
	Utilization area											
Species	No	Low	Moderate	High	No	Low	Moderate	High	No	Low	Moderate	High
Pappea capensis	0	93	40	133	0	487	348	667	0	201	146	274
Portulacaria afra	667	67	107	413	2 529	343	680	1 251	1 042	140	283	508
Euclea undulata	227	173	107	267	861	719	463	549	352	294	190	222
Lycium cinereum	347	267	160	67	157	269	242	36	61	107	98	14
Lycium ferocissimum	67	80	80	40	190	137	151	53	77	55	61	21
Total	1 308	680	494	920	3 737	1 955	1 884	2 556	1532	797	778	1 039

The results of the biomass assessment of all plant species recorded in the KPGR survey plots are presented in Table 5.3. From this data, it is notable that plant density per hectare was the lowest in the low utilization area and highest in the no utilization area. However, important diet plant density per hectare was highest and lowest in the no and moderate utilization areas respectively (Table 5.4).

Evapotranspiration tree equivalents per hectare was the highest and lowest in the no and low utilization areas respectively (Table 5.3). Evapotranspiration tree equivalents of important diet species per hectare, however, was highest in the no utilization area, but lowest in the moderate utilization area (Table 5.4).

Total browse per hectare, i.e. total dry matter per hectare, was highest in the no utilization area, with the second highest and lowest dry matter per hectare occurring within the high and low utilization areas respectively (Table 5.3). Similar results were observed regarding the important diet species (Table 5.4).

Pappea capensis, was observed to be absent within the no utilization area, compared to the high utilization area where plant density per hectare, ETTE per hectare and total dry matter mass was highest in the high utilization area. *Portulacaria afra* had the highest plant density per hectare, ETTE per hectare and total dry matter mass within the no utilization area compared to the other areas (Table 5.4). The presence of *L. cinereum* per hectare, too, was highest in the no utilization areas; however, both *Lycium* species showed the lowest amounts of plants per hectare, ETTE per hectare and total dry matter mass in the high utilization area. The ETTE per hectare and total dry matter mass of *E. undulata* was highest in the no utilization area, but more individuals per hectare were found within the high utilization area.

5.3.2.2. Browsing capacity

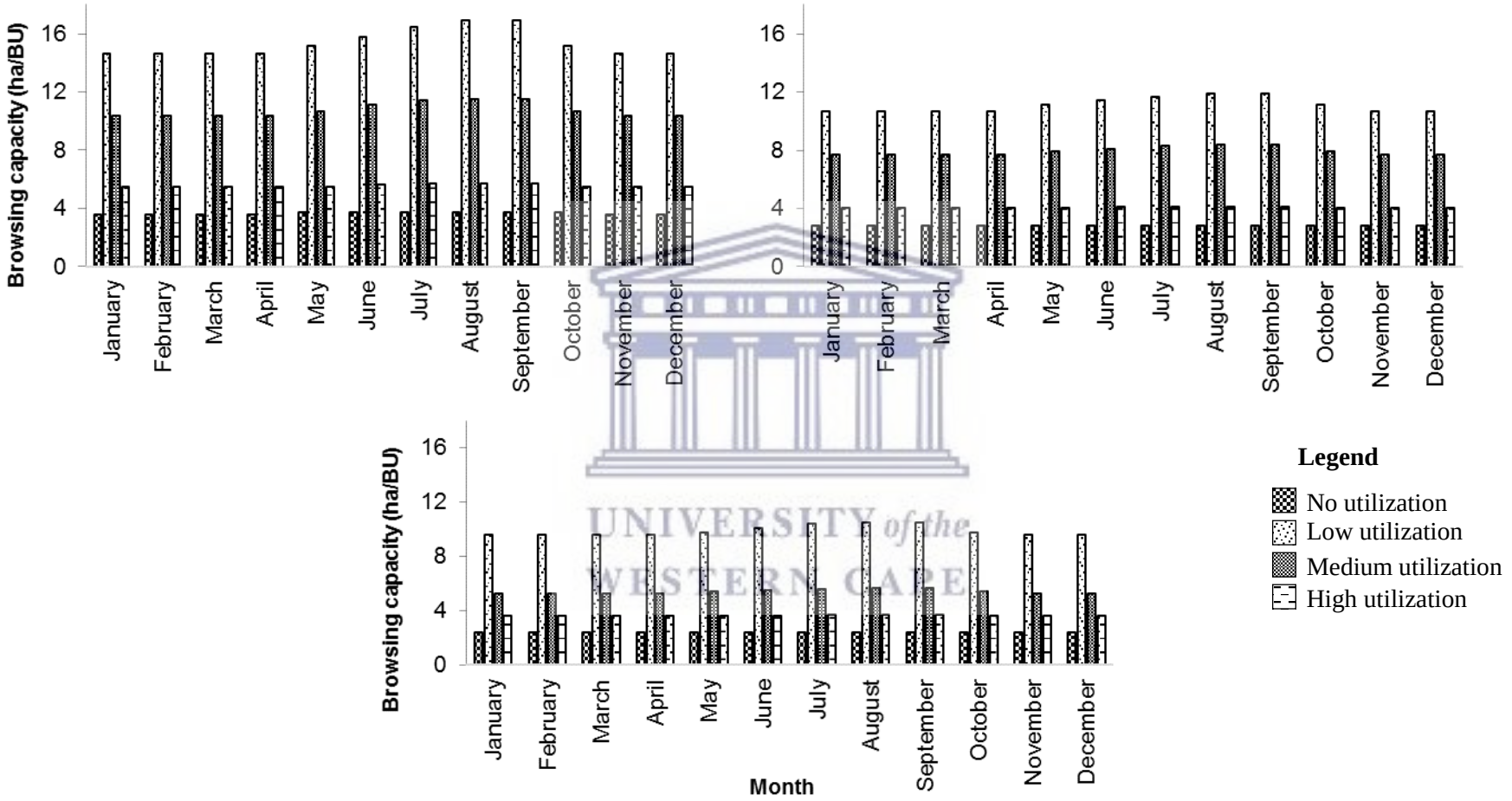

Figure 5.4: Browsing capacity of the (top left) 1.5 m, (top right) < 2 m and (bottom) < 5 m height stratum within each utilization area in KPGR

Hypothesis 1: Browsing capacity will not differ between the different areas.

It is evident that browsing capacity decreased the more the area was utilised in all height strata, due to the number of hectares required to sustain a browser unit being greatest in the low utilization area for each height stratum (Figure 5.4), compared to the no ($p < 0.001$), medium ($p < 0.001$) and high ($p < 0.001$) utilization areas. This may be due to plant density (Table 5.3) and important diet plant density (Table 5.4) increasing from the low to the high utilization area, within which the number of important diet species was greatest.

However, the no utilization browsing capacity was lowest in all height strata compared to low ($p < 0.001$), medium ($p < 0.001$) and high ($p < 0.001$) utilization areas. Steeper slopes (personal observation), as well as the absence of important diet species, such as *P. capensis* (Table 5.3) in the no utilization area, may cause giraffes not to occupy these areas.

Hypothesis 2: Browsing capacity will decrease as the height stratum increases.

It is evident that less hectares are required per browser unit as the height stratum increases (Figure 5.4). More hectares are required per browser unit relying on browse in the less than 1.5 height stratum, compared to the less than 2 ($p < 0.001$) and 5 m ($p < 0.001$) height strata.

Hypothesis 3: Browsing capacity will remain the same between the different seasons.

Browsing capacity differed between seasons, with more hectares required per browser unit in KPGR during winter than during summer ($p < 0.001$) and autumn ($p < 0.001$). Browsing capacity was relatively similar, however, between winter and spring ($p = 0.295$), as well as between the remaining seasons ($p > 0.05$) (Figure 5.4).

5.3.2.3. Number of browser units sustained

The number of calculated browser units that can be sustained, as well as the current browsers currently found on KPGR can be observed in Table 5.6 and 5.7 respectively.

Table 5.5: Table representing the browsing capacity, browser and giraffe numbers that can be sustained in KPGR

	Browsing capacity (ha/BU)			Total browser units sustained			Number of giraffe sustained		
Month	< 1.5 m	< 2 m	< 5 m	< 1.5m	< 2m	< 5 m	< 1.5 m	< 2 m	< 5 m
January	6.4	4.8	4.0	141	188	225	27	36	43

February	6.4	4.8	4.0	141	188	225	27	36	43
March	6.4	4.8	4.0	141	188	225	27	36	43
April	6.4	4.8	4.0	141	188	225	27	36	43
May	6.5	4.9	4.1	138	184	220	27	35	42
June	6.6	4.9	4.1	136	184	220	26	35	42
July	6.7	5	4.2	134	180	214	26	35	41
August	6.8	5	4.2	132	180	214	25	35	41
September	6.8	5	4.2	132	180	214	25	35	41
October	6.5	4.9	4.1	138	184	220	27	35	42
November	6.4	4.8	4.0	141	188	225	27	36	43
December	6.4	4.8	4.0	141	188	225	27	36	43

As observed in Table 5.6, the following browser units that can be sustained by browse at different heights are as follows:

- 1.5 m: average of 138 BU
- < 2 m: average of 185 BU
- < 5 m: average of 221 BU
    - < 5 m = 221 BU = 43 giraffes, therefore browsing capacity = 900 ha/221 BU = 21 ha per giraffe (< 5 m)

Table 5.6: The number of browsing animals currently occupying KPGR (numbers supplied by owner)

	Height (m)				
Species	< 1.5	< 2	< 5	Animals	BU representation
Giraffe	Y	Y	Y	11	57
Eland	Y	Y	N	45	99
Kudu	Y	Y	N	50	50
Zebra	Y	N	N	12	0
Impala	Y	N	N	7	1

Gemsbok	Y	N	N	4	0
Total				129	207

At the time of the study, KPGR was stocked with 129 animals of six different species, which is equivalent to 207 browser units (Table 5.7). All species are able to utilize available browse below 1.5 m. However, only 138 BU can be sustained. All represented species, too, are able to browse up to 2 m (Table 5.7). However, an estimate of only 185 BU can be sustained within this height stratum. Available browse between 2 and 5 m, heights at which giraffes are capable of reaching, allows an additional 36 BU that can be supported.

5.3.3. Tsumkwe Private Game Reserve

5.3.3.1. Available browse

From Table 5.5, it is observed that the no and high utilization areas had the lowest and highest plant density per hectare respectively. This was similar in the case of important diet species, with plant density being the lowest and highest in the no and high utilization areas respectively. (Table 5.6). Evapotranspiration tree equivalents per hectare was lowest in the no utilization area and highest in the medium utilization area (Table 5.5). However, ETTE of important diet species per hectare was highest in the low utilization area, with the lowest ETTE per hectare found within the no utilization area (Table 5.6).

Total dry matter mass was lowest in the no utilization area, compared to the medium utilization area where it was the highest (Table 5.5). However, total dry matter mass of important diet species per hectare was highest in the low utilization area, with total dry matter mass being second highest within the high utilization area (Table 5.6).

Grewia robusta was absent in the no utilization area. However, *G. robusta* plant density, ETTE and total dry matter mass per hectare was highest in the high utilization area (Table 6.6). Similar results were observed for *S. longispina*. *Euclea undulata*, however, had the highest plant density, ETTE and total dry matter mass per hectare in the low utilization area. Similar results were observed for *L. ferocissimum*. *Lycium cinereum*, however, had the highest plant density, ETTE and total dry matter mass per hectare within the medium utilization area.

Table 5.7: Plant density (plants ha^{-1}), evapotranspiration tree equivalents per hectare (ETTE ha^{-1}) and total dry mass per hectare (kg DM ha^{-1}) for all species measured using the BECVOL method in the different utilization areas in TPGR

Utilization area	Plant density (Plants ha^{-1})	Evapotranspiration tree equivalents (ETTE ha^{-1})	Total browse mass (< 5 m) (kg DM ha^{-1})
No utilization	1 759	1 055	417
Low utilization	1 946	2 468	1 000
Medium utilization	4 854	3 950	1 571
High utilization	4 050	3 158	1 245

Table 5.8: Plant density (plants ha^{-1}), evapotranspiration tree equivalents per hectare (ETTE ha^{-1}) and total dry mass per hectare (kg DM ha^{-1}) for all important diet species measured using the BECVOL method in the different utilization areas in TPGR

	Plant density (Plants ha^{-1})				Evapotranspiration tree equivalents (ETTE ha^{-1})				Total browse mass (< 5 m) (kg DM ha^{-1})			
	Utilization area											
Species	No	Low	Moderate	High	No	Low	Moderate	High	No	Low	Moderate	High
Euclea undulata	13	147	40	80	105	1271	299	278	43	529	123	114
Grewia robusta	0	27	27	53	0	79	87	221	0	27	32	78
Lycium cinereum	147	13	160	93	27	11	168	56	10	4	67	22
Lycium ferocissimum	40	53	27	27	185	297	67	91	76	122	27	37
Searsia longispina	0	0	40	93	0	0	177	379	0	0	72	156
Total	200	440	294	346	317	1 658	798	1 025	129	682	321	407

5.3.3.2. Browsing capacity

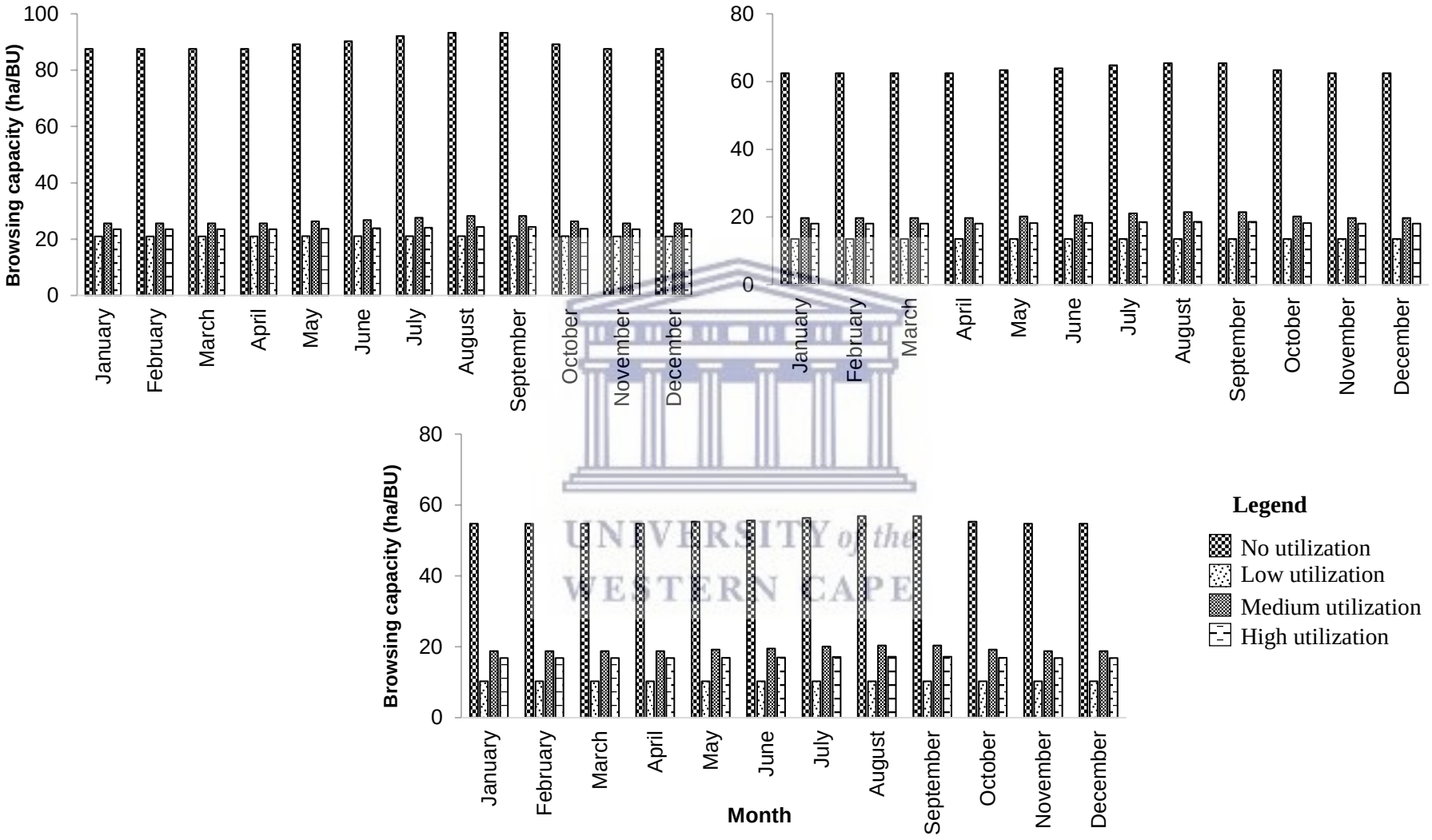

Figure 5.5: Browsing capacity of the (top left) 1.5 m, (top right) < 2 m and (bottom) < 5 m height stratum within each utilization area in TPGR

Hypothesis 1: Browsing capacity will not differ between the different areas.

In TPGR, more hectares are required to sustain a browser unit in the no utilization area, compared to the low ($p < 0.001$), medium ($p < 0.001$) and high ($p < 0.001$) utilization areas, due to the low density of important diet species within the no utilization area (Table 5.6). Although the density of principal diet species tends to increase from the no to the high utilization areas (Table 5.6), fewer hectares are required to sustain a browser unit within the low utilization area, than within the no ($p < 0.001$), medium ($p < 0.001$) and high ($p < 0.001$) utilization areas (Figure 5.5). The high utilization area contains the highest principal diet species density per hectare (Table 5.6), with fewer hectares required to sustain a single browser unit within this area, than what is required in the low ($p < 0.001$) and medium ($p < 0.001$) utilization areas.

Hypothesis 2: Browsing capacity will decrease as the height stratum increases.

It is evident that as the strata height increases, there is a decrease in browsing capacity (Figure 5.5). In other words, more hectares are required to sustain a single browser unit browsing at a height less than 1.5 m than a browser unit browsing at a height less than 2 m ($p < 0.001$) and 5 m ($p < 0.001$).

Hypothesis 3: Browsing capacity will remain the same between the different seasons.

No seasonal change in browsing capacity was evident ($X^2 = 5.079$; $p = 0.166$) (Figure 6.5).

5.3.3.3. Number of browser units sustained

The number of calculated browser units that can be sustained, as well as the different browsers currently found in TPGR can be observed in Tables 5.8 and 5.9 respectively. However, the number of animals currently occupying the area were not supplied by the owner. Giraffe numbers (5 giraffe) were the only numbers available due to the study being based on these individuals.

Table 5.9: Table representing the browsing capacity, browser and giraffe numbers that can be sustained in TPGR

	Browsing capacity (ha/BU)			Total browser units sustained			Number of giraffe sustained		
Month	< 1.5 m	< 2 m	< 5 m	< 1.5m	< 2m	< 5 m	< 1.5 m	< 2 m	< 5 m
January	28.5	20.5	17.5	53	73	86	10	14	16

February	28.5	20.5	17.5	53	73	86	10	14	16
March	28.5	20.5	17.5	53	73	86	10	14	16
April	28.5	20.5	17.5	53	73	86	10	14	16
May	28.9	20.7	17.7	52	72	85	10	14	16
June	29.1	20.8	17.8	52	72	84	10	14	16
July	29.5	21	17.9	51	71	84	10	14	16
August	29.8	21.2	18	50	71	83	10	14	16
September	29.8	21.2	18	50	71	83	10	14	16
October	28.9	20.7	17.7	52	72	85	10	14	16
November	28.5	20.5	17.5	53	73	86	10	14	16
December	28.5	20.5	17.5	53	73	86	10	14	16

As observed in Table 5.8, the following browser units that can be sustained by browse at different heights are as follows:

- 1.5 m: average of 53 BU
- < 2 m: average of 73 BU
- < 5 m: average of 86 BU
    - < 5 m = 86 BU = 17 giraffes, therefore browsing capacity = 1500 ha/221 BU = 88 ha per giraffe (< 5 m)

Table 5.10: Animal species currently present on TPGR

	Height (m)			
Species	< 1.5	< 2	< 5	BU representation
Giraffe	Y	Y	Y	26
Eland	Y	Y	N	2.2
Kudu	Y	Y	N	1
Springbok	Y	N	N	0
Wildebeest	Y	N	N	0

Gemsbok	Y	N	N	0
Roan antelope	Y	N	N	0
Total				29

As observed in Table 5.9, 26 BU (5 giraffe) currently occupy the property. Giraffe have the ability to browse below 1.5 m, 2 m and 5 m. Therefore, a total of 26 BU needs to be supported up to 5 m.

5.4. DISCUSSION

Browsing capacity will not differ between the different areas.

Browsing capacity decreased the more the area was utilised in both KPGR and TPGR, due to the increase in density of principal diet species. On the same scale, the selection of plants displays diet selection, with diet selection ultimately leading to habitat selection on a larger scale (Duncan and Gordon, 1999). However, forage is one factor, amongst many, that determines habitat selection (Janecke and Smit, 2011).

Herbivores tend to spend more time in certain areas due to the limitations in energy requirements (Fabricius, 1989). Ungulates tend to limit their time spent travelling in search of forage by selecting areas with an adequate amount of preferred species (Fabricius, 1989). Therefore, more time is spent feeding and less time travelling (Senft *et al.*, 1987; Fabricius, 1989). For example, in the Northern Cape, eland, which are mixed feeders, prefer areas with a high available biomass of leaves (Fabricius, 1989).

In this study, the utilization of habitats by giraffes is similar. Giraffes tend to congregate and utilise areas more where there is an availability and abundance of preferred plant species (Berry, 1973; van der Jeugd and Prins, 2000; Fennessy, 2004; Deacon, 2015). In Lake Manyara National Park, Tanzania, although giraffe densities differed between different habitats, higher densities were found in the most vegetated areas (van der Jeugd and Prins, 2000). Giraffe populations in Luangwa Valley, Zambia were similar (Berry, 1978). A narrow, elongated home range existed along the Luangwa River, favoured due to the variety and quantity of food throughout the year. Areas lacking in palatable or preferred plant species were less favoured (Berry, 1973).

Utilization of certain areas by giraffe populations in KPGR and TPGR may, too, be due to the presence of principal diet species. In KPGR, a high abundance of the three species forming the bulk of the giraffes' diet, namely *P. capensis*. *P. afra* and *E. undulata* (Chapter 5), were found within the high utilization areas. This area is found within the Grootkop Arid Spekboomveld vegetation type, dominated by the indicator species *P. afra*, as well as the other key species (Chapter 3). TPGR was similar, with the two principal species, *G. robusta* and *S. longispina*, found in greater abundances within the medium and high utilization areas. These areas are positioned within the Kruisrivier Spekboom-Pruimveld vegetation type (Chapter 2), which is dominated by the presence of these species.

In contrast, the no or low utilization of certain areas were a result of the absence of preferred species. In KPGR, *P. capensis*, the most preferred species, was absent within the no utilization area. However, *P. afra*, was highest within this area. This could be due to herbivores not utilizing the area due to its positioning at the bottom of a rocky, steep slope. Giraffes tend avoid rocky habitats (Fennessy, 2004). In TPGR, even though principal diet species, such as *E. undulata* and both *Lycium* species, are present within the no utilization area, the two most preferred species, *G. robusta* and *S. longispina* are absent.

Browsing capacity will decrease as the height stratum increases.

Browse capacity in both study sites decreased as the height stratum of plants increased. This is not surprising, due to the structure of plants, particularly large shrubs and trees having canopies with the majority of their biomass positioned higher above the ground. In South Africa, Woolnough and Du Toit (2001) concluded that leaf dry mass increased with increasing height up the canopy. Giraffe browsing further supported this, with giraffe feeding efficiency increasing higher up the canopy and giraffe obtaining a higher plant matter dry mass per bite. Similar results were observed in KwaZulu-Natal, South Africa, where browse production was highest in the 2.5 – 5 m height stratum, compared to the 0.0 – 0.5 m height stratum which had the lowest browse production (Penderis and Kirkman, 2014).

Browsing capacity will remain the same between the different seasons.

Forage availability, a determinant of habitat selection, may be influenced by seasonal and phenological change in plant species (Fennessy, 2004; Janecke and Smit, 2011; Penderis and Kirkman, 2014; Deacon, 2015). Within giraffes' natural ranges, often dominated by deciduous species, food availability decreases and increases within the dry and wet seasons respectively

(Eamus, 1999). To counter this problem, giraffes need a larger area to meet their daily requirements, and tend to expand their home ranges in search of food (Deacon, 2015).

However, in game ranches, herbivores do not have the advantage of being able to roam over vast areas in search of food during these critical periods due to confined spaces (Janecke and Smit, 2011). Ranchers often resort to hunting or supplementary feeding to compensate for the shortage in browse. However, KPGR and TPGR do not experience this problem, due to the majority of plants within the area being of an evergreen nature. Unlike deciduous plant species shedding leaves as a response to low moisture availability and high evaporative demands during the dry season, evergreen species maintain water transport to their canopies at a sufficient rate (Penderis and Kirkman, 2014). This allows evergreen species to maintain a full canopy all year round, with a less than 10% canopy biomass lost during the dry season (Penderis and Kirkman, 2014). This is highly advantageous, due to browse being available all year round to herbivore populations, and, thus, browsing capacity remaining constant seasonally, as in the case of KPGR and TPGR.

Several recommended stocking rates exist for giraffe in Thicket vegetation. However, the majority of these stocking rates are not based on quantitative research. Within the Western Cape, stocking rates of 19 properties ranged from 30 to 1650 ha per giraffe (Cornelius, 2010). These calculations were based on the size of the properties, and not taking the suitability of the habitat into consideration. Cornelius (2010), however, based browsing capacity estimates within the Western Cape on giraffe observations and vegetation surveys, with a recommended 78.5 ha being the minimum area required to sustain one giraffe. Browsing capacity estimates within KPGR (25 ha/giraffe < 2 m and 21 ha/giraffe < 5 m) and TPGR (107 ha/giraffe < 2 m and 88 ha/giraffe < 5 m) are observed to be lower and higher respectively. However, the recommendation of less than two metres should be considered due to the continuous browsing of both giraffe populations within this height stratum, even though their height allows them to browse up to five metres (Deacon, 2015). In addition, browsing capacities should be adjusted accordingly to the number of other herbivores present on the property. This is suggested to avoid the possibility of interspecific competition (Leuthold and Leuthold, 1978; Deacon, 2015).

5.5. CONCLUSION

There is much confusion regarding the stocking rate of giraffe due to their extralimital status in the Western Cape. This study found KPGR to have a browsing capacity of 25 ha and 21 ha

per giraffe at a browse height stratum of two and five metres respectively. In contrast, TPGR rendered browsing capacities of 107 and 88 ha per giraffe at a browse height stratum of two and five metres respectively. Although these farms are situated in close proximity in the same biome, these values are far from similar. It is therefore seen that giraffe browsing capacities need to be based on quantifiable research and need to be site specific due to the vast differences and heterogeneity of areas within the same vegetation biome.

Both these game farms need knowledge and information to be proactive in their decisions. 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 similar regions of southern Africa.

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 limit giraffes from future mortalities because of low quality foliage.

CHAPTER 6 : GENERAL CONCLUSIONS, MANAGEMENT IMPLICATIONS AND FUTURE RESEARCH

6.1. INTRODUCTION

The general aim of the study was to determine the general and foraging behaviour, as well as site-specific browsing capacities of extralimital giraffe in the Little Karoo of the Western Cape, South Africa. Literature available on this subject is lacking, regardless of giraffe continuously being introduced into the area despite the area being outside their natural distribution. The study therefore sought to achieve the following objectives:

1. To determine the diurnal activity budgets,
2. the diet composition and browsing levels, and
3. the availability of browse and estimated site specific browsing capacities of extralimital giraffe.

6.2. EMPIRICAL FINDINGS

Objective 1: To determine the diurnal activity budgets of extralimital giraffe

In both study sites, browsing was the dominant behaviour displayed by giraffes, followed by walking, rumination, rest and vigilance. However, contrasting results were shown between the study sites regarding sex and seasonal differences. In KPGR, males rested, walked and ruminated more than females, with females browsing more than males. However, in TPGR, males were only found to walk more than females, with females browsing more than males.

Contrasting seasonal differences were also shown between the two study sites. In KPGR, females, males and juveniles spent more time on energy conserving activities, such as resting and rumination during the cooler seasons, whereas these activities occurred more during the warmer seasons in TPGR. Females, however, spent more time on energy consuming activities, such as browsing during the cooler seasons, whereas males browsed more during the warmer seasons in both study sites.

Objective 2: To determine the diet composition and browsing levels of extralimital giraffe

Fifteen plant species were consumed in KPGR, with four principal species, namely *P. capensis*, *P. afra*, *E. undulata* and *Lycium spp*. forming approximately 90% of their diet. The importance of *Lycium spp*. and *R. obovatum* increased during spring and summer. On the other hand, 12 plant species were consumed in KPGR, with five principal species, namely *S. longispina*, *E.*

undulata, *P. capensis*, *V. karroo* and *G. robusta* forming approximately 90% of their diet. The importance of *V. karroo*, *R. obovatum* and *G. robusta* increased during spring and summer.

In both KPGR and TPGR, males browsed more frequently at L3. However, in KPGR, males lowered their browsing level and browsed more at L2 from winter to autumn, whereas in TPGR, males raised their browsing level and browsed more at L5 from winter to autumn. Females in KPGR generally browsed most frequently at L2, but raised their dominant browsing levels to L3 and L4 during winter and spring respectively. Females in TPGR, however, browsed more frequently at L3, decreasing their browsing level and browsing more at L2 during spring and autumn.

Objective 3: To determine the availability of browse and estimated site-specific browsing capacities of extralimital giraffe

The calculated browsing capacity for KPGR and TPGR was 25 and 21 and 107 and 88 ha per giraffe respectively for the respective browse height strata of two and five metres. KPGR and TPGR are therefore within the estimated browsing capacities, however, the recommended browsing capacity of less than two metres should be considered due to the continuous browsing of both giraffe populations at lower levels, and should additionally be adjusted according to the presence of other browsers.

6.3. RESEARCH IMPLICATIONS

This thesis reveals that giraffes are able to adapt to new environments regardless of their historical distribution. By introducing giraffes into new areas, giraffes have taken advantage of browse species different to those consumed within their natural ranges (Hall-Martin, 1974; Dagg and Foster, 1976; Sauer *et al.*, 1977; Pellew, 1983; Caister *et al.*, 2003; Fennessy, 2004; Deacon, 2015). In addition, their survival and ability to produce offspring is an indicator that the quality of available browse is suitable. However, the absence of a distinct dietary shift between seasons in both KPGR and TPGR (Chapter 4) may pose a problem. Within their natural range, plant species composition consists of a mixture of deciduous and evergreen species (Deacon, 2015), resulting in a distinct dietary shift and allowing “rest” of plant species once the quantity of leaves decrease. However, in the study region, the continuous utilization of the same plant species throughout the year might have some negative effects. Therefore, this study suggests continuous examination of the utilization of principal browse species by extralimital giraffe.

Monitoring is an effective tool if used correctly (Hurt and Hardy, 1989). Since the area is outside historical ranges, and giraffes have been shown to cause negative impacts (Foster and Dagg, 1972; Hall-Martin, 1974; Van Aarde and Skinner, 1975; Sauer *et al.*, 1977; Pellew, 1983; Augustine and McNaughton, 1998; Birkett, 2002; Brenneman *et al.*, 2009), monitoring will be extremely beneficial, as it will provide indications of browse lines, heavy decrease in leaf quantity, or the stunted growth of plant individuals (Cornelius, 2010). It will also indicate any niche overlaps and low browsing by extralimital giraffe (Chapter 5), resulting in possible interspecific competition with indigenous herbivores.

The study also reveals that browsing capacities for extralimital giraffe can not be generalised and need to be site specific. Although KPGR and TPGR are situated relatively close to one another, the vegetation types present on both farms are different, although situated in the same biome. Taking this, as well as the low browsing and potential impact of extralimital giraffe into consideration, it is suggested that the minimal policy regarding this species be revised. Requirements for the ownership of giraffe is only adequate fencing, as stated in fencing specifications as per Cape Nature's minimum specifications for adequate enclosure (dated 14 October 1976, as amended). To avoid the deterioration of vegetation, and to prevent negative effects on indigenous herbivores, this policy needs to be revised and stronger measures put in place.

6.4. RECOMMENDATIONS FOR FUTURE STUDIES

Upon completion of the study, it can be seen that there is a need for further research to facilitate the attainment of the goal of the study. Recommendations for future studies are as follows:

6.4.1. Monitoring

Long term monitoring is required for more detailed information on the behaviour and diet of extralimital giraffe, as well as more accurate browsing capacity calculations. In addition, further studies should include the monitoring of other extralimital giraffe throughout the Western Cape and beyond. Furthermore, monitoring should include vegetation monitoring. Vegetation monitoring will help determine changes in vegetation, and provide information on giraffe impacts.

6.4.2. Quantification of available browse and browsing capacity

Easier vegetation sampling methods for quantifying available browse and browsing capacity within Thicket areas needs to be developed due to the dense and intertwined nature of plant

species. Simplified and repeatable techniques will be beneficial especially to farmers who do not have time for tedious methods.

6.5.3. Habitat quality

Future studies on habitat quality are required to provide information on why extralimital giraffe prefer certain plant species and avoid others. These diet preference studies will also determine habitat preferences, allowing for the gaps on the spatial ecology of extralimital species to be filled. In addition, determining habitat qualities may help in habitat and vegetation conservation.

6.5.4. Policies

All research should try and be implemented into policy. More policy on the transportation and ownership of extralimital giraffe will help maintain genetic integrity and prevent inbreeding of the South African giraffe.

6.5. LIMITATIONS OF THE STUDY

The study has offered important baseline knowledge on the adaptive behaviour and diet selection of extralimital giraffes in the Western Cape. However, because of the methodology used, the study encountered two major limitations. Firstly, logistics only allowed for four days of observations per site every three months. This resulted in a relatively small sample size per season. Future studies should try to increase the frequency of observations.

The second limitation was accessibility. Vehicles could not get into certain rocky, steep areas. Therefore, observations in these areas had to be conducted on foot. Reaching these areas by foot often took time, and as a result, observations were lost.

6.6. CONCLUSION

This study has provided previously lacking baseline data about the activity budgets, diet selection and proposed site-specific browsing capacities for extralimital giraffe. In addition, it has provided a basis for future studies to build on. Farmers can reap the benefits this species brings, if managed correctly, and if stronger policies are put in place to avoid potential and negative effects on indigenous flora and fauna.

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APPENDICES

Appendix A

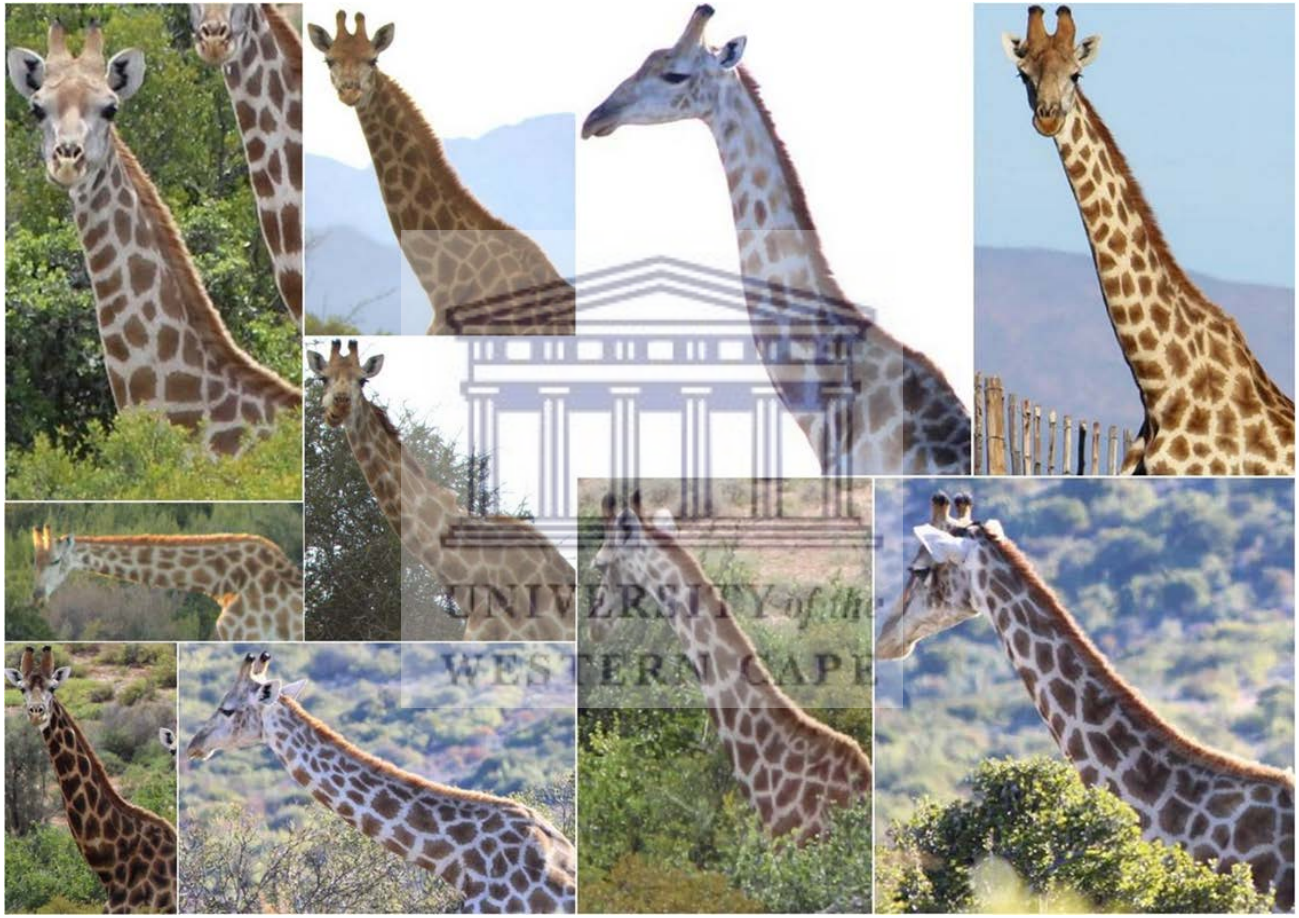

Figure A: Individuals of giraffe herd on Kareesbos Private Game Reserve

Appendix B

Figure B: Individuals of giraffe herd on Tsumkwe Private Game Reserve