FEEDING ECOLOGY OF THE GREATER KUDU (<u>TRAGELAPHUS STREPSICEROS</u>) IN THE CENTRAL FREE STATE

By

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Submitted in fulfilment of the requirements in respect of the Master's Degree Wildlife in the Department of Animal, Wildlife and Grassland Sciences in the Faculty of Natural and Agricultural Sciences at the University of the Free State, Bloemfontein, South Africa

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DECLARATION

I, Vivian Page Butler, declare that the Master's Degree research dissertation that I herewith submit for the Master's Degree qualification Wildlife at the University of the Free State is my independent work, and that I have not previously submitted it for a qualification at another institution of higher education.

....

Signature

Date: 3 February 2017

Dedicated to my mother, Leonora Oliver.

Thank you for all the love and support.

ACKNOWLEDGEMENTS

ABSTRACT

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<u>Key terms</u>: *kudu, wildlife ranching, fencing, food availability, woody species, leaf phenology, diet selection, food preferences, habitat selection, management*

The objective on most wildlife ranches is to accommodate a diversity of wildlife species to satisfy the need for ecotourism, hunting and live sales. However, the small size of many wildlife ranches presents its own unique challenges. One of these is fencing that prevents animals from moving to more favourable areas during times of food shortages. Intensive management is thus required to prevent overstocking that can lead to the deterioration of natural resources or even total habitat destruction in the long term, or alternatively requires the provision of supplementary feed at a high cost over an extended period of time.

The feeding habits of herbivores are largely determined by their food preferences and the availability of their preferred food plants, with food considered the most important resource that limits animal populations. It is thus important that an animal's diet provides all the essential nutrients needed for survival, growth and reproduction. However, the quality and quantity of food available to herbivores can vary considerably from one season to the next or from year to year. A proper management plan is therefore essential for the sustainable utilisation and conservation of the ecosystem on these small fenced wildlife ranches.

The main objectives of this study were to determine the diet and food preferences of kudu throughout the seasonal cycle of food availability and how this affected their habitat selection in a relatively small game fenced area in the central Free State. The potential food available to kudu was first determined in each of the identified plant communities and then in the study area as a whole. As kudu are predominantly browsers, only the woody browse (leaves + shoots < 0.5 cm) up to a feeding height of 2.0 m was considered to be available to kudu in the current study. Forbs were not included as they were rarely encountered in the study area, contributing an insignificant proportion of the herbaceous layer. Leaf phenology of woody species was also taken into account in these calculations due to the winter deciduous nature of several woody species in the study area.

The diet composition and food preferences of kudu varied according to food quality and availability. Although the kudu population's annual diet consisted of mostly woody browse, a considerable amount of grass was consumed from November to March. Kudu also changed their diet selection from mostly deciduous woody species during the growing season to mostly evergreen species during the dry season. In addition to this, kudus' food preferences changed throughout the year due to the timing of leaf emergence and leaf fall in woody species.

Although the habitat selection of kudu was affected by food availability, cover also played an important role in determining their habitat preferences. Kudu showed a definite preference for areas with high woody canopy cover throughout the year, often trading food for more cover. Kudu habitat selection also changed markedly between day and night time, with kudu selecting areas dominated by their preferred food items during the day and areas with more cover, but less of their preferred food items at night. The selection of areas predominantly for feeding or resting was further confirmed by the fact that kudu were less active at night, as they travelled shorter distances during the night compared to the day. Topography also became important in the habitat selection of kudu during the coldest part of the year, with kudu escaping the worst cold by moving to the hills, especially at night when temperatures dropped to well below freezing point. Proper habitat analysis thus plays a crucial role in determining the suitability of fenced areas for kudu, as the availability of sufficient cover is just as important as the food available to these animals.

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CHAPTER 1: INTRODUCTION

Remarkable growth occurred in the South African wildlife industry as a result of a crucial policy change in the form of the Game Theft Act (No. 105 of 1991), allowing ownership of wildlife by private landowners (Cloete *et al.*, 2015). A wildlife ranch which is sufficiently enclosed according to the minimum standards required by Nature Conservation is issued with an exemption certificate permitting hunting, capturing and selling of particular wildlife species throughout the year (National Agricultural Marketing Council (NAMC), 2006). This laid the foundation for wildlife ranching to become a financially viable alternative to conventional agricultural land use and resulted in game numbers increasing to a historic high (Cloete *et al.*, 2015).

The driving force behind growth in the wildlife industry during the 1990's was due to a high demand for animals, as an increasing number of livestock farms were transformed to wildlife ranches. During this time the main focus for wildlife ranches was either hunting or ecotourism. The focus changed slightly during the 2000's with breeding of high value animals or colour variants driving growth in the industry. The breeding and live sales of common game species have also become an attractive alternative. It is predicted that, as the breeding for live sales slows down, a shift will occur towards game meat as a possible opportunity for growth. Even though the drivers of the wildlife ranching industry may change, the four main pillars, namely hunting, breeding, tourism and meat will each play an integral part to ensure sustainability in the long term (Cloete *et al.*, 2015).

Hunting, which includes both biltong- and trophy hunting, is believed to be the largest sector of the wildlife industry in South Africa (Van der Merwe & Saayman 2003; Cloete *et al.*, 2015), with a total estimated contribution of close to R9 billion in 2015. During 2014 the highest income generating species from local hunters (mainly biltong hunting) was the greater kudu (*Tragelaphus strepciceros*), while this species also generated the second most income from trophy hunting. Kudu can thus be considered an economically important species for wildlife ranching (Cloete *et al.*, 2015).

There were over 6000 exempted wildlife ranches in South Africa by 2005, with an average size of approximately 2000 ha per ranch (NAMC, 2006). The objective of most of these ranches is to accommodate a diversity of wildlife species to satisfy the need for ecotourism, hunting and live sales (Van Rooyen, 2010a). However, the small size of many wildlife ranches presents its own unique challenges. Fencing on these ranches prevents both emigration and immigration of individuals or groups of animals. Animals may also be prevented from moving to more favourable areas during times of food shortages. Intensive management is thus needed to prevent overstocking and to ensure the genetic integrity of animal populations (Boone & Hobbs, 2004; Lehmann *et al.*, 2008).

When the stocking rate of an area exceeds its true carrying capacity over an extended period of time, it usually prevents habitat recovery and can lead to the deterioration of natural resources or even total habitat destruction (Petrides, 1975). Overstocking can thus result in a reduction of animal populations through malnutrition or starvation (Petrides, 1975). With food considered the most important resource that limits animal populations (White, 1978), it is important that an animal's diet provides all the essential nutrients needed for survival, growth and reproduction (Van Soest, 1994). However, due to high climatic variability, the quality and quantity of food available to herbivores can vary considerably between seasons. It is thus essential for herbivores to be able to adjust their foraging behaviour in order to maintain adequate nutrient intake (Owen-Smith, 1979).

According to Johnson (1980), the way in which animals utilise their environment is central to animal ecology, especially food and habitat selection. These selections occur in a hierarchical order, where one selection influences the next. The first order of selection occurs when an animal species selects a physical or geographical range. Individuals or different groups of animals then select a home range within their geographical range. The third order of selection occurs when a habitat or plant community within the animal's home range is selected. Lastly, selection takes place between different individual plants or food items occurring in the selected habitat or plant community; this selection can take place between plant species or between individuals of the same plant species (Johnson, 1980; Owen-Smith and Novellie, 1982). The last order of selection can be further divided into plant parts and growth stages eaten on the individual plant selected (Owen-Smith and Novellie, 1982).

The food items with the highest occurrence in an animal's diet can be considered as its principal foods. However, these foods are not necessarily preferred by the animal (Petrides, 1975). For any food item to be considered as preferred it needs to occur more frequently in the animal's diet than it is available in the environment (Neu *et al.*, 1974; Petrides, 1975; Chesson 1978; Johnson, 1980). If the animal does not feed selectively, then the relative proportions of food available in the environment will be reflected in the animal's diet (Petrides, 1975; Chesson 1978; Johnson, 1980). Preference rankings for different food items can be obtained by comparing their relative availability to relative utilisation by the animal (Petrides, 1975; Johnson, 1980). These preference rankings can lead to a better understanding of the animal's ecology and help with practical resource management, like determining habitat suitability for specific species or evaluating carrying capacity (Petrides, 1975).

In view of the potential negative impact exerted on natural resources by the indiscriminate stocking of a large number of wildlife species, a proper management plan is essential for the sustainable utilisation and conservation of the ecosystem. In order to develop such a management plan, the first step will be to identify, describe and map homogenous plant communities or habitats. Based on the variety of plant communities, palatability of plant species, grazing and browsing capacity and veld condition, it is possible to make informed decisions on the most appropriate species of wildlife and optimum numbers of each species that can be accommodated on the specific ranch (Van Rooyen, 2010a).

The main objectives of this study were:

1. To identify, describe and map different plant communities present in the study area;

2. To determine the abundance of potential food in the study area;

3. To determine the diet composition and food preferences of kudu in the study area;

4. To determine if potential food abundance, food preferences, woody canopy cover and topography affected habitat selection by kudu; and

5. To make recommendations concerning the management of kudu in the central Free State based on this study.

CHAPTER 2: STUDY AREA

2.1 GEOGRAPHICAL LOCATION AND SIZE

The study was conducted in a section of the Amanzi Private Game Reserve, situated 13 km north of Brandfort in the Free State Province, South Africa. The study area was approximately 274 ha in size, enclosed by a three meter high game-proof fence. Two water troughs linked to a reservoir provided animals with water throughout the year, while artificial earth dams usually dried up by the end of the dry season (Figure 2.1). Four feeding troughs were placed at permanent locations in the study area to supply animals with dry feed during times of food shortages. Salt licks were also placed in close proximity to the feeding troughs during the winter.

2.2 HISTORICAL BACKGROUND

The Amanzi Private Game Reserve was established in 2003 by combining the farms Klein Rietfontein, Daspunt, Bettysrand, Rooidraai and Anna-Maretha, covering an area of approximately 2 400 ha. The ranch was later expanded to approximately 3 700 ha by including the farm Swartlaagte in 2012. These farms were previously used mainly for cattle farming and crop production. The Amanzi Private Game Reserve is currently used for ecotourism, trophy hunting, as well as breeding of high value and common game species for live sales, with regular game auctions taking place on the ranch.

The wildlife on the ranch is mostly managed as a semi-extensive wildlife system, with areas large enough for self-sustaining wildlife populations, but where human intervention in the form of water provision, supplementation and healthcare is still required from time to time. There are also smaller intensive breeding systems on the ranch, often referred to as game farming, with optimal production of high value game species in mind (Cloete *et al.*, 2015).
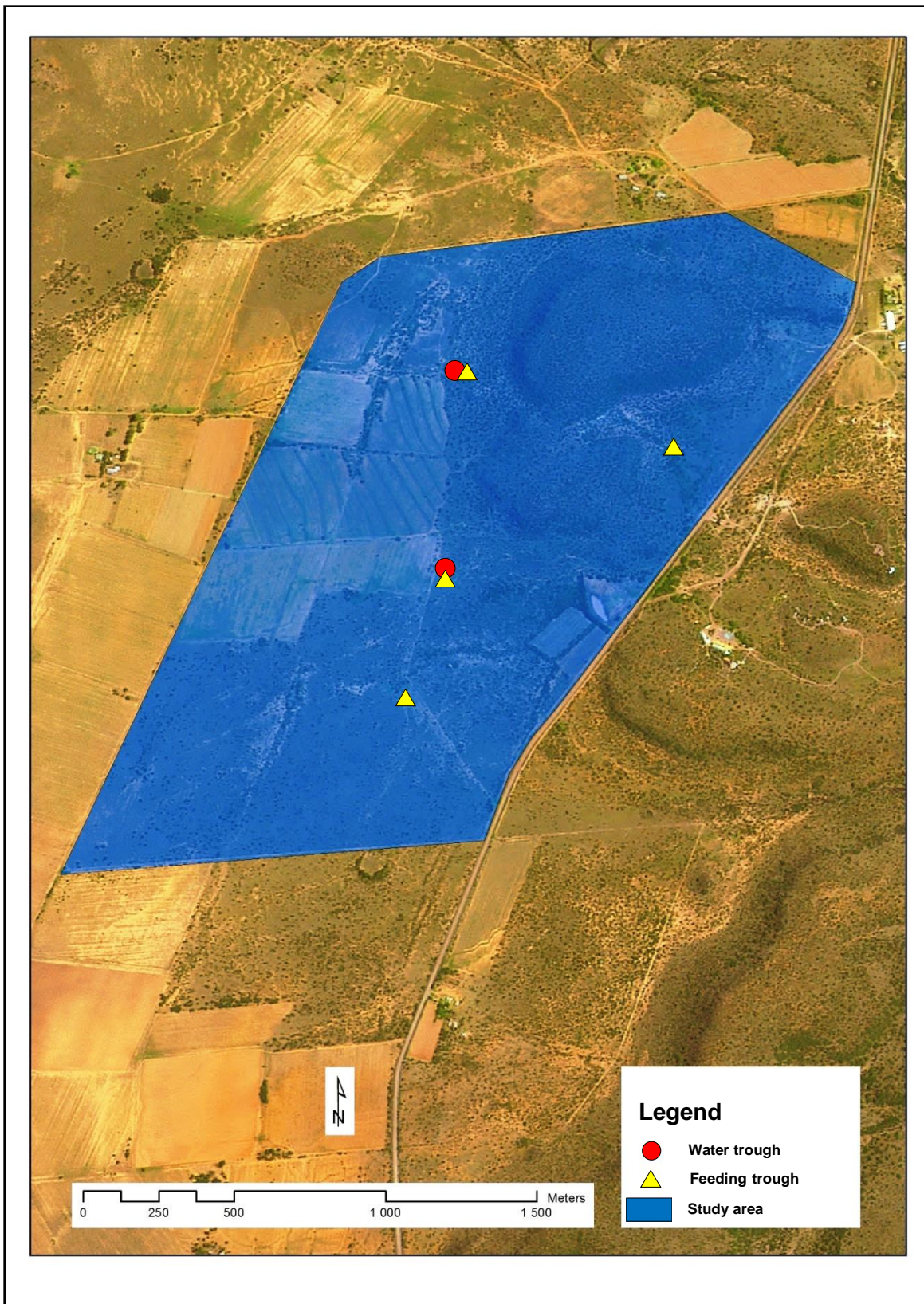
Figure 2.1 Study area in the Amanzi Private Game Reserve, indicating locations of water and feeding troughs

2.3 CLIMATE

Long term rainfall and temperature data were provided by the South African Weather Service, with the closest weather station located at the Glen Agricultural College, approximately 40 km south-west of the study area. Rainfall was also measured in the study area from 2011 to 2014 by using a standard cone-shaped rain gauge.

2.3.1 Rainfall

The study area falls within the summer rainfall region of South Africa, with a mean annual rainfall of about 500 mm (Mucina & Rutherford, 2006). Annual seasonal rainfall (measured from July to June) at the Glen Agricultural College for the period 2000 to 2014 ranged between 208 mm to 701 mm, while the annual seasonal mean was 474 mm (SE ± 42.40) (Figure 2.2). Mean monthly rainfall over the same period indicates that the highest rainfall usually occurs from November to March, while the lowest rainfall occurs from June to August (Figure 2.3). Rainfall measured in the study area was irregularly distributed and mostly unpredictable. However, the highest rainfall still occurred from November to March (Figure 2.4).

2.3.2 Temperature

The study area is characterised by hot summers and cold winters, with over 40 days of frost usually occurring in winter (Mucina & Rutherford, 2006). Temperatures at Glen Agricultural College for the period 2000 to 2014 ranged from a maximum of 38.7°C in summer to a minimum of -9.2°C in winter. The mean daily temperatures for this period peaked during January, while reaching a low during July. The mean daily minimum and maximum temperatures for these months were 15.8°C and 31.1°C, respectively, for January and -1.5°C and 18.8°C, respectively, for July (Figure 2.5).

A climatic diagram for the study area was constructed according to Walter's (1979) example by combining both rainfall and temperature data from Glen Agricultural College for a 15 year period from 2000 to 2014 (Figure 2.6). According to this diagram the wet season stretches from October through to June, while the dry season occurs from July to September.
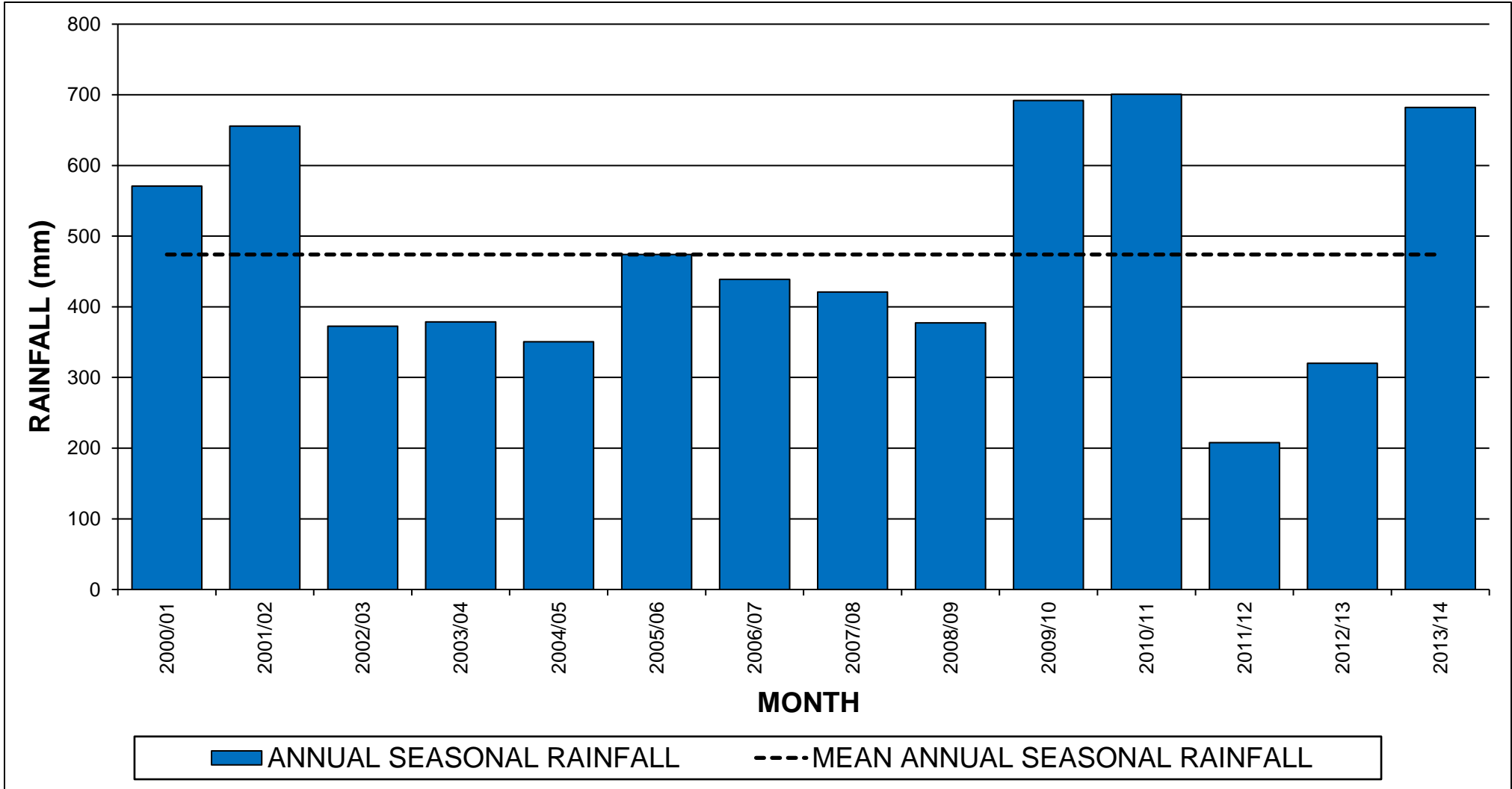
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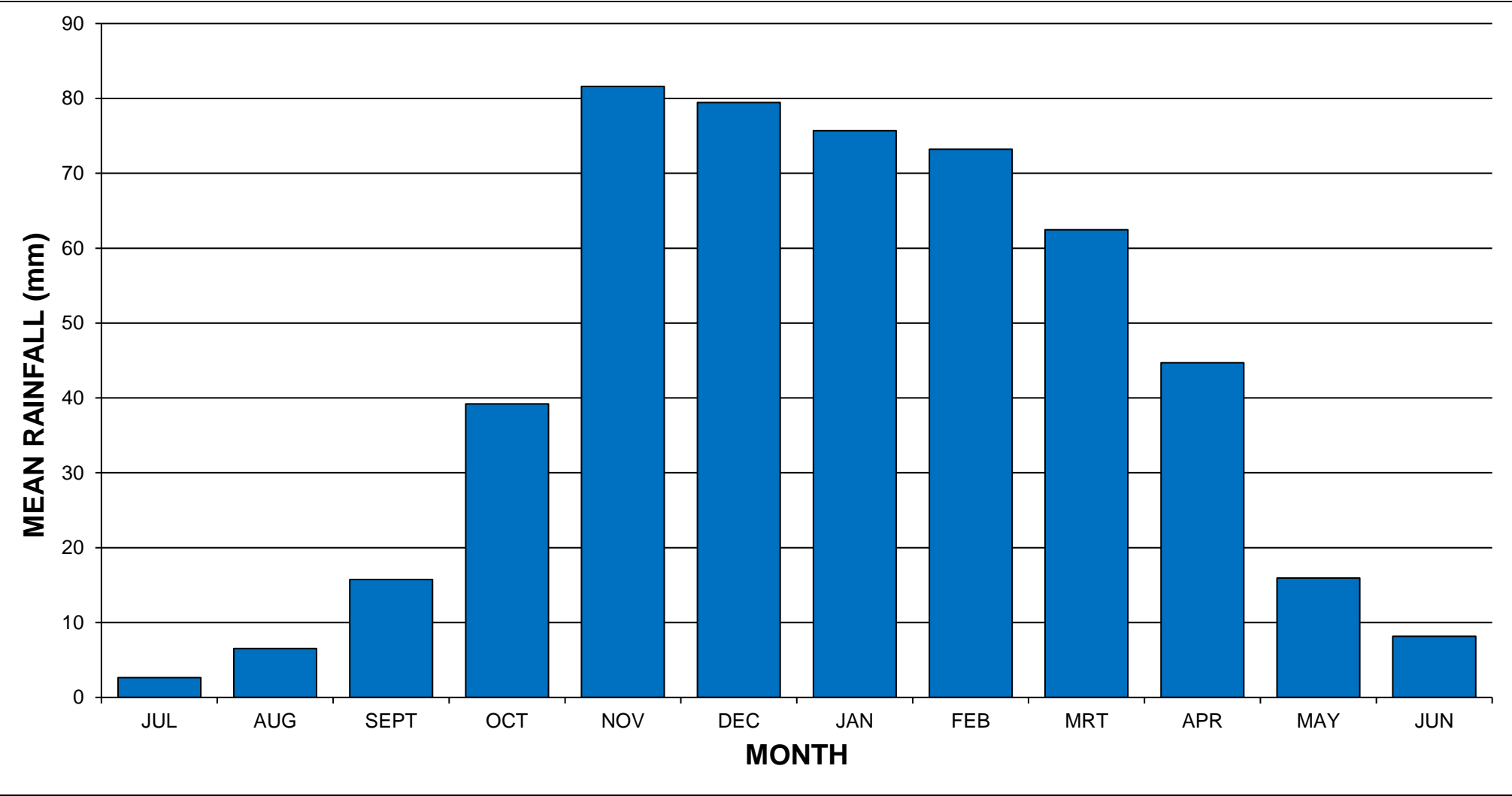
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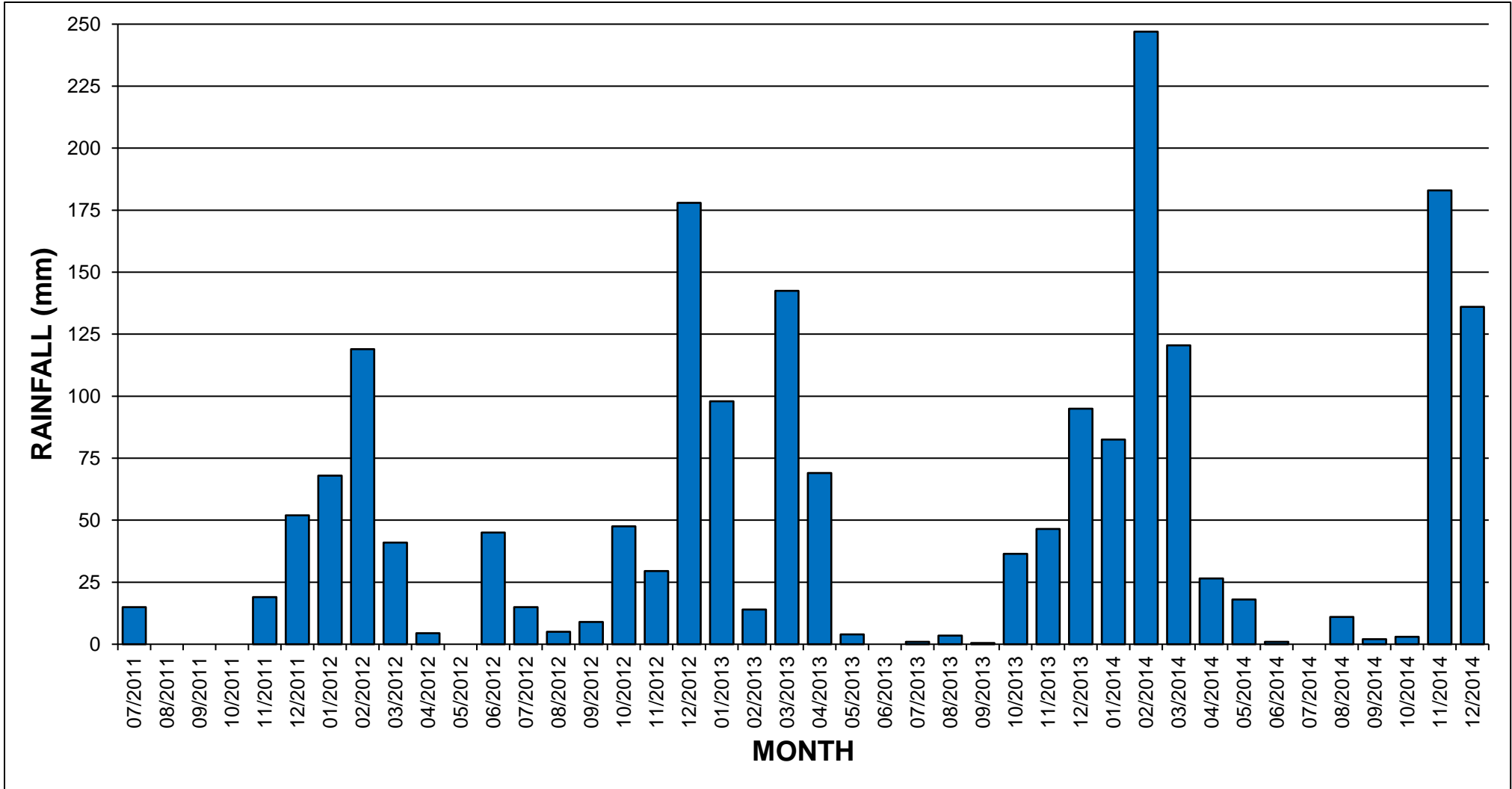
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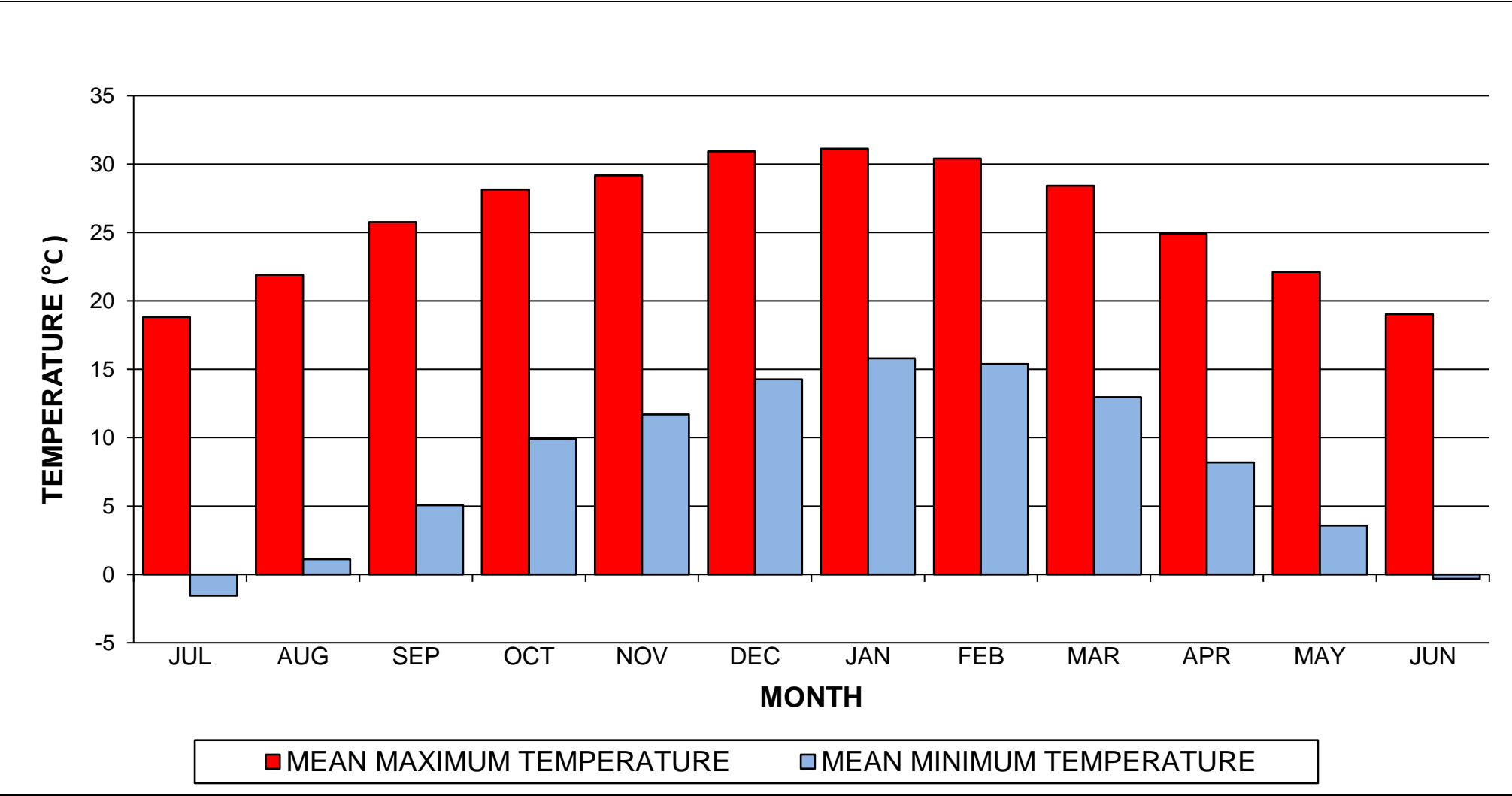
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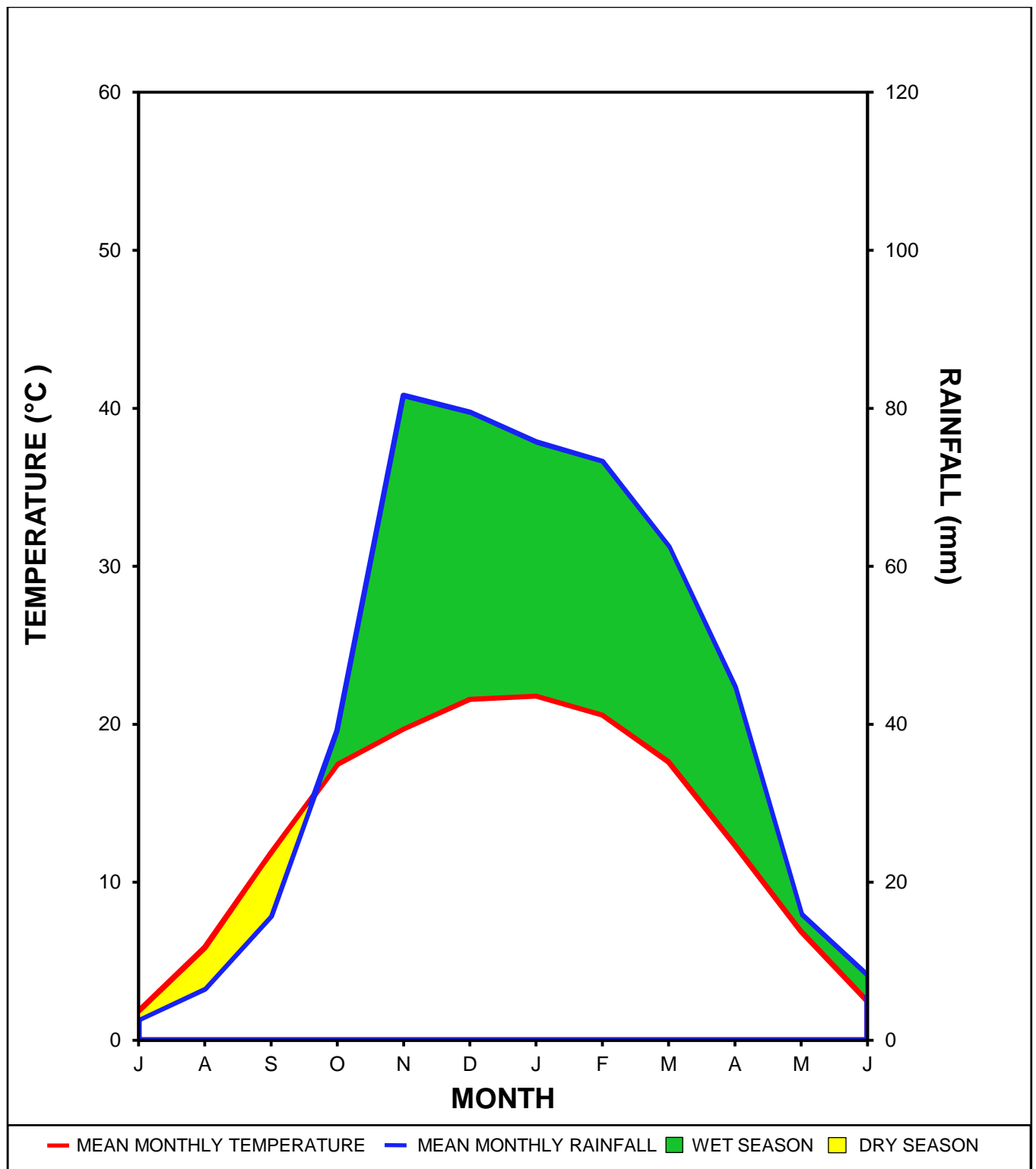
Figure 2.6 Walter's Climate diagram (Walter, 1979), of Glen Agricultural College for the period 2000 to 2014

2.4 VEGETATION AND LANDSCAPE FEATURES

The study area is geographically located in the Grassland Biome (Rutherford & Westfall, 1994) with the vegetation of the area representative of both the Vaal-Vet Sandy Grassland and the Western Free State Clay Grassland (Mucina & Rutherford, 2006). However, the vegetation on the hills is in fact more representative of Winburg Grassy Shrubland that occur in a series of larger patches from Trompsburg through Bloemfontein and Winburg to Ventersburg. The landscape of this vegetation type consists of solitary hills, slopes and escarpments, creating habitats varying from open grassland to shrubland (Mucina & Rutherford, 2006). Two hills are present in the study area linked by a saddle that rises slightly from the surrounding plains. The altitude of the study area ranges from a high of 1 462 m above sea level on the hills in the north to approximately 1 410 m above sea level in the surrounding lower lying areas.

The vegetation in the study area consisted of a combination of natural vegetation and *Digitaria eriantha* planted pastures. The dominant woody species present in the study area were *Searsia ciliata*, *Vachellia karroo, Searsia burchellii, Tarchonanthus camphoratus, Olea europaea* subsp. *africana* and *Buddleja saligna*, while the dominant grass species were *Themeda triandra, Digitaria eriantha*, *Sporobolus fimbriatus*, *Panicum stapfianum, Aristida adscensionis, Aristida canescens, Panicum maximum, Cynodon hirsutus* and *Cynodon dactylon*. A detailed description of plant communities present in the study area is presented in Chapter 3.

2.5 GEOLOGY AND SOILS

Ridges, plateaus and slopes of hills in the Winburg Grassy Shrubland are formed by extensive dolerite sills covering alternating layers of mudstone and sandstone that are of sedimentary origin (Adelaide Subgroup of the Beaufort Group). Major soil forms present are stony Mispah and gravel-rich Glenrosa derived from Jurassic dolerite. The plains of the Western Free State Clay Grassland consist of sandstone, mudstone and shale deposits (Volksrust Formation, Ecca Group). Dry, clayey, duplex soils are characteristic of these areas. The plains of the Vaal-Vet Sandy Grassland consist of aeolian and colluvial sand overlaying sandstone, mudstone and shale of the Karoo Supergroup (mostly Ecca Group). Avalon, Westleigh and Clovelly soil forms occur in these areas (Mucina & Rutherford, 2006).

2.6 GAME POPULATIONS

The study area was stocked with a variety of game species during 2003, but kudu were already present in the area and contained on the ranch after the erection of game-proof fencing. Game species present at the time of the study and their numbers as determined by game counts are listed in Table 2.1, while age and sex ratios for kudu (derived from the same game counts) are listed in Table 2.2.

Table 2.1 Game numbers present in the study area from game counts

COMMON NAME	SCIENTIFIC NAME	JULY 2013	JULY 2014
Blue wildebeest	*Connochaetes taurinus*	8	7
Bontebok	*Damaliscus pygargus pygargus*	31	43
Fallow deer*	*Damma damma*	6	6
Greater kudu	*Tragelaphus strepsiceros*	28	35
Hartmann's mountain zebra	*Equus zebra hartmannae*	23	30
Impala	*Aepyceros melampus*	33	40
Nyala	*Tragelaphus angasii*	14	10
Waterbuck	*Kobus ellipsiprymnus*	3	4

* Exotic species

Table 2.2 Age and sex ratios for kudu present in the study area from game counts

Greater Kudu (*Tragelaphus strepsiceros*)	JULY 2013	JULY 2014
Cow 2 years and older	11	12
Heifer 1-2 years	2	5
Calf ± 6 months	5	8
Bull 12 months	0	0
Bull 18 months	2	0
Bull 24 months	0	2
Bull 30 months	1	0
Bull 3 years	1	1
Bull 4 years	1	1
Bull 5 years and older	5	6
Total	**28**	**35**

CHAPTER 3: VEGETATION CLASSIFICATION, DESCRIPTION AND MAPPING

3.1 INTRODUCTION

Vegetation ecology can best be described as the study of plant cover and its relationship with the environment (Van der Maarel & Franklin, 2013). Vegetation is considered important in ecology as it is regarded as the most obvious physical representation of an ecosystem in most terrestrial parts of the world (Kent, 2012). Vegetation also provides animals with food, either directly or indirectly, and habitat within which they can live, grow and reproduce (Kent, 2012).

In order to achieve the goals of sustainable utilisation and effective conservation, a thorough knowledge of the ecology of a particular area is needed (Edwards, 1972). The classification and description of vegetation provides the information needed to interpret spatial variation between plant species and leads to a better understanding of vegetation-environment relationships (Clegg & O'Connor, 2012).

According to Brown *et al.* (2013), local phytosociological studies in South Africa are essential for proper wildlife management in national parks, nature reserves and private game farms. These studies are also required to establish good conservation policies for both ecosystem and biodiversity management. The identification of different plant communities can be seen as the identification of different ecosystems at a particular hierarchical level. In order to effectively manage a natural area, the first steps would thus be to describe, monitor and manage plant communities (Brown *et al.*, 2013).

A plant community can be defined as a collection of plant species growing in a particular location that show a definite association with each other. Plant species usually grow together due to similar environmental requirements like light, temperature, water, drainage and soil nutrients. Associated plant species may also be able to tolerate the same amount of grazing, burning or trampling pressure. Within plant communities, the presence or absence of particular species is thus considered the most important, while the amount or abundance of each species is of secondary importance (Kent, 2012).

According to Brown *et al.* (2013), the results of phytosociological studies should form the cornerstone of any wildlife management decision. For example, knowledge of the different plant communities and their spatial representation could assist in making informed decisions on the habitat available to wildlife. Vegetation maps are also considered indispensable to wildlife managers as they indicate the location, distribution and abundance of different plant communities (Brown *et al.*, 2013).

The specific objectives of this chapter were:

1. To classify the vegetation in the study area;

2. To describe the vegetation in the study area; and

3. To map the vegetation in the study area.

3.2   METHODOLOGY

The Zurich-Montpellier (Braun-Blanquet) school of total floristic compositions was followed in the classification of the vegetation (Braun- Blanquet 1932; Kent 2012; Mueller-Dombois & Ellenberg 1974; Werger 1973; Westhoff & Van der Maarel 1978). This approach was chosen as it is used worldwide, including many local studies in South Africa (Bredenkamp & Theron, 1978; Kooij *et al.*, 1990; Bezuidenhout 1994; Brown & Bezuidenhout, 2000; De Klerk *et al.*, 2003; Cleaver *et al.*, 2005; Van Staden & Bredenkamp, 2005; Bezuidenhout & Brown, 2008; Bezuidenhout, 2009; Brand *et al.*, 2009; Barrett *et al.*, 2010; Brand *et al.*, 2011; Daemane *et al.*, 2012; Dingaan & Du Preez, 2013). After visual inspection of the study area, the vegetation was stratified into relatively homogenous physiognomic–physiographic units using Google Earth (Version 6.0). A total of 135 sample plots or relevés were then randomly placed within each of the eight identified physiognomic–physiographic units. The number of sample plots allocated to each unit depended on the size of the unit, with more sample plots allocated to larger units. However, a minimum of three sample plots were allocated to each physiognomic–physiographic unit as recommended by Brown *et al.* (2013). The position of each sample plot was saved using a GPS (Global Positioning System) for easy location of sample plots in the field.

Fieldwork was conducted during the growing seasons, from April to May in 2012 and again from March to May in 2013. The plot sizes used during the study were 10x10 m (100 m^2) for tree and shrub communities and 4x4 (16 m^2) for grassland communities (Bredenkamp & Theron, 1978; De Klerk *et al.*, 2003; Cleaver *et al.*, 2005; Bezuidenhout, 2009; Brand *et al.*, 2009). All the rooted plant species present in each sample plot was recorded and a cover-abundance value assigned to each species using the modified Braun-Blanquet cover-abundance scale presented in Table 3.1 (Mueller-Dombois & Ellenberg, 1974). Environmental data that assisted with the description of the different plant communities were recorded in each sample plot. These included, topography, aspect, slope (estimated in degrees), the percentage area covered by rocks, the size of rocks, degree of surface erosion, drainage, soil depth, soil texture and exposure to sunlight. A soil auger was used to drill holes in the ground at each sample plot and soil depth was subsequently measured to a maximum depth of 41 cm with a steel tape measure. Soil samples were collected at 10 cm intervals to determine soil texture. The environmental data was further used to illustrate gradients within and between plant communities and to link these gradients with environmental variables.

Table 3.1 Modified Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg, 1974)

Braun-Blanquet value	Description
r	One or a few individuals, rare, with less than 1% cover of the total sample plot area
+	Infrequent with less than 1% cover of total sample plot area
1	1 - 5% cover of the total sample plot area, frequent with low cover or infrequent with high cover
2a	6 - 12% cover of the total sample plot area, irrespective of the number of individuals
2b	13 - 25% cover of the total sample plot area, irrespective of the number of individuals
3	26 - 50% cover of the total sample plot area, irrespective of the number of individuals
4	51 - 75% cover of the total sample plot area, irrespective of the number of individuals
5	76 - 100% cover of the total sample plot area, irrespective of the number of individuals

Vegetation data was captured using the TURBOVEG computer program (Hennekens, 1996). The data was then exported into the program JUICE (Tichý & Holt, 2006). The JUICE program is designed for editing, classification and analysis of phytosociological tables. The first approximation of the floristic data was obtained in JUICE by applying the modified two-way indicator species analysis (modified TWINSPAN) (Hill, 1979; Roleček *et al.*, 2009). Instead of enforcing a dichotomy of classification, the modified TWINSPAN algorithm divides only the most heterogeneous cluster of the previous hierarchical level during each step. This results in grouping of plant species into vegetation units of similar internal heterogeneity (Brown *et al.*, 2013). Pseudospecies cut levels used in the classification were: 0, 15, 25, 50 and 75. The TWINSPAN classification was refined by applying Braun-Blanquet procedures. To illustrate floristic gradients within and between plant communities and to link these gradients with habitat variables ordination of the vegetation and environmental data was done using CANOCO (Version 4.5) (Ter Braak & Smilauer, 2002). To determine if a linear or unimodal based approach was required a Detrended Correspondence Analysis (DCA) was carried out.

Guidelines for formal syntaxonomical classification, as presented in the International Code of Phytosociological Nomenclature, were used to assign plant community names (Weber *et al.*, 2000). However, specified taxon epithets were not used (Brown *et al.*, 2013). Accordingly, the first name of a plant community can be a diagnostic or co-dominant plant species and the second name is the dominant plant species or the one that dominates the structure. Sub-community names start with their community name followed by a characteristic or dominant plant species for that sub-community (Weber *et al.*, 2000). However, subjective preference was given to perennial plant species in naming plant communities (Brown *et al.*, 2013). Plant species' names in this study conform to those of Germishuizen & Meyer (2003). The only exceptions were the genus *Rhus* that was changed to *Searsia* (Moffett, 2007) and the genus *Acacia* that was changed to *Vachellia* (Kyalangaliwa *et al.*, 2013).

After classifying the vegetation into different communities and sub-communities, a vegetation map of the study area was constructed using ArcMap (Version 10.4). The locations of all the sample plots, indicating their specific numbers, were overlaid on a satellite image of the study area. Each sample plot was also assigned a colour that indicated the plant community they were classified under. Polygons were then created, outlining each plant community, by taking the locations of sample plots and their association with different plant communities into account.

3.3   RESULTS

3.3.1 Classification

A total of four plant communities, one of which was subdivided into two sub-communities, were identified after classification. A phytosociological table representing the hierarchical classification of plant communities is presented in Appendix 1. The location and distribution of the communities are indicated on a vegetation map of the study area (Figure 3.1).

The hierarchical classification of the four plant communities is as follows:

1.   *Persicaria lapathifolia - Panicum coloratum* Community

2.   *Digitaria eriantha - Cynodon dactylon* Community

3.   *Buddleja saligna - Searsia burchellii* Community

    3.1 *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community

    3.2 *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community

4.   *Themeda triandra - Digitaria eriantha* Community

Figure 3.1 Vegetation map of the study area on Amanzi Private Game Reserve

Legend

☐ Camp boundary

Plant communities

🟥 *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community

🟧 *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community

🟨 *Digitaria eriantha - Cynodon dactylon* Community

🟩 *Persicaria lapathifolia - Panicum coloratum* Community

🟦 *Themeda triandra - Digitaria eriantha* Community

3.3.2 Description of plant communities

1. *Persicaria lapathifolia - Panicum coloratum* Community

This community was restricted to the area in and around a man-made earth dam. The soil surface of this community, not covered by standing water, was moist to water-logged in the wet season. However, most of the standing water dried up by the end of the dry season. No rocks were present on the soil surface, with moderate erosion occurring in places. Dark, clayey soils were present in the area, while the soil depth measured was deeper than 40 cm. This community was exposed to full sun, with no trees and shrubs present in the dam area. The diagnostic species of this community were *Persicaria lapahifolia*, *Panicum coloratum* and *Setaria pumila* (Species group A, Appendix 1). *Persicaria lapahifolia* and *P. coloratum* were also dominant in this community (Figure 3.2).

2. *Digitaria eriantha - Cynodon dactylon* Community

The area covered by this community was planted with the perennial grass *Digitaria eriantha* in 2003. It is thus not a natural occurring plant community, but rather a planted pasture. Deep sandy soils that were reddish in colour occurred in the area, with soil depths of 40+ cm measured. No rocks were visible on the soil surface and there were no signs of erosion. This community was exposed to full sun, with mostly saplings present in the woody layer. However, the development of woody saplings was suppressed in this community by annual cutting and harvesting of the herbaceous layer. The harvested grass was mixed with lucerne, maize meal and molasses and used for feeding wildlife during the dry months. However, the herbaceous layer in the study area was not cut between June 2010 and the end of 2014. The diagnostic species of this community were *D. eriantha* (Species Group F, Appendix 1), *Cynodon dactylon*, *Tripteris aghillana* and *Arctotis venusta* (Species Group B, Appendix 1). This plant community was, as excepted, dominated by *D. eriantha* (Figure 3.3).

Figure 3.2 *The Persicaria lapathifolia - Panicum coloratum* Community

Figure 3.3 The Digitaria *eriantha - Cynodon dactylon* Community

3. *Buddleja saligna - Searsia burchellii* Community

This community was situated on the hills and surrounding lower lying flats. Rock cover varied from 0 – 70%, with most rocks located on the hills. The soil in this community consisted mostly of sandy loam, with pockets of calcrete found on the hills. Soil depth varied between 10 and 40+ cm. No surface erosion was visible, except for the area between the two hills. The soil surface was mostly semi-shaded, with some areas fully shaded by the dense canopy cover of the woody layer. The diagnostic species of this community were *Buddleja saligna*, *Searsia burchellii*, *Tarchonanthus camphoratus*, *Grewia occidentalis*, *Aristida congesta* subsp. *congesta*, *Aristida adscensionis*, *Kalanchoe rotundifolia*, *Ehretia alba*, *Enneapogon scoparius*, *Jamesbrittenia aurantiaca* and *Euphorbia inaquilatera* (Species group C, Appendix 1), while *B. saligna*, *S. burchellii, T. camphoratus* and *G. occidentalis* dominated this community (Figure 3.4). This community can be sub-divided into two sub-communities, namely the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community and the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community.

3.1 *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community

This sub-community covered all the hills in the study area (Figure 3.1). Rocks of varying sizes from stones to boulders covered on average 44% of the soil surface. No erosion of the soil surface was visible. The soil consisted mostly of sandy loam, but pockets of calcrete also occurred. The soil was for the most part very shallow (10 cm deep), although soil depth of over 40 cm was measured in the calcrete areas. The soil surface was mostly semi-shaded, although some areas on the southern slopes were fully shaded. The diagnostic species of this sub-community were *Aristida canescens*, *Panicum maximum*, *Olea europaea* subsp*. africana*, *Setaria sphacelata* var. *torta*, *Euclea crispa* subsp. *ovata*, *Indigofera rhytidocarpa*, *Rhynchosia totta*, Eustachys *paspaloides*, *Kalanchoe paniculata*, *Cymbopogon pospischilii*, *Heteropogon contortus*, *Pellaea calomelanos*, *Aloe grandidentata*, *Lantana rugosa*, *Hibiscus trionum*, *Bontea speciosa*, *Crassula lanceolata*, *Commelina africana*, *Tephrosia capensis*, *Cheilanthus hirta*, *Argyrolobium pauciflorum*, *Crassula setosa*, *Crabbea acaulis*, *Diospyros austro-africanum*, *Triraphis andropogonoides*, *Mohria caffrorum*, *Selago albida*, *Gladiolus permeabilis*, *Haemanthus humilis*, *Tragus koeleroides*, *Rhigozum obovatum*, *Cussonia paniculata*, *Boscia albitrunca*, *Fingerhuthia africana* and *Tragus racemosa* (Species group D, Appendix 1). The dominant species of this sub-community were *A. canescens*, *B. saligna*, *P. maximum*, *O. europaea* subsp*. africana*, *S. burchellii*, *T. camphoratus* and *S. ciliata* (Figure 3.5).

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Figure 3.4 The *Buddleja saligna - Searsia burchellii* Community

Figure 3.5 The *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*
Sub-community

3.2 *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community

This sub-community was situated on the flats surrounding the hills in the study area (Figure 3.1). The visible rectangular areas on the vegetation map are old pastures, but are still representative of this sub-community. The soil surface of this sub-community was mostly semi-shaded by the well developed woody layer. The soil surface was mostly covered by less than 10% rocks, with a high degree of surface erosion only occurring in one area between the two hills. No or very little surface erosion was visible in the rest of this community. The soil consisted of sandy loam, with soil depths measured to be deeper than 40 cm. The diagnostic species of this sub-community were *A. adscensionis* (Species group C, Appendix 1), *Cynodon hirsutus*, *Chrysocoma ciliata*, *Geigeria filifolia*, *Urochloa panicoides* and *Aristida bipartita* (Species group E, Appendix 1). The dominant species of this sub-community were *A. adsensionis*, *B. saligna*, *S. burchellii*, *T. camphoratus*, *C. hirsutus*, *V. karroo*, *T. triandra*, *Sporobolus fimbriatus*, *Asparagus suaveolens*, *S. ciliata* and *Eragrostis lehmanniana* (Figure 3.6).

4. *Themeda triandra - Digitaria eriantha* Community

This community was situated in the lower lying plains of the study area. No signs of surface erosion or rocks were visible on the soil surface. This community was mostly exposed to full sun, with some semi-shaded areas. Clayey loam soil occurred in the area, with soil depths of 40+ cm measured. The diagnostic species of this community were *T. triandra* (Species group H, Appendix 1), *D. eriantha*, *Aparugus cooperi*, *Berkheya onopordifolia*, *Ziziphus mucronata*, *Salsola glabrescens*, *Eragrostis superba*, *Chascanum pinnatifidum*, *Drimia elata*, *Searsia lancea*, *Ruschia hamata*, *Antizoma angustifolia*, *Lycium pilifolium*, *Verbena bonariensis*, *Ipomoea oenotheroides*, *Ipomoea oblongata*, *Searsia pyroides*, *Lycium hirsutum*, *Polygonum aviculare* and *Raphionacme dyeri* (Species group F, Appendix 1). This community was dominated by the species *T. triandra*, *V. karroo*, *S. fimbriatus* and *D. eriantha* (Figure 3.7).

Figure 3.6 The *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community

Figure 3.7 The *Themeda triandra - Digitaria eriantha* Community

3.3.3 Ordination

The results of the Detrended Correspondence Analysis (DCA) are presented in Table 3.2. The gradient length of at least one of the four axes was > 4 (axis 1). Thus a unimodal based approach was considered most appropriate. A Canonical Correspondence Analysis (CCA), with "interspecies distance" and "Biplot scaling" was performed next. Species data was log transformed to ensure that they satisfied the parametric assumption of normality. The results for this CCA are presented in Table 3.3.

The VIF (inflation factor) values were inspected to identify collinear variables. The following variables were found to be collinear (had VIF values >20): Hill (topography), Plain (topography), None (no aspect), S (south), No_rocks (size of rocks), Moist (drainage), 0_10 (soil depth), Sloam (sandy loam) and Cloam (clayey loam). The inter-environmental variable correlations were inspected to identify correlations. The following environmental variables were found to be correlated: Hill, Plain, None, No_rocks and 0_10; South and Moist; Sloam and Cloam. The marginal effects were investigated to determine which of the collinear environmental variables were best at explaining the measured species variation. The variable with the lowest "Lambda1" value was accepted. Accordingly only 0_10, South and Sloam was retained, the rest was omitted from further analysis.

A CCA was again performed, after removing the mentioned variables from the dataset. The results for the CCA are presented in Table 3.4. The results indicated that none of the listed variables had VIF values >20, all collinear variables had thus been removed. There was also only a small decrease in the eigenvalues when comparing the results of Tables 3.3 and 3.4. This indicated that the removal of the collinear environmental variables did not detract from the explanatory ability of the remaining environmental variables. A biplot from the results obtained in Table 3.4 is presented in Figure 3.8. This biplot was, however, disjunct with relevés 94, 95, 96 and 97 being outliers, associated with the variables Wlogged (drainage), Clay (soil texture) and Dam (topography). The disjunct nature of the biplot was corrected by removing relevés 94, 95, 96 and 97 and re-analysing the dataset. These results produced the biplot illustrated in Figure 3.9. This biplot was again disjunct, with relevés 191-192, 194-196, 197, 199-204, 206, 208, 215, 219 and 221 being associated with the environmental variable Fsun (exposure to sunlight). The above mentioned relevés were thus removed from the dataset and the data was reanalysed. The CCA results after removing the relevés 94-97, 191-192, 194-196, 197, 199-204, 206, 208, 215, 219 and 221 are presented in Table 3.6. A biplot from the results obtained in Table 3.6 is presented in Figure 3.10.

Table 3.2 Detrended Correspondence Analysis (DCA), testing the length of the gradient to determine if a linear of unimodal based approach was required

AXES	1	2	3	4	Total inertia
Eigenvalues	0.897	0.460	0.174	0.134	5.715
Lengths of gradient	5.929	3.947	2.741	2.009	
Cumulative percentage variance of species data	15.7	23.7	26.8	29.1	
Sum of all eigenvalues					5.715

Table 3.3 Canonical Correspondence Analysis (CCA), with "interspecies distance" and "Biplot scaling"

AXES	1	2	3	4	Total inertia
Eigenvalues	0.880	0.587	0.450	0.137	5.715
Species-environment correlations	0.992	0.969	0.971	0.884	
Cumulative percentage variance of species data	15.4	25.7	33.5	35.9	
Cumulative percentage variance of species-environment relation	30.7	51.1	66.8	71.6	
Sum of all eigenvalues					5.715
Sum of all canonical eigenvalues					2.869

Table 3.4 Canonical Correspondence Analysis (CCA), after removing collinear variables

AXES	1	2	3	4	Total inertia
Eigenvalues	0.880	0.586	0.450	0.136	5.715
Species-environment correlations	0.992	0.969	0.970	0.883	
Cumulative percentage variance of species data	15.4	25.7	33.5	35.9	
Cumulative percentage variance of species-environment relation	31.1	51.7	67.6	72.4	
Sum of all eigenvalues					5.715
Sum of all canonical eigenvalues					2.835

Figure 3.8 Scatter plot of relevés and environmental variables plotting the first and second axes. **Topography**: Hill, Plain, Dam. **Aspect**: None, N, NW, W, SW, S, SE, E, NE. **Slope degree**: Slope. **Rock cover**: Rock cov. **Size of rocks**: No rocks, Gravel, Stones, Rocks, Boulders. **Erosion**: Low, Moderate, High. **Drainage**: Dry, Moist, Wlogged (water-logged). **Exposure to sunlight**: Fsun (Full sun), Sshade (Semi-shade), Fshade (Full shade). **Soil depth**: 0_10 (0-10 cm), 10_20 (10-20 cm), 20_30 (20-30 cm), 30_40 (30-40 cm), 40_50 (40-50 cm). **Soil texture**: Sloam (Sandy loam), Calcrete.

Table 3.5 Canonical Correspondence Analysis (CCA), after removing relevés 94, 95, 96, and 97

AXES	1	2	3	4	Total inertia
Eigenvalues	0.587	0.451	0.136	0.13	4.574
Species-environment correlations	0.969	0.971	0.884	0.828	
Cumulative percentage variance of species data	12.8	22.7	25.7	28.5	
Cumulative percentage variance of species-environment relation	31.3	55.3	62.6	69.5	
Sum of all eigenvalues					4.574
Sum of all canonical eigenvalues					1.877
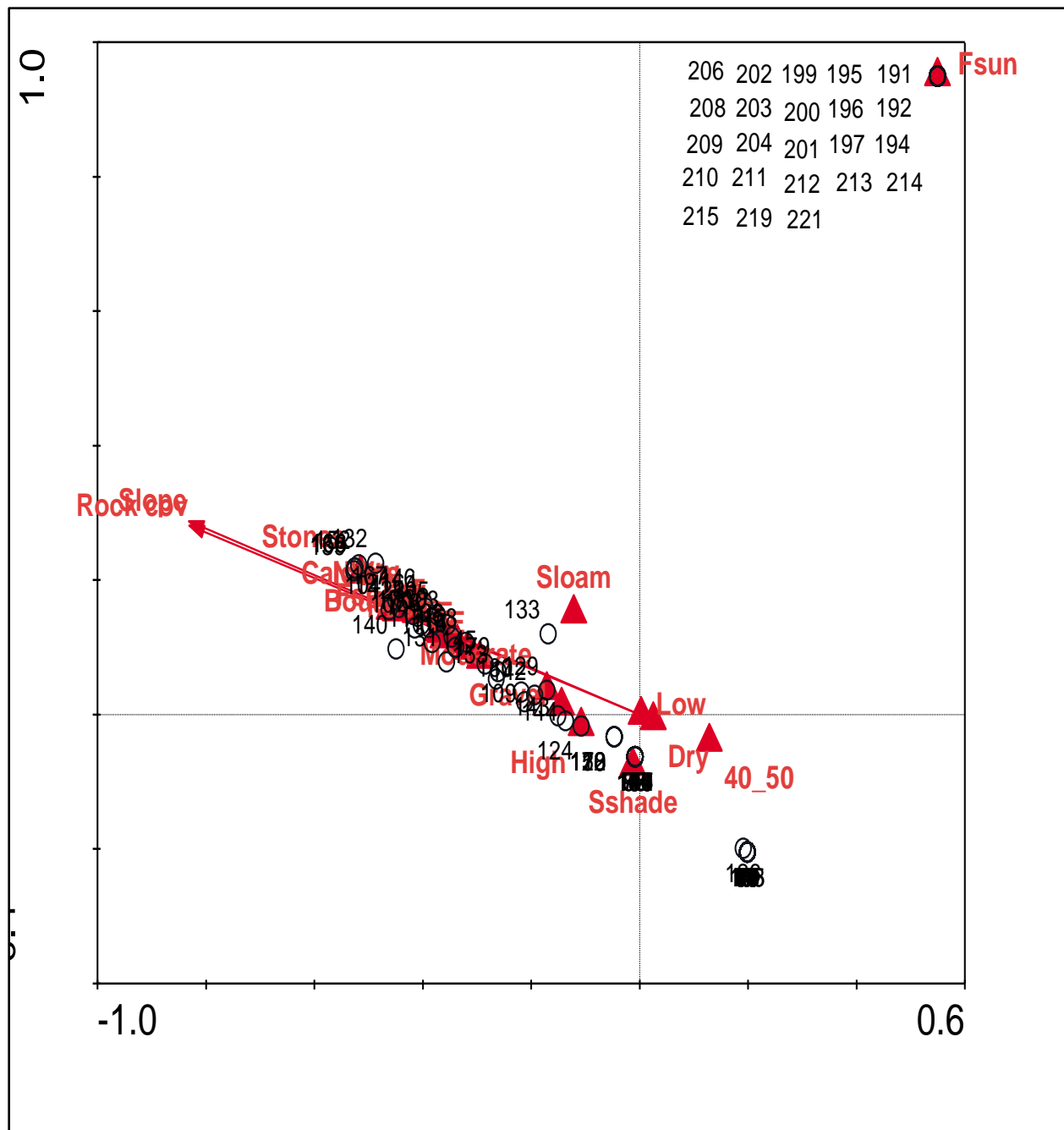
Figure 3.9 Scatter plot of relevés and environmental variables, after removing relevés 94, 95, 96 and 97 from the dataset, plotting the first and second axes. **Topography**: Hill, Plain, Dam. **Aspect**: None, N, NW, W, SW, S, SE, E, NE. **Slope degree**: Slope. **Rock cover**: Rock cov. **Size of rocks**: No rocks, Gravel, Stones, Rocks, Boulders. **Erosion**: Low, Moderate, High. **Drainage**: Dry, Moist, Wlogged (water-logged). **Exposure to sunlight**: Fsun (Full sun), Sshade (Semi-shade), Fshade (Full shade). **Soil depth**: 0_10 (0-10 cm), 10_20 (10-20 cm), 20_30 (20-30 cm), 30_40 (30-40 cm), 40_50 (40-50 cm). **Soil texture**: Sloam (Sandy loam), Calcrete.

Table 3.6 Canonical Correspondence Analysis (CCA), after removing relevés 94, 95, 96, 97, 191,192, 194, 195, 196, 197, 199, 200, 201, 202, 203, 204, 206, 208, 215, 219 and 221 from the dataset

AXES	1	2	3	4	Total inertia
Eigenvalues	0.565	0.141	0.135	0.09	3.863
Species-environment correlations	0.964	0.852	0.863	0.882	
Cumulative percentage variance of species data	14.6	18.3	21.8	24.1	
Cumulative percentage variance of species-environment relation	39.5	49.4	58.8	65.1	
Sum of all eigenvalues					3.863
Sum of all canonical eigenvalues					1.431
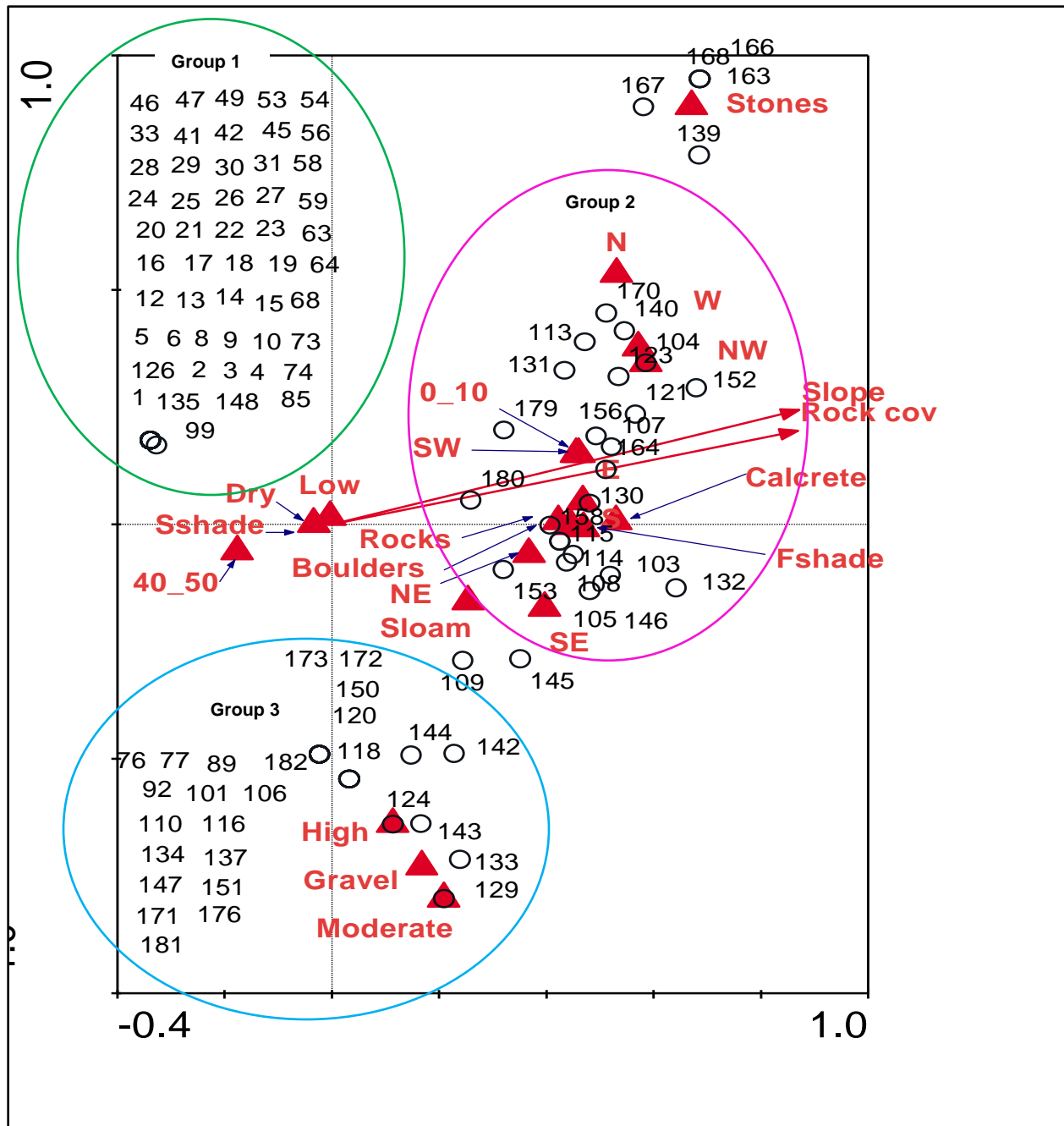
Figure 3.10 Scatter plot of relevés and environmental variables after removing relevés 94, 95, 96, 97, 191,192, 194, 195, 196, 197, 199, 200, 201, 202, 203, 204, 206, 208, 215, 219 and 221, plotting the first and second axes. **Topography**: Hill, Plain, Dam. **Aspect**: None, N, NW, W, SW, S, SE, E, NE. **Slope degree**: Slope. **Rock cover**: Rock cov. **Size of rocks**: No rocks, Gravel, Stones, Rocks, Boulders. **Erosion**: Low, Moderate, High. **Drainage**: Dry, Moist, Wlogged (water-logged). **Exposure to sunlight**: Fsun (Full sun), Sshade (Semi-shade), Fshade (Full shade). **Soil depth**: 0_10 (0-10 cm), 10_20 (10-20 cm), 20_30 (20-30 cm), 30_40 (30-40 cm), 40_50 (40-50 cm). **Soil texture**: Sloam (Sandy loam), Calcrete.

Ordination of the vegetation data and environmental variables showed that most of the plant communities were strongly associated with one or more of the environmental variables. Relevés 94-97, situated in the *Persicaria lapathifolia - Panicum coloratum* Community (Community 1, Appendix 1), were strongly associated with areas that were water logged and had clayey soils (Figure 3.8). The relevés 191-192, 194-196, 197, 199-204, 206, 208, 215, 219 and 221, situated in the *Digitaria eriantha - Cynodon dactylon* Community (Community 2, Appendix 1), were associated with full sun (Figure 3.9). The relevés in group one (Figure 3.10) were associated with low slope, low rock cover, low erosion, semi-shade, good drainage and a soil depth of between 40 and 50 cm. Almost all of these relevés were situated in the *Themeda triandra - Digitaria eriantha* Community (Community 4, Appendix 1). The relevés in group two (Figure 3.10) were strongly associated with high rock cover and steep slopes. These relevés were also strongly associated with one or more of the following environmental variables: soil depth < 10 cm, rocks, boulders, full shade, sandy loam soil, calcrete soil, northern aspect, north-western aspect, western aspect, south-western aspect, southern aspect or north-eastern aspect. All the relevés in this group were situated on the hills in the study area in the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community (Sub-community 3.1, Appendix 1). The relevés in group three (Figure 3.10) were strongly associated with moderate to high erosion and gravel. Most of these relevés were situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community (Sub-community 3.2, Appendix 1).

3.4   DISCUSSION

The study area is situated within the Grassland Biome (Rutherford & Westfall, 1994), with the vegetation of the area described by Mucina & Rutherford (2006) as Vaal-Vet Sandy Grassland and Western Free State Clay Grassland. The study area as well as the surrounding area is, however, unique in that it is dominated by hills that are more representative of the Winburg Grassy Shrubland (Mucina & Rutherford, 2006).

The plant communities described in this study correspond to some extent with the descriptions of other studies done in the central Free State, especially those of Müller (2002) and Botha (2003). The mapped plant communities were used as wildlife management units as each plant community formed basic habitats characterised by their own diversity and ecological capacity to support game species (Bothma *et al.*, 2004).

The *Persicaria lapathifolia - Panicum coloratum* Community can be compared to the *Persicaria lapathifolia - Verbena bonariensis* Sub-community described by Botha (2003) on the Kareefontein Private Nature Reserve, also located in the central Free State. Both communities were situated in man-made earth dams close to standing water. Fluctuating water levels make this habitat one that can only be occupied by species that are adapted to survive extreme conditions (Botha, 2003). Both plant communities were characterised by *Persicaria lapathifolia*.

The *Digitaria eriantha - Cynodon dactylon* Community is very similar to the *Digitaria eriantha – Conyza bonariensis* Sub-community situated in the Kareefontein Private Nature Reserve (Botha, 2003). Both plant communities are the result of planted pastures, with *D. eriantha* considered diagnostic. The absence of *T. triandra* in both communities was also of significance.

The *Buddleja saligna - Searsia burchellii* Community resembles the tree and shrub communities situated on dolerite outcrops in the Kareefontein Private Nature Reserve (Botha, 2003). Species that dominated both the Buddleja *saligna - Searsia burchellii* Community on Amanzi Private Game Reserve and the tree and shrub communities described by Botha (2003) were: *O. europaea* subsp. *africana, B. saligna, S. burchellii* and *S. ciliata*. Of all tree and shrub communities described by Botha (2003), the woody layer of the *Olea europaea – Searsia ciliata* Community was most similar to the *Buddleja saligna - Searsia burchellii* Community in Amanzi Private Game Reserve. The following species were considered diagnostic in the *Olea europaea – Searsia ciliata* Community: *O. europaea* subsp. *africana*, *S. ciliata, G. occidentalis, Gymnosporia polyacantha* and *E. crispa* subsp. *ovata* (Botha, 2003).

The *Olea europaea – Searsia ciliata* Community was dominated by *O. europaea* subsp. *africana*, with the shrub layer consisting of a wide variety of species including *S. burchellii, B. saligna, Diospyros lycioides, Z. mucronata, Rhigozum obovatum, T. camphoratus, C. paniculata, S. ciliata, G. occidentalis, G. polyacantha, E. crispa* subsp. *ovata, Asparagus laricinus, A. suaveolens* and *D. austro-africanum* (Botha, 2003). All of these species also occurred in the woody layer of the *Buddleja saligna - Searsia burchellii* Community, with the exception of *G. polyacantha*. However, the herbaceous layers of the two communities differed somewhat. Although *T. triandra*, *E. lehmanniana* and *A. congesta* were relatively dominant in both communities, species like *P. maximum* and *S. sphacelata var. torta* were more dominant in the *Buddleja saligna - Searsia burchellii* Community. *Aristida canescens* and *S. fimbriatus* were also dominant in the *Buddleja saligna - Searsia burchellii* Community, but did not occur in the *Olea europaea – Searsia ciliata* Community.

The dominance of the pioneer species *A. adscensionis* in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community was an indication of overgrazing, as this species is considered rare in veld in excellent condition, but increases when veld is excessively overgrazed in the long term. According to the owners of Amanzi Private Game Reserve, this area was historically overgrazed by cattle.

The *Themeda triandra - Digitaria eriantha* Community was comparable to the *Vachellia karroo* communities in the central Free State described by Müller (2002). The woody layers of both the *Themeda triandra - Digitaria eriantha* Community and the *Setaria sphacelata - Vachellia karroo* Community were dominated by *V. karroo*, while *Z. mucronata*, *S. lancea*, *S. burchellii*, *S. pyroides*, *A. laricinus*, *A. suaveolens* and *L. hirsutum* occurred in both communities. The woody layer of the *Diospyros lycioides – Searsia pyroides* Community also showed resemblance to the *Themeda triandra - Digitaria eriantha* Community, with both communities dominated by *V. karroo*, while *L. hirsutum, D. lycioides, S. pyroides*, *Z. mucronata* and *A. laricinus* were also represented in both communities. Another community showing resemblance to the *Themeda triandra - Digitaria eriantha* Community was the *Eragrostis lehmanniana - Vachellia karroo* Community. The woody layer of this community, like the others, was dominated by *V. karroo* (Müller, 2002). The herbaceous layers of all the *Vachellia karroo* communities described by Müller (2002) also showed similarity to the *Themeda triandra - Digitaria eriantha* Community. However, the main difference was that both *T. triandra* and *S.fimbriatus* were much more dominant in the *Themeda triandra - Digitaria eriantha* Community

In the central Free State, plant communities dominated by *Vachellia karroo* usually occur along drainage lines. However, they can also form a riparian fringe further away from streams (Müller, 2002). The *Eragrostis lehmanniana - Vachellia karroo* Community described by Müller (2002) was a typical example of where *V. karroo* invaded disturbed grassland. The area to the north-east of the *Themeda triandra - Digitaria eriantha* Community was also in visibly worse condition compared to the rest of this community due to the dominance of pioneer species in the herbaceous layer. There were also signs of bush encroachment by *V. karroo*, probably due to historical overgrazing by cattle. The *Themeda triandra - Digitaria eriantha* Community also resembled the *Vachellia karroo - Sporobolus fimbriatus* Thicket-grassland-transition described by Janecke (2011) on the Wag-'n-Bietjie Private Nature Reserve in the central Free State. Prominent species in both communities included: *V. karroo*, *Z. mucronata, A. laricinus*, *T. triandra* and *S. fimbriatus.*

Ordination results concur with the grouping of relevés into plant communities on the phytosociological table (Appendix 1). These results also indicated the related environmental variables of these communities and sub-communities.

3.5 CONCLUSION

The aims of this study were successfully accomplished as the vegetation in the study area was classified, described and mapped. The identified plant communities serve as the ecological basis for effective vegetation monitoring and wildlife management in the study area. The vegetation was also sufficiently diverse for both browsers and grazers to be accommodated in the area. However, to retain the diversity in the vegetation, monitoring of the herbaceous layer will be important to prevent overgrazing which could lead to further encroachment of *V. karroo*, especially in the *Themeda triandra - Digitaria eriantha* Community. Increasing numbers of *V. karroo* could result in this open shrubland transforming into a thicket area, reducing the grass cover in the herbaceous layer. This will in turn result in a reduction of the number of grazers that the study area could accommodate.

The *Buddleja saligna - Searsia burchellii* Community will be crucial for the survival of browsers as it was the only plant community dominated by evergreen woody species. These species will provide browsers with the only remaining food source during winter as most deciduous woody species in the area lose their leaves during this period. It is, however, crucial to keep in mind that the identification, description and mapping of plant communities were only the first steps in developing a management plan for sustainable utilisation and conservation of the study area. To determine the species composition and optimum numbers of wildlife that the study area can support, the grazing and browsing capacity and veld condition need to be evaluated first.

CHAPTER 4: AN ASSESSMENT OF THE ABUNDANCE OF POTENTIAL FOOD

4.1 INTRODUCTION

According to Owen-Smith (1979) "potential food" refers to all the food items that an animal might consume at some or other time, while "accepted food" refers to the actual food items the animal consumes at a particular point in time. The potential food abundance for any herbivore is determined by the available vegetation as well as the animals' digestive capabilities and body size (Owen-Smith, 1979).

The quality and quantity of food available to animals can vary considerably between seasons (Owen-Smith, 1979). Novellie (1983) found that the period of greatest food abundance in Kruger National Park was during the wet season from January to April, while the period of greatest food scarcity was during the dry season from August to mid-September. Browsers are possibly more affected than grazers by changes in the quantity of their food supply due to leaf fall occurring in deciduous trees (Owen-Smith, 1979).

From previous studies, kudu can be considered to be predominantly browsers, generally consuming very little or no grass (Wilson, 1965; Wilson, 1970; Conybeare, 1975; Giesecke & Van Gylswyk, 1975; Owen-Smith, 1979; Novellie, 1983; Owen-Smith *et al.*, 1983; Owen-Smith & Cooper 1985; du Toit, 1988; Owen-Smith & Cooper, 1989; Breebaart, 2000; Cerling *et al.*, 2003; Codron *et al.*, 2005a; Codron *et al.*, 2005b; Hooimeijer *et al.*, 2005; Codron *et al.*, 2007; Curlewis, 2014; Makhado *et al.*, 2016a; Makhado *et al.*, 2016b). The rumens of browsers have a relatively small capacity and are adapted for rapid food passage, while grazers have relatively large rumens designed for longer food retention. These adaptations are important as grass tends to be digested slower than browse. The digestive capability of kudu would thus limit them from accepting mature grass in their diet (Hofmann & Stewart 1972; Hofmann, 1973; Giesecke & Van Gylswyk 1975).

According to Novellie (1983), when an animal's maximum feeding height is known, along with general information on its diet, it is possible to estimate potential food abundance from appropriate vegetation sampling. Considerable overlap between the feeding height-ranges of kudu (*Tragelaphus strepsiceros*), impala (*Aepyceros melampus*) and steenbok (*Raphicerus campestris*) were found in Kruger National Park, although little overlap occurred between the feeding height-ranges of giraffe (*Giraffa camelopardalis*) and the other three species. Giraffe spent the majority of their feeding time browsing above 2.0 m, while the other species spent almost all their feeding time foraging below 2.0 m (du Toit, 1988; du Toit, 1990a). Giraffe, however, did spend 45% of their feeding time below 2 m in Willem Pretorius Game Reserve (Kok & Opperman, 1980). Despite overlaps occurring in feeding height-ranges, the potential food available to browsers usually increases with their body size as they can reach vegetation at higher levels compared to smaller browsers. In Kruger National Park, for example, giraffe had maximum feeding heights of about 4.5 m, while smaller browsers like kudu, impala and steenbok could only reach maximum feeding heights of about 2 m, 1.5 m and 1 m, respectively (du Toit, 1988; du Toit, 1990a).

Food availability of browsers is also greatly affected by bite size selection, with bite diameters generally increasing with the body size of the animal (Wilson & Kerley, 2003). Plant spinescence is another factor that can limit the amount of food available to browsers by restricting their foraging style and in turn limiting the bite diameters they are able to crop (Wilson, 2002). According to Wilson (2002), browsers altered their feeding style after thorn removal, from mostly front bites (removing single leaves or leaf clusters) to cheek bites (cropping terminal sections of stems with their molars).

Likewise, kudu bite sizes in the Nylsvley Nature Reserve were mostly restricted to single leaves or leaf clusters due to plant spinescence. By contrast, kudu utilised both leaves and shoot ends from unarmed species. Straight thorns were also more effective in preventing shoot bites from kudu compared to hooked thorns. However, newly formed thorns that were not fully hardened did not prevent shoot bites from kudu (Cooper & Owen-Smith, 1986). Reduced maximum bite diameters due to plant spinescence were also found during experimental feeding trials on captive browsers in the Eastern Cape. It is thus important to incorporate bite size selection in the management of wildlife as it provides a better measure of food availability as perceived by browsers (Wilson & Kerley, 2003).

The specific objectives of this chapter were:

1. To quantify the density and browse production of woody species in the study area;

2. To quantify the leaf phenology of woody species in the study area;

3. To quantify the woody browse available to kudu in the study area;

4. To calculate the browsing capacity in each of the plant communities and the study area as a whole;

5. To determine the botanical composition and veld condition of the herbaceous layer in each of the plant communites;

6. To calculate the grazing capacity in each of the plant communites and the study area as a whole;

7. To determine if current stocking density exceeded carrying capacity; and

8. To determine the amount of dry feed supplied to wildlife in the study area.

4.2 METHODOLOGY

4.2.1 Quantification of the woody layer

4.2.1.1 Species composition, density and browse production of woody species

The location of plant survey plots were identified by creating a grid index overlaid on a map of the study area using ArcMap Version 10.4 (Figure 4.1). Each grid block covered an area of 22 500 m^2 (150 x 150 m). The centroid of each grid block was then calculated with ArcMap 10.4 and GPS coordinates of each centroid used to locate those specific points. Grid blocks with centroids outside of the boundary fence were excluded from the survey. Two belt transects with dimensions of 50 x 2.5 m (125 m^2) were placed in each of the grid blocks with their starting points located at the centroid. This was done to confidently fit a 100 x 2.5 m (250 m^2) transect into each grid block without crossing into an adjacent block. The two 50 x 2.5 m transects were, whenever possible, placed in opposite directions to one another (Janecke, 2011).

The dimensions of all rooted, live trees and shrubs above 0.5 m were measured in the two 50 x 2.5 m (125 m^2) belt transects of each grid block. The measurements were taken from March to May 2014 and included the following: (i) maximum tree height, (ii) height where the maximum canopy diameter occurs, (iii) height of first leaves or potential leaf bearing stems, (iv) maximum canopy diameter, and (v) base diameter of the foliage at the height of the first leaves (Smit, 1989a; Smit 1989b; Smit, 1996). Data recorded in each grid block was allocated to one of the four plant communities as described in Chapter 3. This was done by overlaying the grid index and centroids of each grid block on the vegetation map of the study area using ArcMap 10.4. The density (plants/ha), leaf volume (m^3/ha), leaf and shoot dry mass (kg/ha), evapotranspiration tree equivalents (ETTE/ha) and canopied subhabitat index (CSI) estimates of trees and shrubs were calculated for each plant community with the BECVOL 3-model (Biomass Estimates from Canopy Volume) (Smit 1989a, 1989b, 1994, 1996, 2014). This model is derived from the quantitative description of woody plant communities proposed by Smit (1989a, 1989b). It uses least square regression analysis that is based on the relationship between the spatial canopy volume and true leaf dry mass of trees and shrubs (Smit, 2014). The stratified estimates of leaf and shoot dry matter below 1.5 m, 2.0 m and 5.0 m were also calculated with the BECVOL 3-model in addition to total dry matter (Smit, 2014).
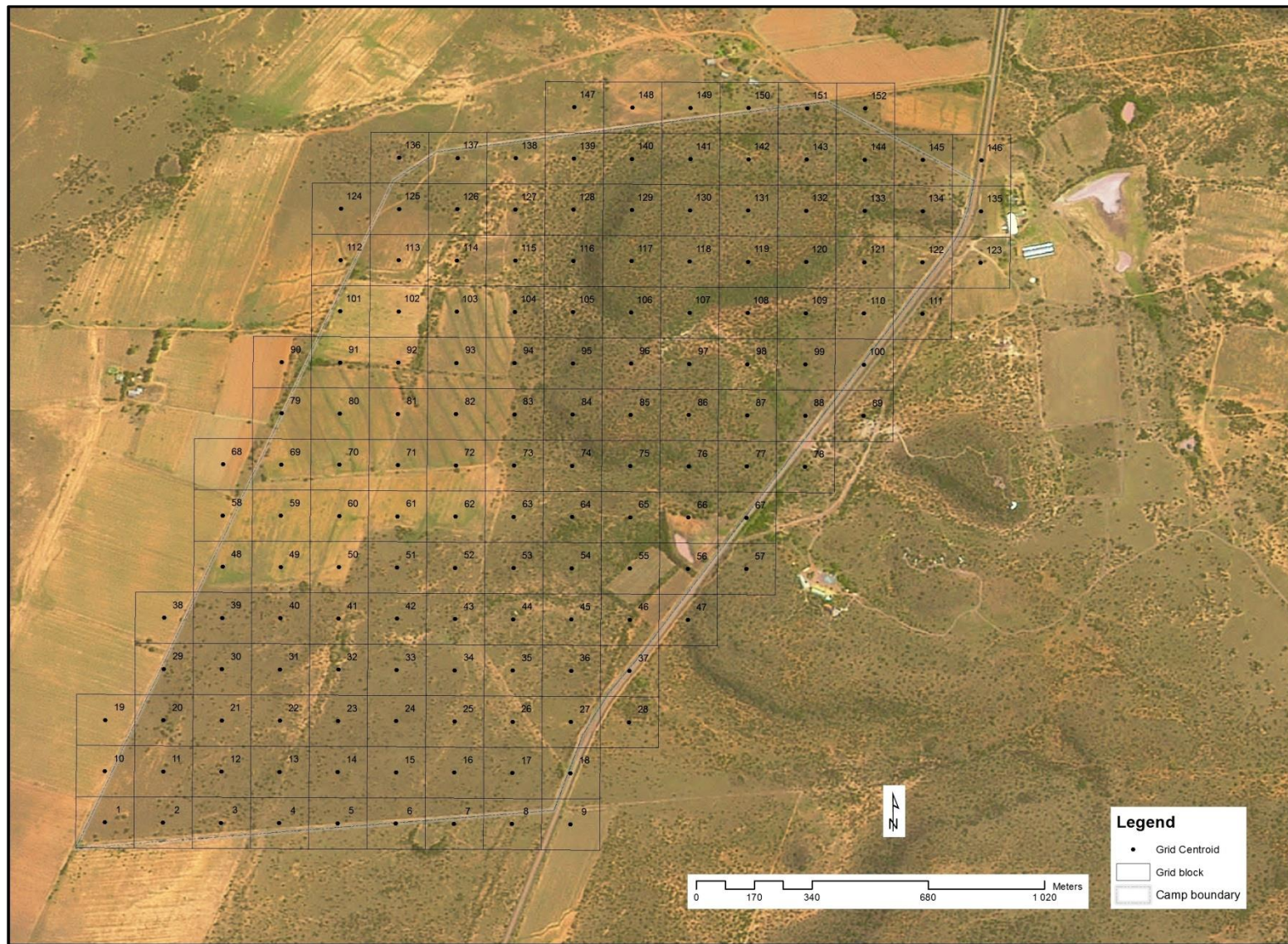
Figure 4.1 Map of the study area overlaid by a grid index. Each grid block covered an area of 22 500 m^2 (150 x 150 m)

The three heights of 1.5 m, 2.0 m and 5.0 m represent the mean maximum browsing height of impala (*Aepyceros melampus*), kudu (*Tragelaphus strepciseros*) and giraffe (*Giraffa camelopardalis*) (Dayton, 1978; du Toit, 1988; du Toit, 1990a), respectively. These feeding heights are referred to as the mean maximum feeding heights as they represent the maximum feeding height for most individuals of each species.

The following are all the values calculated with the BECVOL 3-model (Smit, 2014):

i)   Tree density (plants/ha);

ii)   Leaf volume (m³/ha);

iii)   Evapotranspiration Tree Equivalents (ETTE)/ha (an ETTE is defined as the leaf volume equivalent of a 1.5 m tree = 500 cm³);

iv)   Leaf dry mass below a browsing height of 1.5 m (kg DM/ha);

v)   Leaf dry mass below a browsing height of 2.0 m (kg DM/ha);

vi)   Leaf dry mass below a browsing height of 5.0 m (kg DM/ha);

vi)   Total leaf dry mass (kg DM/ha);

vii)   Shoot dry mass (shoots < 0.5 cm in diameter and below 1.5 m) (kg DM/ha);

viii)   Shoot dry mass (shoots < 0.5 cm in diameter and below 2.0 m) (kg DM/ha);

ix)   Shoot dry mass (shoots < 0.5 cm in diameter and below 5.0 m) (kg DM/ha);

x)   Total shoot dry mass (shoots < 0.5 cm in diameter) (kg DM/ha);

xi)   Total stem dry mass (stems > 0.5 – 2.0 cm in diameter) (kg DM/ha);

xii)   Total Wood dry mass (wood > 2.0 cm in diameter) (kg DM/ha);

xiii)   Total wood dry mass (all fractions) (kg DM/ha);

xiv)   Total dry mass (leaves and wood combined) (kg DM/ha);

xv)   Browse below 1.5 m (leaves and shoots < 0.5 cm in diameter) (kg DM/ha);

xvi)   Browse below 2.0 m (leaves and shoots < 0.5 cm in diameter) (kg DM/ha);

xvii)   Browse below 5.0 m (leaves and shoots < 0.5 cm in diameter) (kg DM/ha);

xviii)   Canopied Subhabitat Index (CSI) based on trees with a minimum height of 2 m (CSI is defined as the canopy spread area and is expressed as a percentage of the total transect area); and

xix)   Canopied Subhabitat Index (CSI) based on trees with a minimum height of 4 m.

4.2.1.2 Leaf phenology of woody species

Twenty plants from each of the sixteen dominant tree and shrub species in the study area were randomly selected and marked with white cable ties. The GPS locations of all the marked plants were also logged. All marked plants were then inspected on the 15th of each month from August 2012 to November 2014. During each observation the following leaf carriage scores were allocated to each of the marked plants: 1 = 1-15%; 2 = 16-40%; 3 = 41-70%; 4 = 71-90% and 5 = 91-100% of full leaf carriage. Leaves were also classified into different phenological states or phenophases, namely: Green Budding leaves (BL); Green Immature leaves (IL); Green Mature leaves (ML); Yellowing leaves (YL) and Dry senescing leaves (DL). The total leaf carriage score of each plant was then subdivided according to the estimate of each phenological state present. For example, a total leaf carriage score of 4 may have consisted of 1 BL and 3 IL (Dekker & Smit, 1996; Janecke, 2011; Janecke & Smit, 2011).

Data was collected over a 28 month period from August 2012 to November 2014. A monthly median value for each phenological state of the 20 marked plants of all 16 woody species was calculated. The sum total of these median values was then calculated for each of the woody species and indicated as a leaf carriage score ranging from zero (totally bare) to five (maximum leaf carriage) (Dekker & Smit, 1996; Janecke 2011; Janecke & Smit, 2011). Spearman correlations were calculated between the leaf carriage scores of all 16 woody species and various monthly variables (rainfall, average temperature, minimum temperature, maximum temperature and daylight length). Pearson instead of Spearman correlation coefficients were used due to the presence of outliers in the data. The null-hypothesis that the Spearman correlation in question is zero was tested. Exact P-values were estimated using Monte Carlo simulation, with the estimated exact two-sided P-value reported.

Four deciduous species were further statistically analysed for differences in leaf carriage patterns. These four species were chosen because their availability greatly affected the diet preferences of kudu (see Chapter 5). The four species included were *Vachellia karroo, Ziziphus mucronata, Searsia ciliata* and *Ehretia alba*.

Leaf carriage scores of all 20 individual plants per species were treated as ordinal data. The period ranging from September 2012 to August 2013 was designated as year one, and the period ranging from September 2013 to August 2014 was designated as year two. The time frames for these two years were chosen to compare one full growing season with the next. The scores for year one were then compared to the scores for year two separately for each woody species by utilising a Cochran-Mantel-Haenszel chi-square test ("row mean score test"). This was done to test the null-hypothesis that the mean scores for year one and year two are the same. The two years were compared after stratifying the data by month (this still involves a single comparison between the two years, but includes adjusting the comparison for potential differences between months).

The monthly scores of *V. karroo* were separately compared as the leaf availability of this species was the most important factor governing kudu diet selection and food preferences (see Chapter 5). Comparisons were made by using the data for the full 28 month observation period. Pairwise comparisons of years by month were carried out using a Cochran-Mantel-Haenszel chi-square test ("row mean score test"), testing the null-hypothesis that the mean scores for the two months in question are the same.

The monthly scores of *V. karroo* were separately compared to those of *Z. mucronata*, *S. ciliata* and *E. alba*. Comparisons were made using a Cochran-Mantel-Haenszel chi-square test ("row mean score test"), testing the null-hypothesis that the mean scores for the two species in question are the same. In these comparisons, the data from January to May each year were not included as most trees had full or close to full leaf cover during this period. All the statistical analyses concerning leaf phenology of woody species were carried out using procedure FREQ of the SAS/STAT 13.1 software (SAS, 2013).

4.2.1.3 Woody browse available to kudu

Only woody browse up to 2.0 m was considered to be available to kudu in the current study even though some individuals could possibly have reached higher. Novellie (1983) recored a maximum feeding height of 2.1 m for kudu cows and a maximum feeding height of 2.3 m for kudu bulls in Kruger National Park. Du Toit (1990a) also found the maximum feeding height for kudu in Kruger National Park to be just above 2.0 m. Novellie (1983) concluded that it was unlikely that kudu could reach 2.5 m unless they reared up on their hind legs, or bulls used their horns to break branches in order to reach them. Including the woody browse above 2.0 m would have led to an overestimation of both food availability and carrying capacity for kudu. This is due to the fact that most individuals would not have been able to reach those heights, with kudu populations usually consisting of a much larger proportion of females and young bulls compared to mature bulls (Allen-Rowlandson, 1980).

According to Wilson & Kerley (2003), bite size selection should be included in the measurements of food availability for browsers. Maximum bite diameters of 5.17 mm and 6.80 mm were recorded for kudu in the Eastern Cape (Wilson & Kerley, 2003) and the Musina area, respectively (Curlewis, 2014). However, it was not stated in either of these studies whether kudu bulls or cows were responsible for the maximum bite diameters recorded. During experimental feeding trials on captive browsers in the Eastern Cape, kudu had larger bite diameters compared to the smaller bushbuck (*Tragelaphus scriptus*), common duiker (*Sylvicapra grimmia*) and blue duiker (*Philantomba monticola*), with bite diameter increasing with increasing body size (Wilson & Kerley, 2003). It was thus decided to only include shoots < 0.5 cm into the potential food available to kudu in the current study as bulls possibly have larger bite diameters compared to cows.

The available leaf dry mass up to 2.0 m was first calculated as kilogram dry mass per hectare (kg DM/ha) for each of the woody species per plant community (See section 4.2.1.1). The leaf dry mass of each woody species was then separately multiplied by the size (also in ha) of each specific plant communtiy. The products calculated per plant community were then summed separately for each of the woody species. These calculated values represented the leaf dry mass of each woody species available to kudu in the study area at full leaf cover.

However, due to the winter deciduous nature of several woody species, leaf availability changed throughout the year. To account for changes in leaf carriage, the leaf dry mass calculated for each of the woody species in the study area was adjusted with a calculated phenology factor for each month (See Table 4.10). As in the case of leaf dry mass, the available shoot dry mass (< 0.5 cm in diameter) up to 2.0 m was also calculated as kilogram dry mass per hectare for each of the woody species per plant community (See section 4.2.1.1). The shoot dry mass of each woody species was then separately multiplied by the size (ha) of each specific plant community. The products calculated per plant community were then summed separately for each of the woody species. The calculated values represented the shoot dry mass of each woody species available to kudu in the study area. Unlike leaf dry mass, these values did not change throughout the year.

To calculate the monthly woody browse available to kudu in the study area, the monthly leaf dry mass values was summed with shoot dry mass for each woody species separately. These monthly woody browse values were then divided into phases of food availability, with averages calculated for phases that included more than one month.

Phases of food availability was used instead of conventional seasons due to the fact that long term rainfall and temperature did not always accurately reflect the availability of food to browsers, especially as early flushing species produced new leaves before the wet season started and green leaves were retained longer into the dry season during warmer years. The following phases were accordingly recognised:

Dry phase: Mostly dry grass available, with predominantly yellow, dry or no leaves retained on deciduous trees and shrubs;

Flush phase: Mostly dry grass available, with predominantly green budding and immature leaves available on deciduous trees and shrubs;

Immature phase: Mostly green grass available, with predominantly green immature leaves available on deciduous trees and shrubs;

Mature phase: Mostly green grass available, with predominantly mature green leaves available on deciduous trees and shrubs; and

Senescent phase: Mostly yellow senescing grass available, with predominantly mature green and yellow senescing leaves retained on deciduous trees and shrubs.

4.2.1.4 Browsing capacity

The browsing capacity of each plant community was calculated separately for each month from September 2013 to September 2014 according to the following formula (Smit, 2006):

$y = d \div \{ [(DM_{1L} \times f_{1L} \times p_{1L}) + (DM_{1S} \times f_{1S}) + (DM_{2L} \times f_{2L} \times p_{2L}) + (DM_{2S} \times f_{2S}) + (DM_{3L} \times f_{3L} \times p_{1L}) + (DM_{3S} \times f_{3S}) + (DM_{xL} \times f_{xL} \times p_{xL}) (DM_{xS} \times f_{xS})...] /r \}$

where: y = hectares required per browser unit (ha/BU);

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

d = number of days in a year (365);

DM_{1L} = leaf DM/ha of species 1;

DM_{2L} = leaf DM/ha of species 2;

DM_{3L} = leaf DM/ha of species 3;

DM_{xL} = leaf DM/ha of species x;

…

f_{1L} = leaf utilization factor for species 1;

f_{2L} = leaf utilization factor for species 2;

f_{3L} = leaf utilization factor for species 3;

f_{xL} = leaf utilization factor for species x;

…

p_{1L} = leaf phenology of species 1;

p_{2L} = leaf phenology of species 2;

p_{3L} = leaf phenology of species 3;

p_{xL} = leaf phenology of species x;

…

DM_{1S} = shoot < 0.5 cm DM/ha of species 1;

DM_{2S} = shoot < 0.5 cm DM/ha of species 2;

DM_{3S} = shoot < 0.5 cm DM/ha of species 3;

DM_{xS} = shoot < 0.5 cm DM/ha of species x;

...

f_{1S} = shoot < 0.5 cm utilization factor for species 1;

f_{2S} = shoot < 0.5 cm utilization factor for species 2;

f_{3S} = shoot < 0.5 cm utilization factor for species 3;

f_{xS} = shoot < 0.5 cm utilization factor for species x; and

...

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

Utilisation factors were based on the criteria that animals will not remove all the available leaves and shoots < 0.5 cm. Utilisation factors thus represented the part of the available browse material (leaves and shoots < 0.5 cm) that could be consumed by animals. This ensured the survival of palatable plant species by allowing them time to recover after being utilised. Diet and feeding preferences of kudu in the study area (see Chapter 5) were also taken into account when assigning utilisation factors. Accordingly, utilisation factors ranging from 0.5 (50%) to 0.1 (10%) were used for leaves and utilisation factors ranging from 0.05 (5%) to 0.20 (20%) were used for shoots < 0.5 cm. The estimated leaf phenology percentages were derived from mean monthly leaf carriage scores of woody species in the study area.

4.2.2 Quantification of the herbaceous layer

4.2.2.1 Species composition and veld condition assessment

The species composition of the herbaceous layer was determined according to the nearest plant method that is based on frequency of occurrence (Everson & Clarke 1987; Smit & Rethman 1999). Two hundred point-observations were recorded in line transects along the borders of each belt transect used in the quantification of the woody layer (see Section 4.2.1.1). Points were spaced 1 m apart, with the herbaceous plant (grass, dwarf karroid shrub or forb) closest to each point recorded. All grasses and dwarf shrubs were identified to species level, while forbs were grouped together. In all readings "bare soil" was recorded when no herbaceous plant occurred within 30 cm of the specific point. When a rock covered the 30 cm radius from a specific point it was recorded as such as it prevented plants from growing there.

The recorded data from each line transect (200 points per transect) was allocated to one of the four plant communities as described in Chapter 3. The proportional contribution of each species was then calculated per plant community. After calculating the proportional contribution of each species, the veld condition of each plant community was assessed according to the Ecological Index Method (Vorster, 1982). For the assessment, all the herbaceous species recorded were classified into the following five ecological groups (Foran *et al.*, 1978; Tainton *et al.*, 1980; Vorster, 1982):

Decreasers: These species are dominant in veld in excellent condition, but decrease when veld is over- or under- grazed;

Increaser 1a: These species increase when veld is moderately undergrazed. This group is usually made up of unpalatable climax species that are able to grow without any defoliation;

Increaser 2a: These species are rare in veld in excellent condition, but increases when veld is moderately overgrazed in the long term. The increase of this group of species usually coincides with the decrease of Decreasers. The sub-climax and dis-climax grasses, palatable karoo bushes and taller shrubs belong to this group. Veld can be ecologically classified into a good to fair condition when these species dominate;

Increaser 2b: These species are rare in veld in excellent condition, but increases when veld is heavily overgrazed for a period of time. The decrease of increaser 2a species usually corresponds with the increase of this group. Perennial pioneer grasses as well as less palatable karoo bushes and taller shrubs are classified into this group. Veld in general fair to poor condition is dominated by this group; and

Increaser 2c: These species are rare in veld in excellent condition, but increases when veld is excessively overgrazed in the long term. This group increases when Increaser 2b species decrease. This group is mostly made up of rain-dependant annual grasses, ephemerals, hardy unpalatable karoo bushes, taller shrubs and poisonous plants. Veld dominated by this group is usually in fair to poor condition.

The following relative index values were assigned to each ecological group: Decreasers = 10; Increasers 1a and 2a = 7; Increasers 2b = 4; and Increaser 2c = 1 (Vorster, 1982). The veld condition score was calculated by multiplying the percentage contributions of each species with their relative index value. The sum of these products represents the veld condition score, with a theoretical maximum of 1 000 (100% Decreasers) and theoretical minimum of 100 (100% Increaser 2c species). The veld condition score was then converted to a veld condition index, expressed as a percentage of the veld benchmark (Van Rooyen, 2010b). The line transect with the highest veld condition score in each plant community was chosen as the veld benchmark as recommended by Van Rooyen (2010b).

The veld condition index values were then divided into the following proportional veld condition classes: 0 – 20% indicating veld in very poor condition; > 20 – 40% indicating veld in poor condition; > 40 – 60% indicating veld in fair condition; > 60 – 80% indicating veld in good condition; and > 80 – 100% indicating veld in excellent condition (Vorster, 1982).

4.2.2.2 Grazing capacity

The grazing capacity of each plant community was calculated with the equation used in the Grazer Unit method (Bothma *et al.*, 2004):

GU/100 ha = 0.547 x { [c + (r – 419) x 0.23] x a x f x ($\log_{10}g$ - 1) $^{0.4}$ }

where: GU/100ha = grazing capacity in Grazer Units (GU) per 100 ha;

GU = metabolic equivalent of a blue wildebeest with an average body mass of 180 kg;

c = the veld condition index (%);

r = the mean annual rainfall over the past two years in the study area (mm);

a = a topography index of accessibility on a scale of 0.1 – 1.0, with 1.0 = fully accessible;

f = a fire factor on a scale of 0.8 – 1.0, with 0.8 recent fire and 1.0 = the absence of fire; and

g = the percentage grass cover.

4.2.3 Stocking density at current carrying capacity

To determine if the current stocking density exceeded the carrying capacity, the animal numbers of each species were converted into grazer and browser units by using their relative body weights, diets and daily food intake (Smit, 2006). Substitution values for the different species to be stocked were first calculated according to Smit (2006) and presented in Table 4.1. The following norms were used in these calculations: A grazer unit (GU) is defined as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean body mass of 180 kg and a browser unit (BU) defined as the metabolic equivalent of a kudu (100% browser) with a mean body mass of 140 kg (Dekker, 1997). The daily food requirements of a GU was calculated as 4.5 kg (2.5% of body mass for a blue wildebeest) and the daily food requirements of a BU calculated as 3.5 kg (2.5% of body mass for a kudu) (Owen-Smith, 1988; Owen-Smith, 1999; Smit, 2006).

The following is an example of how to calculate the substitution values for nyala with a mean body mass of 73 kg, a diet consisting of 20% grass and 80% browse and daily food intake of 1.90 kg (2.6% of its body mass):

(Daily food intake of an nyala x grass in diet) / Daily food intake of a blue wildebeest)

(1.90 x 0.2) / 4.5 = 0.08 GU equivalents

(Daily food intake of an nyala x browse in diet) / Daily food intake of a kudu)

(1.90 x 0.80) / 3.5 = 0.43 BU equivalents

Table 4.1 Substitution values calculated for the different game species present in the study area

GAME SPECIES	Mean body mass (kg)[a]	Daily food intake (% of mass)[b]	% grass in diet[c]	% browse in diet[c]	Grazer unit equivalents[d]	Browser unit equivalents[e]
Blue wildebeest	180	2.5	87	13	0.87	0.17
Bontebok	60	2.8	90	10	0.34	0.05
Fallow deer	45	2.7	50	50	0.14	0.17
Greater kudu	140	2.5	15	85	0.12	0.85
Hartmann's mountain zebra	240	4.1	95	5	2.08	0.14
Impala	41	2.7	45	55	0.11	0.17
Nyala	73	2.6	20	80	0.08	0.43
Waterbuck	205	2.8	84	16	1.07	0.26

[a] The mean body mass of game species represents all ages and sexes in the population (Van Rooyen, 2010b; McElligott *et al.*, 2001).

[b] The daily food intake rates are the same as those used by Smit (2006).

[c] The diets of all the game species are the same as those used in Van Rooyen (2010b), except for fallow deer diet from Chaudhary (1985).

[d] A grazer unit (GU) is defined as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean body mass of 180 kg (Dekker, 1997).

[e] A browser unit (BU) is defined as the metabolic equivalent of a kudu (100 % browser) with a mean body mass of 140 kg (Dekker, 1997).

After calculating the substitution values, the number of each species present in the study area was multiplied by their relavent substitution values to determine the number of grazer and browser units required for the animals stocked.

4.2.4 Dry feed

The dry feed supplied to wildlife consisted of a mixture of grass (*Digitaria eriantha*), lucerne, maize meal and molasses. Feed was supplied in four rectangular feeding troughs (Figure 4.2), which were placed and left at permanent locations in the study area during feeding periods. Staff members working on the game reserve mixed the feed and placed it in large bags after which it was transported to the feeding troughs. The staff members delivering the feed recorded the date, time and amount of feed supplied at each trough. In order to calculate the weight of dry feed supplied, the average weight of one bag (19.09 kg) was multiplied by all the bags fed on a specific day, month or year. Ten bags full of dry feed were weighed to determine the average weight of one bag. Data of dry feed supplied was only presented as descriptive statistics.

4.3   RESULTS

4.3.1 Quantification of the woody layer

4.3.1.1 Species composition, density and browse production of woody species

A total of 23 woody species were recorded in the study area from 1 696 measured woody plants in 122 belt transects. A list of all the recorded woody species is presented in Table 4.2. According to a grid index overlaid on a vegetation map of the study area, 57 transects were situated in the *Buddleja saligna - Searsia burchellii* Community, 42 situated in the *Themeda triandra - Digitaria eriantha* Community, 21 situated in the *Digitaria eriantha - Cynodon dactylon* Community and two situated in the *Persicaria lapathifolia - Panicum coloratum* Community. The number of woody plants per hectare in each of the plant communites is presented in Table 4.3.

Figure 4.2 Feeding trough (3 x 0.5 x 0.5 m) with dry feed supplied

Table 4.2 List of all the species recorded in the survey of the woody layer

SCIENTIFIC NAME	COMMON NAME
FAMILY: Asparagaceae	
Asparagus laricinus	-
Asparagus suaveolens	-
FAMILY: Capparaceae	
Boscia albitrunca	Shepherd's tree
FAMILY: Buddlejaceae	
Buddleja saligna	False Olive
FAMILY: Araliaceae	
Cussonia paniculata	Highveld Cabbage tree
FAMILY: Ebenaceae	
Diospyros austro-africanum	Star-apple
Diospyros lycioides	Bluebush
Euclea crispa subsp. *ovata*	Blue guarri
Euclea crispa subsp. *crispa*	Blue guarri
FAMILY: Boraginaceae	
Ehretia alba	White puzzle bush
FAMILY: Tiliaceae	
Grewia occidentalis	Cross-berry
FAMILY: Celastraceae	
Gymnosporea karroica	-
FAMILY: Solanaceae	
Lycium hirsutum	-
FAMILY: Oleaceae	
Olea europaea subsp. *africana*	Wild olive
FAMILY: Santalaceae	
Osyris lanceolata	Bark Bush
FAMILY: Bigoniaceae	
Rhigozum obovatum	Yellow pomegranate
FAMILY: Anacardiaceae	
Searsia burchellii	Karoo kuni-bush
Searsia ciliata	Sour karee
Searsia lancea	Karee
Searsia pyroides	Common wild currant
FAMILY: Asteraceae	
Tarchonanthus camphoratus	Wild camphor bush
FAMILY: Fabaceae	
Vachellia karroo	Sweet thorn
FAMILY: Rhamnaceae	
Ziziphus mucronata	Buffalo-thorn

Table 4.3 Woody plant density (plants/ha) recorded in each of the identified plant communites

SCIENTIFIC NAME	PLANT COMMUNITY			
	Buddleja saligna – Searsia burchellii Community	*Themeda triandra – Digitaria eriantha* Community	*Digitaria eriantha – Cynodon dactylon* Community	*Persicaria lapathifolia - Panicum coloratum* Community
Asparagus laricinus	5	49	0	0
Asparagus suaveolens	25	11	0	0
Boscia albitrunca	2	0	0	0
Buddleja saligna	118	0	0	0
Cussonia paniculata	2	0	0	0
Diospyros austro-africanum	2	0	0	0
Diospyros lycioides	10	10	2	0
Ehretia alba	21	0	0	0
Euclea crispa subsp. *ovata*	10	0	0	0
Euclea crispa subsp. *crispa*	2	0	0	0
Grewia occidentalis	19	0	0	0
Gymnosporea karroica	3	0	0	0
Lycium hirsutum	0	6	0	0
Olea europaea subsp. *africana*	74	0	0	0
Osyris lanceolata	1	0	0	0
Rhigozum obovatum	45	0	0	0
Searsia burchellii	90	2	2	0
Searsia ciliata	150	91	0	0
Searsia lancea	6	10	2	0
Searsia pyroides	0	8	0	0
Tarchonanthus camphoratus	191	2	0	0
Vachellia karroo	45	168	61	0
Ziziphus mucronata	12	19	0	0
Totals	**833**	**376**	**67**	**0**

The highest woody plant density per hectare was recorded in the *Buddleja saligna - Searsia burchellii* Community, followed by the *Themeda triandra - Digitaria eriantha* Community and the *Digitaria eriantha - Cynodon dactylon* Community. No woody species were recorded in the *Persicaria lapathifolia - Panicum coloratum* Community. The total number of woody plants with their percentage availability in each plant community and in the study area as a whole is presented in Table 4.4. In terms of individual plants, the dominant woody species recorded in the *Buddleja saligna - Searsia burchellii* Community were *Tarchonathus camphoratus*, *S. ciliata* and *Buddleja saligna*, while *Searsia burchellii* and *Olea europaea* subsp. *africana* were also abundant. The *Themeda triandra - Digitaria eriantha* Community was dominated by *V. karroo* followed by *S. ciliata* and *Asparagus laricinus*. The only dominant woody species recorded in the *Digitaria eriantha - Cynodon dactylon* Community was *V. karroo*. When combining the plant communities, the woody species with the highest overall numbers in the study area were *S. ciliata*, closely followed by *T. camphoratus* and *V. karroo*. Other woody species found in high numbers were *B. saligna, S. burchellii* and *O. europaea* subsp. *africana.*

The number of Evapotranaspiration Tree Equivalents per hectare (ETTE/ha) in each of the plant communities is presented in Table 4.5, where one ETTE equals the mean leaf volume of a single stemmed tree of 1.5 m = 500 cm³ leaf volume (Smit, 1989a). The *Buddleja saligna - Searsia burchellii* Community had the higest number ETTE/ha followed by the *Themeda triandra - Digitaria eriantha* Community and the *Digitaria eriantha - Cynodon dactylon* Community. *Searsia burchellii* and *O. europaea* subsp. *africana* contributed the most ETTE/ha in the *Buddleja saligna - Searsia burchellii* Community, followed by *B. saligna* and *T. camphoratus*. *Vachellia karroo* contributed the most ETTE/ha in the *Themeda triandra - Digitaria eriantha* Community, while *Searsia lancea* and *Z. mucronata* contributed the second and third most, respectively. With very little other woody species available in the *Digitaria eriantha - Cynodon dactylon* Community, *V. karroo* contributed the most ETTE/ha. The dry mass of leaves, shoots (< 0.5 cm) and browse (leaves + shoots < 0.5 cm) per hectare is presented in Tables 4.6 – 4.8. Dry mass of the different components were compared up to three different feeding heights (1.5 m, 2.0 m and 5.0 m), while trees were taken to be at full leaf cover. The *Buddleja saligna - Searsia burchellii* Community had the most leaves, shoots and browse available per hectare followed by the *Themeda triandra - Digitaria eriantha* Community and the *Digitaria eriantha - Cynodon dactylon* Community. The woody species contributing the highest amount of dry mass of all three components up to 1.5 and 2.0 m in the *Buddleja saligna - Searsia burchellii* Community was *S. burchellii,* while *T. camphoratus* contributed the second highest amount at both these feeding levels. When taking dry mass up to 5.0 m into account, *S. burchellii* still contributed the most, but was closely followed on this occasion by *O. europaea* subsp. *africana.*

Table 4.4 Total number of plants of each recorded woody species available in the study area

| SCIENTIFIC NAME | PLANT COMMUNITY | | | | | | | | STUDY AREA (274.08 ha) | |
| | *Buddleja saligna - Searsia burchellii* Community (131.49 ha) | | *Themeda triandra - Digitaria eriantha* Community (95.74 ha) | | *Digitaria eriantha – Cynodon dactylon* Community (44.87 ha) | | *Persicaria lapathifolia - Panicum coloratum* Community (1.98 ha) | | | |
	Number	%	Number	%	Number	%	Number	%	Number	%
Asparagus laricinus	657	0.60	4 691	13.03	0	0.00	0	0.00	5 348	3.60
Asparagus suaveolens	3 287	3.00	1 053	2.93	0	0.00	0	0.00	4 340	2.92
Boscia albitrunca	263	0.24	0	0.00	0	0.00	0	0.00	263	0.18
Buddleja saligna	15 516	14.17	0	0.00	0	0.00	0	0.00	15 516	10.45
Cussonia paniculata	263	0.24	0	0.00	0	0.00	0	0.00	263	0.18
Diospyros austro-africanum	263	0.24	0	0.00	0	0.00	0	0.00	263	0.18
Diospyros lycioides	1 315	1.20	957	2.66	90	2.99	0	0.00	2 362	1.59
Ehretia alba	2 761	2.52	0	0.00	0	0.00	0	0.00	2 761	1.86
Euclea crispa subsp. *ovata*	1 315	1.20	0	0.00	0	0.00	0	0.00	1 315	0.86
Euclea crispa subsp. *crispa*	263	0.24	0	0.00	0	0.00	0	0.00	263	0.18
Grewia occidentalis	2 498	2.28	0	0.00	0	0.00	0	0.00	2 498	1.68
Gymnosporea karroica	394	0.36	0	0.00	0	0.00	0	0.00	394	0.27
Lycium hirsutum	0	0.00	574	1.59	0	0.00	0	0.00	574	0.39
Olea europaea subsp. *africana*	9 730	8.88	0	0.00	0	0.00	0	0.00	9 730	6.55
Osyris lanceolata	131	0.12	0	0.00	0	0.00	0	0.00	131	0.09
Rhigozum obovatum	5 917	5.40	0	0.00	0	0.00	0	0.00	5 917	3.98
Searsia burchellii	11 834	10.80	191	0.53	90	2.99	0	0.00	12 115	8.16
Searsia ciliata	19 724	18.01	8 712	24.20	0	0.00	0	0.00	28 436	19.14
Searsia lancea	789	0.72	957	2.66	90	2.99	0	0.00	1 836	1.24
Searsia pyroides	0	0.00	766	2.13	0	0.00	0	0.00	766	0.52
Tarchonanthus camphoratus	25 115	22.93	191	0.53	0	0.00	0	0.00	25 306	17.04
Vachellia karroo	5 917	5.40	16 084	44.68	2 737	91.02	0	0.00	24 738	16.65
Ziziphus mucronata	1 578	1.44	1 819	5.05	0	0.00	0	0.00	3 397	2.29
Totals	**109 530**	**100**	**35 995**	**100**	**3 007**	**100**	**0**	**100**	**148 532**	**100**

Table 4.5 Evapotranspiration Tree Equivalents per hectare (ETTE/ha) in each plant community

SCIENTIFIC NAME	PLANT COMMUNITY			
	Buddleja saligna – Searsia burchellii Community	*Themeda triandra – Digitaria eriantha* Community	*Digitaria eriantha – Cynodon dactylon* Community	*Persicaria lapathifolia - Panicum coloratum* Community
Asparagus laricinus	10	40	0	0
Asparagus suaveolens	15	5	0	0
Boscia albitrunca	6	0	0	0
Buddleja saligna	912	0	0	0
Cussonia paniculata	27	0	0	0
Diospyros austro-africanum	1	0	0	0
Diospyros lycioides	178	21	1	0
Ehretia alba	84	0	0	0
Euclea crispa subsp. *ovata*	7	0	0	0
Euclea crispa subsp. *crispa*	14	0	0	0
Grewia occidentalis	127	0	0	0
Gymnosporea karroica	2	0	0	0
Lycium hirsutum	0	11	0	0
Olea europaea subsp. *africana*	1 904	0	0	0
Osyris lanceolata	2	0	0	0
Rhigozum obovatum	177	0	0	0
Searsia burchellii	2 061	19	25	0
Searsia ciliata	108	53	0	0
Searsia lancea	114	243	16	0
Searsia pyroides	0	25	0	0
Tarchonanthus camphoratus	754	2	0	0
Vachellia karroo	168	1 267	160	0
Ziziphus mucronata	39	119	0	0
Totals	**6 710**	**1 805**	**202**	**0**

Table 4.6 Available leaf dry mass up to three different feeding heights at full leaf cover (kg DM/ha)

SCIENTIFIC NAME	PLANT COMMUNITY											
	Buddleja saligna – Searsia burchellii Community			*Themeda triandra – Digitaria eriantha* Community			*Digitaria eriantha – Cynodon dactylon* Community			*Persicaria lapathifolia - Panicum coloratum* Community		
	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m
Asparagus laricinus	2	2	2	9	9	9	0	0	0	0	0	0
Asparagus suaveolens	3	3	3	1	1	1	0	0	0	0	0	0
Boscia albitrunca	1	1	1	0	0	0	0	0	0	0	0	0
Buddleja saligna	34	63	200	0	0	0	0	0	0	0	0	0
Cussonia paniculata	0	0	6	0	0	0	0	0	0	0	0	0
Diospyros austro-africanum	0	0	0	0	0	0	0	0	0	0	0	0
Diospyros lycioides	5	13	40	3	4	5	0	0	0	0	0	0
Ehretia alba	6	12	19	0	0	0	0	0	0	0	0	0
Euclea crispa subsp. *ovata*	1	1	1	0	0	0	0	0	0	0	0	0
Euclea crispa subsp. *crispa*	0	1	3	0	0	0	0	0	0	0	0	0
Grewia occidentalis	2	4	27	0	0	0	0	0	0	0	0	0
Gymnosporea karroica	0	0	0	0	0	0	0	0	0	0	0	0
Lycium hirsutum	0	0	0	2	3	3	0	0	0	0	0	0
Olea europaea subsp. *africana*	41	91	419	0	0	0	0	0	0	0	0	0
Osyris lanceolata	0	0	0	0	0	0	0	0	0	0	0	0
Rhigozum obovatum	10	19	41	0	0	0	0	0	0	0	0	0
Searsia burchellii	146	220	454	2	3	4	2	3	5	0	0	0
Searsia ciliata	23	24	24	12	12	12	0	0	0	0	0	0
Searsia lancea	1	2	20	3	9	51	0	1	3	0	0	0
Searsia pyroides	0	0	0	4	5	5	0	0	0	0	0	0
Tarchonanthus camphoratus	81	118	166	0	0	0	0	0	0	0	0	0
Vachellia karroo	3	10	37	37	78	265	10	16	35	0	0	0
Ziziphus mucronata	3	5	9	8	14	23	0	0	0	0	0	0
Totals	**362**	**589**	**1 472**	**81**	**138**	**378**	**12**	**20**	**43**	**0**	**0**	**0**

Table 4.7 Available shoots dry mass (< 0.5 cm in diameter) up to three different feeding heights (kg DM/ha)

SCIENTIFIC NAME	PLANT COMMUNITY											
	Buddleja saligna – Searsia burchellii Community			*Themeda triandra – Digitaria eriantha* Community			*Digitaria eriantha – Cynodon dactylon* Community			*Persicaria lapathifolia - Panicum coloratum* Community		
	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m
Asparagus laricinus	2	2	2	7	7	7	0	0	0	0	0	0
Asparagus suaveolens	3	3	3	1	1	1	0	0	0	0	0	0
Boscia albitrunca	1	1	1	0	0	0	0	0	0	0	0	0
Buddleja saligna	32	55	176	0	0	0	0	0	0	0	0	0
Cussonia paniculata	0	1	5	0	0	0	0	0	0	0	0	0
Diospyros austro-africanum	0	0	0	0	0	0	0	0	0	0	0	0
Diospyros lycioides	4	12	37	2	3	4	0	0	0	0	0	0
Ehretia alba	5	10	16	0	0	0	0	0	0	0	0	0
Euclea crispa subsp. *ovata*	1	1	1	0	0	0	0	0	0	0	0	0
Euclea crispa subsp. *crispa*	0	1	3	0	0	0	0	0	0	0	0	0
Grewia occidentalis	38	52	127	0	0	0	0	0	0	0	0	0
Gymnosporea karroica	0	0	0	0	0	0	0	0	0	0	0	0
Lycium hirsutum	0	0	0	2	2	2	0	0	0	0	0	0
Olea europaea subsp. *africana*	39	84	388	0	0	0	0	0	0	0	0	0
Osyris lanceolata	0	0	0	0	0	0	0	0	0	0	0	0
Rhigozum obovatum	10	18	41	0	0	0	0	0	0	0	0	0
Searsia burchellii	137	205	424	2	2	4	1	2	5	0	0	0
Searsia ciliata	19	19	19	9	9	9	0	0	0	0	0	0
Searsia lancea	1	3	18	2	8	48	0	1	3	0	0	0
Searsia pyroides	0	0	0	3	4	5	0	0	0	0	0	0
Tarchonanthus camphoratus	69	101	144	0	0	0	0	0	0	0	0	0
Vachellia karroo	4	9	32	36	68	237	8	14	31	0	0	0
Ziziphus mucronata	2	4	7	7	12	20	0	0	0	0	0	0
Totals	**367**	**581**	**1 444**	**71**	**116**	**337**	**9**	**17**	**39**	**0**	**0**	**0**

Table 4.8 Available woody browse (leaves + shoots < 0.5 cm) up to three different feeding heights at full leaf cover (kg DM/ha)

SCIENTIFIC NAME	PLANT COMMUNITY											
	Buddleja saligna – Searsia burchellii Community			*Themeda triandra – Digitaria eriantha* Community			*Digitaria eriantha – Cynodon dactylon* Community			*Persicaria lapathifolia - Panicum coloratum* Community		
	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m
Asparagus laricinus	4	4	4	16	16	16	0	0	0	0	0	0
Asparagus suaveolens	6	6	6	2	2	2	0	0	0	0	0	0
Boscia albitrunca	2	2	2	0	0	0	0	0	0	0	0	0
Buddleja saligna	66	119	376	0	0	0	0	0	0	0	0	0
Cussonia paniculata	0	1	11	0	0	0	0	0	0	0	0	0
Diospyros austro-africanum	0	0	0	0	0	0	0	0	0	0	0	0
Diospyros lycioides	9	25	76	5	7	9	0	0	0	0	0	0
Ehretia alba	11	21	35	0	0	0	0	0	0	0	0	0
Euclea crispa subsp. *ovata*	2	3	3	0	0	0	0	0	0	0	0	0
Euclea crispa subsp. *crispa*	1	1	6	0	0	0	0	0	0	0	0	0
Grewia occidentalis	40	56	153	0	0	0	0	0	0	0	0	0
Gymnosporea karroica	1	1	1	0	0	0	0	0	0	0	0	0
Lycium hirsutum	0	0	0	4	5	5	0	0	0	0	0	0
Olea europaea subsp. *africana*	80	175	807	0	0	0	0	0	0	0	0	0
Osyris lanceolata	0	1	1	0	0	0	0	0	0	0	0	0
Rhigozum obovatum	20	37	81	0	0	0	0	0	0	0	0	0
Searsia burchellii	282	424	878	4	5	8	3	5	10	0	0	0
Searsia ciliata	41	43	43	21	21	21	0	0	0	0	0	0
Searsia lancea	2	5	38	5	17	99	0	1	6	0	0	0
Searsia pyroides	0	0	0	7	9	10	0	0	0	0	0	0
Tarchonanthus camphoratus	151	218	310	1	1	1	0	0	0	0	0	0
Vachellia karroo	8	19	69	73	145	502	18	30	66	0	0	0
Ziziphus mucronata	5	9	16	15	25	43	0	0	0	0	0	0
Totals	**731**	**1 170**	**2 916**	**153**	**253**	**716**	**21**	**36**	**82**	**0**	**0**	**0**

Vachellia karroo contributed the higest dry mass up to 1.5 m in the *Themeda triandra - Digitaria eriantha* Community. The second highest dry mass at this feeding height was provided by *S. ciliata*. This changed when taking dry mass up to 2.0 m into account, with *V. karroo* contributing the most followed by *Z. mucronata*. At 5.0 m, *V. karroo* still contributed the highest dry mass, but in this case *S. lancea* provided the second highest dry mass followed by *Z. mucronata*. In the *Digitaria eriantha - Cynodon dactylon* Community only *V. karroo* contributed meaningfully to the leaf dry mass up to all three feeding heights.

4.3.1.2 Leaf phenology of woody species

Woody species were classified as either deciduous or evergreen species according to their leaf carriage patterns. Species that lost all their leaves at some or other time were classified as deciduous species, while species that retained most of their leaves were classified as evergreen. The following species were accordingly classified as deciduous: *V. karroo*, *Diospyros lycioides*, *Searsia pyroides, E. alba, Z. mucronata, Grewia occidentalis, S. ciliata, Lycium hirsutum, Asparagus laricinus* and *Asparagus suaveolens*, while the following species were classified as evergreen: *T. camphoratus, B. saligna, Euclea crispa* subsp. *ovata, S. lancea, O. europaea* subsp. *africana* and *S. burchellii*. However, most evergreen tree and shrub species, situated on the northern slopes in the study area, retained only dry leaves from November 2013 to January 2014 (Figure 4.3). This happened after a prolonged period with very little rain and high daily temperatures. These trees and shrubs did, however, recover quickly after above average rainfall was recorded in February 2014, with a total of 247 mm measured that month. By middle February 2014 the majority of their dry leaves were shed and they produced new growth (Figure 4.4).

Vachellia karroo

A significant difference ($p < 0.001$) was found when comparing the leaf carriage scores of *V. karroo* between the two years recorded in the study period (Figure 4.5). The growing season of this species started in September of each year, with very little or no leaves retained by the end of August. No significant difference ($p > 0.05$) was found between the leaf carriage scores of September 2012 and September 2014, with both budding and immature leaves present during these months.

Figure 4.3 Only dry leaves were retained on this *Olea europaea* subsp. *africana* tree in November 2013

Figure 4.4 Mostly immature leaves were present on the same *Olea europaea* subsp. *africana* tree, depicted in Figure 4.3, after shedding the majority of its dry leaves during February 2014

Figure 4.5 Leaf phenology of *Vachellia karroo* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves and DL = Dry leaves

However, a significant difference ($p < 0.001$) was observed between the leaf carriage scores of September 2012 and September 2013 as well as between the leaf carriage scores of September 2013 and September 2014. This was due to a delay in leaf flush during 2013, with *V. karroo* trees first producing immature leaves by October 2013. There was a significant difference ($p < 0.05$) in the leaf carriages scores of *V. karroo* between October 2012 and October 2013, although the median leaf carriage scores of these two months were the same. No significant difference ($p > 0.05$) was found when comparing the leaf carriage scores between October 2013 and October 2014. Rapid growth occurred in *V. karroo* trees after good rains in November 2014, with significant differences ($p < 0.01$) found between the leaf carriage scores of November 2014 and those of the same month during the previous two years. There was no significant difference between the leaf carriage scores of November 2012 and November 2013 ($p > 0.05$).

Even though most trees reached full leaf cover by December, a significant difference ($p < 0.05$) could still be found when comparing the leaf carriage scores of this month. This was likely due to more trees reaching full leaf cover in December 2012 compared to December 2013. Most *V. karroo* trees retained full leaf cover from January to April, with no significant differences ($p > 0.05$) occurring between the leaf carriage scores of these months. However, a secondary flush did occur after above average rainfall in February 2014, with more budding and immature leaves produced from February to March 2014. The active growing period of *V. karroo* stretched from September to the end of March, with the first yellow leaves becoming visible during April.

During 2013 the first leaf fall occurred in May, with leaf fall gradually increasing until very little leaves were retained by the end of August. A significant difference ($p < 0.01$) between the leaf carriage scores of May 2013 and May 2014 was evident, with most trees retaining all their leaves during this month in 2014. No significant difference ($p > 0.05$) was found when comparing the leaf carriage scores of June 2013 with that of June 2014. However, when comparing the median leaf carriage scores between these months, it was found to be lower in 2014. The rapid leaf fall during June 2014, occurring after the first frost, resulted in a lower median score for this month.

Fewer leaves were retained on *V. karroo* trees during July 2014 compared to July 2013, with a significant difference ($p < 0.001$) found between the leaf carriage scores of these months. No significant difference ($p > 0.05$) was observed between the leaf carriage scores of August 2012 and August 2013. However, significant differences ($p < 0.05$) occurred between the leaf carriage scores of August 2014 compared to both August 2013 and August 2012. Not only were less leaves retained on trees during August 2014, but leaves were also in a dry phenological state compared to yellow leaves retained during the previous two years.

Diospyros lycioides

There were some striking similarities between the leaf carriage patterns of *D. lycioides* and *V. karroo*, with the active growing period of both species occurring from September to March (Figure 4.6). Immature leaves were first noticed on *D. lycioides* shrubs during September of both 2012 and 2014, but only emerged during October in 2013. In 2012, most individuals of this species reached full leaf cover by December, while full leaf cover was only reached by most during January in 2013. A secondary flush was also evident during February 2014 after above average rainfall that month. The first yellow leaves were visible in April and leaf fall started during May of each year. Leaf fall continued through to August, with very little or no leaves retained by the end of that month.

Searsia pyroides

The period of active growth in *S. pyroides* stretched from September to the end of March, similar to the growing periods of both *V. karroo* and *D. lycioides* (Figure 4.7). However, unlike the other two species, the first immature leaves of *S. pyroides* only emerged during October each year. A secondary flush was also evident during February 2014 after above average rainfall that month. Yellowing leaves were visible from April, with very little or no dry leaves retained by the end of August. Leaf fall occurred from May 2013, increasing gradually through to August. During 2014, most *S. pyroides* individuals retained all their leaves in May. However, rapid leaf fall was noticed after the first frost in June 2014.
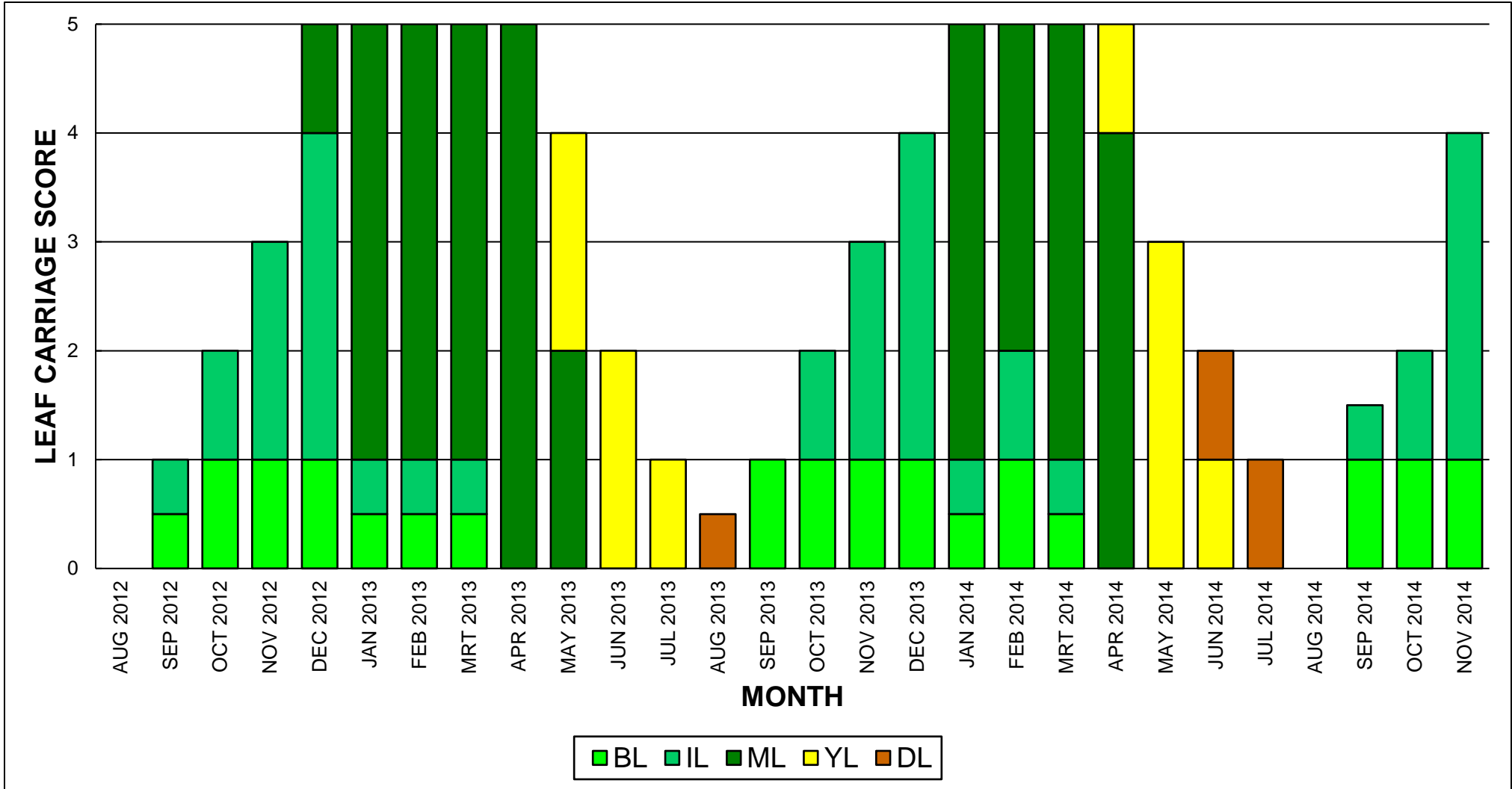
Figure 4.6 Leaf phenology of *Diospyros lycioides* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves
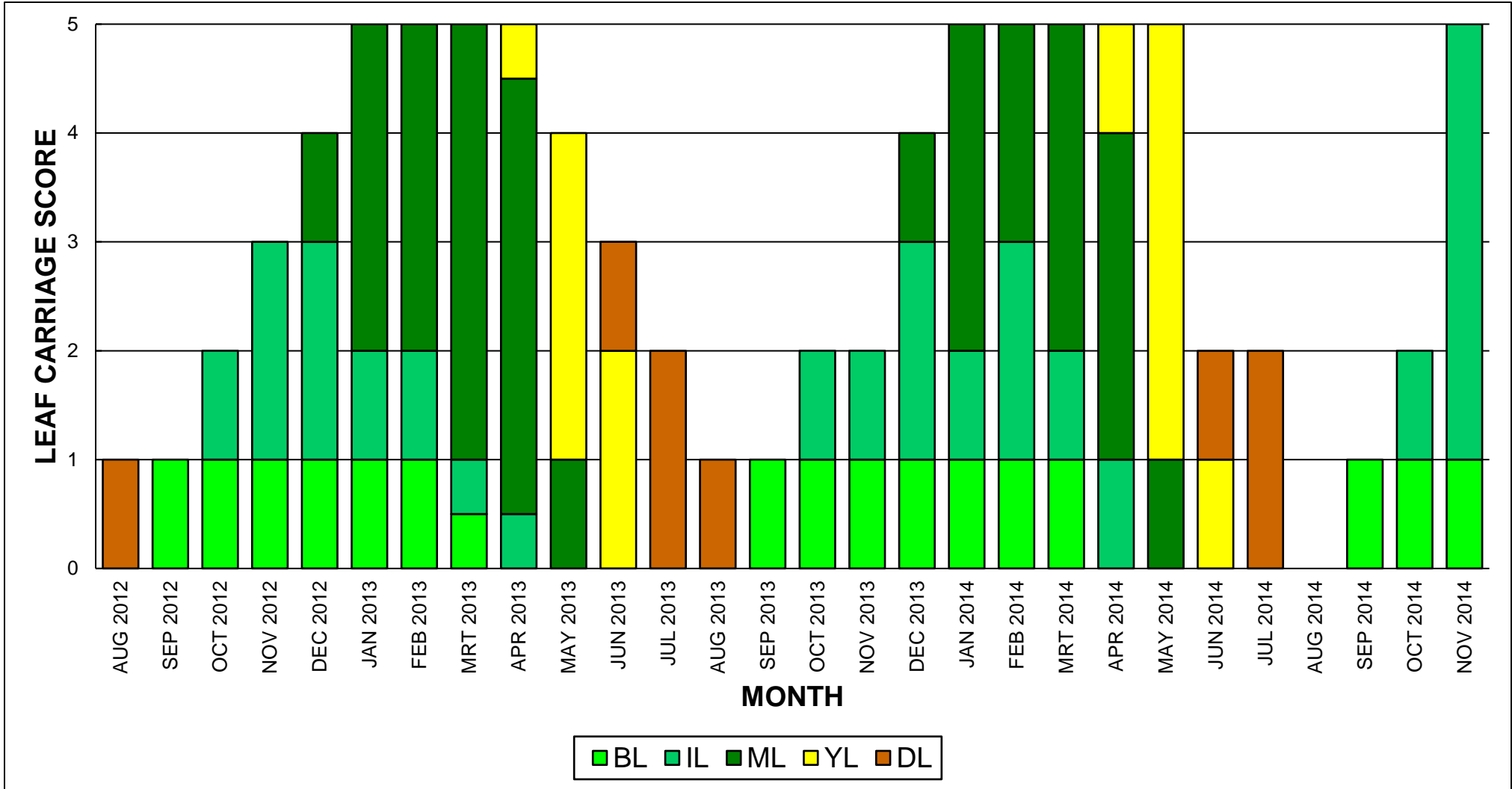
Figure 4.7 Leaf phenology of *Searsia pyroides* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves

Ehretia alba

The leaf carriage scores of *E. alba* differed significantly (p < 0.01) from year to year (Figure 4.8). New growth started in September and continued to the end of March. Although budding leaves were visible as early as September, immature leaves only emerged during November. After above average rainfall in February 2014 a secondary flush was also observed in this species. Full leaf carriage was reached during January of both 2012 and 2013. However, after good early rains most individuals achieved full leaf cover by middle November in 2014. The first yellow leaves appeared on *E. alba* shrubs during April of both years. Leaf fall started in May 2013 and continued slowly with dry leaves retained in September of that year. On the contrary, leaf fall started a month later the next year, initially at a slow rate until rapid leaf fall occurred in August.

Ziziphus mucronata

When comparing the leaf carriage scores of *Z. mucronata* between years, a significant difference (p < 0.001) was found (Figure 4.9). The first buds appeared in October every year, with immature leaves emerging in November and full leaf cover reached by January. Active growth took place between October and March. Leaf senescence started during April in 2013, while mature leaves only started to change colour a month later in 2014. The first leaf fall was noticed in June during both years, with trees still maintaining yellow leaves during August. However, very little or no leaves were retained by middle September, especially during 2014.

Grewia occidentalis

During both 2013 and 2014 *G. occidentalis* trees produced buds by October (Figure 4.10). However, new budding leaves were already visible during September 2012. Despite the early buds noticed in 2012, immature leaves emerged in November of all three years. The first active growing season recorded stretched from September 2012 to March in 2013. On the contrary, the following growing season was shorter and only lasted from October 2013 to February 2014. No new leaves were formed during March 2014, with only immature and mature leaves visible on trees. The first yellow leaves appeared in April and leaf fall started in May. Leaf fall continued gradually until July, with rapid leaf fall occurring in August. Most remaining leaves were dry by August and no leaves from the previous season were left on the trees by September.
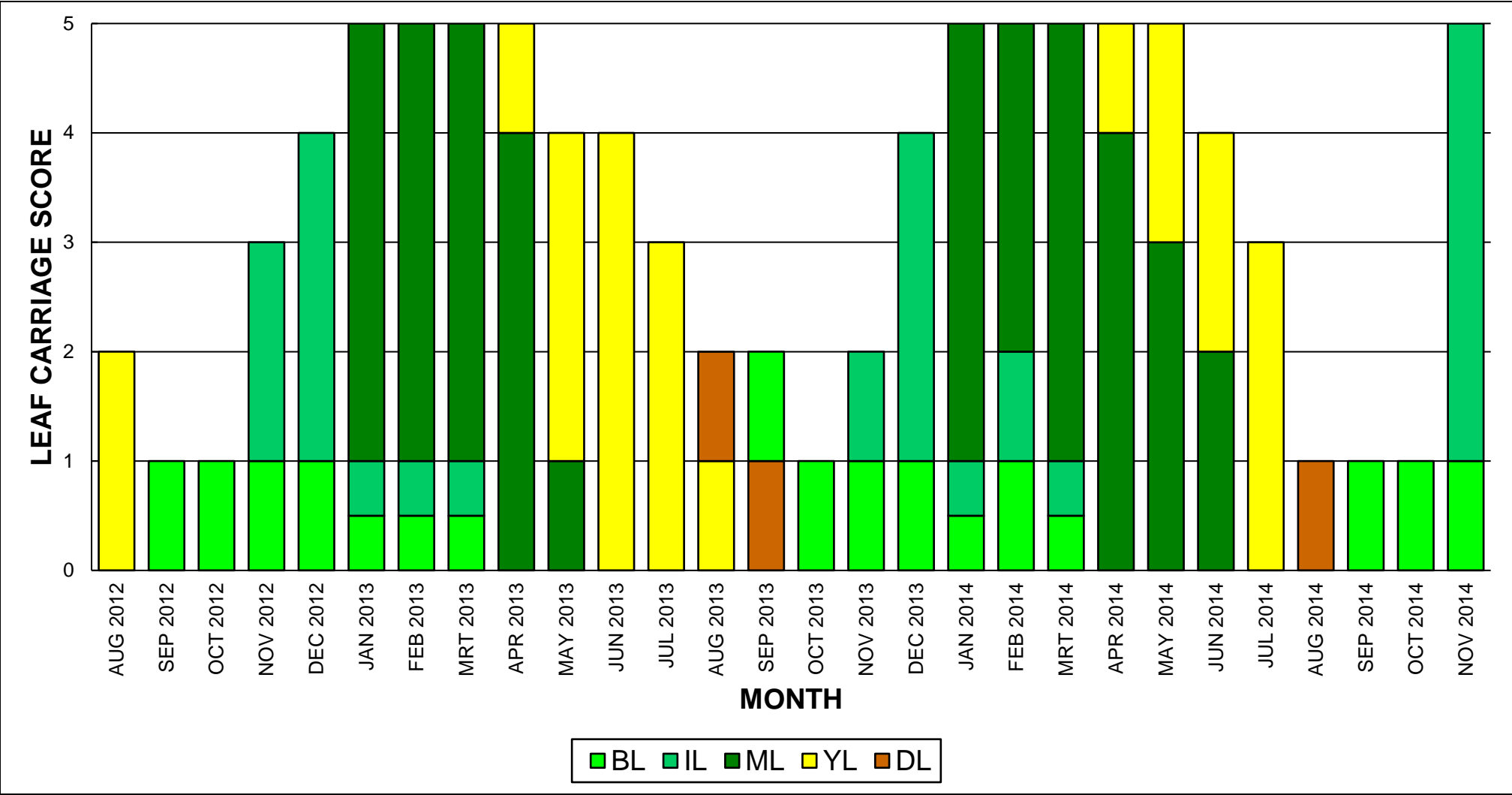
Figure 4.8 Leaf phenology of *Ehretia alba* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves
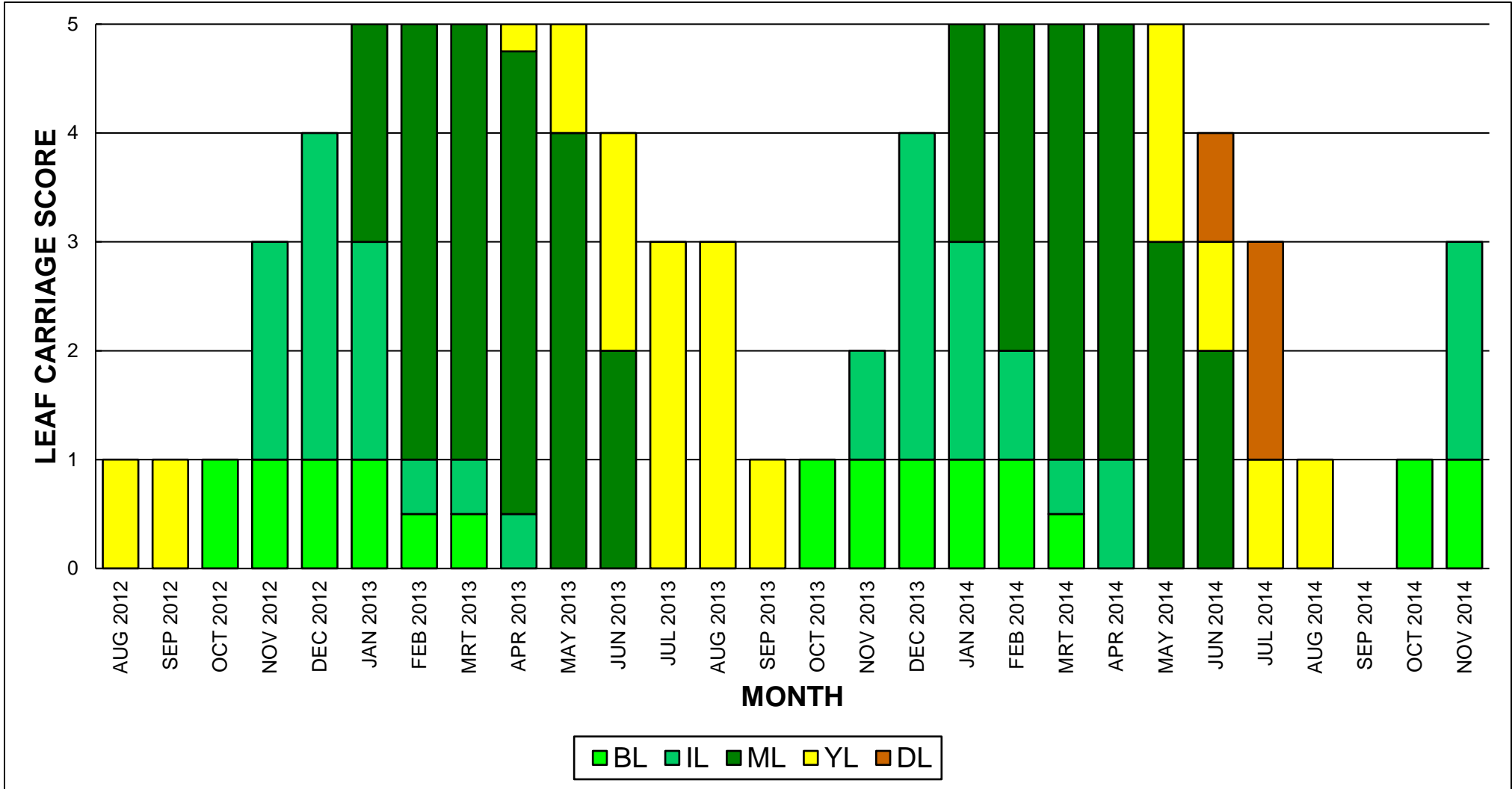
Figure 4.9 Leaf phenology of *Ziziphus mucronata* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves
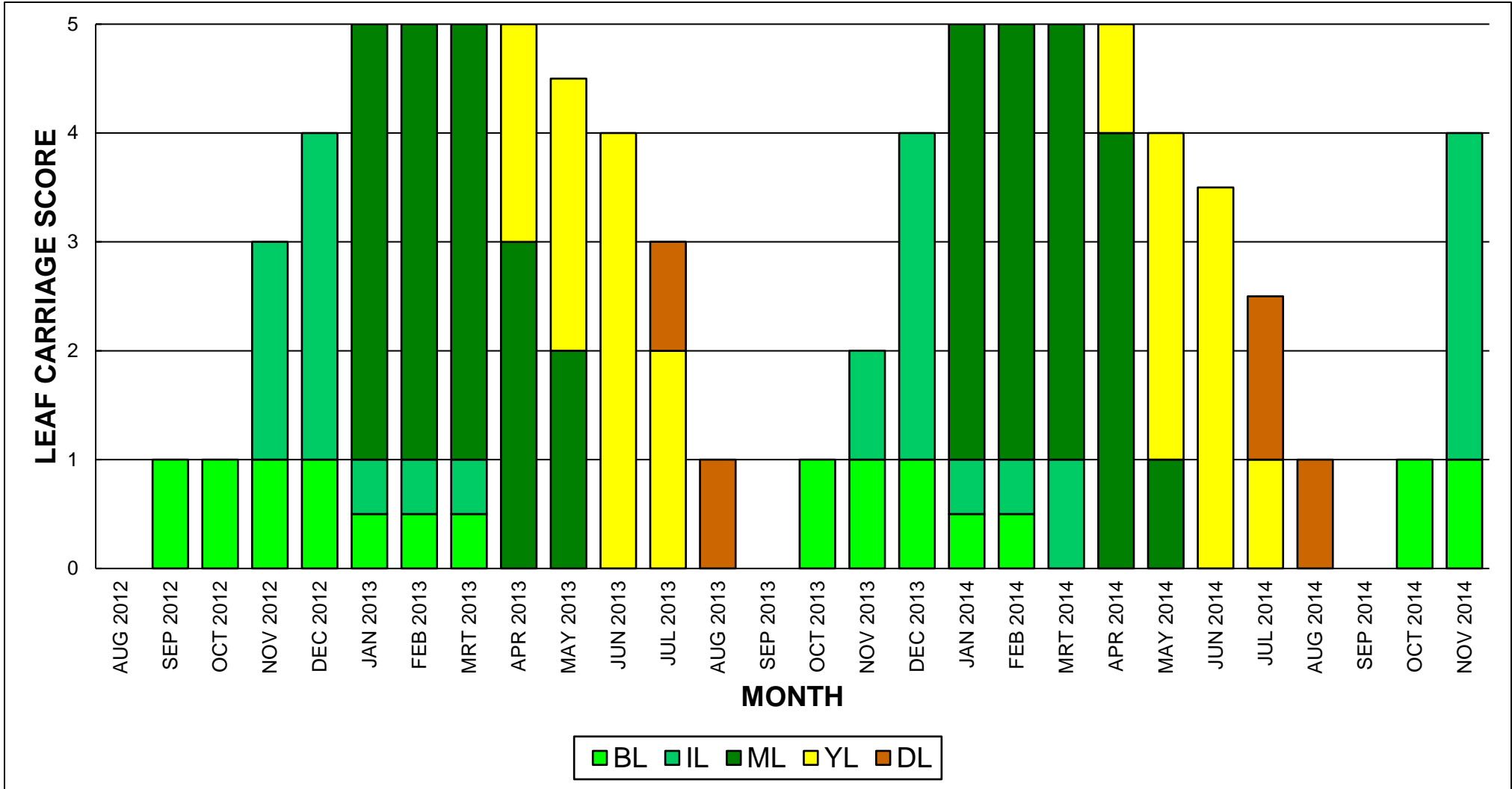
Figure 4.10 Leaf phenology of *Grewia occidentalis* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves

Searsia ciliata

A significant difference ($p < 0.001$) was found when comparing the leaf carriage scores of *S. ciliata* between years (Figure 4.11). The first buds and immature leaves appeared together during the month of November for 2012 and 2014. Buds were already visible during October in 2013, while the emergence of immature leaves only occurred a while later in December of that year. This resulted in full leaf cover being reached a month later, in February 2014, compared to January the previous year. Leaf senescence started in April of both 2013 and 2014, although leaf fall differed between the two years. Leaves were shed from July to October in 2013 and from June to October in 2014. There was a drastic increase in leaf fall from July to August in 2013 and the same happened from June to July in 2014. A reasonable amount of leaves remained on these shrubs during August 2013 and August 2014. However, very little yellow leaves were present by September of all the years.

Lycium hirsutum

No clear leaf carriage pattern was observed in *L. hirsutum* (Figure 4.12). New leaves were produced and shed soon thereafter at irregular intervals. New budding leaves were produced at the following dates: August 2012, December 2012 to January 2013, April to June 2013, November to December 2013, February to April 2014, June to September 2014 and again in November 2014.

Asparagus laricinus

The *Asparagus* species in the study area have no true leaves, but rather modified branches functioning as leaves or phyllocladia (Venter & Joubert, 1985). The phyllocladia of these species were referred to as leaves for comparison with other species. The growing season of *A. laricinus* started in October in both 2012 and 2014 (Figure 4.13). However, budding leaves were already visible during September in 2013. The first immature leaves emerged during November and most of these shrubs had full leaf cover by December. The first active growing season stretched from October 2012 to April 2013, while the next one started in September 2013 and lasted until March 2014.
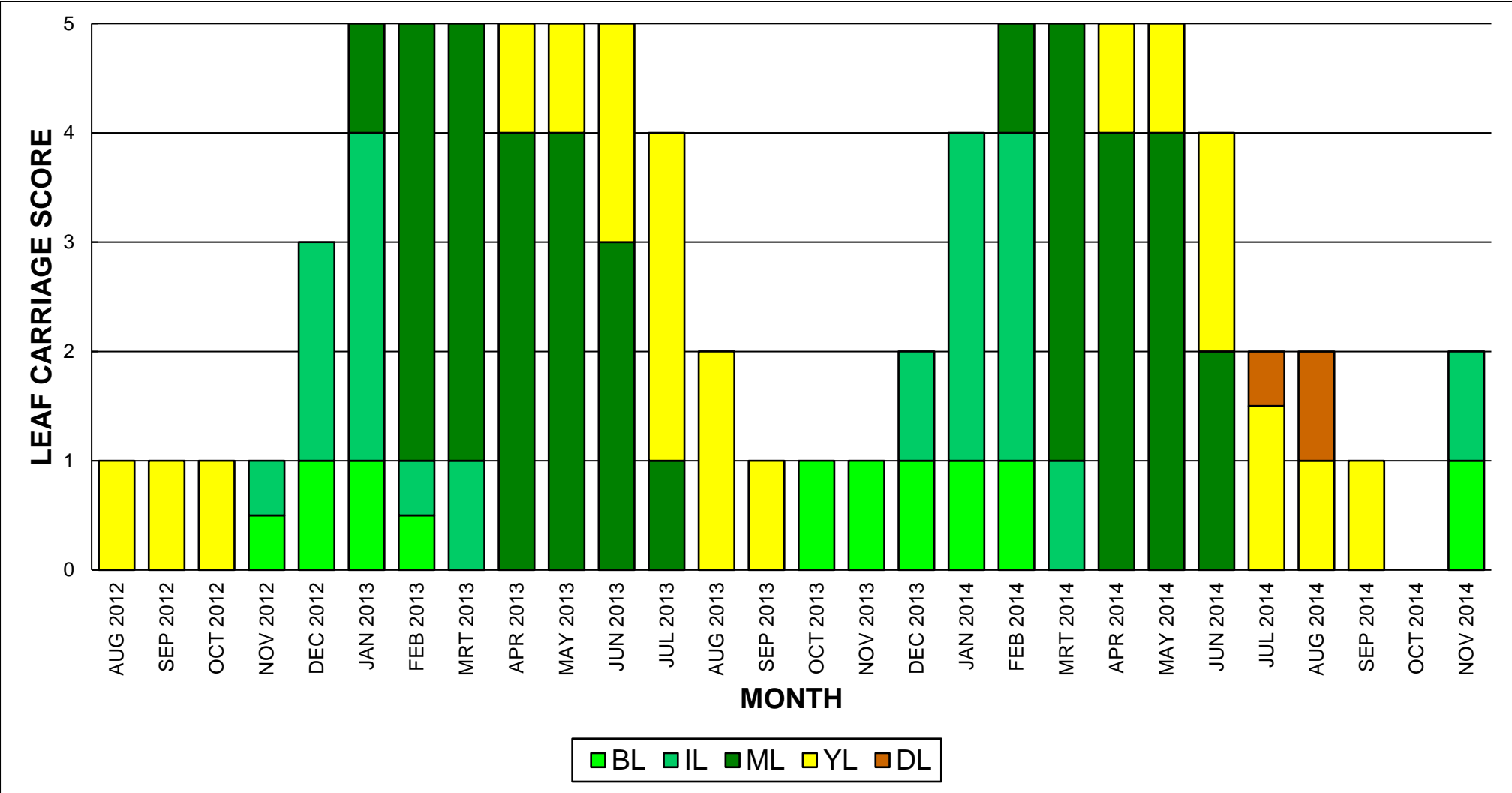
Figure 4.11 Leaf phenology of *Searsia ciliata* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves
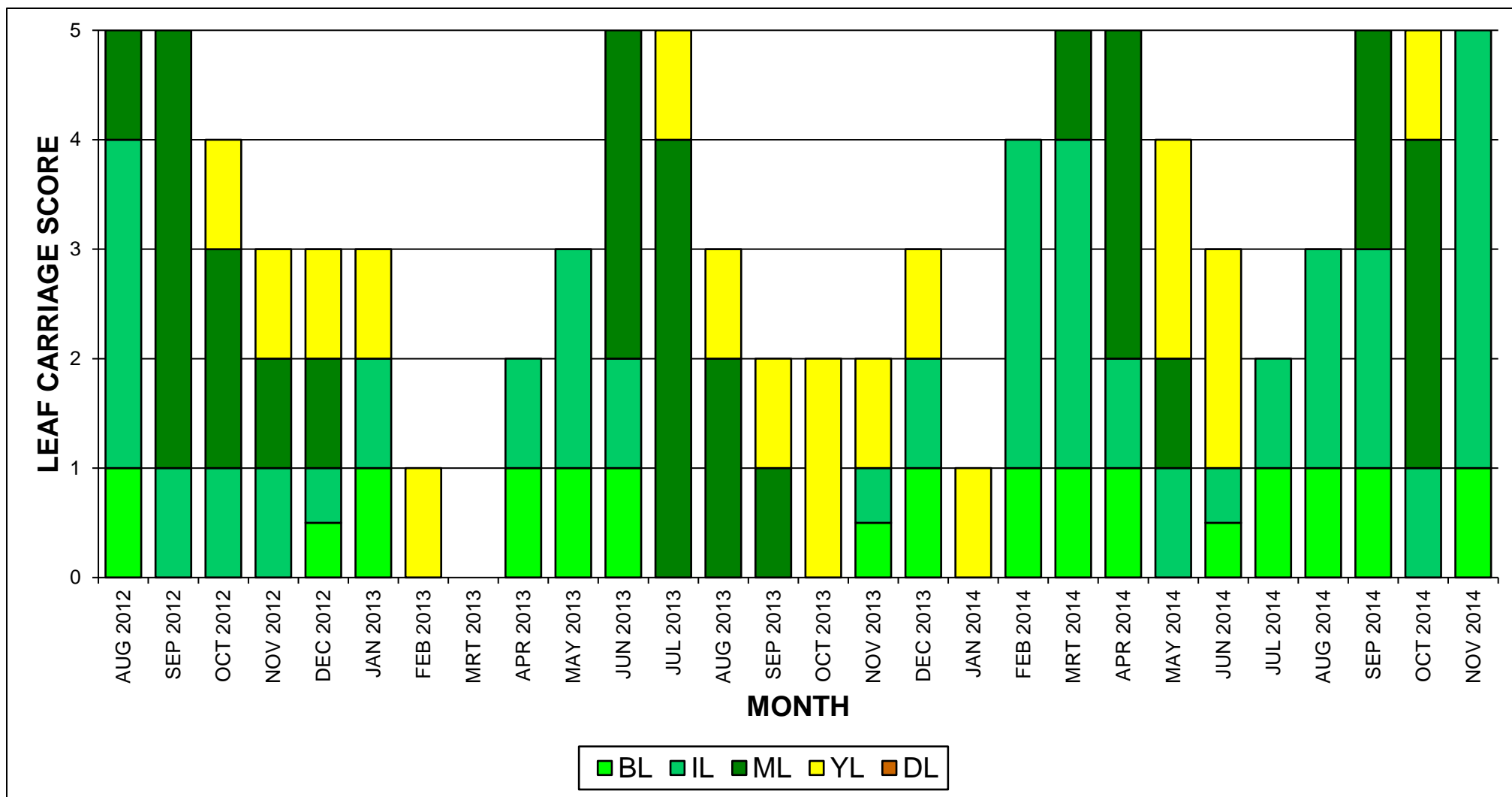
Figure 4.12 Leaf phenology of *Lycium hirsutum* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves
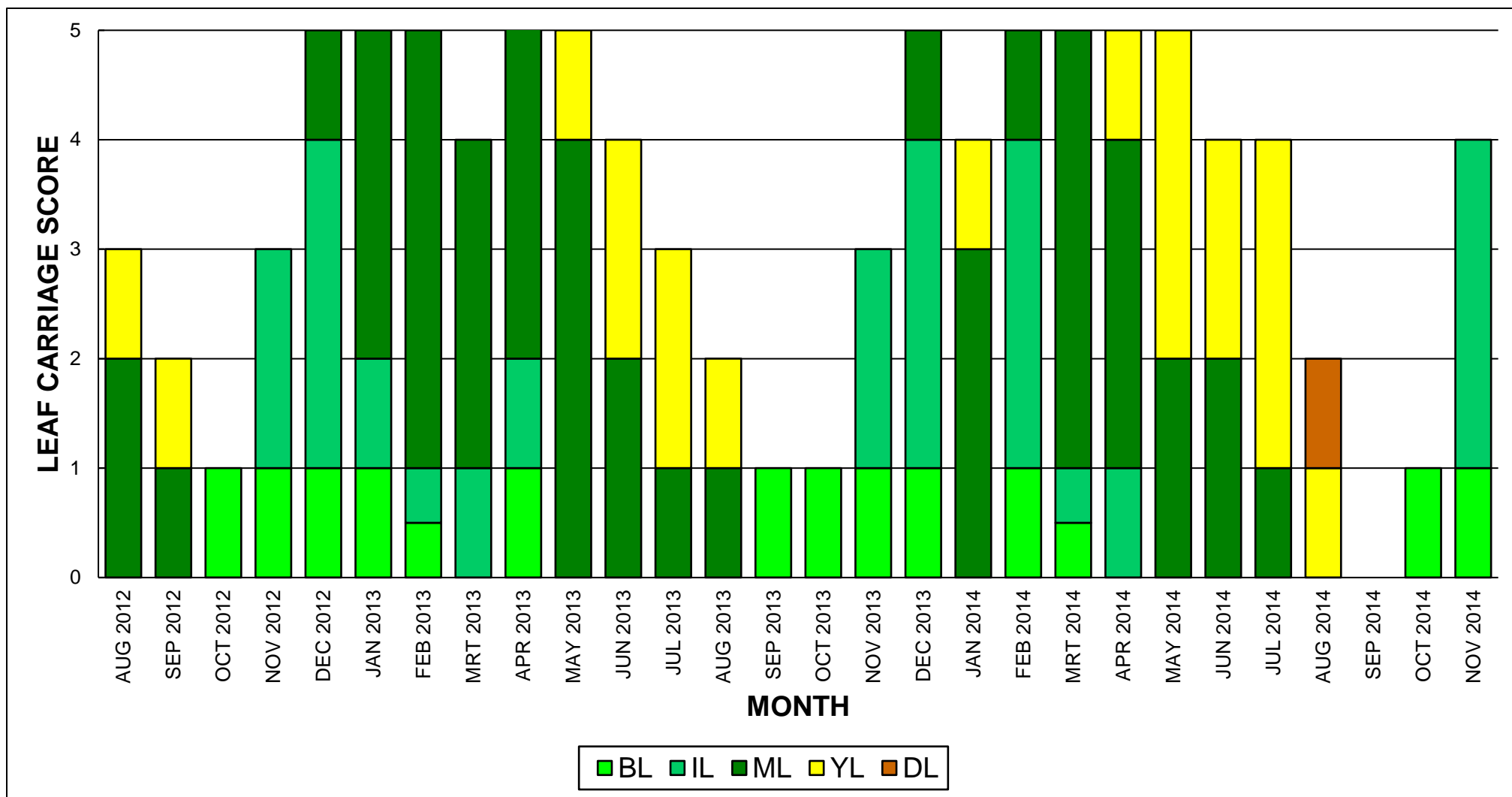
Figure 4.13 Leaf phenology of *Asparagus laricinus* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves

Unlike most other woody species in the study area, some leaves on *A. laricinus* shrubs were shed and replaced before the growing season ended. For example, yellow leaves were shed during March 2013, but replaced by the next month. Likewise, during January 2014, yellow leaves were shed and replaced by middle February of that year. Some leaves turned yellow in May 2013 after the first active growing season ended. Leaves were steadily dropped from July to August that year, but mature leaves were retained until the end of August.

During September 2013 very little yellow leaves were visible as budding leaves emerged. After the second growing season, the first yellow leaves were visible during April 2014. However, the first leaf fall was only recorded in June of that year. Very little leaves were shed from June to July 2014, but more rapid leaf fall occurred between July and August of that year. Only yellow and dry leaves were retained during August 2014, with most shrubs leafless in the following month.

Asparagus suaveolens

Unlike *A. laricinus,* this shrub species had a much shorter active growing season (Figure 4.14). The first buds were visible during November, along with immature leaves. Full leaf cover was reached in December of both 2012 and 2013, while full leaf cover was achieved in less than a month in 2014. The first active growing season stretched from November to December in 2013, while a slightly longer second active growing season was recorded from November 2013 to February 2014. However, the second active growing season was interrupted by shrubs shedding yellow leaves in January and replacing them by middle February. After the first active growing season, yellow leaves were noticed in February 2013. However, most *A. suaveolens* shrubs maintained full leaf cover until the end of July that year.

Leaf fall started in August 2013 and progressed steadily, with some dry leaves retained in October 2013. Leaf fall started a month earlier in 2014, but very little leaves were shed from July to August that year. Mature leaves were still present on shrubs during both September 2012 and September 2013, although only yellow and dry leaves were retained in September 2014. Rapid leaf fall then occurred from September to October 2014, with most shrubs retaining very little dry leaves.
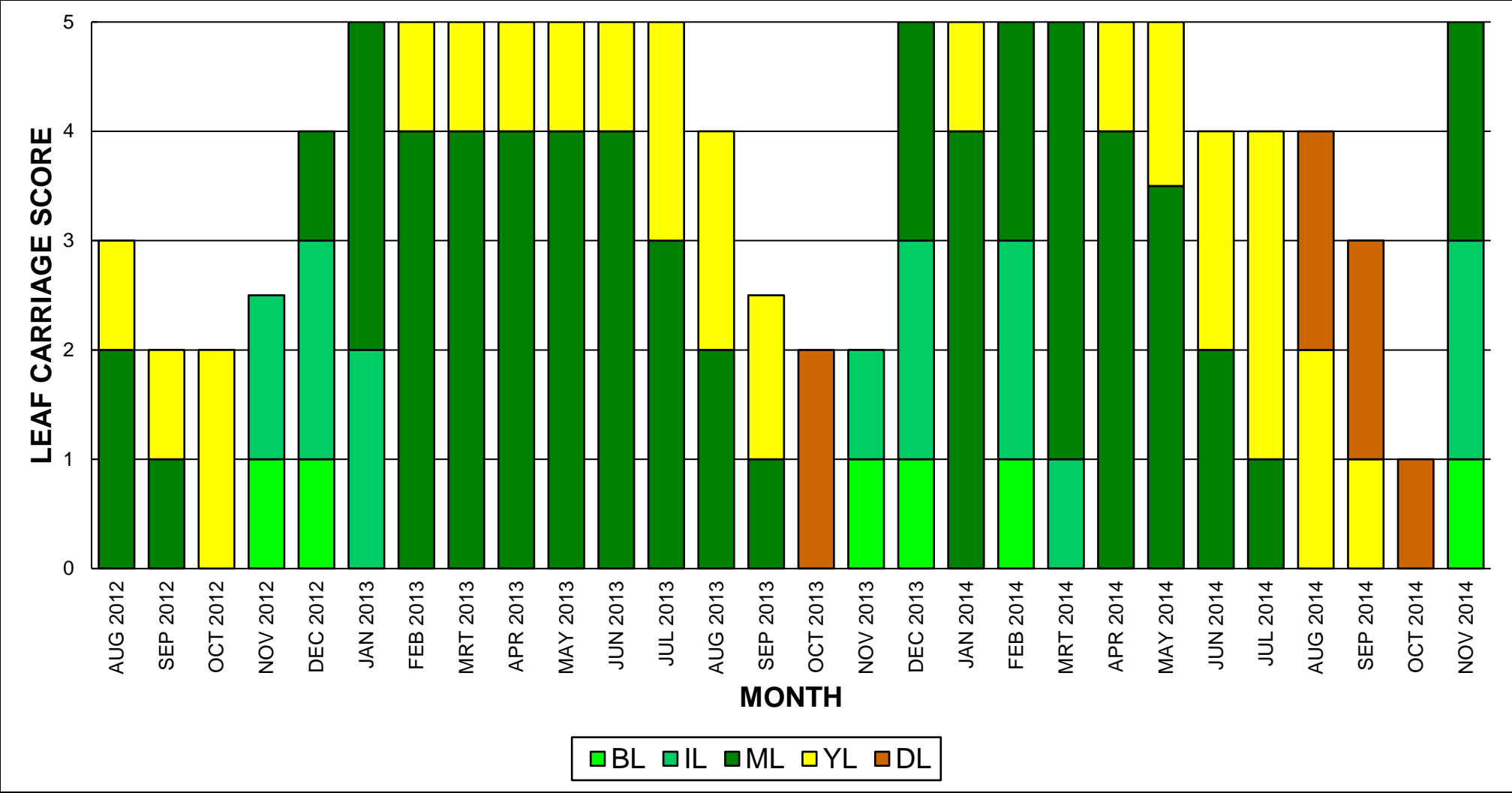
Figure 4.14 Leaf phenology of *Asparagus suaveolens* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves

Tarchonanthus camphoratus

Right through the study period, budding and immature leaves were always present on these shrubs (Figure 4.15). However, there were periods when more budding and immature leaves were produced. These periods can be considered as the active growth stage of *T. camphoratus*. The active growth periods stretched from November 2012 to March 2013 and from December 2013 to March 2014, starting again in November 2014. Full leaf cover was maintained from January to June in 2013 and from January to July in 2014. A secondary flush also occurred during February 2014. Leaf senescence took place from May each year. The first leaves were shed during July 2013 and a month later the next year, during August 2014. Leaf fall continued steadily, with some yellow leaves remaining in November 2012 and November 2014. However, most shrubs only had budding and immature leaves left by November 2013.

Buddleja saligna

Shrubs of this species had buds and immature leaves present right through the study period, except for September 2013 (Figure 4.16). Periods of active growth, when more budding and immature leaves were present, stretched from November to January in 2013 and from December to April in 2014. More budding and immature leaves were again produced during November 2014. A secondary flush, with excessive growth, occurred from February to March 2014. Very little or no yellow leaves were retained during these periods of active growth. Most shrubs reached and maintained full leaf cover from December 2012 to July 2013, while full leaf cover was only reached again in January 2014, but maintained until September of that year. Leaf fall occurred from August to November in 2013, but only occurred during October in 2014.
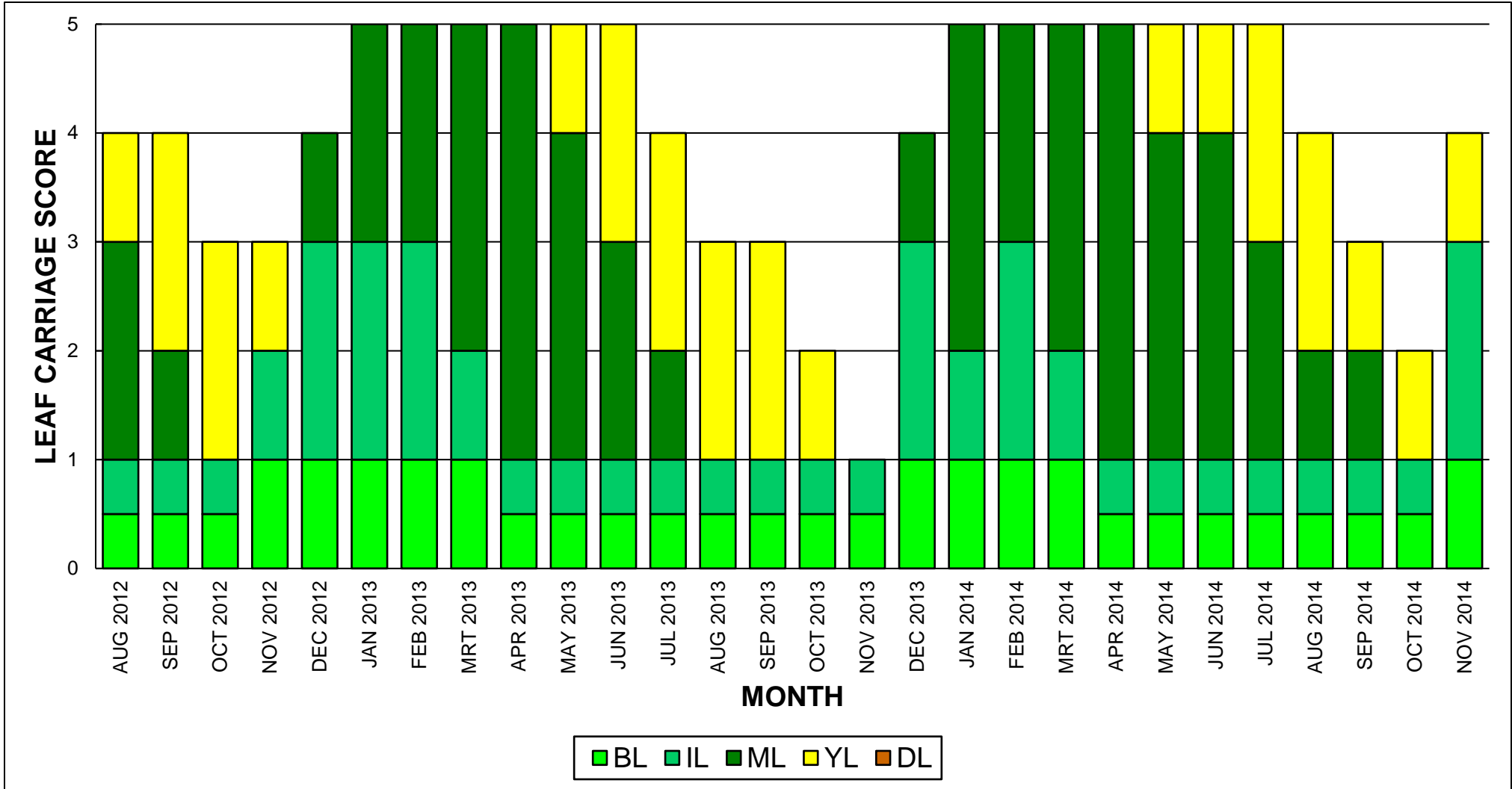
Figure 4.15 Leaf phenology of *Tarchonanthus camphoratus* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves
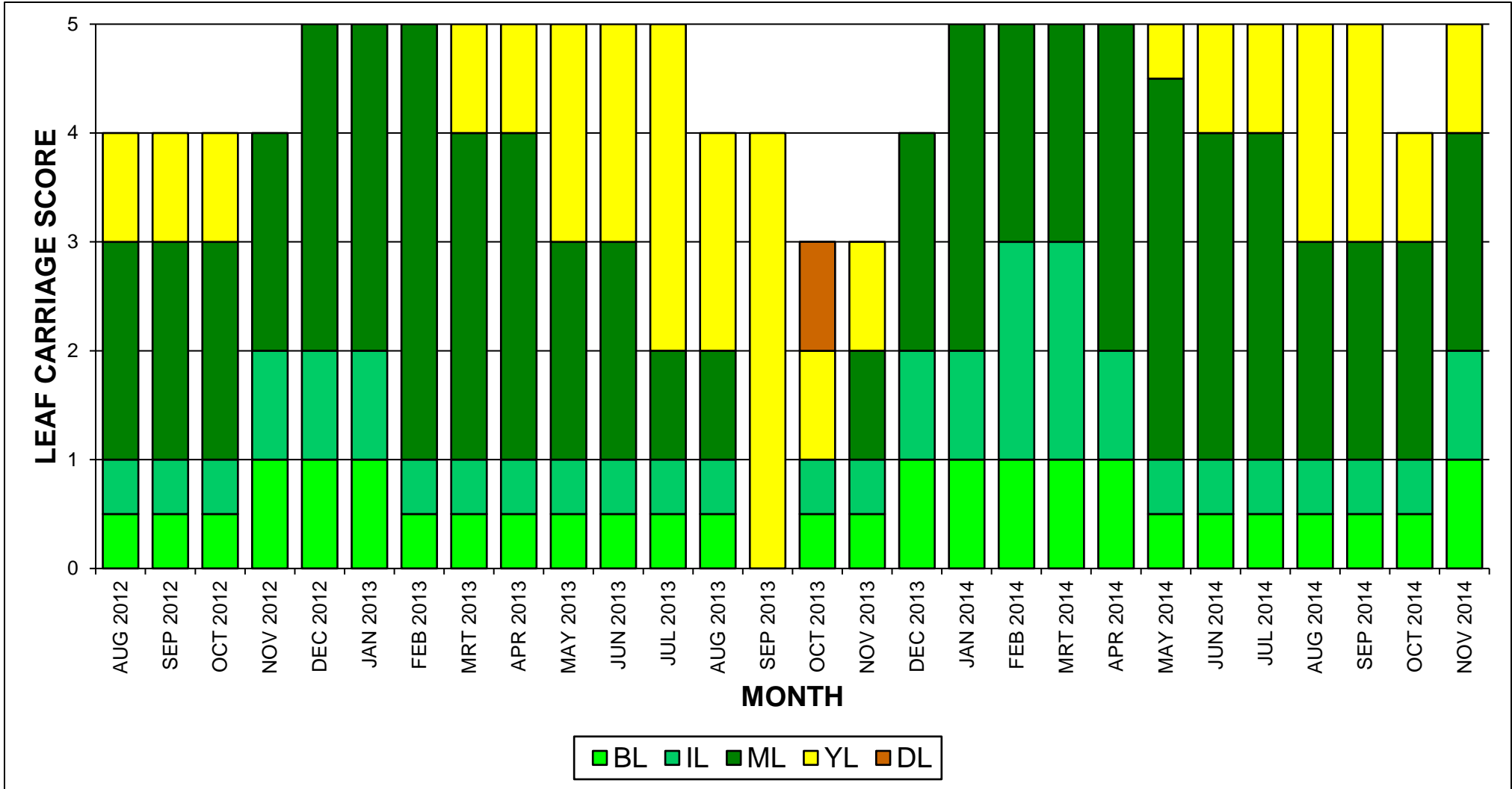
Figure 4.16 Leaf phenology of *Buddleja saligna* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves

Euclea crispa subsp. *ovata*

Very short active growing periods were recorded in *E. crispa* subsp. *ovata* (Figure 4.17). An active growing period occurred from February to March in 2013, while this period extended from January to March in 2014. The next active growing period started earlier than normal, with these shrubs producing budding leaves during October 2014. The first yellow leaves appeared in June each year, remaining until December in 2013 and until September in 2014. Some yellow leaves produced during 2012 remained until March 2013. Leaf fall occurred from January to March and from September to December in 2013 as well as in October 2014.

Searsia lancea

The active growing season in *S. lancea* started during November in both 2012 and 2014 (Figure 4.18). During 2013 the active growing season started a month later in December. The first active growing season stretched between November 2012 and April 2013, while the second active growing season was a month shorter, starting in December 2013 and ending in April 2014. Above normal growth occurred in February 2014 during a secondary flush. Leaf senescence started in August during 2013 and a month earlier in 2014, during July. The first leaf fall was noticed in November 2012 and all yellow leaves were shed by December of that year. During 2013 leaf fall started in October, with the last yellow leaves retained on trees during December. Leaves shed after middle October 2014 were quickly replaced by budding and immature leaves in November 2014.

Olea europaea subsp. *africana*

Budding and immature leaves were present right through the year in this species (Figure 4.19). Despite this, definite active growing seasons could still be determined as these trees produced more buds and immature leaves at certain times of the year. The active growing season stretched from February to March in 2013 and from February to April in 2014. An early start to the next active growing season occurred in November 2014 after good rains that month. A secondary flush also occurred in this species, with excessive growth visible during February and March 2014.
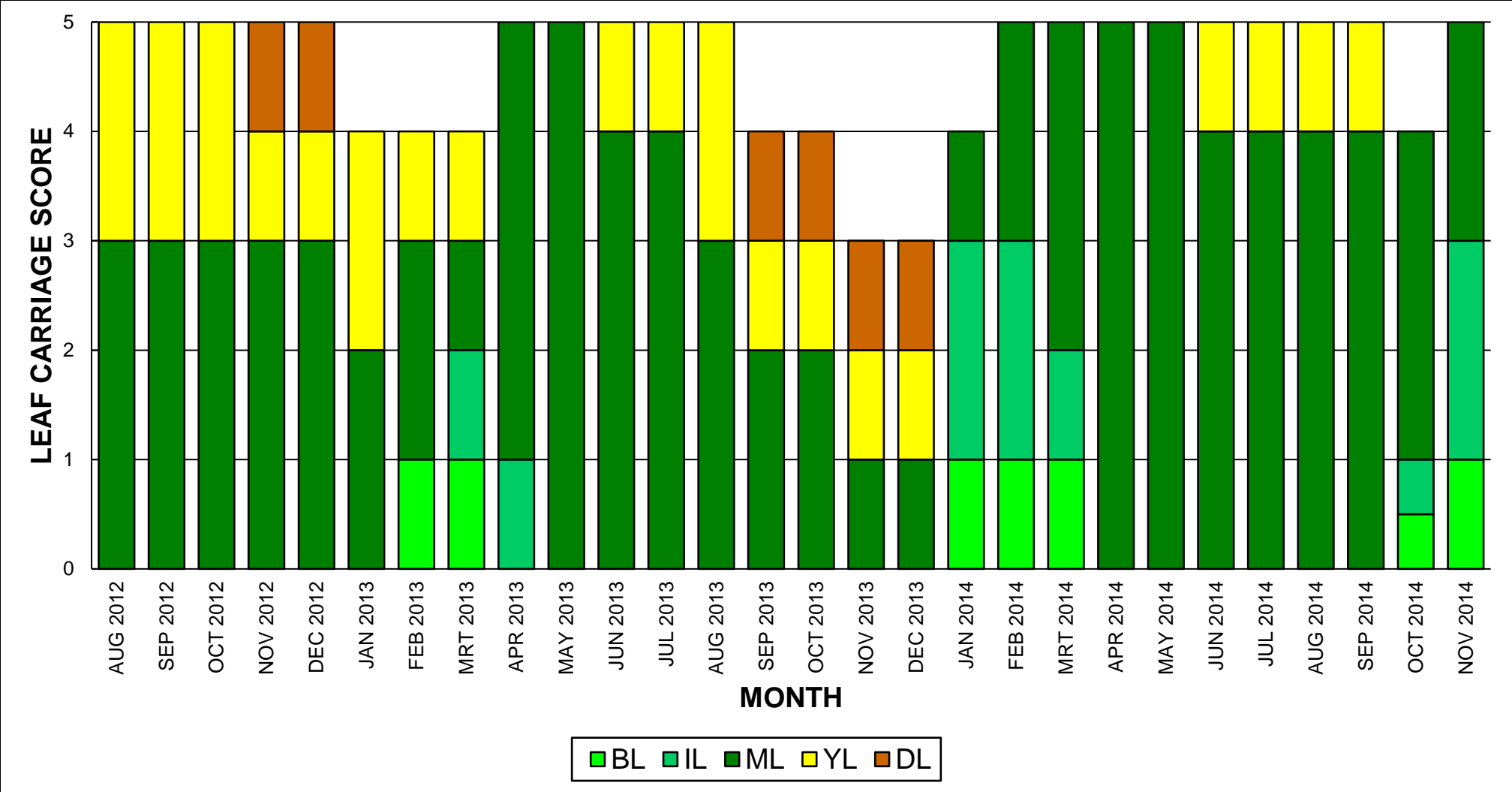
Figure 4.17 Leaf phenology of *Euclea crispa* subsp. *ovata* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves
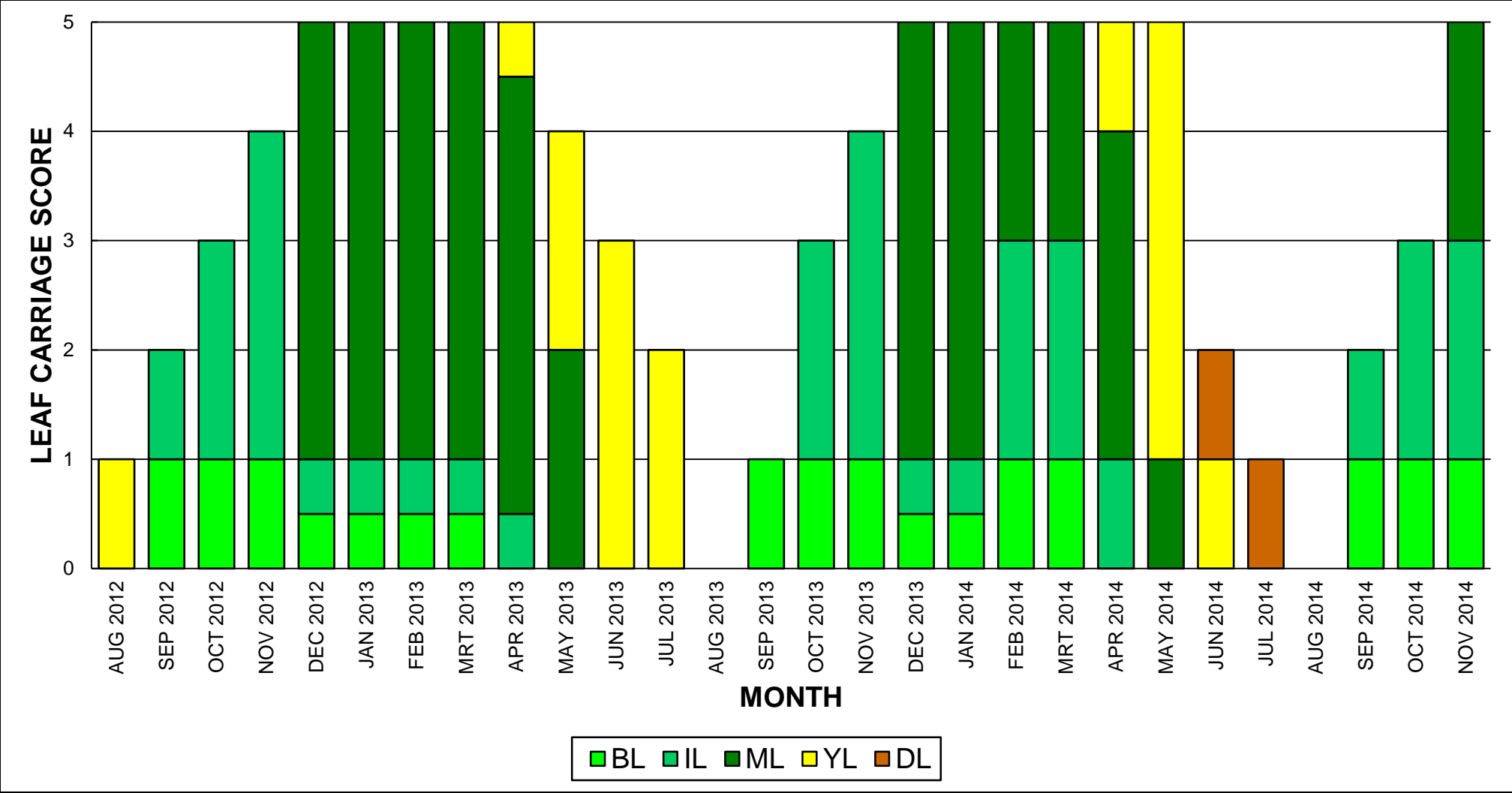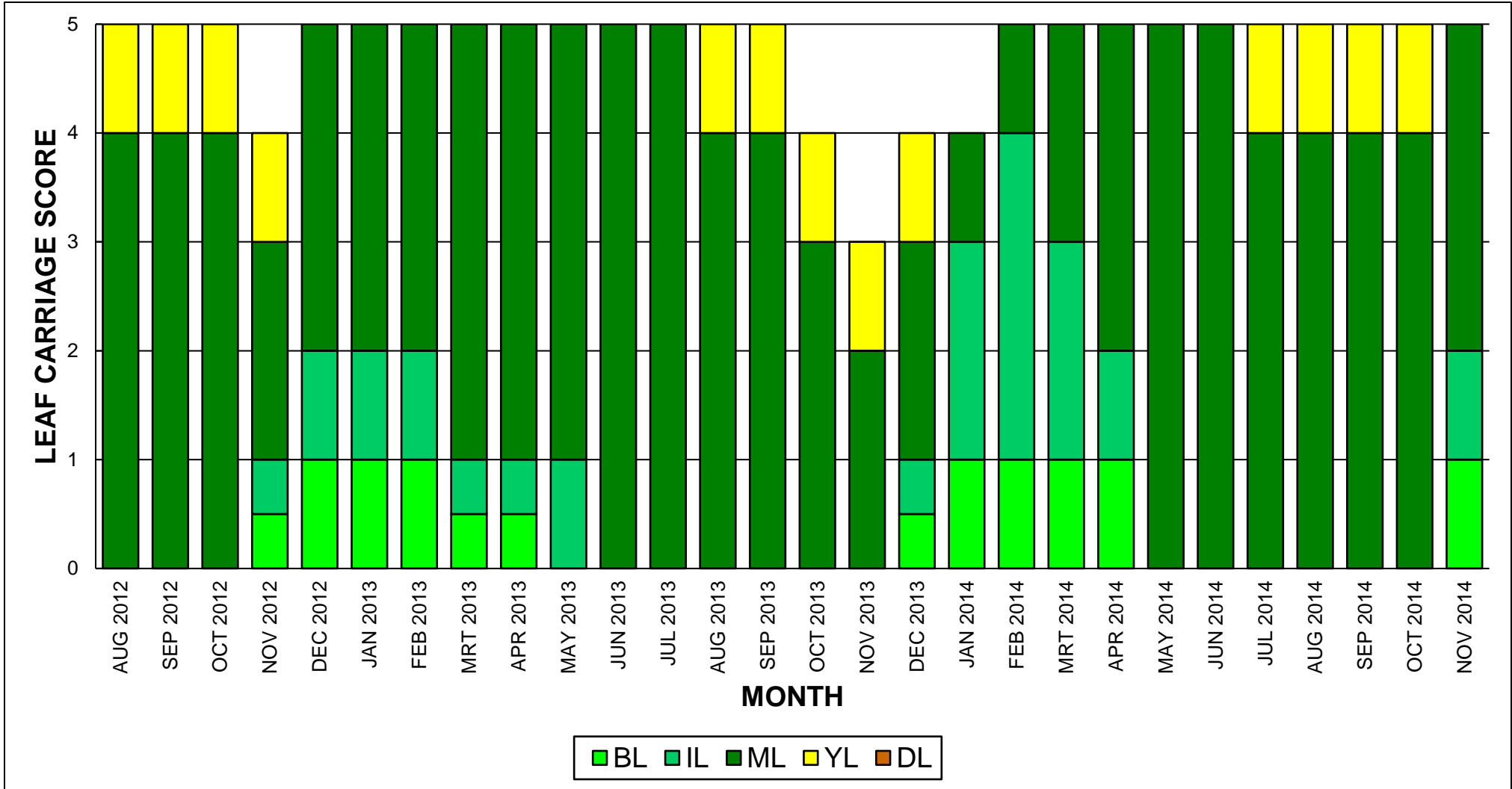
Figure 4.18 Leaf phenology of *Searsia lancea* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves.
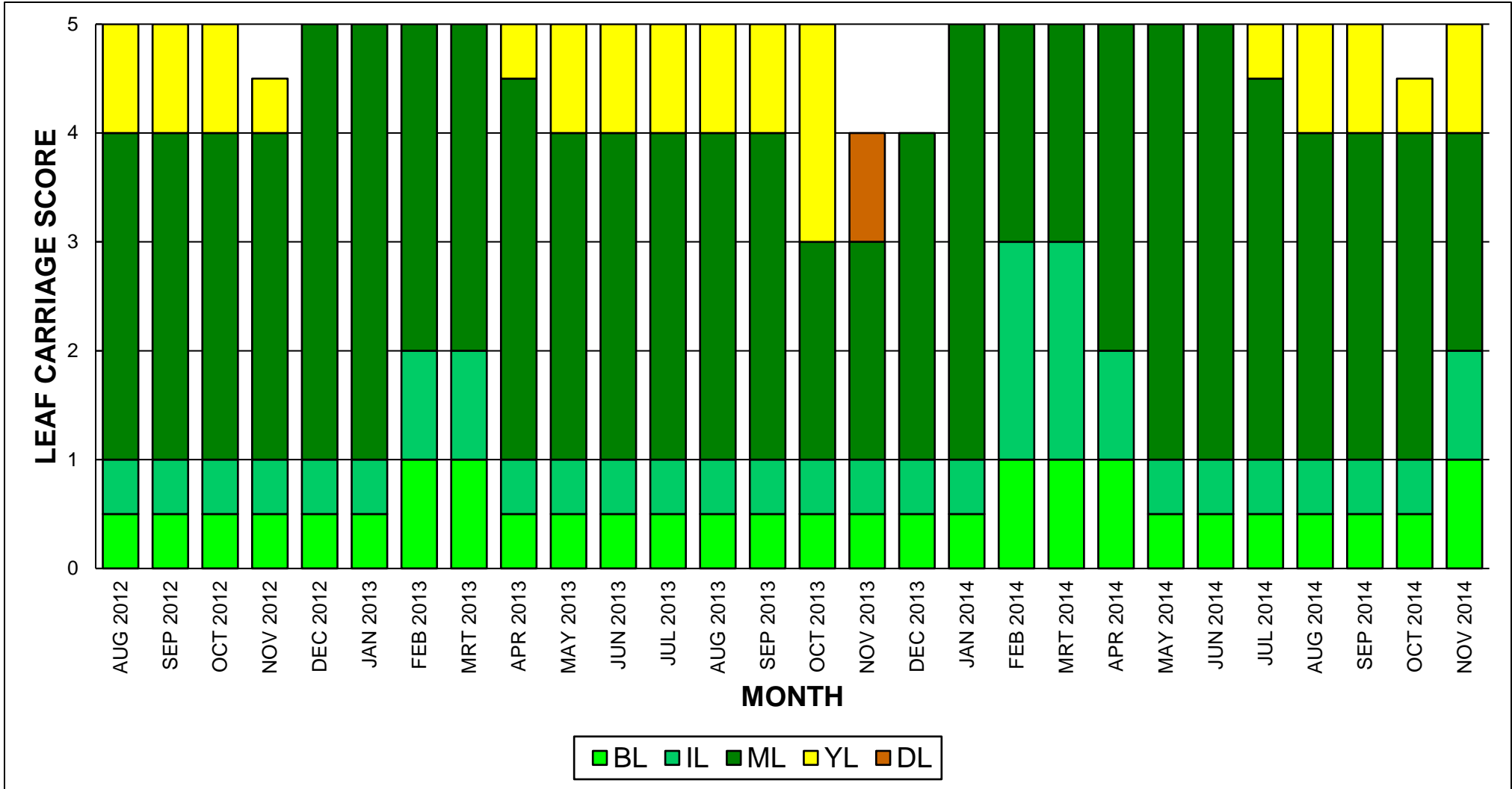
Figure 4.19 Leaf phenology of *Olea europaea* subsp. *africana* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves

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Yellow leaves appeared on *O. europaea* subsp. *africana* trees in April during 2013, but during 2014 yellow leaves were only visible on these trees from July. Leaf senescence took place from April to November in 2013, with most trees retaining some dry leaves by November 2013. Leaf shedding started in November of both 2012 and 2013, while leaves were shed during October 2014. Leaves were replaced quickly after shedding resulting in these trees only experiencing short periods when they were not at full leaf cover. Full leaf cover of this species was maintained until October in 2012 and again occurred from December 2012 to October 2013 and from January to September in 2014.

Searsia burchellii

Buds and immature leaves were present on these shrubs during all months of the study period, except for October 2013 (Figure 4.20). The budding and immature leaves present for most of the year seemed to be in a state of dormancy, with very little or no growth taking place (Figure 4.21). However, more than the usual budding and immature leaves were present during certain times of the year (Figure 4.22) and these periods were considered to be the active growing seasons for this species. The active growing season of *S. burchellii* started in November of both 2012 and 2014. This was not the case in November 2013, when active growth was delayed and only started in January 2014. The active growing periods stretched from November 2012 to January 2013 and from January to April in 2014. Evidence of a secondary flush was visible during February 2014 with excessive growth taking place during that month. The earliest sign of leaf senescence was witnessed in July 2014, with leaves only starting to change colour in August the previous year. Full leaf cover was maintained for most of the year in these shrubs, with only October 2013 being the exception. The few leaves that dropped generally made no difference to the leaf carriage scores allocated.
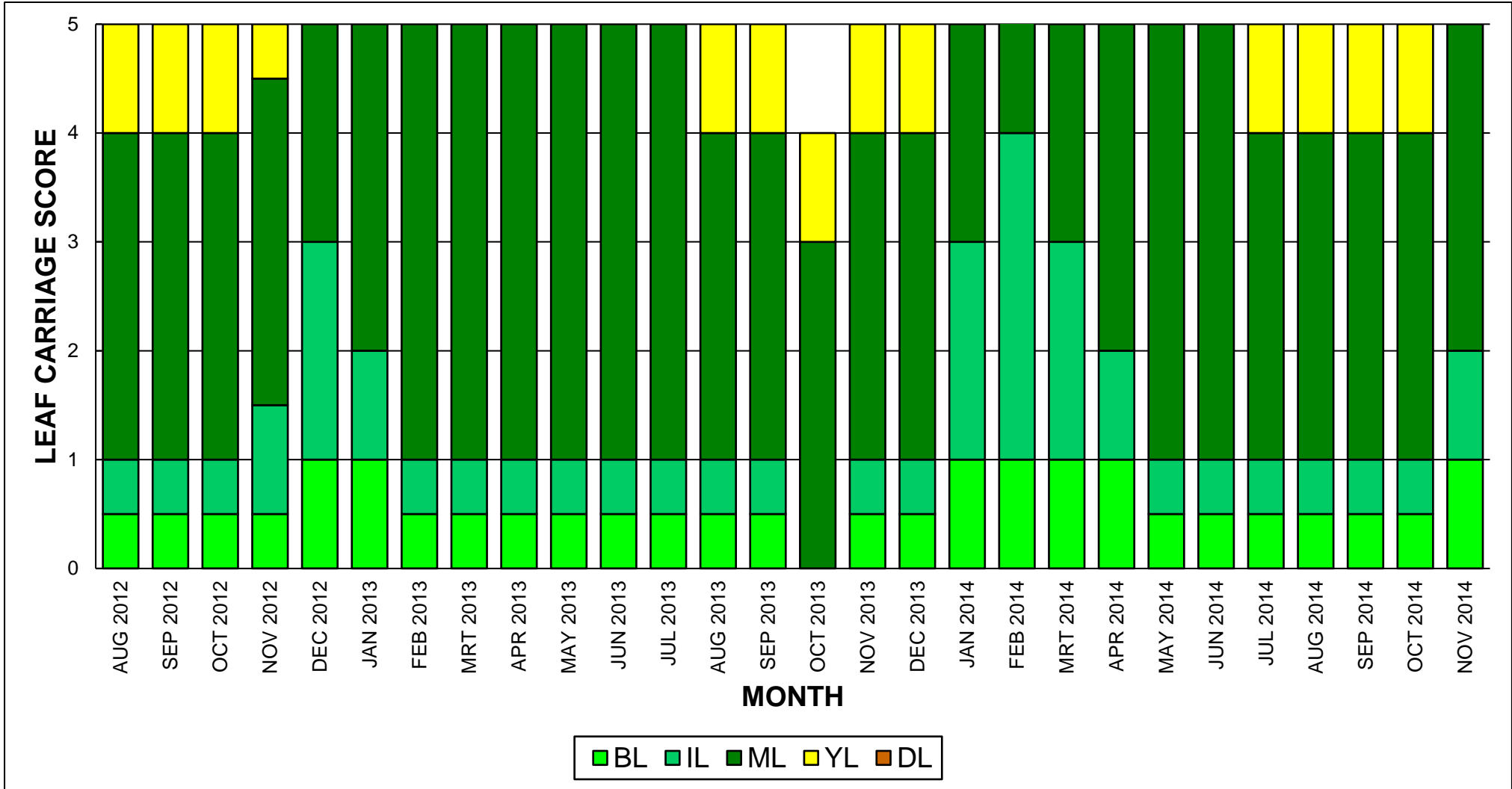
Figure 4.20 Leaf phenology of *Searsia burchellii* during the 28 month period from August 2012 to November 2014. Explanation of legend abbreviations: BL = Budding leaves; IL = Immature leaves; ML = mature leaves; YL = Yellow leaves; and DL = Dry leaves

Figure 4.21 *Searsia burchellii* shoot during September 2013, with mature green leaves as well as brown budding and immature leaves

Figure 4.22 *Searsia burchellii* shoot during January 2013, with green budding and immature leaves

Leaf phenology comparison between the four major deciduous food species

The four deciduous species which were further statistically analysed were chosen due to their abundance in the study area and importance in the kudu diet. Their availability also greatly affected the diet preferences of kudu in the study area (see Chapter 5).

At the start of the growing season, in September 2012, *V. karroo* produced significantly ($p < 0.001$) more leaves compared to *E. alba*. During this month *V. karroo* already produced immature leaves, while only buds were visible on *E.rigida*. There were no significant differences ($p > 0.05$) between the leaf carriage scores of *V. karroo* and that of *Z. mucronata* and *S. ciliata* during September 2012. This was due to both *Z. mucronata* and *S. ciliata* retaining yellow leaves from the previous growing season. During October 2012 *V. karroo* produced significantly ($p < 0.001$) more leaves compared to both *Z. mucronata* and *E. alba*, while the yellow leaves retained on *S. ciliata* was now significantly ($p < 0.001$) less compared to the new leaves formed in *V. karroo*. By November 2012 budding and immature leaves were visible in all four species. However, significantly ($p < 0.01$) more leaves were present in *V. karroo* during this month in comparison to both *Z. mucronata* and *S. ciliata*. No significant difference ($p < 0.05$) was found between the leaf carriage scores of *V. karroo* and *E. alba* during this month. Full leaf cover was reached by *V. karroo* during December 2012, with these trees having significantly ($p < 0.001$) more leaves compared to the other species.

From June to August in 2013, *Z. mucronata*, *S. ciliata* and *E. alba* retained significantly ($p < 0.001$) more leaves compared to *V. karroo*, when comparing each month separately. A slow start to the next growing season occurred, with no immature leaves emerging on deciduous species in September 2013. During this time *V. karroo* trees were leafless except for budding leaves, while the other three species retained some leaves from the previous season. This resulted in *V. karroo* having significantly ($p < 0.01$) less leaves compared to both *Z. mucronata* and *E. alba*. However, no significant difference ($p < 0.05$) was found between the leaf carriage scores of *V. karroo* and *S. ciliata* as very little yellow leaves were retained on the latter. A fair amount of immature leaves were formed on *V. karroo* trees during October 2013, unlike the other three species that only produced buds. Significant differences ($p < 0.001$) were accordingly found between the leaf carriage scores of *V. karroo* and each of the other species.

Some immature leaves emerged from both *Z. mucronata* and *E. alba* during November 2013. However, *S. ciliata* still only produced budding leaves by this month. As in the previous month, significantly ($p < 0.001$) more leaves were present on *V. karroo* trees compared to *Z. mucronata*, *S. ciliata* and *E. alba*. Full leaf cover was attained by most *V. karroo* trees in December 2013. However, at the same time the other three species still lagged behind producing significantly ($p < 0.05$) less leaves. The first immature leaves finally emerged from *S.ciliata* during this month. Leaf fall started in all four species during June in 2014. However, during this month significantly ($p < 0.001$) less leaves were retained by *V. karroo* compared to the other species, with rapid leaf fall occurring in this species. This trend continued until August 2014 as *V. karroo* retained significantly ($p < 0.001$) less leaves compared to the other species.

The new growing season started in September 2014, with *V. karroo* producing budding and immature leaves. Buds were also visible on *E. alba* during this month. *S. ciliata* retained some yellow leaves from the previous season, but most *Z. mucronata* trees were leafless during this month. During October 2014, *S. ciliata* was mostly leafless, while *Z. mucronata* and *E. alba* only produced buds. When comparing the leaf carriage scores of *V. karroo* to those of the other three species, significantly more ($p < 0.001$) leaves were present on *V. karroo* for both September and October in 2014. By November 2014 *E. alba* caught up to *V. karroo*, with no significant differences ($p > 0.05$) found between their respective leaf carriage scores. Both of these species were mostly at full leaf cover by this time. The other two species, namely *Z. mucronata* and *S. ciliata* had significantly less ($p < 0.001$) leaves compared to *V. karroo*, although they both had budding and immature leaves present in November 2014.

Relationship between leaf phenology and climate

The results of the correlation analyses between the monthly leaf carriage scores of all 16 woody species and monthly climate variables are presented in Table 4.9. Correlation coefficients ranging between 0.652 and 0.778 indicated strong positive correlations between total monthly rainfall (independent variable) and the leaf carriage scores (dependent variable) of *D. lycioides*, *S. pyroides* and *V. karroo* ($p < 0.001$). Moderately positive correlations were also observed between rainfall and the leaf phenology of *A. laricinus*, *E. alba*, *G. occidentalis* and *Z. mucronata,* with correlation coefficients ranging from 0.433 to 0.562 ($p < 0.05$). Only weak to very weak correlations were found between rainfall and leaf phenology of the remaining species. These correlations were also not statistically significant ($p > 0.05$).

Table 4.9 Correlation coefficients between monthly leaf carriage scores (dependent variables) of dominant woody species and monthly climate variables (Independent variable) for 28 months from August 2012 to November 2014

SPECIES	TOTAL RAINFALL	MEAN TEMP	MEAN MIN TEMP	MEAN MAX TEMP	MEAN DAYLENGTH
Asparagus laricinus	**r = 0.458** **P < 0.05**	r = 0.214 P > 0.05	r = 0.360 P > 0.05	r = 0.076 P > 0.05	r = 0.114 P > 0.05
Asparagus suaveolens	r = 0.317 P > 0.05	r = 0.067 P > 0.05	r = 0.219 P > 0.05	r = - 0.047 P > 0.05	r = - 0.064 P > 0.05
Buddleja saligna	r = 0.099 P > 0.05	r = - 0.094 P > 0.05	r = 0.038 P > 0.05	r = - 0.172 P > 0.05	r = - 0.259 P > 0.05
Diospyros lycioides	**r = 0.734** **P < 0.001**	**r = 0.669** **P < 0.001**	**r = 0.788** **P < 0.001**	**r = 0.607** **P < 0.001**	**r = 0.542** **P < 0.01**
Ehretia alba	**r = 0.511** **P < 0.01**	r = 0.297 P > 0.05	**r = 0.444** **P < 0.05**	r = 0.191 P > 0.05	r = 0.164 P > 0.05
Euclea crispa subsp. *ovata*	r = - 0.194 P > 0.05	**r = - 0.547** **P < 0.01**	**r = - 0.492** **P < 0.01**	**r = - 0.590** **P < 0.01**	**r = - 0.537** **P < 0.01**
Grewia occidentalis	**r = 0.562** **P < 0.01**	**r = 0.393** **P < 0.05**	**r = 0.548** **P < 0.01**	r = 0.310 P > 0.05	r = 0.237 P > 0.05
Lycium hirsutum	r = - 0.154 P > 0.05	r = - 0.295 P > 0.05	r = - 0.297 P > 0.05	r = - 0.330 P > 0.05	r = - 0.236 P > 0.05
Olea europaea subsp. *africana*	r = - 0.017 P > 0.05	r = - 0.265 P > 0.05	r = - 0.190 P > 0.05	r = - 0.258 P > 0.05	r = -0.300 P > 0.05
Searsia burchellii	r = - 0.060 P > 0.05	r = - 0.012 P > 0.05	r = 0.012 P > 0.05	r = - 0.060 P > 0.05	r = - 0.095 P > 0.05
Searsia ciliata	r = 0.267 P > 0.05	r = 0.000 P > 0.05	r = 0.175 P > 0.05	r = -0.058 P > 0.05	r = - 0.180 P > 0.05
Searsia lancea	r = - 0.246 P > 0.05	**r = - 0.424** **P < 0.05**	r = - 0.337 P > 0.05	**r = - 0.404** **P < 0.05**	**r = - 0.522** **P < 0.01**
Searsia pyroides	**r = 0.652** **P < 0.001**	**r = 0.487** **P < 0.01**	**r = 0.626** **P < 0.001**	**r = 0.425** **P < 0.05**	r = 0.359 P > 0.05
Tarchonanthus camphoratus	r = 0.141 P > 0.05	r = - 0.088 P > 0.05	r = 0.073 P > 0.05	r = - 0.155 P > 0.05	r = - 0.254 P > 0.05
Vachellia karroo	**r = 0.778** **P < 0.001**	**r = 0.663** **P < 0.001**	**r = 0.776** **P < 0.001**	**r = 0.589** **P < 0.01**	**r = 0.572** **P < 0.01**
Ziziphus mucronata	**r = 0.433** **P < 0.05**	r = 0.244 P > 0.05	**r = 0.404** **P < 0.05**	r = 0.173 P > 0.05	r = 0.082 P > 0.05

When comparing the mean monthly temperatures to leaf carriage scores, *D. lycioides* and *V. karroo* had correlation coefficients of 0.669 and 0.663, respectively, indicating strong positive correlations that were statistically significant ($p < 0.001$). The leaf carriage scores and mean monthly temperatures of *G. occidentalis* and *S. pyroides* were also significantly ($p < 0.05$) correlated, with moderately positive correlations found for both species. Negative correlation coefficients of -0.547 and -0.424 were found between the mean monthly temperatures and leaf carriage scores of *E. crispa* subsp. *ovata* and *S. lancea*, respectively. This indicated moderately negative correlations, which were statistically significant ($p < 0.05$). The correlations between mean monthly temperatures and phenology of all the other species were not significant ($p > 0.05$) (Table 4.9).

Stronger positive correlations were found between mean minimum temperatures and leaf carriage scores than between mean maximum temperatures and leaf carriage scores. However, stronger negative correlations were found between mean maximum temperatures and leaf carriage scores than between mean minimum temperatures and leaf carriage scores.

Correlation coefficients ranging between 0.626 and 0.788 indicated strong positive correlations between mean minimum temperatures and the leaf carriage scores of *D. lycioides*, *S. pyroides* and *V. karroo* ($p < 0.001$). There were also moderately positive correlations found between mean minimum temperatures and the leaf carriage scores of *E. alba*, *G. occidentalis* and *Z. mucronata* that were statistically significant ($p < 0.05$). Moderately negative correlations between the mean maximum temperatures and leaf phenology of both *E. crispa* subsp. *ovata* ($r = -0.59$) and *S. lancea* ($r = -0.404$) were found ($p < 0.05$) (Table 4.9).

No species were strongly correlated with mean daylight length. However, there were moderately positive correlations between mean daylight length and leaf carriage scores of *D. lycioides* ($r = 0.542$) and *V. karroo* ($r = 0.572$), which were statistically significant ($p < 0.01$). There were also moderately negative correlations between mean daylight length and leaf carriage scores of *E. crispa* subsp. *ovata* ($r = -0.537$) and *S. lancea* (0.522), that were statistically significant ($p < 0.01$). The correlations between mean monthly daylight length and phenology of all the other species were not significant ($p > 0.05$) (Table 4.9).

As significant differences (p > 0.001) were found between the leaf carriage scores of *V.karroo* within the same months of different years, it was decided to compare climate variables that could have influenced the timing and rate of leaf fall, as well as the onset of the growing season. When comparing the mean minimum temperatures between years it was evident that temperatures were higher during both June and July in 2013, compared to the same months in 2014. The higher temperatures in 2013 corresponded with longer leaf retention during that year. On the other hand, lower temperatures were recorded in both August and September in 2013, compared to the same months in 2012 and 2014 (Figure 4.23). The lower temperatures recorded in 2013 corresponded with a delay in leaf flush and could have been a limiting factor for growth in *V. karroo* trees.

Less rain was recorded during September 2013 compared to the same month in 2012 and 2014 (Figure 4.24). This corresponded with a delay in leaf-flush in 2013. However, the difference of 1.5 mm less rainfall recorded in September 2013 compared to September 2014 did probably not result in a delay in leaf-flush. Only when combining the rainfall of August and September were larger differences found between years, with 4 mm recorded in 2013, compared to 14 mm and 13 mm recorded in 2012 and 2014, respectively. Rainfall during previous months could therefore also be considered to have an effect on leaf-flush.

4.3.1.3 Woody browse available to kudu

The woody browse (leaves + shoots < 0.5 cm) present up to 2.0 m during different phases of food availability was considered to be the best measure of potential food availability for kudu. Leaf phenology of all recorded woody species was thus also taken into account in these calculations. The monthly leaf phenology factors used to calculate the available browse are presented in Table 4.10. These factors were derived from leaf carriage scores of woody species in the study area. The woody browse obtainable by kudu in the different phases of food availability is presented in Tables 4.11 – 4.17.
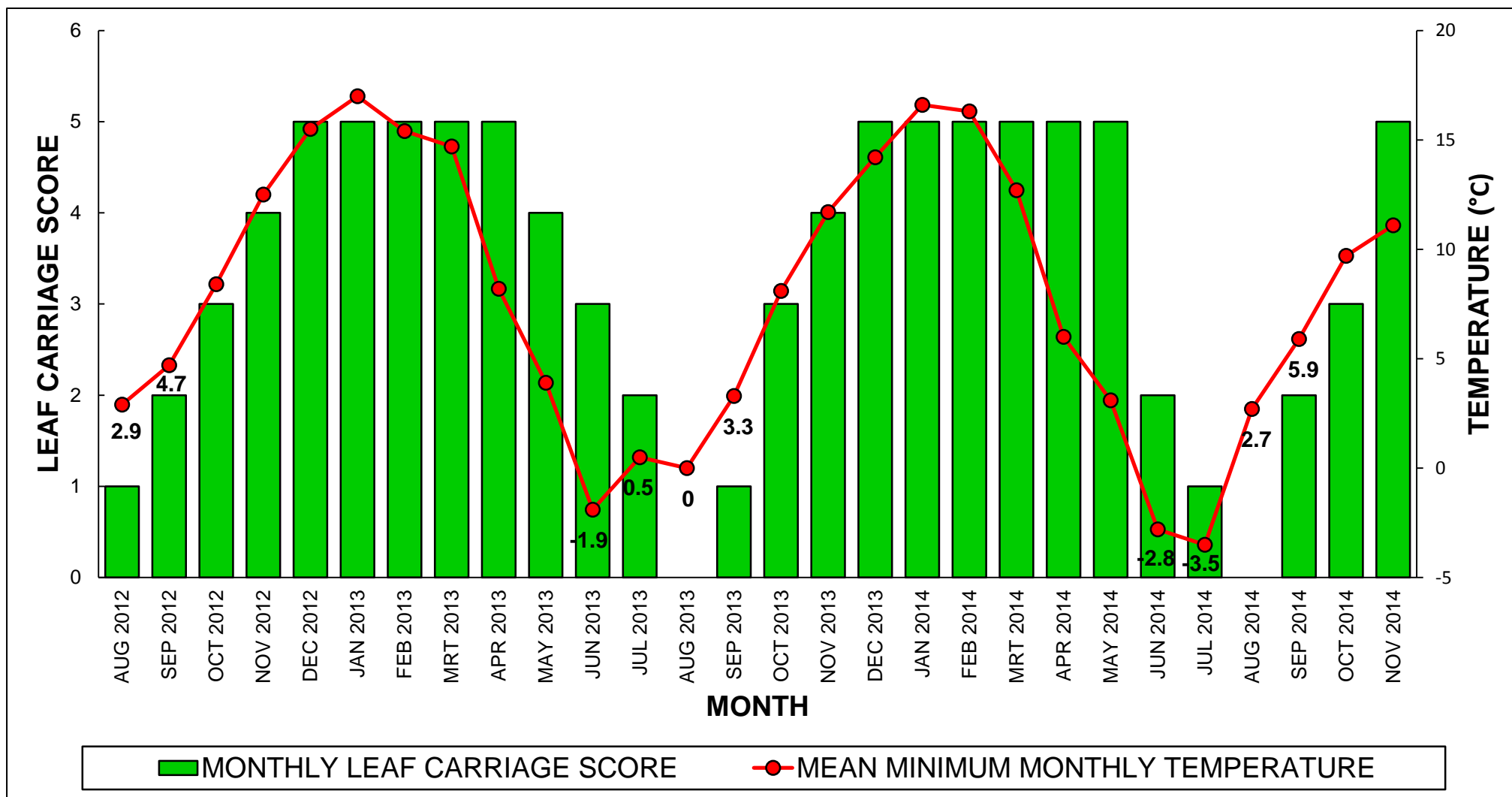
Figure 4.23 Leaf phenology of *Vachellia karroo* compared to the mean minimum temperatures during the 28 month period from August 2012 to November 2014
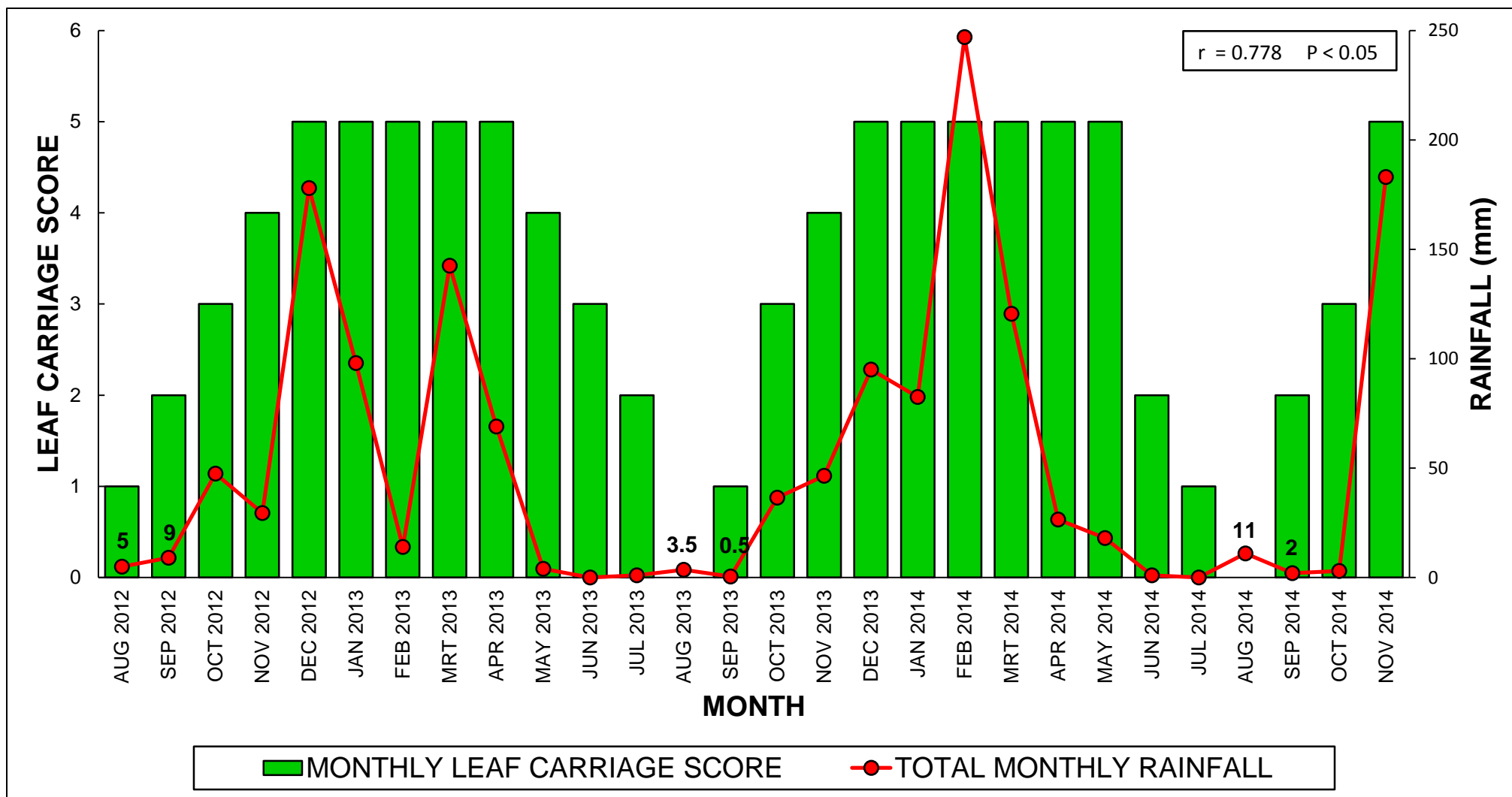
Figure 4.24 Leaf phenology of *Vachellia karroo* compared to the total monthly rainfall during the 28 month period from August 2012 to November 2014

Table 4.10 List of all the species recorded in the survey of the woody layer, indicating leaf phenology factors that were used in calculating the browse available to kudu and browsing capacity

SCIENTIFIC NAME	SEP 2013	OCT 2013	NOV 2013	DEC 2013	JAN 2014	FEB 2014	MRT 2014	APR 2014	MAY 2014	JUN 2014	JUL 2014	AUG 2014	SEP 2014
Asparagus laricinus	0.00	0.00	0.60	1.00	0.90	1.00	1.00	1.00	1.00	0.90	0.80	0.40	0.00
Asparagus suaveolens	0.50	0.10	0.30	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.80	0.70	0.30
Boscia albitrunca	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Buddleja saligna	0.70	0.60	0.60	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Cussonia paniculata	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Diospyros austro-africanum	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Diospyros lycioides	0.00	0.30	0.60	0.90	1.00	1.00	1.00	1.00	0.60	0.40	0.10	0.00	0.20
Ehretia alba	0.10	0.00	0.30	0.80	1.00	1.00	1.00	1.00	1.00	0.90	0.60	0.10	0.00
Euclea crispa subsp. *ovata*	0.80	0.80	0.70	0.70	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Euclea crispa subsp. *crispa*	0.80	0.80	0.70	0.70	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Grewia occidentalis	0.00	0.00	0.20	0.80	1.00	1.00	1.00	1.00	0.90	0.80	0.50	0.10	0.00
Gymnosporea karroica	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Lycium hirsutum	0.40	0.40	0.30	0.60	0.10	0.80	1.00	1.00	0.80	0.70	0.40	0.60	1.00
Olea europaea subsp. *africana*	1.00	1.00	0.90	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Osyris lanceolata	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Rhigozum obovatum	0.40	0.30	0.20	0.40	0.90	1.00	1.00	1.00	1.00	0.60	0.50	0.30	0.40
Searsia burchellii	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Searsia ciliata	0.10	0.00	0.00	0.30	0.90	1.00	1.00	1.00	1.00	0.80	0.40	0.30	0.10
Searsia lancea	1.00	0.90	0.70	0.80	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Searsia pyroides	0.00	0.20	0.40	0.90	1.00	1.00	1.00	1.00	1.00	0.40	0.30	0.00	0.00
Tarchonanthus camphoratus	0.60	0.40	0.10	0.80	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.40
Vachellia karroo	0.00	0.50	0.90	1.00	1.00	1.00	1.00	1.00	1.00	0.30	0.10	0.00	0.40
Ziziphus mucronata	0.10	0.00	0.20	0.80	1.00	1.00	1.00	1.00	1.00	0.80	0.60	0.10	0.00

Table 4.11 Woody browse (leaves + shoots < 0.5 cm) (kg DM) available to kudu in the study area during the dry phase (Sep 2013)

| SCIENTIFIC NAME | PLANT COMMUNITY | | | | | | | | STUDY AREA (274.08 ha) | |
| | *Buddleja saligna - Searsia burchellii* Community (131.49 ha) | | *Themeda triandra - Digitaria eriantha* Community (95.74 ha) | | *Digitaria eriantha - Cynodon dactylon* Community (44.87 ha) | | *Persicaria lapathifolia - Panicum coloratum* Community (1.98 ha) | | | |
	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%
Asparagus laricinus	262.98	0.19	670.18	5.29	0.00	0.00	0.00	0.00	933.16	0.63
Asparagus suaveolens	591.71	0.44	143.61	1.13	0.00	0.00	0.00	0.00	735.32	0.49
Boscia albitrunca	262.98	0.19	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.18
Buddleja saligna	13 030.66	9.64	0.00	0.00	0.00	0.00	0.00	0.00	13 030.66	8.76
Cussonia paniculata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Diospyros austro-africanum	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Diospyros lycioides	1 577.88	1.17	287.22	2.27	0.00	0.00	0.00	0.00	1 865.10	1.25
Ehretia alba	1 472.69	1.09	0.00	0.00	0.00	0.00	0.00	0.00	1 472.69	0.99
Euclea crispa subsp. *ovata*	236.68	0.18	0.00	0.00	0.00	0.00	0.00	0.00	236.68	0.16
Euclea crispa subsp. *crispa*	236.68	0.18	0.00	0.00	0.00	0.00	0.00	0.00	236.68	0.16
Grewia occidentalis	6 837.48	5.06	0.00	0.00	0.00	0.00	0.00	0.00	6 837.48	4.60
Gymnosporea karroica	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Lycium hirsutum	0.00	0.00	306.37	2.42	0.00	0.00	0.00	0.00	306.37	0.21
Olea europaea subsp. *africana*	23 010.75	17.03	0.00	0.00	0.00	0.00	0.00	0.00	23 010.75	15.47
Osyris lanceolata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Rhigozum obovatum	3 366.14	2.49	0.00	0.00	0.00	0.00	0.00	0.00	3 366.14	2.26
Searsia burchellii	55 883.25	41.35	478.70	3.78	224.35	23.81	0.00	0.00	56 586.30	38.04
Searsia ciliata	2 813.89	2.08	976.55	7.71	0.00	0.00	0.00	0.00	3 790.44	2.55
Searsia lancea	657.45	0.49	1 627.58	12.85	89.74	9.52	0.00	0.00	2 374.77	1.60
Searsia pyroides	0.00	0.00	382.96	3.02	0.00	0.00	0.00	0.00	382.96	0.26
Tarchonanthus camphoratus	22 589.98	16.72	0.00	0.00	0.00	0.00	0.00	0.00	22 589.98	15.19
Vachellia karroo	1 183.41	0.88	6 510.32	51.40	628.18	66.67	0.00	0.00	8 321.91	5.59
Ziziphus mucronata	591.71	0.44	1 282.92	10.13	0.00	0.00	0.00	0.00	1 874.63	1.26
Totals	**135 132.28**	**100**	**12 666.41**	**100**	**942.27**	**100**	**0.00**	**0**	**148 740.96**	**100**

Table 4.12 Woody browse (leaves + shoots < 0.5 cm) (kg DM) available to kudu in the study area during the flush phase (Oct 2013)

| SCIENTIFIC NAME | PLANT COMMUNITY | | | | | | | | STUDY AREA (274.08 ha) | |
| | *Buddleja saligna - Searsia burchellii* Community (131.49 ha) | | *Themeda triandra - Digitaria eriantha* Community (95.74 ha) | | *Digitaria eriantha - Cynodon dactylon* Community (44.87 ha) | | *Persicaria lapathifolia - Panicum coloratum* Community (1.98 ha) | | | |
	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%
Asparagus laricinus	262.98	0.20	670.18	4.13	0.00	0.00	0.00	0.00	933.16	0.64
Asparagus suaveolens	433.92	0.34	105.31	0.65	0.00	0.00	0.00	0.00	539.23	0.37
Boscia albitrunca	262.98	0.20	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.18
Buddleja saligna	12 202.27	9.50	0.00	0.00	0.00	0.00	0.00	0.00	12 202.27	8.36
Cussonia paniculata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Diospyros austro-africanum	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Diospyros lycioides	2 090.69	1.63	402.11	2.48	0.00	0.00	0.00	0.00	2 492.8	1.71
Ehretia alba	1 314.90	1.02	0.00	0.00	0.00	0.00	0.00	0.00	1 314.90	0.90
Euclea crispa subsp. *ovata*	236.68	0.18	0.00	0.00	0.00	0.00	0.00	0.00	236.68	0.16
Euclea crispa subsp. *crispa*	236.68	0.18	0.00	0.00	0.00	0.00	0.00	0.00	236.68	0.16
Grewia occidentalis	6 837.48	5.32	0.00	0.00	0.00	0.00	0.00	0.00	6 837.48	4.68
Gymnosporea karroica	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Lycium hirsutum	0.00	0.00	306.37	1.89	0.00	0.00	0.00	0.00	306.37	0.21
Olea europaea subsp. *africana*	23 010.75	17.91	0.00	0.00	0.00	0.00	0.00	0.00	23 010.75	15.76
Osyris lanceolata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Rhigozum obovatum	3 116.31	2.43	0.00	0.00	0.00	0.00	0.00	0.00	3 116.31	2.13
Searsia burchellii	52 990.47	41.24	449.98	2.78	210.89	16.43	0.00	0.00	53 651.34	36.75
Searsia ciliata	2 498.31	1.94	861.66	5.32	0.00	0.00	0.00	0.00	3 359.97	2.30
Searsia lancea	631.15	0.49	1 541.41	9.51	85.25	6.64	0.00	0.00	2 257.81	1.55
Searsia pyroides	0.00	0.00	478.70	2.95	0.00	0.00	0.00	0.00	478.70	0.33
Tarchonanthus camphoratus	19 486.82	15.16	0.00	0.00	0.00	0.00	0.00	0.00	19 486.82	13.35
Vachellia karroo	1 840.86	1.43	10 244.18	63.20	987.14	76.92	0.00	0.00	13 072.18	8.95
Ziziphus mucronata	525.96	0.41	1 148.88	7.09	0.00	0.00	0.00	0.00	1 674.84	1.15
Totals	**128 505.17**	**100**	**16 208.78**	**100**	**1 283.28**	**100**	**0.00**	**0**	**145 997.23**	**100**

Table 4.13 Woody browse (leaves + shoots < 0.5 cm) (kg DM) available to kudu in the study area during the immature phase (Nov-Dec 2013)

SCIENTIFIC NAME	PLANT COMMUNITY								STUDY AREA (274.08 ha)	
	Buddleja saligna - Searsia burchellii Community (131.49 ha)		*Themeda triandra - Digitaria eriantha* Community (95.74 ha)		*Digitaria eriantha - Cynodon dactylon* Community (44.87 ha)		*Persicaria lapathifolia - Panicum coloratum* Community (1.98 ha)			
	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%
Asparagus laricinus	473.36	0.35	1 359.51	6.18	0.00	0.00	0.00	0.00	1 832.87	1.14
Asparagus suaveolens	670.60	0.49	162.76	0.74	0.00	0.00	0.00	0.00	833.36	0.52
Boscia albitrunca	262.98	0.19	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.16
Buddleja saligna	13 030.66	9.54	0.00	0.00	0.00	0.00	0.00	0.00	13 030.66	8.13
Cussonia paniculata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Diospyros austro-africanum	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Diospyros lycioides	2 945.38	2.16	593.59	2.70	0.00	0.00	0.00	0.00	3 538.97	2.21
Ehretia alba	2 261.63	1.65	0.00	0.00	0.00	0.00	0.00	0.00	2 261.63	1.41
Euclea crispa subsp. *ovata*	223.53	0.16	0.00	0.00	0.00	0.00	0.00	0.00	223.53	0.14
Euclea crispa subsp. *crispa*	223.53	0.16	0.00	0.00	0.00	0.00	0.00	0.00	223.53	0.14
Grewia occidentalis	7 100.46	5.20	0.00	0.00	0.00	0.00	0.00	0.00	7 100.46	4.43
Gymnosporea karroica	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Lycium hirsutum	0.00	0.00	335.09	1.52	0.00	0.00	0.00	0.00	335.09	0.21
Olea europaea subsp. *africana*	21 814.19	15.96	0.00	0.00	0.00	0.00	0.00	0.00	21 814.19	13.61
Osyris lanceolata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Rhigozum obovatum	3 116.31	2.28	0.00	0.00	0.00	0.00	0.00	0.00	3 116.31	1.94
Searsia burchellii	55 883.25	40.89	478.70	2.18	224.35	13.59	0.00	0.00	56 586.30	35.30
Searsia ciliata	3 129.46	2.29	1 091.44	4.96	0.00	0.00	0.00	0.00	4 220.90	2.63
Searsia lancea	604.85	0.44	1 455.25	6.62	80.77	4.89	0.00	0.00	2 140.87	1.34
Searsia pyroides	0.00	0.00	718.05	3.27	0.00	0.00	0.00	0.00	718.05	0.45
Tarchonanthus camphoratus	21 038.40	15.39	0.00	0.00	0.00	0.00	0.00	0.00	21 038.40	13.12
Vachellia karroo	2 498.31	1.83	13 978.04	63.56	1 346.10	81.52	0.00	0.00	17 822.45	11.12
Ziziphus mucronata	854.69	0.63	1 819.06	8.27	0.00	0.00	0.00	0.00	2 673.75	1.67
Totals	**136 657.55**	**100**	**21 991.49**	**100**	**1 651.22**	**100**	**0.00**	**0**	**160 300.26**	**100**

Table 4.14 Woody browse (leaves + shoots < 0.5 cm) (kg DM) available to kudu in the study area during the mature phase (Jan – Mar 2014)

| SCIENTIFIC NAME | PLANT COMMUNITY | | | | | | | | STUDY AREA (274.08 ha) | |
| | Buddleja saligna - Searsia burchellii Community (131.49 ha) | | Themeda triandra - Digitaria eriantha Community (95.74 ha) | | Digitaria eriantha - Cynodon dactylon Community (44.87 ha) | | Persicaria lapathifolia - Panicum coloratum Community (1.98 ha) | | | |
	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%
Asparagus laricinus	525.96	0.34	1 531.84	6.33	0.00	0.00	0.00	0.00	2 057.80	1.14
Asparagus suaveolens	788.94	0.51	191.48	0.79	0.00	0.00	0.00	0.00	980.42	0.54
Boscia albitrunca	262.98	0.17	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.15
Buddleja saligna	15 515.82	10.06	0.00	0.00	0.00	0.00	0.00	0.00	15 515.82	8.62
Cussonia paniculata	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Diospyros austro-africanum	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Diospyros lycioides	3 287.25	2.13	670.18	2.77	0.00	0.00	0.00	0.00	3 957.43	2.20
Ehretia alba	2 892.78	1.88	0.00	0.00	0.00	0.00	0.00	0.00	2 892.78	1.61
Euclea crispa subsp. *ovata*	262.98	0.17	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.15
Euclea crispa subsp. *crispa*	262.98	0.17	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.15
Grewia occidentalis	7 363.44	4.77	0.00	0.00	0.00	0.00	0.00	0.00	7 363.44	4.09
Gymnosporea karroica	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Lycium hirsutum	0.00	0.00	363.81	1.50	0.00	0.00	0.00	0.00	363.81	0.20
Olea europaea subsp. *africana*	23 010.75	14.92	0.00	0.00	0.00	0.00	0.00	0.00	23 010.75	12.78
Osyris lanceolata	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Rhigozum obovatum	4 865.13	3.15	0.00	0.00	0.00	0.00	0.00	0.00	4 865.13	2.70
Searsia burchellii	55 883.25	36.23	478.70	1.98	224.35	13.51	0.00	0.00	56 586.30	31.42
Searsia ciliata	5 654.07	3.67	2 010.54	8.31	0.00	0.00	0.00	0.00	7 664.61	4.26
Searsia lancea	657.45	0.43	1 627.58	6.72	89.74	5.41	0.00	0.00	2 374.77	1.32
Searsia pyroides	0.00	0.00	861.66	3.56	0.00	0.00	0.00	0.00	861.66	0.48
Tarchonanthus camphoratus	28 796.31	18.67	0.00	0.00	0.00	0.00	0.00	0.00	28 796.31	15.99
Vachellia karroo	2 498.31	1.62	13 978.04	57.75	1 346.10	81.08	0.00	0.00	17 822.45	9.90
Ziziphus mucronata	1 183.41	0.77	2 489.24	10.28	0.00	0.00	0.00	0.00	3 672.65	2.04
Totals	**154 237.77**	**100**	**24 203.07**	**100**	**1 660.19**	**100**	**0.00**	**0**	**180 101.03**	**100**

Table 4.15 Woody browse (leaves + shoots < 0.5 cm) (kg DM) available to kudu in the study area during the senescent phase (Apr – May 2014)

| SCIENTIFIC NAME | PLANT COMMUNITY | | | | | | | | STUDY AREA (274.08 ha) | |
| | Buddleja saligna - Searsia burchellii Community (131.49 ha) | | Themeda triandra - Digitaria eriantha Community (95.74 ha) | | Digitaria eriantha - Cynodon dactylon Community (44.87 ha) | | Persicaria lapathifolia - Panicum coloratum Community (1.98 ha) | | | |
	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%
Asparagus laricinus	525.96	0.34	1 531.84	6.33	0.00	0.00	0.00	0.00	2057.80	1.14
Asparagus suaveolens	788.94	0.51	191.48	0.79	0.00	0.00	0.00	0.00	980.42	0.55
Boscia albitrunca	262.98	0.17	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.15
Buddleja saligna	15 515.82	10.08	0.00	0.00	0.00	0.00	0.00	0.00	15 515.82	8.63
Cussonia paniculata	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Diospyros austro-africanum	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Diospyros lycioides	2 945.38	1.91	593.59	2.45	0.00	0.00	0.00	0.00	3 538.97	1.97
Ehretia alba	2 892.78	1.88	0.00	0.00	0.00	0.00	0.00	0.00	2 892.78	1.61
Euclea crispa subsp. ovata	262.98	0.17	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.15
Euclea crispa subsp. crispa	262.98	0.17	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.15
Grewia occidentalis	7 363.44	4.78	0.00	0.00	0.00	0.00	0.00	0.00	7 363.44	4.10
Gymnosporea karroica	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Lycium hirsutum	0.00	0.00	449.98	1.86	0.00	0.00	0.00	0.00	449.98	0.25
Olea europaea subsp. africana	23 010.75	14.95	0.00	0.00	0.00	0.00	0.00	0.00	23 010.75	12.80
Osyris lanceolata	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.07
Rhigozum obovatum	4 865.13	3.16	0.00	0.00	0.00	0.00	0.00	0.00	4 865.13	2.71
Searsia burchellii	55 883.25	36.31	478.70	1.98	224.35	13.51	0.00	0.00	56 586.30	31.48
Searsia ciliata	5 654.07	3.67	2 010.54	8.30	0.00	0.00	0.00	0.00	7 664.61	4.26
Searsia lancea	657.45	0.43	1 627.58	6.72	89.74	5.41	0.00	0.00	2 374.77	1.32
Searsia pyroides	0.00	0.00	861.66	3.56	0.00	0.00	0.00	0.00	861.66	0.48
Tarchonanthus camphoratus	28 796.31	18.71	0.00	0.00	0.00	0.00	0.00	0.00	28 796.31	16.02
Vachellia karroo	2 498.31	1.62	13 978.04	57.73	1 346.10	81.08	0.00	0.00	17 822.45	9.91
Ziziphus mucronata	1 183.41	0.77	2 489.24	10.28	0.00	0.00	0.00	0.00	3 672.65	2.04
Totals	153 895.90	100	24 212.65	100	1 660.19	100	0.00	0	179768.74	100

Table 4.16 Woody browse (leaves + shoots < 0.5 cm) (kg DM) available to kudu in the study area during the dry phase (Jun – Aug 2014)

| SCIENTIFIC NAME | PLANT COMMUNITY | | | | | | | | STUDY AREA | |
| | *Buddleja saligna - Searsia burchellii* Community (131.49 ha) | | *Themeda triandra - Digitaria eriantha* Community (95.74 ha) | | *Digitaria eriantha - Cynodon dactylon* Community (44.87 ha) | | *Persicaria lapathifolia - Panicum coloratum* Community (1.98 ha) | | (274.08 ha) | |
	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%
Asparagus laricinus	447.07	0.30	1 273.34	8.34	0.00	0.00	0.00	0.00	1 720.41	1.05
Asparagus suaveolens	710.05	0.48	172.33	1.13	0.00	0.00	0.00	0.00	882.38	0.54
Boscia albitrunca	262.98	0.18	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.16
Buddleja saligna	15 515.82	10.53	0.00	0.00	0.00	0.00	0.00	0.00	15 515.82	9.48
Cussonia paniculata	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Diospyros austro-africanum	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Diospyros lycioides	1 919.75	1.30	363.81	2.38	0.00	0.00	0.00	0.00	2 283.56	1.40
Ehretia alba	2 103.84	1.43	0.00	0.00	0.00	0.00	0.00	0.00	2 103.84	1.29
Euclea crispa subsp. *ovata*	262.98	0.18	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.16
Euclea crispa subsp. *crispa*	262.98	0.18	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.16
Grewia occidentalis	7 100.46	4.82	0.00	0.00	0.00	0.00	0.00	0.00	7 100.46	4.34
Gymnosporea karroica	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Lycium hirsutum	0.00	0.00	263.81	2.38	0.00	0.00	0.00	0.00	363.81	0.22
Olea europaea subsp. *africana*	23 010.75	15.62	0.00	0.00	0.00	0.00	0.00	0.00	23 010.75	14.06
Osyris lanceolata	131.49	0.09	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.08
Rhigozum obovatum	3 615.98	2.45	0.00	0.00	0.00	0.00	0.00	0.00	3 615.98	2.21
Searsia burchellii	55 883.25	37.93	478.70	3.13	224.35	22.12	0.00	0.00	56 586.30	34.59
Searsia ciliata	4 076.19	2.77	1 436.10	9.40	0.00	0.00	0.00	0.00	5 512.29	3.37
Searsia lancea	657.45	0.45	1 627.58	10.66	89.74	8.85	0.00	0.00	2 374.77	1.45
Searsia pyroides	0.00	0.00	478.70	3.13	0.00	0.00	0.00	0.00	478.7	0.29
Tarchonanthus camphoratus	28 796.31	19.55	0.00	0.00	0.00	0.00	0.00	0.00	28 796.31	17.6
Vachellia karroo	1 314.90	0.89	7 257.09	47.52	699.97	69.03	0.00	0.00	9 271.96	5.67
Ziziphus mucronata	854.69	0.58	1 819.06	11.91	0.00	0.00	0.00	0.00	2 673.75	1.63
Totals	**147 321.40**	**100**	**15 270.52**	**100**	**1 014.06**	**100**	**0.00**	**0**	**163 605.99**	**100**

Table 4.17 Woody browse (leaves + shoots < 0.5 cm) (kg DM) available to kudu in the study area during the flush phase (Sep 2014)

| SCIENTIFIC NAME | PLANT COMMUNITY | | | | | | | | STUDY AREA (274.08 ha) | |
| | *Buddleja saligna - Searsia burchellii* Community (131.49 ha) | | *Themeda triandra - Digitaria eriantha* Community (95.74 ha) | | *Digitaria eriantha - Cynodon dactylon* Community (44.87 ha) | | *Persicaria lapathifolia - Panicum coloratum* Community (1.98 ha) | | | |
	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%	< 2.0m	%
Asparagus laricinus	262.98	0.19	670.18	4.26	0.00	0.00	0.00	0.00	933.16	0.61
Asparagus suaveolens	512.81	0.38	124.46	0.79	0.00	0.00	0.00	0.00	637.27	0.42
Boscia albitrunca	262.98	0.19	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.17
Buddleja saligna	15 515.82	11.48	0.00	0.00	0.00	0.00	0.00	0.00	15 515.82	10.20
Cussonia paniculata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Diospyros austro-africanum	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Diospyros lycioides	1 919.75	1.42	363.81	2.31	0.00	0.00	0.00	0.00	2 283.56	1.50
Ehretia alba	1 314.90	0.97	0.00	0.00	0.00	0.00	0.00	0.00	1 314.90	0.86
Euclea crispa subsp. *ovata*	262.98	0.19	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.17
Euclea crispa subsp. *crispa*	262.98	0.19	0.00	0.00	0.00	0.00	0.00	0.00	262.98	0.17
Grewia occidentalis	6 837.48	5.06	0.00	0.00	0.00	0.00	0.00	0.00	6 837.48	4.50
Gymnosporea karroica	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Lycium hirsutum	0.00	0.00	478.70	3.04	0.00	0.00	0.00	0.00	478.70	0.31
Olea europaea subsp. *africana*	23 010.75	17.03	0.00	0.00	0.00	0.00	0.00	0.00	23 010.75	15.13
Osyris lanceolata	131.49	0.10	0.00	0.00	0.00	0.00	0.00	0.00	131.49	0.09
Rhigozum obovatum	3 366.14	2.49	0.00	0.00	0.00	0.00	0.00	0.00	3 366.14	2.21
Searsia burchellii	55 883.25	41.35	478.70	3.04	224.35	18.25	0.00	0.00	56 586.30	37.20
Searsia ciliata	2 813.89	2.08	976.55	6.20	0.00	0.00	0.00	0.00	3 790.44	2.49
Searsia lancea	657.45	0.49	1 627.58	10.33	89.74	7.30	0.00	0.00	2 374.77	1.56
Searsia pyroides	0.00	0.00	382.96	2.43	0.00	0.00	0.00	0.00	382.96	0.25
Tarchonanthus camphoratus	19 486.82	14.42	0.00	0.00	0.00	0.00	0.00	0.00	19 486.82	12.81
Vachellia karroo	1 709.37	1.26	9 497.41	60.30	915.35	74.45	0.00	0.00	12 122.13	7.97
Ziziphus mucronata	525.96	0.39	1 148.88	7.29	0.00	0.00	0.00	0.00	1 674.84	1.10
Totals	**135 132.27**	**100**	**15 749.23**	**100**	**1 229.44**	**100**	**0.00**	**0**	**152 110.94**	**100**

During all the phases, *S. burchellii* provided most of the available browse to kudu in the study area, followed by either *O. europaea* subsp. *africana* or *T. camphoratus*. However, the woody species with the largest affect on potential food availability was *V. karroo*, with this species being both deciduous and abundant.

The potential food available to kudu increased from a low in the flush phase to a high in the mature phase. A rapid decrease then occurred in the potential food available to kudu from the senescent phase to the dry phase, with another substantial decrease occurring from the dry phase to the flush phase. The increase or decrease in the proportional availability of evergreen species was mostly affected by the fluctuations of deciduous species, with the overall proportional availability of evergreen species increasing as deciduous species decreased and vice versa.

4.3.1.4 Browsing capacity

Utilisation factors for leaves and shoots used in calculating browsing capacity are presented in Table 4.18. The calculated browsing capacities and browser units that can be supported up to three different feeding heights are presented in Tables 4.19 - 4.20. The highest browsing capacity was recorded in the *Buddleja saligna - Searsia burchellii* Community, followed by the *Themeda triandra - Digitaria eriantha* Community and the *Digitaria eriantha - Cynodon dactylon* Community (Table 4.19). Browsing capacity could not be calculated for the *Persicaria lapathifolia - Panicum coloratum* Community as no woody species were present in this plant community.

The hectares required per browser unit did not change much throughout the study period when considering the *Buddleja saligna - Searsia burchellii* Community. However, large differences were recorded between months in both the *Themeda triandra - Digitaria eriantha* and the *Digitaria eriantha - Cynodon dactylon* Communities. For example, the browsing capacity up to 2 m in the *Themeda triandra - Digitaria eriantha* Community ranged from 51 ha/BU in September 2013 to 16.5 ha/BU in February 2014. There was also a substantial difference in the browsing capacity calculated up to 2 m in the *Themeda triandra - Digitaria eriantha* Community when comparing September 2013 to September 2014, with 51 ha/BU and 31.5 ha/BU calculated, respectively.

Table 4.18 Utilisation factors for leaves and shoots that were used in calculating the browsing capacity

SCIENTIFIC NAME	LEAVES	SHOOTS (< 0.5 cm)
Asparagus laricinus	0.20	0.10
Asparagus suaveolens	0.20	0.10
Boscia albitrunca	0.50	0.20
Buddleja saligna	0.20	0.10
Cussonia paniculata	0.10	0.05
Diospyros austro-africanum	0.10	0.10
Diospyros lycioides	0.40	0.10
Ehretia alba	0.40	0.05
Euclea crispa subsp. ovata	0.10	0.05
Euclea crispa subsp. crispa	0.10	0.05
Grewia occidentalis	0.50	0.10
Gymnosporea karroica	0.10	0.05
Lycium hirsutum	0.10	0.05
Olea europaea subsp. africana	0.30	0.20
Osyris lanceolata	0.10	0.05
Rhigozum obovatum	0.10	0.05
Searsia burchellii	0.40	0.20
Searsia ciliata	0.40	0.10
Searsia lancea	0.30	0.20
Searsia pyroides	0.10	0.10
Tarchonanthus camphoratus	0.10	0.05
Vachellia karroo	0.50	0.20
Ziziphus mucronata	0.40	0.15

Table 4.19 Browsing capacity of each plant community in hectares required per browser unit (ha/BU)*

MONTH	YEAR	Buddleja saligna – Searsia burchellii Community			Themeda triandra – Digitaria eriantha Community			Digitaria eriantha – Cynodon dactylon Community			Persicaria lapathifolia - Panicum coloratum Community		
		< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m
September	2013	9.4	5.8	2.2	91.1	51.0	15.6	491.3	260.7	119.4	-	-	-
October	2013	10.2	6.2	2.3	56.4	29.3	8.8	254.5	146.0	66.7	-	-	-
November	2013	9.8	5.9	2.2	39.7	20.7	6.4	179.9	106.4	48.8	-	-	-
December	2013	8.9	5.4	2.1	32.8	17.7	5.7	168.1	99.5	45.6	-	-	-
January	2014	8.2	5.0	2.0	30.1	16.7	5.6	168.1	99.3	45.4	-	-	-
February	2014	8.2	5.0	1.9	29.5	16.5	5.5	168.1	99.0	45.3	-	-	-
March	2014	8.2	5.0	1.9	29.5	16.5	5.5	168.1	99.0	45.3	-	-	-
April	2014	8.2	5.0	1.9	29.5	16.5	5.5	168.1	99.0	45.3	-	-	-
May	2014	8.2	5.1	2.0	29.8	16.6	5.5	168.1	99.0	45.3	-	-	-
June	2014	8.4	5.2	2.0	46.3	27.4	9.5	311.6	175.0	80.1	-	-	-
July	2014	8.8	5.4	2.1	61.8	36.5	12.4	412.1	224.1	102.6	-	-	-
August	2014	9.1	5.6	2.2	80.9	47.6	15.2	491.3	260.7	119.4	-	-	-
September	2014	9.5	5.8	2.2	59.6	31.5	9.5	277.7	157.7	72.2	-	-	-

* A browser unit (BU) is defined as the metabolic equivalent of a kudu (100 % browser) with a mean body mass of 140 kg (Dekker, 1997).

Table 4.20 Estimated number of browser units (BU)* that the study area can support at three different browsing heights (< 1.5 m, < 2.0 m & < 5.0 m)

MONTH	YEAR	*Buddleja saligna – Searsia burchellii* Community (131.49 ha)			*Themeda triandra - Digitaria eriantha* Community (95.74 ha)			*Digitaria eriantha – Cynodon dactylon* Community (44.87 ha)			*Persicaria lapathifolia - Panicum coloratum* Community (1.98 ha)			STUDY AREA (274.08 ha)		
		< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	< 5.0m	< 1.5m	< 2.0m	<5.0m	< 1.5m	< 2.0m	< 5.0m
September	**2013**	13.99	22.67	59.77	1.05	1.87	6.13	0.09	0.17	0.38	0.00	0.00	0.00	15.13	**24.71**	66.28
October	2013	12.89	21.21	57.17	1.70	3.27	10.88	0.18	0.31	0.67	0.00	0.00	0.00	14.77	24.79	68.72
November	2013	13.42	22.29	59.77	2.41	4.63	14.96	0.25	0.42	0.92	0.00	0.00	0.00	16.08	27.34	75.65
December	2013	14.77	24.35	62.61	2.91	5.41	16.79	0.27	0.45	0.98	0.00	0.00	0.00	17.95	30.21	80.38
January	2014	16.04	26.30	65.75	3.18	5.73	17.10	0.27	0.45	0.99	0.00	0.00	0.00	19.49	32.48	83.84
February	2014	16.04	26.30	69.21	3.25	5.80	17.41	0.27	0.45	0.99	0.00	0.00	0.00	19.56	32.55	87.61
March	2014	16.04	26.30	69.21	3.25	5.80	17.41	0.27	0.45	0.99	0.00	0.00	0.00	19.56	32.55	87.61
April	2014	16.04	26.30	69.21	3.25	5.80	17.41	0.27	0.45	0.99	0.00	0.00	0.00	19.56	32.55	87.61
May	2014	16.04	25.78	65.75	3.21	5.77	17.41	0.27	0.45	0.99	0.00	0.00	0.00	19.52	32.00	84.15
June	2014	15.65	25.29	65.75	2.07	3.49	10.08	0.14	0.26	0.56	0.00	0.00	0.00	17.86	29.04	76.39
July	2014	14.94	24.35	62.61	1.55	2.62	7.72	0.11	0.20	0.44	0.00	0.00	0.00	16.60	27.17	70.77
August	**2014**	14.45	23.48	59.77	1.18	2.01	6.30	0.09	0.17	0.38	0.00	0.00	0.00	15.72	**25.66**	66.45
September	2014	13.84	22.67	59.77	1.61	3.04	10.08	0.16	0.28	0.62	0.00	0.00	0.00	15.61	25.99	70.47

* A browser unit (BU) is defined as the metabolic equivalent of a kudu (100 % browser) with a mean body mass of 140 kg (Dekker, 1997).

The browser unit values calculated at the end of each dry phase (September 2013 and August 2014) were the most important as they represented the critical period when browse resources were at their lowest for kudu (Table 4.20). The study area could support a total of 24.71 browser units up to a feeding height of 2 m in September 2013 and 25.66 browser units in August 2014. The *Buddleja saligna - Searsia burchellii* Community could support the most browser units, followed by the *Themeda triandra - Digitaria eriantha* Community and *Digitaria eriantha - Cynodon dactylon* Community.

4.3.2 Quantification of the herbaceous layer

4.3.2.1 Species composition and veld condition assessment

A total of 24 perennial grass species, 11 annual grass species, 10 dwarf shrub species and nine forb species were recorded from 24 400 point observations in the 122 line transects. A list of all the herbaceous species (grasses, dwarf shrubs and forbs), including the ecological groups they were classified into and their relative index values, are presented in Table 4.21. The results of the species composition and veld condition assessment in each plant community are presented in Tables 4.22 – 4.25.

A total of 13 perennial grass species, eight annual grass species, five dwarf shrub species and five forb species were recorded in the *Themeda triandra - Digitaria eriantha* Community (Table 4.22). Perennial grasses contributed 83.18% to the composition of the herbaceous layer in this plant community, while annual grasses only contributed 7.51%. Dwarf shrubs and forbs were found at low densities making up 0.79% and 0.05% of the herbaceous layer, respectively. Most of the soil in this plant community was covered, with only 8.49% consisting of bare patches (soil in a radius of 30 cm from the measured point not covered by herbaceous plants). The herbaceous layer of the *Themeda triandra - Digitaria eriantha* Community was considered to be in a climax succession stage due to 77.72% of all point observations in this plant community consisting of climax species. The dominant species recorded were the climax grass species, namely *Themeda triandra*, (45.46%), *Sporobolus fimbriatus* (15.17%) and *Panicum stapfianum* (9.68%). The veld condition score for the *Themeda triandra - Digitaria eriantha* Community was 818.49 and when compared to the high benchmark of 966.50 this plant community had a veld condition index of 84.69%, rendering the veld in excellent condition.

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Table 4.21 List of all the herbaceous species recorded in the study area

SCIENTIFIC NAME	PLANT SUCCESSION	ECOLOGICAL GROUP	RELATIVE INDEX VALUE
PERENNIAL GRASSES			
Aristida canescens	Sub-climax	Increaser IIb	4
Aristida diffusa	Sub-climax	Increaser IIb	4
Brachiaria serrata	Climax	Decreaser	10
Cenchrus ciliaris	Climax	Decreaser	10
Cymbopogon pospischilii	Climax	Increaser IIb	4
Digitaria eriantha	Climax	Decreaser	10
Digitaria argyrograpta	Climax	Decreaser	10
Elionurus muticus	Climax	Increaser Ia/IIa	7
Enneapogon scoparius	Climax	Increaser IIb	4
Eragrostis chloromelas	Sub-climax	Increaser IIa	7
Eragrostis curvula	Sub-climax	Increaser Ia/IIa	7
Eragrostis lehmanniana	Sub-climax	Increaser IIb	4
Eragrostis micrantha	Sub-climax	Increaser IIb	4
Eragrostis obtusa	Sub-climax	Increaser IIb	4
Eragrostis superba	Sub-climax	Increaser IIb	4
Eustachys paspaloides	Climax	Decreaser	10
Heteropogon contortus	Sub-climax	Increaser Ia/IIa	7
Panicum maximum	Climax	Decreaser	10
Panicum coloratum	Climax/Creeper	Decreaser	10
Panicum stapfianum	Climax	Decreaser	10
Setaria sphacelata var. *torta*	Sub-climax/Creeper	Increaser Ia/IIa	7
Sporobolus fimbriatus	Climax	Decreaser	10
Themeda triandra	Climax	Decreaser	10
Triraphis andropogonoides	Climax	Increaser IIb	4
ANNUAL GRASSES			
Aristida adscensionis	Pioneer	Increaser IIc	1
Aristida bipartita	Sub-climax	Increaser IIb	4
Aristida congesta subsp. *congesta*	Pioneer	Increaser IIc	1
Chloris virgata	Pioneer	Increaser IIb	4
Cynodon dactylon	Pioneer/Creeper	Increaser IIb	4
Cynodon hirsutus	Pioneer/Creeper	Increaser IIb	4
Setaria pumila	Pioneer	Increaser IIc	1
Setaria verticillata	Pioneer	Increaser IIc	1
Tragus koeleroides	Pioneer	Increaser IIc	1
Tragus racemosa	Pioneer	Increaser IIc	1
Urochloa panicoides	Pioneer	Increaser IIc	1

Table 4.21 (Continued)

SCIENTIFIC NAME	PLANT SUCCESSION	ECOLOGICAL STATUS	ECOLOGICAL INDEX VALUE
DWARF SHRUBS			
Chrysocoma ciliata	-	Increaser IIc	1
Felicia muricata	-	Increaser IIc	1
Indigofera rhytidocarpa	-	Increaser IIc	1
Lycium cinereum	-	Increaser IIc	1
Pentzia globosa	-	Increaser IIc	1
Plinthus karooicus	-	Increaser IIc	1
Rosenia humilis	-	Increaser IIc	1
Salsola glabrescens	-	Increaser IIc	1
Selago albida	-	Increaser IIc	1
Selago densiflora	-	Increaser IIc	1
FORBS			
Arctotis venusta	-	Increaser IIc	1
Crabbea acaulis	-	Increaser IIc	1
Berkheya onopordifolia	-	Increaser IIc	1
Heliotropium lanceolatum	-	Increaser IIc	1
Hibiscus pusillus	-	Increaser IIc	1
Pavonia patens	-	Increaser IIc	1
Persicaria lapathifolia	-	Increaser IIc	1
Schkuhria pinnata	-	Increaser IIc	1
Tephrosia capensis	-	Increaser IIc	1

Table 4.22 Species composition and veld condition of the herbaceous layer in the *Themeda triandra - Digitaria eriantha* Community

SPECIES	SPECIES COMPOSTION (%)	VELD CONDITION SCORE	BENCHMARK SCORE	VELD CONDITION INDEX
	(n = 8 400)			
Themeda triandra	45.46	454.60		
Sporobolus fimbriatus	15.17	151.70		
Panicum stapfianum	9.68	96.80		
Bare soil	8.49	0.00		
Digitaria eriantha	5.64	56.40		
Eragrostis obtusa	4.31	17.24		
Cynodon hirsutus	2.83	11.32		
Cynodon dactylon	1.96	7.84		
Aristida adscensionis	1.18	1.18		
Tragus racemosa	0.94	0.94		
Digitaria argyrograpta	0.89	8.90		
Cymbopogon pospischilii	0.85	3.40		
Eragrostis lehmanniana	0.72	2.88		
Pentzia globosa	0.49	0.49		
Eragrostis chloromelas	0.28	1.96		
Chloris virgata	0.24	0.96		
Aristida congesta subsp. *congesta*	0.18	0.18		
Urochloa panicoides	0.15	0.15		
Felicia muricata	0.14	0.14		
Plinthus karooicus	0.07	0.07		
Eragrostis curvula	0.06	0.42		
Eragrostis superba	0.06	0.24		
Rosenia humilis	0.06	0.06		
Forbs	0.05	0.05		
Brachiaria serrata	0.03	0.30		
Lycium cinereum	0.03	0.03		
Setaria sphacelata var. *torta*	0.03	0.21		
Setaria verticillata	0.03	0.03		
TOTAL	**100**	**818.49**	**966.50**	**84.69%**
				EXCELLENT CONDITION

Table 4.23 Species composition and veld condition of the herbaceous layer in the *Buddleja saligna - Searsia burchellii* Community

SPECIES	SPECIES COMPOSTION (%)	VELD CONDITION SCORE	BENCHMARK SCORE	VELD CONDITION INDEX
	(n = 11 400)			
Themeda triandra	15.39	153.90		
Aristida canescens	14.99	59.96		
Bare soil	10.56	0.00		
Panicum maximum	10.34	103.40		
Rock/Stone	8.47	0.00		
Sporobolus fimbriatus	5.91	59.10		
Aristida adscensionis	5.33	5.33		
Panicum stapfianum	4.67	46.70		
Cynodon hirsutus	3.85	15.40		
Aristida congesta subsp. *congesta*	3.21	3.21		
Eragrostis lehmanniana	2.99	11.96		
Setaria sphacelata var. *torta*	2.45	17.15		
Cynodon dactylon	1.97	7.88		
Eragrostis chloromelas	1.41	9.87		
Cymbopogon pospischilii	1.01	4.04		
Digitaria argyrograpta	1.01	10.10		
Urochloa panicoides	0.71	0.71		
Eustachys paspaloides	0.68	6.80		
Forbs	0.53	0.53		
Heteropogon contortus	0.53	3.71		
Eragrostis obtusa	0.52	2.08		
Pentzia globosa	0.42	0.42		
Aristida bipartita	0.40	1.60		
Digitaria eriantha	0.38	3.80		
Enneapogon scoparius	0.37	1.48		
Chloris virgata	0.28	1.12		
Cenchrus ciliaris	0.22	2.20		
Tragus koeleroides	0.21	0.21		
Eragrostis superba	0.18	0.72		
Brachiaria serrata	0.17	1.70		
Triraphis andropogonoides	0.17	0.68		
Tragus racemosa	0.16	0.16		
Plinthus karooicus	0.10	0.10		
Felicia muricata	0.09	0.09		

Table 4.23 (Continued)

SPECIES	SPECIES COMPOSTION (%)	VELD CONDITION SCORE	BENCHMARK SCORE	VELD CONDITION INDEX
	(n = 11 400)			
Eragrostis micrantha	0.07	0.28		
Setaria verticillata	0.05	0.05		
Aristida diffusa	0.04	0.16		
Indigofera rhytidocarpa	0.04	0.04		
Chrysocoma ciliata	0.03	0.03		
Elionurus muticus	0.02	0.14		
Eragrostis curvula	0.02	0.14		
Selago albida	0.04	0.04		
Selago densiflora	0.02	0.02		
Salsola glabrescens	0.01	0.01		
TOTAL	**100**	**537.00**	**804.00**	**66.79%**
				GOOD
				CONDITION

Table 4.24 Species composition and veld condition of the herbaceous layer in the *Digitaria eriantha - Cynodon dactylon* Community

SPECIES	SPECIES COMPOSTION (%)	VELD CONDITION SCORE	BENCHMARK SCORE	VELD CONDITION INDEX
	(n = 4 200)			
Digitaria eriantha	61.24	612.40		
Cynodon dactylon	19.26	77.04		
Bare soil	8.19	0.00		
Cynodon hirsutus	6.48	25.92		
Eragrostis lehmanniana	3.02	12.08		
Aristida congesta subsp. *congesta*	0.38	0.38		
Tragus racemosa	0.31	0.31		
Aristida adscensionis	0.21	0.21		
Eragrostis chloromelas	0.19	1.33		
Themeda triandra	0.19	1.90		
Sporobolus fimbriatus	0.12	1.20		
Urochloa panicoides	0.10	0.10		
Chloris virgata	0.07	0.28		
Lycium cinereum	0.07	0.07		
Forbs	0.05	0.05		
Chrysocoma ciliata	0.05	0.05		
Panicum stapfianum	0.05	0.50		
Eragrostis obtusa	0.02	0.08		
TOTAL	**100**	**733.90**	**867.00**	**84.65%**
				EXCELLENT
				CONDITION

Table 4.25 Species composition and veld condition of the herbaceous layer in the *Persicaria lapathifolia - Panicum coloratum* Community

SPECIES	SPECIES COMPOSTION (%) (n = 400)	VELD CONDITION SCORE	BENCHMARK SCORE	VELD CONDITION INDEX
Panicum coloratum	40.50	405.00		
Bare Ground	19.50	0.00		
Tragus racemosa	17.00	17.00		
Eragrostis lehmanniana	10.50	42.00		
Forbs	6.50	6.50		
Setaria pumila	2.00	2.00		
Aristida adscensionis	1.50	1.50		
Chloris virgata	1.00	4.00		
Plinthus karooicus	1.00	1.00		
Selago densiflora	0.50	0.50		
TOTAL	**100**	**479.50**	**625.50**	**76.66%**
				GOOD CONDITION

The herbaceous layer of the *Buddleja saligna - Searsia burchellii* Community were made up by 23 perennial grass species, 10 annual grass species, eight dwarf shrub species and six forb species (Table 4.23). Perennial grasses contributed more than half of the herbaceous layer with 63.54%, while annual grasses contributed 16.17%, dwarf shrubs 0.73% and forbs 0.53%. Bare soil was recorded in 10.56% of the point observations, while rocks were recorded in 8.47%. The herbaceous layer of this plant community was in a climax succession stage with more climax grasses (40.34%) compared to sub-climax (23.60%) and pioneer grasses (15.77%). The species with the highest occurrence was the climax species *T. triandra* (15.39%), followed by the sub-climax species *Aristida canescens* (14.99%) and the climax species *Panicum maximum* (10.34%). The herbaceous layer of the *Buddleja saligna - Searsia burchellii* Community was still considered to be in good condition, with a veld condition score of 537.00 and a veld condition index of 66.79%.

The herbaceous layer of the *Digitaria eriantha - Cynodon dactylon* Community were made up of seven perennial grass species, six annual grass species, two dwarf shrub species and one forb species (Table 4.24). Perennial grasses contributed the most to this plant community and consisted mostly of the climax grass *Digitaria eriantha* (61.24%). The annual grass *Cynodon dactylon* also made up a substantial amount of the point observations with 19.26%. Forbs as well as dwarf shrubs only occurred in very low numbers and were rarely recorded. No rocks were visible in this plant community, but bare patches were recorded in places. Due to the dominance of *D.* eriantha, the *Digitaria eriantha - Cynodon dactylon* Community was considered to be in a climax succession stage.

The *Digitaria eriantha - Cynodon dactylon* Community had a veld condition score of 733.90 and a veld condition index of 84.65%, indicating veld in excellent condition. However, it must be remembered that the *Digitaria eriantha - Cynodon dactylon* Community is a planted pasture and not a natural plant community, wtih *D. eriantha* expected to be the dominant species. It is thus more important to know the proportional contribution of *D. eriantha* compared to all other "unwanted" species in this plant community. A veld condition index was, however, still calculated to determine the grazing capacity of this plant community.

The *Persicaria lapathifolia - Panicum coloratum* Community had the fewest recorded species, with two perennial grass species, four annual grass species, two dwarf shrub species and one forb species (Table 4.25). Perennial grasses contributed more than half of the herbaceous layer with 51.00%, while annual grasses contributed 21.50%, forbs 6.50% and dwarf shrubs 1.50%. Bare soil was recorded in 19.50% of the point observations.

The herbaceous layer of the *Persicaria lapathifolia - Panicum coloratum* Community was in a climax succession stage with more climax grasses (40.50%) recorded compared to sub-climax grasses (10.50%) and pioneer grasses (21.50%). The species with the highest occurrence was the climax species *Panicum coloratum* (40.50%), followed by the sub-climax species *Eragrostis lehmanniana* (17.33%). The herbaceous layer of this plant community was considered to be in good condition, with a veld condition score of 479.50 and a veld condition index of 76.66%.

4.3.2.2 Grazing capacity

The calculated grazing capacities in each plant community and the number of grazer units that could be supported in the study area are presented in Tables 4.26 - 4.27. The study area covered 274.08 ha and during 2014 it was calculated that it could support a total of 188.21 grazer units.

The *Themeda triandra - Digitaria eriantha* Community and the *Digitaria eriantha - Cynodon dactylon* Community had the highest grazing capacities. However, the *Digitaria eriantha - Cynodon dactylon* Community only provided 33.24 of the 188.21 grazer units due to the relatively small area it covered. In contrast, the *Themeda triandra - Digitaria eriantha* Community covered a much larger area and consequently supported more grazer units. The lowest grazing capacitiy was recorded in the *Buddleja saligna - Searsia burchellii* Community, but due to this plant community covering the largest area it supported the most grazer units.

4.3.3 Stocking density at current carrying capacity

The current stocking density in the study area, with the number of grazer and browser units that are required is presented in Table 4.28. A total of 97 grazer units and 50 browser units were required for the 175 animals present in the study area during 2014. The 35 kudu in the study area required 30 browser units and 4 grazer units.

Table 4.26 Grazing capacity in each of the plant communities during 2014, calculated in hectares required per grazer unit (ha/GU)*

PLANT COMMUNITY	ha/GU
Themeda triandra - Digitaria eriantha Community	1.35
Buddleja saligna - Searsia burchellii Community	1.59
Digitaria eriantha - Cynodon dactylon Community	1.35
Persicaria lapathifolia - Panicum coloratum Community	1.47

* A grazer unit (GU) is defined as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean body mass of 180 kg (Dekker, 1997).

Table 4.27 Estimated number of grazer units (GU)* that the study area could support in 2014

PLANT COMMUNITY	SIZE (ha)	GU
Themeda triandra - Digitaria eriantha Community	95.74	70.92
Buddleja saligna - Searsia burchellii Community	131.49	82.70
Digitaria eriantha - Cynodon dactylon Community	44.87	33.24
Persicaria lapathifolia - Panicum coloratum Community	1.98	1.35
Total	**274.08**	**188.21**

* A grazer unit (GU) is defined as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean body mass of 180 kg (Dekker, 1997).

Table 4.28 Stocking densities in the study area during July 2014, with total grazer and browser units required at these densities

GAME SPECIES	Total number of animals stocked	Grazer Units required	Browser Units required
Blue wildebeest	7	6	1
Bontebok	43	15	2
Fallow deer	6	1	1
Greater kudu	35	4	30
Hartmann's mountain zebra	30	62	4
Impala	40	4	7
Nyala	10	1	4
Waterbuck	4	4	1
Total	**175**	**97**	**50**

4.3.4 Dry feed

Dry feed was supplied from April to November in 2013 and from June to November in 2014. Feeding times ranged from 8:00 to 17:00 daily, although most feeding in the study area took place after 14:00. Feed was supplied once a day according to the consumption of the animals, with more feed supplied when the feed from the previous day was finished and less or no feed supplied when little was consumed. No dry feed was supplied when it rained. More dry feed was supplied during 2013 compared to 2014, with more feeding days on average per month and more feed supplied on average per day (Table 4.29).

Table 4.29 Dry feed supplied from January 2013 to December 2014 (kg)

MONTH	YEAR	NUMBER OF DAYS SUPPLIED	AVG SUPPLIED PER DAY (kg)	TOTAL SUPPLIED (kg)
January	2013	0	0.00	0.00
February	2013	0	0.00	0.00
March	2013	0	0.00	0.00
April	2013	10	146.99	1 660.83
May	2013	15	250.65	3 760.73
June	2013	29	271.27	7 865.08
July	2013	30	301.62	9 048.66
August	2013	22	261.15	5 746.09
September	2013	26	285.59	7 426.01
October	2013	24	299.14	7 177.84
November	2013	20	245.31	4 906.13
December	2013	0	0.00	0.00
January	2014	0	0.00	0.00
February	2014	0	0.00	0.00
March	2014	0	0.00	0.00
April	2014	0	0.00	0.00
May	2014	0	0.00	0.00
June	2014	16	232.71	3 722.55
July	2014	21	237.29	5 058.85
August	2014	21	198.15	4 161.62
September	2014	22	229.08	5 039.76
October	2014	20	225.26	4 505.24
November	2014	19	209.04	3 970.72
December	2014	0	0.00	0.00
YEAR	**2013**	**176**	**270.31**	**47 591.08**
YEAR	**2014**	**119**	**221.63**	**26 458.74**

4.4 DISCUSSION

The *Buddleja saligna - Searsia burchellii* Community had the highest tree and shrub species diversity in the study area and the highest density of plants per hectare. However, woody plant density was not a good indication of the food available to animals due to the large size variation that occurred between some woody species. The *Buddleja saligna - Searsia burchellii* Community had by far the highest dry mass (leaves + shoots < 0.5 cm) available per hectare when compared to any of the other plant communities. Second to the *Buddleja saligna - Searsia burchellii* Community, the *Themeda triandra - Digitaria eriantha* Community had the highest dry mass available per hectare, followed by the *Digitaria eriantha - Cynodon dactylon* Community.

The quantity of browse available is also not constant and can vary considerably between seasons (Owen-Smith, 1979). Most deciduous species produced immature leaves after the first good rains (over 10 mm), while *V. karroo* and *D. lycioides* produced immature leaves before the onset of the rainy season. Similar trends were also observed in other studies. According to Janecke (2011) *V. karroo* and *D. lycioides* produced new leaves during September in the central Free State, irrespective of rainfall, while *S. pyroides* and *Z. mucronata* produced immature leaves after the first spring rains.

Milton (1987) reported that *V. karroo, Vachellia luederitzii* and *Senegalia burkei* produced new leaves before the first heavy rains fell in Nylsvley Nature Reserve, while at the same time *Senegalia caffra, Senegalia mellifera, Vachellia nilotica* and *Vachellia tortilis* only produced buds. Dekker & Smit (1996) also observed that six out of twelve woody species produced new leaves before the onset of rains in Musina, while the other species produced leaves rapidly after the first rains. The same phenomenon was observed by Hall-Martin & Fuller (1975), with nine out of 15 deciduous species producing new leaves before the rainy season got underway in Malawi. Styles and Skinner (1997) also found that young mopane leaves emerged independently of rainfall in the Northern Tuli Game Reserve when most other species were leafless.

Full leaf cover was reached by most deciduous species in the study area during January, with leaf senescence usually starting in April and the first leaf fall occurring a month later. The early flushing species retained very little leaves during July and were mostly leafless by August. In contrast, most other deciduous species retained some yellow leaves until the end of August. The differences between deciduous species was clearly demonstrated by *E. alba, Z. mucronata* and *S. ciliata* retaining significantly more leaves ($p < 0.001$) compared to *V. karroo* from June to August. However, the early flushing *V. karroo* trees produced significantly more leaves ($p < 0.05$) during September and October compared to the other three species that were mostly leafless during this time. According to Hall-Martin & Fuller (1975) the fact that some trees produced leaves long before the start of the wet season and retained their leaves well into the dry season indicated that temperature, moisture availability and day length are probably the driving forces behind changes in leaf phenology.

The availability of groundwater plays an important role in leaf fall and emergence as illustrated by results from a study done on the influence of tree thinning on the vegetative growth and browse production of *Colophospermum mopane* trees (Smit, 2001). In this study it was found that trees at lower densities produced leaves at an earlier stage during spring and retained their leaves for longer periods during winter compared to trees at higher densities (Smit, 2001). Water availability to woody plants is not only affected by the overlap and lateral spread of root systems, but also the depth of these root systems (Casper & Jackson, 1997). Buys (1990) suggested that woody species are not dependent on rain to produce new growth as they can reach water deep below ground level.

Strong positive correlations were found between the mean minimum temperatures and monthly leaf carriage scores of the early flushing species *V. karroo* and *D. lycioides*. Similar results are reported by Janecke (2011) that found strong positive correlations between minimum temperature and leaf phenology of *V. karroo, D. lycioides* and *S. pyroides*. The correlation coefficients indicated that the leaf phenology of *V. karroo* and *D. lycioides* followed the pattern of rising and falling temperatures from summer to winter. Strong positive correlations were also found between total monthly rainfall and the monthly leaf carriage scores of *V. karroo* and *D. lycioides*, with these two species producing more leaves as the wet season came into full swing and losing leaves progressively as the dry season approached.

However, Janecke (2011) only found moderate correlations between phenology of *V. karroo, D. lycioides* and *S. pyroides* and monthly rainfall totals. The weaker correlations could possibly be explained by differences in rainfall that was measured approximately 20 km from the Wag-'n-Bietjie Private Nature Reserve (Janecke & Smit, 2011) as opposed to rainfall being measured in the study area at Amanzi Private Game Reserve.

Only moderately positive correlations were found between the monthly leaf carriage scores of *V. karroo* and *D. lycioides* and mean monthly daylight length. The fact that these two species produced new leaves before the rains started, suggests that temperature is the major driving force behind leaf emergence in both *V. karroo* and *D. lycioides.* Leaf phenology of the deciduous species *E. alba*, *Z. mucronata*, *G. occidentalis, A. laricinus* and *S. ciliata* was either moderately or weakly correlated to both temperature and rainfall. However, they only produced new leaves after the first rains, suggesting that rainfall could in fact be the trigger for leaf emergence in these species. On the other hand, it could also be possible that leaf emergence is triggered by higher temperatures compared to the early flushing species.

Most leaf fall in evergreen species occurred from October to November. However, these species retained most of their leaves throughout the year, with *T. camphorates* being the only exception. The budding and immature leaves present for most of the year on *T. camphoratus, B. saligna, O. europaea* subsp. *africana* and *S. burchellii* seemed to be in a state of dormancy, with the abundance of immature leaves only increasing in these species somewhere from November to April. Only these periods were considered as the active growing periods in evergreen species.

However, some evergreen species were recorded to simply retain dry leaves from November 2013 to January 2014. This occurred after the study area experienced a prolonged period of very little rainfall in 2013. The lack of rainfall coupled with high daily temperatures from October that year, resulted in most evergreen species on the northern slopes being covered in dry leaves. This is an example of a drought-avoidance strategy where reserves are usually accumulated in the plants' stems or roots prior to drought (Chaves *et al.*, 2002). These conditions changed quickly in February 2014, with above average rainfall recorded for that month. By middle February most evergreen trees and shrubs shed their dry leaves and were covered by mainly immature leaves.

Janecke (2011) found no significant differences ($p > 0.05$) when comparing the leaf phenology of deciduous species between four years in the Wag-'n-Bietjie Private Nature Reserve located in the central Free State. However, significant differences ($p < 0.05$) were found when comparing the leaf carriage scores of *V. karroo, E. alba, Z. mucronata* and *S. ciliata* between the two years in the current study. The differences in scores between years were mostly due to a delay in leaf flush in 2013, with immature leaves appearing later than usual in most deciduous species.

The delay in leaf emergence during 2013 could have been caused by less underground water being available during September 2013 compared to the same month the next year. However, it does not explain why new leaves still emerged during October 2013 with only 0.5 mm rainfall recorded from the first of September to the 15th of October that year. Leaf emergence during October 2013 could thus not have been triggered by rainfall. In this case, the delay was probably caused by lower minimum temperatures recorded during August and September in 2013 compared to the same months the next year. Du Toit (1966) confirmed that minimum temperatures lower than 3°C inhibited growth in *V. karroo* trees.

Rapid leaf fall that occurred after the first frost in June 2014 could also have contributed to the significant differences found between leaf carriage scores of different years. No frost was observed during 2013, with warmer minimum temperatures recorded during both June and July that year. The warmer temperatures in 2013 corresponded with deciduous trees retaining their leaves for longer. These results suggest that the leaf phenology of woody species can change dramatically from year to year, having profound consequences on the food available to browsers.

Janecke & Smit (2011) considered the availability of browse to be the most important limiting factor for browsers in a confined (fenced) area during the late dry season. Results of the present study indicate that the period with the lowest browse availability was during the flush phase in either September or October. However, the critical period for browsers could potentially stretch from August to middle October, with the lowest browsing capacities recorded during September 2013 and August 2014. The critical period for browsers ends with the emergence of immature leaves in most *V. karroo* trees. This was in accordance with Theron (2005), who reported that the critical period for giraffe in the central Free State was from August to October and not the total dry season.

According to Janecke (2011), the critical period for browsers in the Wag-'n-Bietjie Private Nature Reserve was from July/August to October, with a peak in September when almost no leaves were available on deciduous species. This period ended when budding leaves turned into immature leaves (Janecke & Smit, 2011). The critical period for browsers and mixed-feeders differed somewhat in other geographical regions of South Africa. Dekker & Smit (1996) found the availability of browse to be at the lowest from September to November on the Musina Experimental Farm, while the critical period when very little browse was available for impala in the Timbavati Private Nature Reserve was during October (Pietersen, Meissner & Pietersen, 1993).

The deciduous species *S. ciliata*, *Z. mucronata*, *A. laricinus*, *A. suaveolens* and *E. alba* were considered to be important to the food supply of kudu in the study area during the critical period as these retained some leaves until the time when *V. karroo* trees produced immature leaves. *V. karroo* became a crucial food source during September and October when most other deciduous species were leafless. According to Janecke & Smit (2011) *Z. mucronata* was also important in sustaining browsers in the Wag-'n-Bietjie Private Nature Reserve during the onset of the critical period as they still retained mature and/or dry leaves until August. The shrub species *A. laricinus, L. hirsutum* and *Lycium echinatum* retained up to 50% of their full leaf cover during the critical period and were also considered important to browsers during this time (Janecke & Smit, 2011). Kok & Opperman (1980) also reported that *Asparagus* species became more important in the diets of giraffe during the dry season as they retained their leaves for longer than most other deciduous species in the Willem Pretorius Nature Reserve.

Styles and Skinner (1997) found that mopane trees were crucial for the carrying capacity in the Northern Tuli Game Reserve, as these trees produced new leaves at the end of the dry season when other woody species were leafless. *V. karroo* played a similar important role during September and October when most deciduous species were leafless in the Amanzi Private Game Reserve. However, the study area did have a good supply of evergreen species for browsers to utilise during the critical periods. This was evident with the evergreen species *S. burchellii* making up most of the browseable material within reach of kudu throughout the year. According to Kok & Opperman (1980), giraffe in the Willem Pretorius Nature Reserve also changed their diet from mainly deciduous to mainly evergreen species during the winter, preferring to browse on *S. burchellii* (referred to as *Searsia undulata* by Kok & Opperman, 1980).

According to Janecke & Smit (2011) stocking rates are of critical importance, with a conservative stocking rate preventing damage to browse resources and lowering the risk of animal mortalities as a result of malnutrition. The number of browser units that the study area in the Amanzi Private Game Reserve could sustain up to a feeding height of two meters, was calculated to be 32.55 between February and April in 2014. However, only 25.66 browser units could be sustained during the critical period in August 2014. When comparing the stocking rate to the available browser units, browsers were overstocked by 17 browser units in February 2014 and by 24 browser units in August 2014. In a confined (fenced) area such as the study area the only option to maintain these high stocking rates, without the risk of suffering animal losses, is by providing supplementary feeding during the critical period.

As very little grass was recorded in the diets of kudu in previous studies (Wilson, 1965; Wilson, 1970; Conybeare, 1975; Giesecke & Van Gylswyk, 1975; Owen-Smith, 1979), Novellie (1983) decided to only include browse when estimating the potential food abundance of kudu in Kruger National Park. According to Novellie (1983) grass contributed a substantial proportion of the vegetation biomass in Kruger National Park and including grass would have resulted in a false impression of habitat quality for kudu. However, Novellie (1983) did include forbs along with woody plants into the potential food available to kudu. In the current study only woody plants were considered as potential food available to kudu, as forbs were rarely encountered in the study area and thus contributed an insignificant proportion of the herbaceous layer. Grasses were also excluded in this study on the same grounds used by Novellie (1983). However, since grazer and mixed feeder species were present in the study area surveys of the herbaceous layer were still conducted to determine the grazing capacity of the study area for management purposes.

The *Digitaria eriantha - Cynodon dactylon* Community and the *Themeda triandra - Digitaria eriantha* Community had the highest grazing capacities. However, due the relatively small size of the *Digitaria eriantha - Cynodon dactylon* Community it only contributed 33.24 of the 188.21 grazer units calculated for the study area. Most grazer units were contributed by the *Buddleja saligna - Searsia burchellii* Community. This was mainly due to the large area it covered as it had the lowest grazing capacity of all the plant communities. The study area was understocked by 91 grazer units in terms of the ecological grazing capacity. However, if an economic grazing capacity was used at 70% of the ecological grazing capacity, as recommended by Van Rooyen (2010b), then the study area would only have been understocked by 35 grazer units.

According to Janecke & Smit (2011) it is not necessary to supply feed to browsers in areas of the central Free State that have sufficient evergreen species to sustain those browsers. However, the supply of feed was considered to be a necessity during the critical period in the Wag-'n-Bietjie Private Nature Reserve where no other browse resources were available.

The study area in Amanzi Private Game Reserve was overstocked in terms of browsers during 2014. The number of browsers should thus have been reduced to avoid damage to the browse resource and possible game losses. The alternative option was to supply animals with enough feed to sustain them through the critical period. The latter option was chosen out of a tourism and financial point of view. Dry feed was supplied to animals from June until the wet season was well under way in November. Janecke & Smit (2011) suggested that adjustment to feeding programmes should be made in accordance with leaf phenology patterns of woody species. This would, however, be difficult to implement as most game farms have a combination of browsers and grazers. Dry feed in the study area was adjusted according to its consumption by wildlife. However, the consumption of dry feed remained relatively constant throughout the dry and flush phases. Thus, supplying too little feed during the early dry season, when deciduous trees still retained a decent amount of leaves, could lead to extra competition between grazers, which could result in injuries. The same would apply to reducing the feed supplied when deciduous species produced new leaves at the start of the growing season.

4.5   CONCLUSION

From this study it was clear that some deciduous species produced leaves earlier than others. The early flushing species *V. karroo* had the largest impact on browse availability in the study area as this species was both abundant and produced new leaves during the time when browse availability was at a yearly low. However, later flushing species possibly served as an important food source to browsers during the critical period (from August to middle October) as they still retained some of their leaves throughout this time. When managing browsers in small enclosed areas it is thus important to take leaf phenology of woody species into account as carrying capacity will usually be much higher during mature compared to dry phases of food availability. Game numbers should be adjusted accordingly by reducing the number of game during dry phases if they exceeded carrying capacity. The alternative would be to supply game with dry feed when overstocked.

CHAPTER 5: DIET COMPOSITION AND FOOD PREFERENCES OF KUDU

5.1   INTRODUCTION

According to Giesecke & Van Gylswyk (1975) the feeding habits of herbivores will largely depend on the animals' food preferences and the availability of their preferred food plants during the observation period. If no selection took place then an animal's diet would simply reflect the relative proportions of food available in the environment (Petrides, 1975; Chesson 1978; Johnson, 1980). Petrides (1975) considered food items with the highest occurrence in an animal's diet as their principle foods. However, conclusions about the preference of selected food items cannot be drawn without taking food availability into account. Only when food items are proportionally more utilised than they are available, can they be considered as preferred (Neu *et al.*, 1974; Petrides, 1975; Chesson 1978; Johnson, 1980). According to Owen-Smith & Cooper (1987), the proportion of a particular food item in an animal's diet depends on the encounter rate, frequency of acceptance, feeding duration and eating rate.

Kudu are regarded as predominantly browsers that consume very little or no grass (Wilson, 1965; Wilson, 1970; Conybeare, 1975; Giesecke & Van Gylswyk, 1975; Owen-Smith, 1979; Novellie, 1983; Owen-Smith *et al.*, 1983; Owen-Smith & Cooper 1985; du Toit, 1988; Owen-Smith & Cooper, 1989; Breebaart, 2000; Cerling *et al.*, 2003; Codron *et al.*, 2005a & b; Hooimeijer *et al.*, 2005; Codron *et al.*, 2007; Curlewis, 2014; Makhado *et al.*, 2016a & b). A small rumen capacity designed for rapid throughput of food apparently limits kudu from accepting mature grass in their diet (Hofmann & Stewart, 1972; Hofmann, 1973; Giesecke & Van Gylswyk 1975). However, according to Conybeare (1975) grass may in fact be an important food source to kudu in some areas depending on local conditions.

The diet of kudu also varies depending on food availability (Conybeare, 1975; Owen-Smith, 1979; Novellie, 1983; Owen-Smith *et al.*, 1983; Owen-Smith & Cooper 1985; du Toit, 1988; Owen-Smith & Cooper, 1989; Breebaart, 2000; Hooimeijer *et al.*, 2005; Curlewis, 2014; Makhado *et al.*, 2016a & b). During the pre-rain flush in both Hwange and Kruger National Park, kudu browsed predominantly on the new leaves of trees and shrubs (Conybeare, 1975; Owen-Smith, 1979; Novellie, 1983; du Toit, 1988). This was due to woody species producing new leaves earlier than the plants in the herbaceous layer, resulting in browse that was both more abundant and of higher nutritional value (Novellie, 1983).

However, kudu spent most of their feeding time from February to April in the Wankie National Park utilising plants in the herbaceous layer. This was confirmed by the stomach contents of kudu containing proportionally more grass and forbs compared to browse from trees and shrubs (Conybeare, 1975). Kudu in the Tshokwane area of Kruger National Park also spent most of their feeding time during the late wet season utilising plants in the herbaceous layer (Owen-Smith, 1979; Novellie, 1983; du Toit, 1988). Contrary to the above findings, a number of authors reported that kudu utilised woody browse as their principle food source throughout the year (Owen-Smith & Cooper, 1985; Breebaart, 2000; Hooimeijer *et al.*, 2005; Curlewis, 2014).

Kudu also utilise a wide variety of plant species, with Brynard & Pienaar (1960) listing a total of 147 plant species utilised by kudu in the Kruger National Park. Nevertheless, only a small number of plant species usually contribute the bulk of kudu diets in any given time of the year (Wilson, 1965; Wilson, 1970; Conybeare, 1975; Owen-Smith, 1979; Novellie, 1983; Owen-Smith *et al.*, 1983; Owen-Smith & Cooper, 1985; du Toit, 1988; Owen-Smith & Cooper, 1989; Breebaart, 2000; Hooimeijer *et al.*, 2005; Curlewis, 2014; Makhado *et al.*, 2016a & b). According to Wilson (1965), kudu can probably survive even without their preferred food plants as long as enough browse was available.

The specific objectives of this chapter were:

1. To determine the diet composition of kudu in the study area during the different phases of food availability; and

2. To determine the food preferences of kudu in the study area during the different phases of food availability.

5.2 METHODOLOGY

5.2.1 Diet composition

Kudu were observed from sunrise to sunset for five days each month from September 2013 to September 2014. Observations were carried out on foot from slopes in the study area and made through 16x50 binoculars mounted on a tripod, with observation distances ranging from less than 10 to about 500 m. Focal-animal sampling, as described by Altmann (1974), was used to record kudu foraging behaviour. A focal animal was selected and observed continuously for 15 minutes while using a voice recorder to record its detailed activity sequence to the nearest second. The focal sampling period would be terminated at the end of each 15 minute recording or if the observed individual went out of sight for more than two minutes. If the observed animal was feeding at the end of the 15 minute sampling period, the observation would continue until the animal stopped feeding on the specific plant. Whenever possible a different individual would be selected for every 15 minute focal sampling period, thus ensuring data representative of the whole kudu population.

The total duration of feeding time for each food type or species was used to determine the diet composition of kudu (Owen-Smith, 1979; Novellie, 1983; du Toit, 1988). Feeding time is considered to be a more accurate measure of the quantity of food ingested when compared to most other methods, including bite frequency, rumen content analysis, faecal analysis and vegetation-based sampling (Owen-Smith, 1979; Novellie, 1983; du Toit, 1988). Feeding time, as described by Owen-Smith (1979), consisted of moving the head towards, plucking off and chewing food items. Food types consisted of browse, grass and dry feed (a mixture of grass, lucerne, maize meal and molasses), with browse further divided into deciduous trees and shrubs, evergreen trees and shrubs, dwarf shrubs and forbs. Due to tall grass in the foreground, it was sometimes difficult to determine whether kudu were utilising grass, forbs, dwarf shrubs or woody plant seedlings when feeding at ground level. All of these recordings were consequently grouped into an unidentified feeding at ground level category. The date and time, as well as the sex and age of the individual observed, were also recorded at the start of each focal sampling period. Accurate sex identification was made easy due to distinct sexual dimorphism in greater kudu (Jarman, 1974). However, calves under one year of age were not sexed. This was due to difficulty detecting the short horns of bull calves at a distance, as they were usually obscured by their ears between six months and one year of age (Allen-Rowlandson, 1980).

Bulls were divided into different age classes by using horn shape according to the classification of Allen-Rowlandson (1980). The following age classes were used: 12 months, 18 months, 24 months, 30 months, three years, four years and five years. Bulls were, however, not classified older than five years of age, due to considerable variation in horn growth of older males and possible shorter horns caused by wear and tear (Simpson, 1971; Simpson, 1972a). Females were divided into the following age classes according to body size: one to two year old heifers and cows two years and older (Allen-Rowlandson, 1980).

The monthly diet composition data of all kudu were grouped annually (September 2013 to August 2014) and divided into phases of food availability rather than seasons, based on long term rainfall and temperature. This was done as rainfall and temperature does not always accurately reflect food availability to browsers.

The following phases of food availability were accordingly recognised:

Dry phase: Mostly dry grass available, with predominantly yellow, dry or no leaves retained on deciduous trees and shrubs;

Flush phase: Mostly dry grass available, with predominantly green budding and immature leaves available on deciduous trees and shrubs;

Immature phase: Mostly green grass available, with predominantly green immature leaves available on deciduous trees and shrubs;

Mature phase: Mostly green grass available, with predominantly mature green leaves available on deciduous trees and shrubs; and

Senescent phase: Mostly yellow senescing grass available, with predominantly mature green and yellow senescing leaves retained on deciduous trees and shrubs.

Diet composition data was then further separated to determine the diets of cows and socially mature bulls, respectively. Bulls from four years of age were considered socially mature (Furstenburg, 2005). Comparisons between phases of food availability were conducted separately for the different food types, by fitting a generalized linear model with the following specifications:

I) Dependant variable: time spent on food type per observation day and phase;

II) Independent variable: phase (7 levels, that is, 6 degrees of freedom);

III) Error distribution: binomial;

IV) Link function: log; and

V) Scale parameter: estimated from Pearson chi-square statistic.

From the generalized model, estimates of the relevant proportions of food type per phase were calculated. The phases were compared pairwise by calculating estimates and associated 95% confidence intervals and P-values for relevant ratios of time spent feeding. The above analysis was repeated separately for the whole kudu population, cows and socially mature bulls. Feeding times of the two sexes were also compared in the same manner. The statistical analysis was carried out using the GENMOD procedure of the SAS software (SAS, 2009).

5.2.2 Food preferences

The relative preferences that herbivores display for plant species are used to determine their value as food resources (Petrides, 1975). Foraging ratios is most commonly used as an index of food preference by dividing the proportional contribution of a plant species in the diet of an animal by the plant species' proportional availability in the environment. Plant species with foraging ratios greater than one are considered to be preferred, while plant species with foraging ratios smaller than one are considered neglected (Petrides, 1975). However, conclusions drawn about preference are dependent on the food types considered to be available to the animal. Although the absolute values of foraging ratios might differ when choosing to include or exclude a food type, their relative values will remain the same (Owen-Smith & Cooper, 1987). Johnson (1980), therefore, suggested that ranking preference among food types or species are more meaningful than simply classifying them as preferred or neglected.

Following Owen-Smith & Cooper (1987), only the most abundant woody species were included in this analysis to avoid the problem that rare plant species often produced the highest preference ratios. Food preferences were consequently calculated by dividing the proportional time spent feeding on each of the most abundant woody species with their proportional availability in the study area during each phase. Availability of each woody species was calculated as browse dry mass (leaves and shoots < 0.5 cm) up to a feeding height of 2.0 m (see Chapter 4).

Preference ratings, derived from dividing the percentage of feeding time with the percentage of availability, were then ranked from highest to lowest (Johnson, 1980). If a woody species was utilised proportionally more than its availability, it was considered to be preferred, and if a woody species was utilised proportionally less than its availability, it was considered to be neglected. Woody species that were available, but not utilised, were classified as avoided (Petrides, 1975). Food preferences were separately calculated for the kudu population as a whole, cows and socially mature bulls.

5.3 RESULTS

5.3.1 Diet composition

All the plant species recorded in the diet of kudu are listed in Table 5.1. A total of 289 271 feeding seconds were recorded for kudu of all sex and age classes, combined, from September 2013 to September 2014. Of these recorded feeding seconds, 152 432 were for cows and 97 167 for socially mature bulls, respectively. The kudu population's annual diet (September 2013 to August 2014) was comprised of 65.90% browse, 16.94% grass, 15.56% dry feed and 1.61% unidentified feeding at ground level. Browse in their diet was comprised of 46.05% deciduous trees and shrubs, 18.67% evergreen trees and shrubs, 0.93% dwarf shrubs and 0.24% forbs (Figure 5.1). During the observation period dry feed was provided from September to November in 2013 and from June to September in 2014. The tree and shrubs species mostly utilised were *Vachellia karroo, Searsia burchellii, Ziziphus mucronata, Searsia ciliata* and *Ehretia alba,* comprising 55.75% of the kudu population's annual diet (Table 5.2).

The dry phase extended into September during 2013, with the pre-rain flush only starting in October. Dry feed formed the bulk of the kudu population's diet during the dry phase of 2013, making up 50.33% of their feeding time. Kudu also utilised more evergreen than deciduous trees and shrubs during this period, with 34.35% of their feeding time spent browsing evergreen species compared to only 13.79% spent utilising deciduous species. The dominant evergreen species utilised by kudu during this phase was *S. burchellii* comprising 16.25% of the kudu population's diet, while *Searsia lancea* and *Buddleja saligna* comprised 8.17% and 4.18% of their diet respectively. Kudu also spent some time utilising deciduous species during the dry phase, with *S. ciliata* comprising 6.81% and *Z. mucronata* 4.16% of their diet.

Table 5.1 List of all the plant species recorded in the diet of kudu on Amanzi Private Game Reserve

FAMILY NAME	SCIENTIFIC NAME	COMMON NAME
Deciduous trees and shrubs		
Asparagaceae	*Asparagus laricinus*	-
Asparagaceae	*Asparagus suaveolens*	-
Ebenaceae	*Diospyros lycioides*	Bluebush
Boraginaceae	*Ehretia alba*	White puzzle bush
Tiliaceae	*Grewia occidentalis*	Cross-berry
Solanaceae	*Lycium hirsutum*	-
Anacardiaceae	*Searsia ciliata*	Sour karee
Anacardiaceae	*Searsia pyroides*	Common wild currant
Fabaceae	*Vachellia karroo*	Sweet thorn
Rhamnaceae	*Ziziphus mucronata*	Buffalo-thorn
Evergreen trees and shrubs		
Buddlejaceae	*Buddleja saligna*	False Olive
Ebenaceae	*Diospyros austro-africanum*	Star-apple
Ebenaceae	*Euclea crispa* subsp. *ovata*	Blue guarri
Oleaceae	*Olea europaea* subsp. *africana*	Wild olive
Anacardiaceae	*Searsia burchellii*	Karoo kuni-bush
Anacardiaceae	*Searsia lancea*	Karee
Asteraceae	*Tarchonanthus camphoratus*	Wild camphor bush
Dwarf shrubs		
Asteraceae	*Chrysocoma ciliata*	-
Asteraceae	*Felicia muricata*	-
Solanaceae	*Lycium cinereum*	-
Asteraceae	*Pentzia globosa*	-
Forbs		
Fabaceae	*Elephantorrhiza elephantina*	Dwarf Elephant-root
Apocynaceae	*Gomphocarpus fruticosus*	Milkweed
Grass		
Poaceae	*Cynodon hirsutus*	Quick Grass
Poaceae	*Digitaria eriantha*	Common Finger grass

Figure 5.1 The kudu population's diet, comprised of different food types

Table 5.2 The contribution of browse species, grass and dry feed to the kudu population's diet, during the period September 2013 to September 2014

	PHASE							
SPECIES	DRY (SEP 2013)	FLUSH (OCT 2013)	IMMATURE (NOV-DEC 2013)	MATURE (JAN-MRT 2014)	SENESCENT (APR-MAY 2014)	DRY (JUN-AUG 2014)	FLUSH (SEP 2014)	ANNUAL (SEP 2013-AUG 2014)
Vachellia karroo	1.97	**59.46**	**19.26**	**39.45**	**42.61**	1.08	**76.32**	**25.20**
Searsia burchellii	**16.25**	**11.59**	0.29	1.41	**12.50**	**27.77**	0.04	**11.95**
Ziziphus mucronata	4.16	0.94	2.04	**7.72**	**22.45**	**6.77**	0.00	**7.30**
Searsia ciliata	**6.81**	0.00	0.41	**9.71**	**6.12**	**9.88**	0.00	**6.09**
Ehretia alba	0.30	0.00	4.37	1.65	**5.24**	12.25	0.00	**5.21**
Buddleja saligna	4.18	4.96	4.45	0.01	0.35	2.80	0.00	2.56
Tarchonanthus camphoratus	1.42	0.00	2.53	0.44	1.46	2.39	0.00	1.54
Searsia lancea	**8.17**	0.19	0.11	0.07	0.21	1.75	**10.77**	1.15
Pentzia globosa	0.00	0.00	1.76	2.64	0.13	0.00	0.00	0.93
Olea europaea subsp. *africana*	3.23	0.00	0.15	0.23	1.08	1.43	0.00	0.84
Grewia occidentalis	0.00	0.00	3.32	0.00	0.00	0.00	0.00	0.66
Asparagus laricinus	0.10	0.00	1.08	0.28	0.51	0.94	0.00	0.60
Diospyros austro-africanum	0.00	0.00	0.00	0.00	0.02	2.07	0.00	0.55
Diospyros lycioides	0.00	0.36	1.31	0.16	1.14	0.00	1.24	0.49
Searsia pyroides	0.00	0.00	0.00	1.16	0.00	0.00	0.00	0.25
Asparagus suaveolens	0.45	0.00	0.07	0.02	0.38	0.50	0.00	0.24
Other browse species	1.56	0.08	0.88	0.23	0.00	0.03	0.00	0.36
(Unidentified at ground level)	0.97	0.44	0.75	4.32	2.33	0.41	0.00	1.61
(Grass)	0.11	0.00	49.11	30.49	3.47	0.78	1.10	16.94
(Dry Feed)	50.33	21.98	8.12	0.00	0.00	29.15	10.53	15.56
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

When comparing the dry phase of 2013 to the flush phase of the same year, the proportion of time kudu spent browsing increased significantly ($p < 0.05$) from 48.59% in the dry phase to 77.53% in the flush phase and the proportion of time spent utilising dry feed decreased significantly ($p < 0.05$) from 50.33% to 21.96%, respectively. Kudu also spent significantly ($p < 0.01$) more time utilising deciduous trees and shrubs in the flush phase, with the proportion of deciduous species increasing in the kudu population's diet from 13.79% in the dry phase to 60.73% in the flush phase. At the same time the proportion of evergreen trees and shrubs decreased in the kudu population's diet, from 34.35% to 16.73%, although no significant ($p > 0.05$) differences were found. Kudu showed a marked increase in the utilisation of the deciduous *V. karroo* during the flush phase of 2013, with this species increasing in the kudu population's diet from 1.97% in the dry phase to 59.46% in the flush phase. At the same time, the other early flushing species, *Diospyros lycioides*, increased slightly in the kudu population's diet, while all other deciduous species decreased.

The occurrence of browse decreased significantly ($p < 0.01$) in the kudu population's diet from 77.53% in the flush phase of 2013 to 42.02% in the immature phase. Utilisation of dry feed also decreased, although not significantly ($p > 0.05$), from 21.96% in the flush phase of 2013 to 8.12% in the immature phase. The decrease of both browse and dry feed were due to kudu spending 49.11% of their feeding time grazing in the immature phase. Consequently, the proportion of both deciduous and evergreen species decreased, with deciduous species decreasing significantly ($p < 0.01$) in the kudu population's diet from 60.73% in the flush phase of 2013 to 31.84% in the immature phase and evergreen species decreasing, although not significantly ($p > 0.05$), from 16.73% to 7.54%. The dominant browse species in the kudu population's diet during the immature phase was still *V. karroo* making up 19.26% of their feeding time, while *B. saligna* and *E. alba* contributed 4.45% and 4.37%, respectively. The proportion of time kudu spent grazing then decreased significantly ($p < 0.05$) from 49.11% in the immature phase to 30.49% in the mature phase. When grass decreased significantly in the kudu population's diet, the proportion of browse increased significantly ($p < 0.05$) form 42.02% in the immature phase to 65.18% in the mature phase. At the same time, the occurrence of deciduous species in the kudu population's diet increased significantly ($p < 0.01$) from 31.84% to 60.23%. However, the occurrence of evergreen species decreased in the kudu population's diet from 7.54% to 2.16% (not significant $p > 0.05$). The key browse species utilised by kudu during the mature phase were the deciduous species *V. karroo*, *S. ciliata* and *Z. mucronata* that made up 39.45%, 9.71% and 7.72% of the kudu population's diet, respectively.

Another significant (p < 0.001) decrease occurred in the proportion of time kudu spent grazing, from 30.49% in the mature phase to 3.47% in the senescent phase. As a result, the proportion of time kudu spent browsing increased significantly (p < 0.001) from 65.18% to 94.20%. The occurrence of both evergreen and deciduous species increased in the kudu population's diet from the mature to the senescent phase, with evergreen species increasing significantly (p < 0.05) from 2.16% to 15.62% and deciduous species increasing, although not significantly (p > 0.05), from 60.23% to 78.45%. The main species browsed during the senescent phase were the deciduous species *V. karroo* and *Z. mucronata*. However, kudu also started to utilise more evergreen trees and shrubs, with *S. burchellii* in particular increasing in the kudu population's diet from 1.41% in the mature phase to 12.50% in the senescent phase.

Very little grazing took place from the senescent phase through to the flush phase of 2014, with grass making up less than 2% of the kudu population's diet in both the dry and flush phases. Dry feed made up 29.15% of the kudu population's diet during the dry phase of 2014, resulting in a significant (p < 0.001) decrease in the proportion of time kudu spent browsing during the dry phase compared to the senescent phase when no dry feed was provided. A significant (p < 0.01) increase was again observed in the proportion of evergreen species utilised by kudu, this time increasing from 15.62% in the senescent phase to 38.25% in the dry phase. At the same time, the proportion of deciduous species in the kudu population's diet decreased significantly (p < 0.001) from 78.45% to 31.42%. *V. karroo* made very little contribution to the kudu population's diet during the dry phase of 2014, with the utilisation of this species decreasing from 42.61% in the senescent phase to 1.08% in the dry phase. The dominant browse species recorded in the kudu population's diet during the dry phase was the evergreen species *S. burchellii* followed by three deciduous species, namely *E. alba, S. ciliata* and *Z. mucronata.*

The proportion of browse in the kudu population's diet then increased significantly (p < 0.05) from 69.66% in the dry phase of 2014 to 88.37% in the flush phase of the same year. At the same time, the proportion of dry feed in their diet decreased significantly (p < 0.05) from 29.15% to 10.53%. Kudu also utilised more deciduous species and less evergreen species during the flush phase compared to the dry phase. The proportion of time spent utilising deciduous species increased significantly (p < 0.001) from 31.42% in the dry phase of 2014 to 77.56% in the flush phase of the same year, while the proportion of time spent utilising evergreen species decreased significantly (p < 0.05) from 38.25% to 10.80%. Once again *V. karroo* made up the largest part of the kudu population's diet, increasing from 1.08% in the dry phase to 76.32% the flush phase. Only three other woody species were recorded in their diet during the flush phase, with *S. lancea* being the only one of those making a substantial contribution to their diet.

When comparing the kudu diet between the two dry phases, kudu utilised significantly ($p < 0.05$) more dry feed and significantly less ($p < 0.05$) browse during 2013. There were, however, no significant differences ($p > 0.05$) between either the amount of deciduous or evergreen trees and shrubs in their diet. The dominant browse species in the kudu population's diet during both dry phases was *S. burchellii*.

September was divided into the dry phase during 2013, but into the flush phase during 2014. This was due to a delay in the pre-rain flush occurring in 2013, with no immature leaves present on deciduous trees during September 2013 (see Chapter 4). When comparing September 2014 and September 2013, significantly ($p < 0.05$) more browse and significantly ($p < 0.05$) less dry feed was included in the kudu population's diet during September 2014. The kudu population's diet was also made up of significantly ($p < 0.01$) more deciduous trees and shrubs in September 2014. However, no significant differences were found between the proportions of evergreen trees and shrubs utilised by kudu during both Septembers ($p > 0.05$). *V. karroo* was the dominant browse species in the kudu population's diet during September 2014, while the same species only made up a small proportion of their diet during the same month in 2013. Likewise, *S. burchellii* was the dominant browse species in the kudu population's diet during September 2013, but this species was hardly utilised during September 2014.

Cows spent 64.85% of their annual feeding time (September 2013 to August 2014) browsing, 18.87% grazing and 14.48% utilising dry feed. Browse in their diet consisted of 50.56% deciduous trees and shrubs, 13.15% evergreen trees and shrubs, 0.76% dwarf shrubs and 0.38% forbs (Figure 5.2). The same tree and shrub species which largely contributed to the entire kudu population's diet also made up most of the cows' diet. Together these five species, namely *V. karroo, S. burchellii, Z. mucronata, S. ciliata* and *E. alba* contributed 56.73% to their annual diet (Table 5.3). Of these five species *V. karroo* dominated cows' browsing time in all phases, except for the dry phases of 2013 and 2014, when most time was spent utilising *S. burchellii.* During the dry phase of 2013, cows spent 62.28% of their feeding time utilising dry feed and only 37.44% browsing. At this time cows utilised more evergreen trees and shrubs compared to deciduous trees and shrubs, with 23.85% of their diet made up of evergreen species and 13.59% made up of deciduous species. The evergreen species mostly utilised by cows during this phase was *S. burchellii*, comprising 11.77% of their diet, followed by *B. saligna* with 7.55% and *S. lancea* with 2.71%. Only one deciduous species contributed substantially to the diet of cows at this time, namely *S. ciliata* comprising 11.04% of their diet.
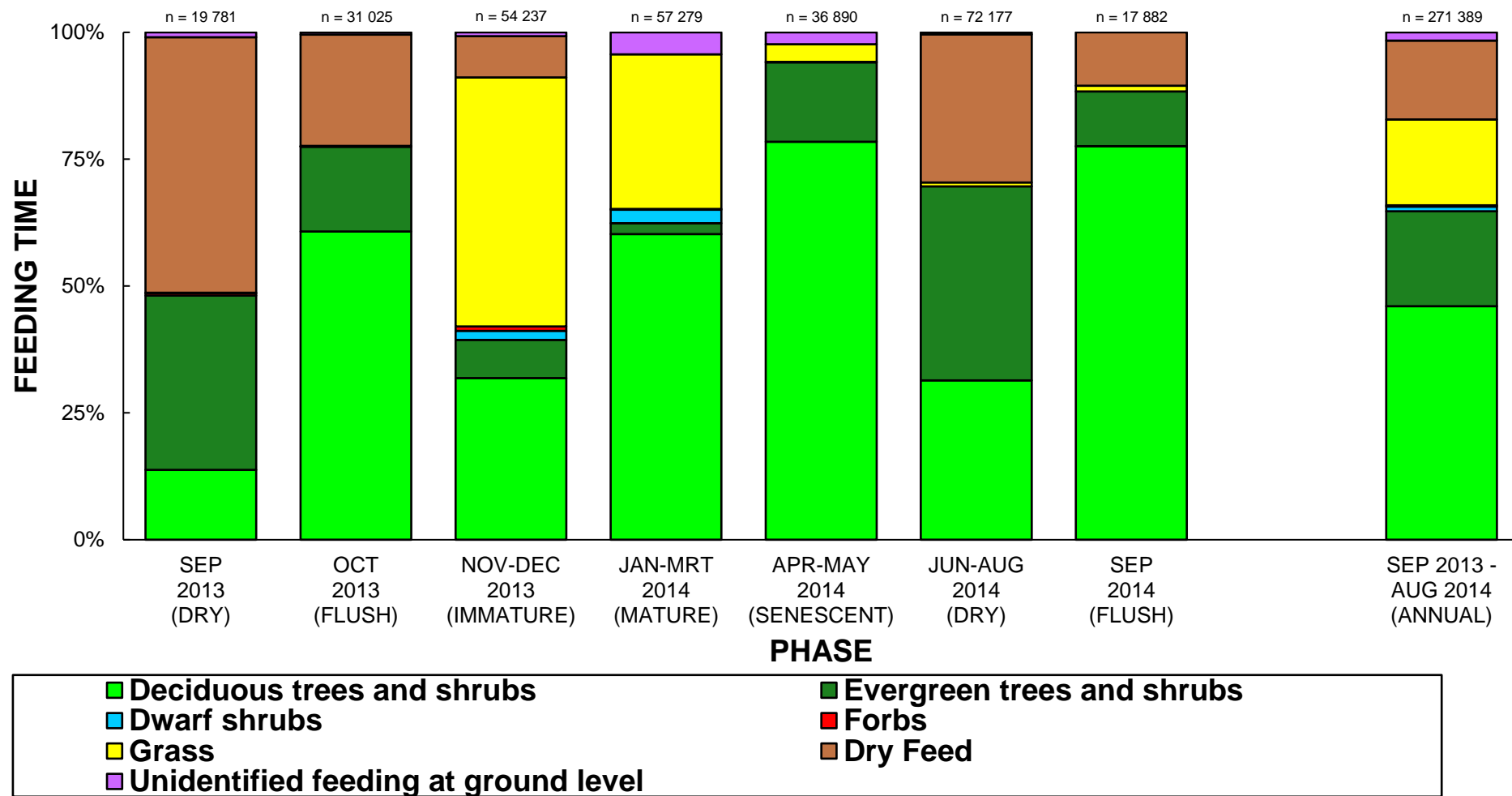
Figure 5.2 The diet composition of cows, comprised of different food types

Table 5.3 The contribution of browse species, grass and dry feed to the diet of cows, during the period September 2013 to September 2014

	PHASE							
SPECIES	DRY (SEP 2013)	FLUSH (OCT 2013)	IMMATURE (NOV-DEC 2013)	MATURE (JAN-MRT 2014)	SENESCENT (APR-MAY 2014)	DRY (JUN-AUG 2014)	FLUSH (SEP 2014)	ANNUAL (SEP 2013-AUG 2014)
Vachellia karroo	2.11	**65.16**	**17.88**	**42.88**	**52.19**	1.98	**89.59**	**28.55**
Searsia burchellii	**11.77**	**7.97**	0.24	0.03	2.90	**19.63**	0.00	**7.60**
Ziziphus mucronata	0.00	0.00	2.45	**6.46**	**21.27**	**10.90**	0.00	**7.06**
Searsia ciliata	**11.04**	0.00	0.64	**10.39**	**6.00**	**11.87**	0.00	**6.88**
Ehretia alba	0.43	0.00	1.36	1.50	**6.11**	**19.58**	0.00	**6.64**
Buddleja saligna	**7.55**	2.94	0.96	0.00	0.77	2.04	0.00	1.70
Tarchonanthus camphoratus	1.83	0.00	2.40	0.71	2.14	1.99	0.00	1.50
Searsia lancea	2.71	0.28	0.20	0.13	0.50	2.87	1.24	1.10
Diospyros austro-africanum	0.00	0.00	0.00	0.00	0.00	3.79	0.00	1.04
Pentzia globosa	0.00	0.00	0.40	2.95	0.00	0.00	0.00	0.72
Asparagus laricinus	0.00	0.00	1.14	0.07	0.29	1.33	0.00	0.64
Searsia pyroides	0.00	0.00	0.00	1.46	0.00	0.00	0.00	0.31
Asparagus suaveolens	0.00	0.00	0.02	0.02	0.82	0.56	0.00	0.25
Diospyros lycioides	0.00	0.53	0.49	0.03	0.14	0.00	2.40	0.20
Olea europaea subsp. *africana*	0.00	0.00	0.16	0.00	0.00	0.55	0.00	0.19
Grewia occidentalis	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other browse species	0.00	0.36	1.57	0.40	0.00	0.06	0.00	0.47
(Unidentified at ground level)	0.28	0.63	0.42	6.11	1.40	0.51	0.00	1.80
(Grass)	0.00	0.00	60.99	26.87	5.48	0.85	2.13	18.87
(Dry Feed)	62.28	22.13	8.68	0.00	0.00	21.48	4.64	14.48
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

When comparing the dry phase of 2013 to the flush phase of the same year, the proportion of browse increased significantly ($p < 0.05$) in the diets of cows, from 37.44% in the dry phase to 77.23% in the flush phase. The proportion of dry feed also decreased significantly ($p < 0.05$) from 62.28% to 22.13%. Cows also utilised significantly ($p < 0.05$) more deciduous species in the flush phase compared to the dry phase in 2013. At this time, deciduous species increased in their diet from only 13.59% to 65.69%. Even though cows utilised less evergreen species in the flush phase of 2013 compared to the previous dry phase, no significant differences ($p > 0.05$) were found. Although cows browsed mostly deciduous species in the flush phase of 2013, only two deciduous species were utilised, namely *V. karroo* and *D. lycioides*. Both of these deciduous species produced new leaves before all the other deciduous species in the study area. *V. karroo* contributed the most to the diet of cows during this time of any single species, increasing from 2.11% in the dry phase of 2013 to 65.16% in the following flush phase.

Cows spent most of their feeding time grazing in the immature phase, with grass contributing 60.99% of their diet during this phase. This resulted in a significant ($p < 0.001$) decrease in the occurrence of browse in their diet from the flush phase (77.23%) to the immature phase (29.91%) in 2013. At the same time, dry feed in their diets decreased from 22.13% to 8.68%, although no significant differences were found ($p > 0.05$). The proportion of both deciduous and evergreen species in the cows' diets also decreased from the flush to the immature phase in 2013, with deciduous species showing a significant decrease ($p < 0.001$) from 65.69% to 23.98%. However, even though evergreen species decreased from 11.18% to 3.95%, no significant difference was found ($p > 0.05$). *V. karroo* was the dominant browse species recorded in the diet of cows during the immature phase with 17.88%. All the other browse species contributed less than 3% to their diet during this time. It was, however, interesting to note that *Gomphocarpus fruticosus* made up 1.57% of their diet during the immature phase as it is considered to be a poisonous species.

The proportion of time cows spent grazing then decreased significantly ($p < 0.001$) from 60.99% in the immature phase to 26.87% in the mature phase. As grass decreased significantly in the cows' diet, the proportion of browse in their diet increased significantly ($p < 0.01$) from 29.91% to 67.02%. The occurrence of deciduous species in the diet of cows also increased significantly ($p < 0.001$) from 23.98% in the immature phase to 62.95% in the mature phase. Evergreen species continued to decrease in the cows' diet from 3.95% in the immature phase to 0.87% in the mature phase, with no significant differences found ($p > 0.05$).

Three deciduous species, namely *V. karroo*, *S. ciliata* and *Z. mucronata* were mostly utilised by cows during the mature phase, constituting 42.88%, 10.39% and 6.46% of their diet, respectively. Although dwarf shrubs occurred in the diet of cows during the flush and immature phases of 2013, they were only really utilised by cows in the mature phase, especially *P. globosa*, which made up 2.95% of their diet. The occurrence of dwarf shrubs in the diet of cows could in fact have been higher when considering that 6.11% of their feeding records in the mature phase could not be identified when they were feeding at ground level.

Grass again decreased significantly ($p < 0.001$) in the cows' diet from 26.87% in the mature phase to 5.48% in the senescent phase. This resulted in the proportion of browse increasing significantly ($p < 0.01$) in their diet at the same time from 67.02% to 93.12%. The proportion of deciduous species in their diet also increased significantly ($p < 0.05$) from the 62.95% recorded in the mature phase to 86.81% recorded in the senescent phase. An increase in the proportion of evergreen species in the cows' diet was recorded for the first time during the senescent phase after evergreen species decreased in each consecutive phase from the flush phase in 2013. However, this was not a significant ($p > 0.05$) increase, with the proportion of evergreen species only increasing from 0.87% in the mature phase to 6.31% in the senescent phase. Cows spent more than half their feeding time in the senescent phase utilising *V. Karroo* (52.19%), while *Z. mucronata* also contributed substantially to their diet with 21.27%.

With dry feed supplied from June in 2014, the diet of cows was comprised of 21.48% dry feed, 77.16% browse, 0.85% grass and 0.51% unidentified feeding at ground level in the dry phase of 2014. Due to dry feed being available, a significant ($p < 0.05$) decrease occurred in the time cows spent browsing, from 93.12% in the senescent phase to 77.16% in the dry phase of 2014. Cows again increased their utilisation of evergreen species, this time significantly ($p < 0.01$) from 6.31% in the senescent phase to 30.93% in the dry phase of 2014. At the same time, deciduous species decreased significantly ($p < 0.001$) in their diet from 86.81% to 46.23%. However, it was interesting to note that cows still utilised more deciduous species compared to evergreen species in the dry phase of 2014. Cows mostly utilised the evergreen species *S. burchellii* in the dry phase of 2014. However, the deciduous species *E. alba, S. ciliata* and *Z. mucronata* also made substantial contributions to their diet.

A significant (p < 0.05) increase was recorded in the time cows spent browsing in the flush phase of 2014, with browse increasing in their diets from 77.16% in the dry phase of 2014 to 93.24% in the flush phase of the same year. Cows also utilised significantly (p < 0.05) less dry feed during the flush phase of 2014, decreasing from 21.48% in the dry phase of 2014 to 4.64% in the flush phase. The proportion of deciduous species in their diet increased significantly (p < 0.001) during the flush phase of 2014, from 46.23% in the dry phase of 2014 to 91.99%. At the same time, evergreen species in the cows' diet decreased significantly (p < 0.05) from 30.93% to 1.24%. Only three woody species were utilised by cows during the flush phase of 2014, with *V. karroo* making up 89.59% of the cows' diet, followed by *D. lycioides* with 2.40 % and *S. lancea* with 1.24%.

Cows utilised significantly (p < 0.05) more browse and significantly (p < 0.05) less dry feed in September 2014 compared to the same month in the previous year. During September 2014 their diet was comprised of 93.24% browse, 4.64% dry feed and 2.13% grass, while their diets consisted of 37.44% browse, 62.28% dry feed and 0.28% unidentified feeding at ground level during September 2013. Cows also utilised significantly (p < 0.01) more deciduous species and significantly (p < 0.05) less evergreen species in September 2014 compared to September 2013. The proportion of deciduous species in the cows' diets increased from 13.59% in September 2013 to 91.99% in September 2014, while the proportion of evergreen species in their diets simultaneously decreased from 23.85% to 1.24%. When comparing the diet of cows between the two dry phases, cows utilised significantly (p < 0.05) more dry feed and significantly less (p < 0.05) browse during 2013. There were, however, no significant differences (p > 0.05) between either the amount of deciduous or evergreen trees and shrubs in their diet.

The annual diet of socially mature bulls (September 2013 to August 2014) was comprised of 63.47% browse, 18.39% grass, 16.28% dry feed and 1.87% feeding at ground level that could not be identified (Figure 5.3). The 63.47% browse in the annual diet of socially mature bulls was comprised of 36.90% deciduous trees and shrubs, 25.14% evergreen trees and shrubs, 1.36% dwarf shrubs and 0.07% forbs. Socially mature bulls also spent more than half of their annual feeding time utilising the five woody species mostly utilised by cows, namely *V. karroo, S. burchellii, Z. mucronata, S. ciliata* and *E. alba* (Table 5.4). Socially mature bulls utilised *V. karroo* the most in all phases, except for the dry phases of both 2013 and 2014. During both dry phases, *S. burchellii* made the largest contribution towards the diet of socially mature bulls.
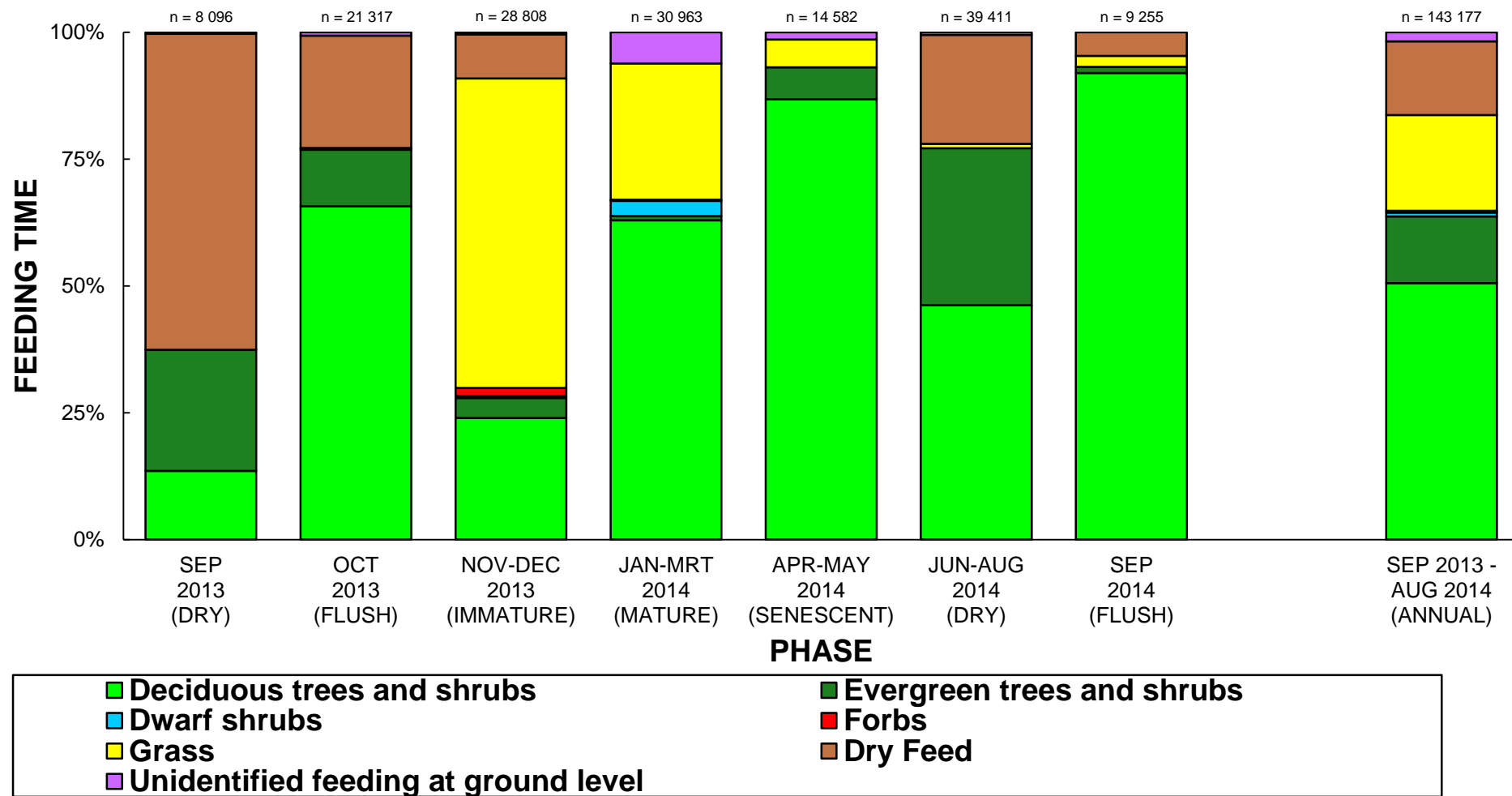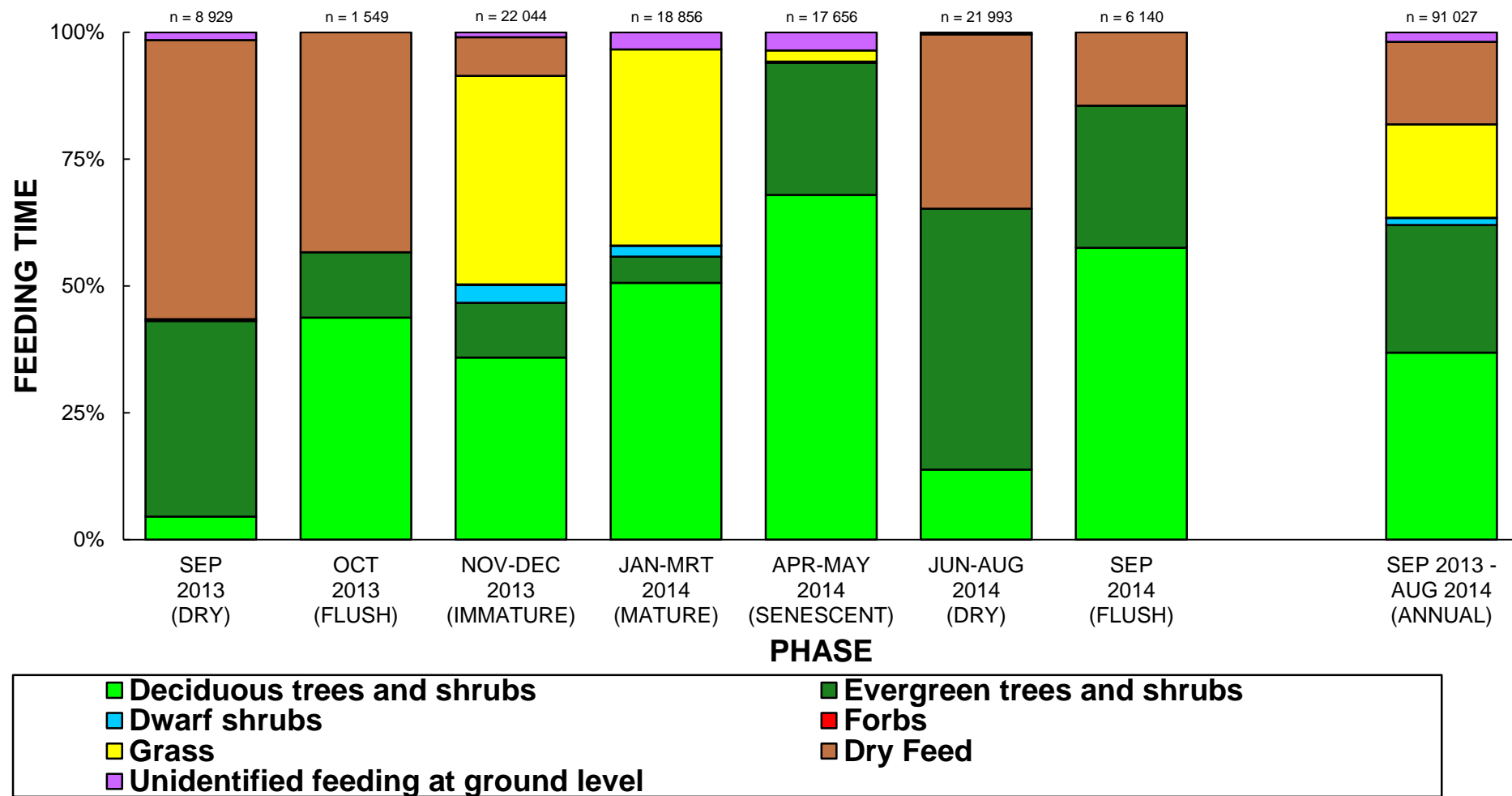
Figure 5.3 The diet composition of socially mature bulls, comprised of different food types

Table 5.4 The contribution of browse species, grass and dry feed to the diet of socially mature bulls, during the period September 2013 to September 2014

	PHASE							
SPECIES	DRY (SEP 2013)	FLUSH (OCT 2013)	IMMATURE (NOV-DEC 2013)	MATURE (JAN-MRT 2014)	SENESCENT (APR-MAY 2014)	DRY (JUN-AUG 2014)	FLUSH (SEP 2014)	ANNUAL (SEP 2013-AUG 2014)
Vachellia karroo	2.45	**42.61**	**19.60**	**32.84**	**30.51**	0.00	**57.54**	**18.43**
Searsia burchellii	**19.83**	**10.97**	0.41	4.23	**23.63**	**41.43**	0.11	**17.70**
Ziziphus mucronata	0.60	1.16	1.41	**5.76**	**22.15**	1.23	0.00	**6.21**
Searsia ciliata	0.00	0.00	0.16	**8.36**	**6.64**	**9.63**	0.00	**5.39**
Ehretia alba	0.28	0.00	**8.56**	2.55	**5.58**	2.90	0.00	4.41
Buddleja saligna	0.66	1.94	**7.19**	0.04	0.07	3.05	0.00	2.60
Olea europaea subsp. *africana*	1.81	0.00	0.16	0.70	2.25	3.71	0.00	1.70
Searsia lancea	**15.66**	0.00	0.00	0.00	0.02	0.60	**27.87**	1.68
Tarchonanthus camphoratus	0.58	0.00	3.02	0.17	0.00	2.61	0.00	1.45
Pentzia globosa	0.00	0.00	3.45	2.17	0.27	0.00	0.00	1.34
Grewia occidentalis	0.00	0.00	**5.38**	0.00	0.00	0.00	0.00	1.30
Diospyros lycioides	0.00	0.00	0.62	0.46	2.26	0.00	0.00	0.68
Asparagus laricinus	0.21	0.00	0.17	0.66	0.70	0.02	0.00	0.34
Asparagus suaveolens	1.00	0.00	0.00	0.00	0.11	0.07	0.00	0.14
Diospyros austro-africanum	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.01
Searsia pyroides	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Other browse species	0.37	0.00	0.17	0.04	0.00	0.00	0.00	0.09
(Unidentified at ground level)	1.50	0.00	0.98	3.35	3.55	0.42	0.00	1.87
(Grass)	0.00	0.00	41.09	38.66	2.21	0.00	0.00	18.39
(Dry Feed)	55.03	43.32	7.62	0.00	0.00	34.35	14.48	16.28
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

During the dry phase of 2013, socially mature bulls spent 55.03% of their feeding time utilising dry feed and 43.47% browsing. Evergreen species were also utilised more than deciduous species during this time. The two woody species that made the largest contribution to the diet of socially mature bulls were *S. burchellii* and *S. lancea*, contributing 19.83% and 15.66% to their diet, respectively. The deciduous species contributing most to their diet was *V. karroo* with only 2.45%.

In the diet of socially mature bulls, browse increased from 43.47% in the dry phase of 2013 to 56.68% in the flush phase of that year, while the utilisation of dry feed decreased from 55.03% to 43.32% at the same time. However, no significant ($p > 0.05$) differences were found when comparing both food types between these two phases. Socially mature bulls did, however, spend significantly ($p < 0.05$) more time browsing deciduous trees and shrubs in the flush phase compared to the dry phase of 2013, with deciduous species increasing in their diet from only 4.55% to 43.77%. Evergreen species decreased significantly ($p < 0.05$) in their diet at the same time from 38.55% to 12.91%. Socially mature bulls only browsed four woody species during the flush phase of 2013, with *V. karroo* contributing 42.61% to their diet and *S. burchellii* contributing 10.97%.

Socially mature bulls spent proportionally less time browsing in the immature phase compared to the flush phase of 2013, with browse decreasing in their diet from 56.68% to 50.31%. However, no significant differences were found ($p > 0.05$) in time spent browsing between these two phases. The utilisation of dry feed decreased significantly ($p < 0.05$) from 43.32% in the flush phase of 2013 to 7.62% in the immature phase. Both the decrease in time spent browsing and time spent utilising dry feed coincided with socially mature bulls starting to graze. During the immature phase socially mature bulls dedicated 41.09% of their feeding time to grazing.

There were no significant differences ($p > 0.05$) found in both the proportion of deciduous or evergreen species in the diet of socially mature bulls between the flush and the immature phase of 2013. However, both food types decreased from the flush to the immature phase, with deciduous species decreasing from 43.77% to 35.91% and evergreen species decreasing from 12.91% to 10.78%. During the immature phase, socially mature bulls mostly utilised the deciduous species *V. karroo*, *E. alba* and *Grewia occidentalis*, as well as the evergreen shrub *B. saligna.* The dwarf shrub *P. globosa* was also recorded in their diet during this time.

During the mature phase a slight increase in the proportion of time socially mature bulls spent browsing was recorded. At the same time, socially mature bulls spent slightly less time grazing. However, there were no significant differences ($p > 0.05$) found when comparing these two food types between the immature and the mature phase, with browse increasing in the diet of socially mature bulls from 50.31% in the immature phase to 57.99% in the mature phase and grass decreasing in their diet at the same time from 41.09% to 38.66%. The proportion of deciduous species recorded in the diet of socially mature bulls increased from 35.91% in the immature phase to 50.64% in the mature phase. At the same time the proportion of evergreen species recorded in their diet decreased from 10.78% to 5.14%. However, no significant differences ($p > 0.05$) were found in the time socially mature bulls spent utilising either deciduous or evergreen species between these two phases. During the mature phase *V. karroo*, *S. ciliata* and *Z. mucronata* were mostly utilised by socially mature bulls, contributing 32.84%, 8.36% and 5.76% to their diet, respectively.

The proportion of browse in the diet of socially mature bulls then increased significantly ($p < 0.05$) from 57.99% in the mature phase to 94.24% in the senescent phase as grass decreased significantly ($p < 0.05$) in their diet from 38.66% to 2.21%. The proportion of evergreen species in their diet also increased significantly ($p < 0.05$) from 5.14% in the mature phase to 26.01% in the senescent phase. No significant difference ($p > 0.05$) was found in the time socially mature bulls spent utilising deciduous species between the mature and the senescent phases, even though the proportion of deciduous species increased in their diet from 50.64% in the mature phase to 67.97% in the senescent phase. During the senescent phase the diet of socially mature bulls were mostly comprised of three woody species, namely *V.karroo*, *S. burchellii* and *Z. mucronata*.

Socially mature bulls spent most of their feeding time in the dry phase of 2014 browsing, even though dry feed was available. Their utilisation of browse did, however, decrease significantly ($p < 0.05$) from 94.24% in the senescent phase to 65.23% in the dry phase. During this time socially mature bulls utilised significantly ($p < 0.05$) more evergreen species, with evergreen species increasing in their diet from 26.01% in the senescent phase to 51.39% in the dry phase of 2014. At the same time deciduous species decreased significantly ($p < 0.001$) in their diet from 67.97% to 13.85%. The woody species with the highest occurrence in the diet of socially mature bulls during the dry phase of 2014 was *S. burchellii*, making up 41.43% of their diet. The deciduous species *S. ciliata* also made a substantial contribution to their diet during this time with 9.63%.

No significant difference (p > 0.05) was found when comparing the proportion of browse utilised by socially mature bulls between the dry and the flush phases of 2014. However, browse did increase in their diet from 65.23% in the dry phase to 85.52% in the flush phase. There was also no significant difference (p > 0.05) in the proportion of dry feed utilised by socially mature bulls when comparing the dry phase to the flush phase in 2014. A decrease in the utilisation of dry feed did, however, occur from 34.35% in the dry phase to 14.48% in the flush phase.

The proportion of deciduous species also increased significantly (p < 0.01) in the diet of socially mature bulls from 13.85% in the dry phase to 57.54% in the flush phase of 2014. The proportion of evergreen species decreased at the same time, although not significantly (p > 0.05), from 51.39% to 27.98%. During the flush phase of 2014 almost all the feeding time of socially mature bulls was spent utilising just two woody species, with the deciduous species *V. karroo* contributing 57.54% to their diet and the evergreen species *S. lancea* contributing 27.87% of their diet.

There were no significant differences (p > 0.05) when comparing the diet of socially mature bulls between the two dry phases. However, when comparing the diet of socially mature bulls between September 2013 and September 2014, they utilised significantly (p < 0.05) more browse and significantly (p < 0.05) less dry feed during September 2014. Socially mature bulls also utilised significantly (p < 0.05) more deciduous species in September 2014 compared to September 2013. However, no significant difference (p > 0.05) was found when comparing the proportion of evergreen species in the diet of socially mature bulls between the September months of both years.

The diets of cows and socially mature bulls were remarkably similar, with no significant differences (p > 0.05) found when comparing their proportional utilisation of browse, grass and dry feed in each of the separate phases. However, a constant trend emerged with socially mature bulls utilising proportionally more evergreen species and proportionally less deciduous species compared to cows. This was especially evident in the senescent, dry and flush phases of 2014 when bulls utilised significantly more (p < 0.05) evergreen species and significantly less (p < 0.05) deciduous species compared to cows.

5.3.2 Food preferences

Kudu showed an overall preference for deciduous trees and shrubs in all the phases of food availability, with these species utilised more than their proportional availability in the study area (Tables 5.5 – 5.11). In contrast, evergreen trees and shrubs as a whole were considered to be neglected during all the phases of food availability. This was due to them being utilised proportionally less than their availability, even though they contributed more to the diet of kudu during the dry phases compared to deciduous trees and shrubs.

Although kudu showed an overall preference for deciduous over evergreen trees and shrubs, this was not always the case on a species by species basis. For example, during the dry phase of 2013, kudu showed the highest preference for the evergreen species *S. lancea* followed by the deciduous species *Z. mucronata, S. ciliata* and *Asparagus suaveolens* (Table 5.5). At the same time all the other woody species, including *S. burchellii*, that made the largest contribution to the diet of kudu, were utilised less than their availability.

The only woody species preferred by kudu during the flush phase of 2013 were *V. karroo* and *Z. mucronata*, with *B. saligna, S. burchellii, D. lycioides* and *S. lancea* all utilised less than their proportional availability (Table 5.6). The food preferences of kudu changed dramatically during the immature phase, as most deciduous species produced new leaves. During this time kudu showed the highest preference for *E. alba* followed by *V. karroo, Z. mucronata*, *Asparagus laricinus, G. occidentalis, D. lycioides* and *B. saligna* (Table 5.7). Other species utilised during the immature phase, but considered to be neglected, were *Tarchonanthus camphoratus, S. ciliata, A. suaveolens, S. lancea, Olea europaea* subsp. *africana* and *S. burchellii*.

Kudu preferred fewer species during the mature phase compared to the immature phase as the leaf phenology of deciduous species changed from predominantly immature leaves to mature leaves (Table 5.8). The highest preference was again shown for *V. karroo*, although kudu also showed a high preference for *Z. mucronata.* Other species that were preferred during the mature phase were *S. ciliata* and *E. alba*. All the other woody species were either neglected or avoided during this phase.

Table 5.5 Kudu food preference during the dry phase of 2013 (Sep)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Searsia burchellii	33.77	38.04	0.8878	6	Neglected
Searsia lancea	16.98	1.60	10.6125	1	**Preferred**
Searsia ciliata	14.15	2.55	5.5490	3	**Preferred**
Buddleja saligna	8.69	8.76	0.9920	5	Neglected
Ziziphus mucronata	8.63	1.26	6.8492	2	**Preferred**
Olea europaea subsp. *africana*	6.70	15.47	0.4331	9	Neglected
Vachellia karroo	4.10	5.59	0.7335	7	Neglected
Tarchonanthus camphoratus	2.94	15.19	0.1935	11	Neglected
Asparagus suaveolens	0.93	0.49	1.8980	4	**Preferred**
Ehretia alba	0.63	0.99	0.6364	8	Neglected
Asparagus laricinus	0.20	0.63	0.3175	10	Neglected
Diospyros lycioides	0.00	1.25	0.0000	-	Avoided
Grewia occidentalis	0.00	4.60	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.26	0.0000	-	Avoided
Other tree and shrub species	2.28	1.33	1.7143	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	28.64	20.09	1.4256	1	**Preferred**
Evergreen trees and shrubs	71.36	79.92	0.8929	2	Neglected
Total	**100**	**100**			

Table 5.6 Kudu food preference during the flush phase of 2013 (Oct)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	76.72	8.95	8.5721	1	**Preferred**
Searsia burchellii	14.95	36.75	0.4068	4	Neglected
Buddleja saligna	6.40	8.36	0.7656	3	Neglected
Ziziphus mucronata	1.21	1.15	1.0522	2	**Preferred**
Diospyros lycioides	0.47	1.71	0.2749	5	Neglected
Searsia lancea	0.25	1.55	0.1583	6	Neglected
Asparagus laricinus	0.00	0.64	0.0000	-	Avoided
Asparagus suaveolens	0.00	0.37	0.0000	-	Avoided
Ehretia alba	0.00	0.90	0.0000	-	Avoided
Grewia occidentalis	0.00	4.68	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	15.76	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.13	0.0000	-	Avoided
Searsia ciliata	0.00	2.30	0.0000	-	Avoided
Tarchonanthus camphoratus	0.00	13.35	0.0000	-	Avoided
Other woody species	0.00	1.40	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	78.40	23.37	3.3547	1	**Preferred**
Evergreen trees and shrubs	21.60	76.63	0.2819	2	Neglected
Total	**100**	**100**			

Table 5.7 Kudu food preference during the immature phase of 2013 (Nov - Dec)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	48.91	11.12	4.3984	2	**Preferred**
Buddleja saligna	11.30	8.13	1.3899	7	**Preferred**
Ehretia alba	11.09	1.41	7.8652	1	**Preferred**
Grewia occidentalis	8.42	4.43	1.9007	5	**Preferred**
Tarchonanthus camphoratus	6.43	13.12	0.4901	8	Neglected
Ziziphus mucronata	5.18	1.67	3.1018	3	**Preferred**
Diospyros lycioides	3.31	2.21	1.4977	6	**Preferred**
Asparagus laricinus	2.75	1.14	2.4123	4	**Preferred**
Searsia ciliata	1.03	2.63	0.3916	9	Neglected
Searsia burchellii	0.74	35.30	0.0210	13	Neglected
Olea europaea subsp. *africana*	0.38	13.61	0.0279	12	Neglected
Searsia lancea	0.28	1.34	0.2090	11	Neglected
Asparagus suaveolens	0.18	0.52	0.3462	10	Neglected
Rhigozum obovatum	0.00	1.94	0.0000	-	Avoided
Other woody species	0.00	1.42	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	80.87	27.73	2.9163	1	**Preferred**
Evergreen trees and shrubs	19.13	72.26	0.2647	2	Neglected
Total	**100**	**100**			

Table 5.8 Kudu food preference during the mature phase of 2013 (Jan - Mar)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	63.26	9.90	6.3899	1	**Preferred**
Searsia ciliata	15.57	4.26	3.6549	3	**Preferred**
Ziziphus mucronata	12.39	2.04	6.0735	2	**Preferred**
Ehretia alba	2.64	1.61	1.6398	4	**Preferred**
Searsia burchellii	2.25	31.42	0.0716	8	Neglected
Tarchonanthus camphoratus	0.71	15.99	0.0444	10	Neglected
Asparagus laricinus	0.45	1.14	0.3947	5	Neglected
Olea europaea subsp. *africana*	0.37	12.78	0.0290	11	Neglected
Diospyros lycioides	0.26	2.20	0.1182	6	Neglected
Searsia lancea	0.11	1.32	0.0833	7	Neglected
Asparagus suaveolens	0.03	0.54	0.0556	9	Neglected
Buddleja saligna	0.02	8.62	0.0023	12	Neglected
Grewia occidentalis	0.00	4.09	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.70	0.0000	-	Avoided
Other tree and shrub species	1.93	1.41	1.3688	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	96.53	29.16	3.3104	1	**Preferred**
Evergreen trees and shrubs	3.46	70.86	0.0488	2	Neglected
Total	**100**	**100**			

Table 5.9 Kudu food preference during the senescent phase of 2013 (Apr - May)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	45.30	9.91	4.5711	2	**Preferred**
Ziziphus mucronata	23.87	2.04	11.7010	1	**Preferred**
Searsia burchellii	13.29	31.48	0.4222	8	Neglected
Searsia ciliata	6.51	4.26	1.5282	4	**Preferred**
Ehretia alba	5.57	1.61	3.4596	3	**Preferred**
Tarchonanthus camphoratus	1.55	16.02	0.0968	10	Neglected
Diospyros lycioides	1.21	1.97	0.6142	6	Neglected
Olea europaea subsp. *africana*	1.15	12.80	0.0898	11	Neglected
Asparagus laricinus	0.54	1.14	0.4737	7	Neglected
Asparagus suaveolens	0.40	0.55	0.7273	5	Neglected
Buddleja saligna	0.37	8.63	0.0429	12	Neglected
Searsia lancea	0.22	1.32	0.1667	9	Neglected
Grewia occidentalis	0.00	4.10	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.71	0.0000	-	Avoided
Other tree and shrub species	0.02	1.46	0.0137	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	83.40	29.02	2.8739	1	**Preferred**
Evergreen trees and shrubs	16.60	70.98	0.2339	2	Neglected
Total	**100**	**100**			

Table 5.10 Kudu food preference during the dry phase of 2014 (Jun - Aug)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Searsia burchellii	39.87	34.59	1.1526	7	**Preferred**
Ehretia alba	17.59	1.29	13.6357	1	**Preferred**
Searsia ciliata	14.18	3.37	4.2077	3	**Preferred**
Ziziphus mucronata	9.72	1.63	5.9632	2	**Preferred**
Buddleja saligna	4.02	9.48	0.4241	8	Neglected
Tarchonanthus camphoratus	3.43	17.60	0.1949	10	Neglected
Searsia lancea	2.51	1.45	1.7310	4	**Preferred**
Olea europaea subsp. *africana*	2.06	14.06	0.1465	11	Neglected
Vachellia karroo	1.55	5.67	0.2734	9	Neglected
Asparagus laricinus	1.34	1.05	1.2762	6	**Preferred**
Asparagus suaveolens	0.72	0.54	1.3333	5	**Preferred**
Diospyros lycioides	0.00	1.40	0.0000	-	Avoided
Grewia occidentalis	0.00	4.34	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.21	0.0000	-	Avoided
Other tree and shrub species	3.02	1.31	2.3053	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	45.10	22.01	2.0491	1	**Preferred**
Evergreen trees and shrubs	54.91	77.98	0.7042	2	Neglected
Total	**100**	**100**			

Table 5.11 Kudu food preference during the flush phase of 2014 (Sep)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	86.37	7.97	10.8369	1	**Preferred**
Searsia lancea	12.18	1.56	7.8077	2	**Preferred**
Diospyros lycioides	1.40	1.50	0.9333	3	Neglected
Searsia burchellii	0.04	37.20	0.0012	4	Neglected
Asparagus laricinus	0.00	0.61	0.0000	-	Avoided
Asparagus suaveolens	0.00	0.42	0.0000	-	Avoided
Buddleja saligna	0.00	10.20	0.0000	-	Avoided
Ehretia alba	0.00	0.86	0.0000	-	Avoided
Grewia occidentalis	0.00	4.50	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	15.13	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.21	0.0000	-	Avoided
Searsia ciliata	0.00	2.49	0.0000	-	Avoided
Tarchonanthus camphoratus	0.00	12.81	0.0000	-	Avoided
Ziziphus mucronata	0.00	1.10	0.0000	-	Avoided
Other woody species	0.00	1.43	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	87.77	22.22	3.9500	1	**Preferred**
Evergreen trees and shrubs	12.22	77.77	0.1571	2	Neglected
Total	**100**	**100**			

The same four species kudu preferred during the mature phase were also preferred during the senescent phase, although a change in their rankings occurred (Table 5.9). As the leaves of most deciduous species started to change colour in the senescent phase, kudu showed the highest preference for *Z. mucronata* followed by *V. karroo, E. alba* and *S. ciliata*. All the other woody species were again either neglected or avoided.

The three species most preferred by kudu during the dry phase of 2014 were all deciduous species, namely *E. alba*, *Z. mucronata* and *S. ciliata* (Table 5.10). They were followed in preference by the evergreen species *S. lancea,* the deciduous species *A. suaveolens* and *A. laricinus* and lastly the evergreen species *S. burchellii*. *Buddleja saligna, V. karroo, T. camphoratus* and *O. europaea* subsp. *africana* were all utilised, but proportionally less so than their availability during the dry phase of 2014. During the flush phase of 2014 both *V. karroo* and *S. lancea* were preferred by kudu, while *D. lycioides* and *S. burchellii* were neglected (Table 5.11). All other woody species were avoided during this phase.

Kudu cows also showed an overall preference for deciduous trees and shrubs, while evergreen trees and shrubs as a whole were neglected in all phases of food availability (Tables 5.12 – 5.18). Although cows' preferences changed during different phases of food availability, they always showed the highest preference for one of the deciduous species. During the dry phase of 2013 cows preferred to utilise the deciduous species *S. ciliata*, followed by the evergreen species *S. lancea* and *B. saligna*, and the deciduous species *E. alba* and *V. karroo* (Table 5.12). At this time cows also utilised *S. burchellii* and *T. camphoratus*, although less so than their proportional availability.

After the pre-rain flush occurred in October 2013, cows preferred to utilise *V. karroo*, with all other woody species neglected or avoided during this flush phase (Table 5.13). The preference for *V. karroo* continued into the immature phase, although cows also showed a preference for other deciduous species namely, *Z. mucronata, A. laricinus* and *E. alba* (Table 5.14). During the immature phase eight other woody species were also utilised, although all of them were neglected. From the immature phase to the mature phase *A. laricinus* was replaced as one of the preferred species by *S. ciliata* (Table 5.15). The other preferred species remained in the same order, namely *V. karroo* followed by *Z. mucronata, S. ciliata* and lastly *E.rigida*.

Table 5.12 Food preference of cows during the dry phase of 2013 (Sep)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Searsia burchellii	31.44	38.04	0.8265	6	Neglected
Searsia ciliata	29.50	2.55	11.5686	1	**Preferred**
Buddleja saligna	20.16	8.76	2.3014	3	**Preferred**
Searsia lancea	7.23	1.60	4.5188	2	**Preferred**
Vachellia karroo	5.64	5.59	1.0092	5	**Preferred**
Tarchonanthus camphoratus	4.88	15.19	0.3213	7	Neglected
Ehretia alba	1.15	0.99	1.1616	4	**Preferred**
Asparagus laricinus	0.00	0.63	0.0000	-	Avoided
Asparagus suaveolens	0.00	0.49	0.0000	-	Avoided
Diospyros lycioides	0.00	1.25	0.0000	-	Avoided
Grewia occidentalis	0.00	4.60	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	15.47	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.26	0.0000	-	Avoided
Ziziphus mucronata	0.00	1.26	0.0000	-	Avoided
Other tree and shrub species	0.00	1.33	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	36.29	20.09	1.8064	1	**Preferred**
Evergreen trees and shrubs	63.71	79.92	0.7972	2	Neglected
Total	**100**	**100**			

Table 5.13 Food preference of cows during the flush phase of 2013 (Oct)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	84.76	8.95	9.4704	1	**Preferred**
Searsia burchellii	10.36	36.75	0.2819	4	Neglected
Buddleja saligna	3.83	8.36	0.4581	2	Neglected
Diospyros lycioides	0.69	1.71	0.4035	3	Neglected
Searsia lancea	0.36	1.55	0.2323	5	Neglected
Asparagus laricinus	0.00	0.64	0.0000	-	Avoided
Asparagus suaveolens	0.00	0.37	0.0000	-	Avoided
Ehretia alba	0.00	0.90	0.0000	-	Avoided
Grewia occidentalis	0.00	4.68	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	15.76	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.13	0.0000	-	Avoided
Searsia ciliata	0.00	2.30	0.0000	-	Avoided
Tarchonanthus camphoratus	0.00	13.35	0.0000	-	Avoided
Ziziphus mucronata	0.00	1.15	0.0000	-	Avoided
Other tree and shrub species	0.00	1.40	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	85.45	23.37	3.6564	1	**Preferred**
Evergreen trees and shrubs	14.55	76.63	0.1899	2	Neglected
Total	**100**	**100**			

Table 5.14 Food preference of cows during the immature phase of 2013 (Nov - Dec)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	63.99	11.12	5.7545	1	**Preferred**
Ziziphus mucronata	8.77	1.67	5.2515	2	**Preferred**
Tarchonanthus camphoratus	8.57	13.12	0.6532	7	Neglected
Ehretia alba	4.88	1.41	3.4610	4	**Preferred**
Asparagus laricinus	4.09	1.14	3.5877	3	**Preferred**
Buddleja saligna	3.43	8.13	0.4219	9	Neglected
Searsia ciliata	2.30	2.63	0.8745	5	Neglected
Diospyros lycioides	1.75	2.21	0.7919	6	Neglected
Searsia burchellii	0.84	35.30	0.0238	12	Neglected
Searsia lancea	0.73	1.34	0.5448	8	Neglected
Olea europaea subsp. *africana*	0.57	13.61	0.0419	11	Neglected
Asparagus suaveolens	0.06	0.52	0.1154	10	Neglected
Grewia occidentalis	0.00	4.43	0.0000	-	Avoided
Rhigozum obovatum	0.00	1.94	0.0000	-	Avoided
Other tree and shrub species	0.00	1.42	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	85.84	27.73	3.0956	1	**Preferred**
Evergreen trees and shrubs	14.14	72.26	0.1957	2	Neglected
Total	**100**	**100**			

Table 5.15 Food preference of cows during the mature phase of 2014 (Jan - Mar)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	67.27	9.90	6.7949	1	**Preferred**
Searsia ciliata	16.30	4.26	3.8263	3	**Preferred**
Ziziphus mucronata	10.13	2.04	4.9657	2	**Preferred**
Ehretia alba	2.35	1.61	1.4596	4	**Preferred**
Tarchonanthus camphoratus	1.12	15.99	0.0700	8	Neglected
Searsia lancea	0.20	1.32	0.1515	5	Neglected
Asparagus laricinus	0.11	1.14	0.0965	6	Neglected
Diospyros lycioides	0.04	2.20	0.0182	9	Neglected
Searsia burchellii	0.04	31.42	0.0013	10	Neglected
Asparagus suaveolens	0.04	0.54	0.0741	7	Neglected
Olea europaea subsp. *africana*	0.01	12.78	0.0008	11	Neglected
Buddleja saligna	0.00	8.62	0.0000	-	Avoided
Grewia occidentalis	0.00	4.09	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.70	0.0000	-	Avoided
Other tree and shrub species	2.40	1.41	1.7021	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	98.64	29.16	3.3827	1	**Preferred**
Evergreen trees and shrubs	1.37	70.86	0.0193	2	Neglected
Total	**100**	**100**			

Table 5.16 Food preference of cows during the senescent phase of 2014 (Apr - May)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	56.04	9.91	5.6549	2	**Preferred**
Ziziphus mucronata	22.84	2.04	11.1961	1	**Preferred**
Ehretia alba	6.56	1.61	4.0745	3	**Preferred**
Searsia ciliata	6.44	4.26	1.5117	5	**Preferred**
Searsia burchellii	3.12	31.48	0.0991	9	Neglected
Tarchonanthus camphoratus	2.30	16.02	0.1436	8	Neglected
Asparagus suaveolens	0.88	0.55	1.6000	4	**Preferred**
Buddleja saligna	0.82	8.63	0.0950	10	Neglected
Searsia lancea	0.54	1.32	0.4091	6	Neglected
Asparagus laricinus	0.31	1.14	0.2719	7	Neglected
Diospyros lycioides	0.15	1.97	0.0761	11	Neglected
Grewia occidentalis	0.00	4.10	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	12.80	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.71	0.0000	-	Avoided
Other tree and shrub species	0.00	1.46	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	93.22	29.02	3.2123	1	**Preferred**
Evergreen trees and shrubs	6.78	70.98	0.0955	2	Neglected
Total	**100**	**100**			

Table 5.17 Food preference of cows during the dry phase of 2014 (Jun - Aug)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Searsia burchellii	25.44	34.59	0.7355	7	Neglected
Ehretia alba	25.38	1.29	19.6744	1	**Preferred**
Searsia ciliata	15.39	3.37	4.5668	3	**Preferred**
Ziziphus mucronata	14.13	1.63	8.6687	2	**Preferred**
Searsia lancea	3.72	1.45	2.5655	4	**Preferred**
Buddleja saligna	2.64	9.48	0.2785	9	Neglected
Tarchonanthus camphoratus	2.57	17.60	0.1460	10	Neglected
Vachellia karroo	2.56	5.67	0.4515	8	Neglected
Asparagus laricinus	1.73	1.05	1.6476	5	**Preferred**
Asparagus suaveolens	0.73	0.54	1.3519	6	**Preferred**
Olea europaea subsp. *africana*	0.72	14.06	0.0512	11	Neglected
Diospyros lycioides	0.00	1.40	0.0000	-	Avoided
Grewia occidentalis	0.00	4.34	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.21	0.0000	-	Avoided
Other tree and shrub species	4.99	1.31	3.8092	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	59.92	22.01	2.7224	1	**Preferred**
Evergreen trees and shrubs	40.08	77.98	0.5140	2	Neglected
Total	**100**	**100**			

Table 5.18 Food preference of cows during the flush phase of 2014 (Sep)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	96.09	7.97	12.0565	1	**Preferred**
Diospyros lycioides	2.57	1.50	1.7133	2	**Preferred**
Searsia lancea	1.33	1.56	0.8526	3	Neglected
Asparagus laricinus	0.00	0.61	0.0000	-	Avoided
Asparagus suaveolens	0.00	0.42	0.0000	-	Avoided
Buddleja saligna	0.00	10.20	0.0000	-	Avoided
Ehretia alba	0.00	0.86	0.0000	-	Avoided
Grewia occidentalis	0.00	4.50	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	15.13	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.21	0.0000	-	Avoided
Searsia burchellii	0.00	37.20	0.0000	-	Avoided
Searsia ciliata	0.00	2.49	0.0000	-	Avoided
Tarchonanthus camphoratus	0.00	12.81	0.0000	-	Avoided
Ziziphus mucronata	0.00	1.10	0.0000	-	Avoided
Other tree and shrub species	0.00	1.43	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	98.66	22.22	4.4401	1	**Preferred**
Evergreen trees and shrubs	1.33	77.77	0.0171	2	Neglected
Total	**100**	**100**			

Cows preferred five deciduous species during the senescent phase, with *Z. mucronata* most preferred followed by *V. karroo, E. alba, A. suaveolens* and *S. ciliata* (Table 5.16). The other woody species in the study area were either neglected or avoided. Cows showed the highest or second highest preference for *V. karroo* right through from the flush phase of 2013 to the senescent phase. However, the preference for *V. karroo* changed dramatically during the dry phase of 2014, with this species neglected after shedding most of their leaves (Table 5.17). The woody species that cows showed the highest preference for during the dry phase of 2014 was *E. alba*, followed by *Z. mucronata, S. ciliata, S. lancea, A. laricinus* and *A. suaveolens*. Out of these preferred species only *S. lancea* was evergreen. Cows neglected or avoided the other species during this phase, even though *S. burchellii* contributed the largest proportion of the cows' diet. The two early flushing species, *V. karroo* and *D. Lycioides*, were the only woody species preferred by cows during the flush phase of 2014 (Table 5.18). The only other woody species that cows utilised during this time was *S. lancea*.

Socially mature bulls displayed a higher overall preference for evergreen trees and shrubs during the dry phases. However, during the flush, immature, mature and senescent phases socially mature bulls had a higher overall preference for deciduous trees and shrubs (Tables 5.19 – 5.25). The evergreen species *S. lancea* ranked the highest in preference for socially mature bulls during the dry phase of 2013, followed by the deciduous species *A. suaveolens*, the evergreen species *S. burchellii* and the deciduous species *Z. mucronata* and *V. karroo* (Table 5.19). All the other woody species were utilised less than their proportional availability or were completely avoided.

During the flush phase of 2013 socially mature bulls only preferred two deciduous species, namely *V. karroo* and *Z. mucronata* (Table 5.20). The other two species utilised by socially mature bulls during this time were both neglected. A total of 11 woody species were then utilised by socially mature bulls in the immature phase of which five were considered to be preferred (Table 5.21). Of the preferred species *E. alba* ranked the highest, followed by *V. karroo, G. occidentalis, B. saligna* and *Z. mucronata*. *Buddleja saligna* was the only evergreen species preferred during the immature phase. The food preferences of socially mature bulls then changed somewhat in the mature phase with only deciduous species being preferred (Table 5.22). *Vachellia karroo* had the highest ranking during this phase, followed by *Z. mucronata*, *S. ciliata*, *E. alba* and *A. laricinus*.

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Table 5.19 Food preference of socially mature bulls during the dry phase of 2013 (Sep)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Searsia burchellii	46.02	38.04	1.2098	3	**Preferred**
Searsia lancea	36.33	1.60	22.7063	1	**Preferred**
Vachellia karroo	5.69	5.59	1.0179	5	**Preferred**
Olea europaea subsp. *africana*	4.21	15.47	0.2721	8	Neglected
Asparagus suaveolens	2.31	0.49	4.7143	2	**Preferred**
Buddleja saligna	1.53	8.76	0.1747	9	Neglected
Ziziphus mucronata	1.40	1.26	1.1111	4	**Preferred**
Tarchonanthus camphoratus	1.35	15.19	0.0889	10	Neglected
Ehretia alba	0.65	0.99	0.6566	7	Neglected
Asparagus laricinus	0.49	0.63	0.7778	6	Neglected
Diospyros lycioides	0.00	1.25	0.0000	-	Avoided
Grewia occidentalis	0.00	4.60	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.26	0.0000	-	Avoided
Searsia ciliata	0.00	2.55	0.0000	-	Avoided
Other tree and shrub species	0.00	1.33	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	10.54	20.09	0.5246	2	Neglected
Evergreen trees and shrubs	89.44	79.92	1.1191	1	**Preferred**
Total	**100**	**100**			

Table 5.20 Food preference of socially mature bulls during the flush phase of 2013 (Oct)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	75.17	8.95	8.3989	1	**Preferred**
Searsia burchellii	19.36	36.75	0.5268	3	Neglected
Buddleja saligna	3.42	8.36	0.4091	4	Neglected
Ziziphus mucronata	2.05	1.15	1.7826	2	**Preferred**
Asparagus laricinus	0.00	0.64	0.0000	-	Avoided
Asparagus suaveolens	0.00	0.37	0.0000	-	Avoided
Diospyros lycioides	0.00	1.71	0.0000	-	Avoided
Ehretia alba	0.00	0.90	0.0000	-	Avoided
Grewia occidentalis	0.00	4.68	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	15.76	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.13	0.0000	-	Avoided
Searsia ciliata	0.00	2.30	0.0000	-	Avoided
Searsia lancea	0.00	1.55	0.0000	-	Avoided
Tarchonanthus camphoratus	0.00	13.35	0.0000	-	Avoided
Other tree and shrub species	0.00	1.40	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	77.22	23.37	3.3042	1	**Preferred**
Evergreen trees and shrubs	22.78	76.63	0.2973	2	Neglected
Total	**100**	**100**			

Table 5.21 Food preference of socially mature bulls during the immature phase of 2013 (Nov - Dec)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	41.97	11.12	3.7743	2	**Preferred**
Ehretia alba	18.33	1.41	13.0000	1	**Preferred**
Buddleja saligna	15.41	8.13	1.8954	4	**Preferred**
Grewia occidentalis	11.52	4.43	2.6005	3	**Preferred**
Tarchonanthus camphoratus	6.47	13.12	0.4931	7	Neglected
Ziziphus mucronata	3.02	1.67	1.8084	5	**Preferred**
Diospyros lycioides	1.33	2.21	0.6018	6	Neglected
Searsia burchellii	0.87	35.30	0.0246	11	Neglected
Asparagus laricinus	0.37	1.14	0.3245	8	Neglected
Searsia ciliata	0.35	2.63	0.1331	9	Neglected
Olea europaea subsp. *africana*	0.34	13.61	0.0250	10	Neglected
Asparagus suaveolens	0.00	0.52	0.0000	-	Avoided
Rhigozum obovatum	0.00	1.94	0.0000	-	Avoided
Searsia lancea	0.00	1.34	0.0000	-	Avoided
Other tree and shrub species	0.00	1.42	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	76.89	27.73	2.7728	1	**Preferred**
Evergreen trees and shrubs	23.09	72.26	0.3195	2	Neglected
Total	**100**	**100**			

Table 5.22 Food preference of socially mature bulls during the mature phase of 2014 (Jan - Mar)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	58.88	9.90	5.9475	1	**Preferred**
Searsia ciliata	14.99	4.26	3.5188	3	**Preferred**
Ziziphus mucronata	10.34	2.04	5.0686	2	**Preferred**
Searsia burchellii	7.58	31.42	0.2412	7	Neglected
Ehretia alba	4.57	1.61	2.8385	4	**Preferred**
Olea europaea subsp. *africana*	1.26	12.78	0.0986	8	Neglected
Asparagus laricinus	1.19	1.14	1.0439	5	**Preferred**
Diospyros lycioides	0.82	2.20	0.3727	6	Neglected
Tarchonanthus camphoratus	0.30	15.99	0.0188	9	Neglected
Buddleja saligna	0.08	8.62	0.0093	10	Neglected
Asparagus suaveolens	0.00	0.54	0.0000	-	Avoided
Grewia occidentalis	0.00	4.09	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.70	0.0000	-	Avoided
Searsia lancea	0.00	1.32	0.0000	-	Avoided
Other tree and shrub species	0.00	1.41	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	90.79	29.16	3.1135	1	**Preferred**
Evergreen trees and shrubs	9.22	70.86	0.1301	2	Neglected
Total	**100**	**100**			

Table 5.23 Food preference of socially mature bulls during the senescent phase of 2014 (Apr - May)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	32.47	9.91	3.2765	3	**Preferred**
Searsia burchellii	25.14	31.48	0.7986	6	Neglected
Ziziphus mucronata	23.57	2.04	11.5539	1	**Preferred**
Searsia ciliata	7.07	4.26	1.6596	4	**Preferred**
Ehretia alba	5.94	1.61	3.6894	2	**Preferred**
Diospyros lycioides	2.40	1.97	1.2183	5	**Preferred**
Olea europaea subsp. *africana*	2.40	12.80	0.1875	9	Neglected
Asparagus laricinus	0.75	1.14	0.6579	7	Neglected
Asparagus suaveolens	0.12	0.55	0.2182	8	Neglected
Buddleja saligna	0.07	8.63	0.0081	11	Neglected
Searsia lancea	0.02	1.32	0.0152	10	Neglected
Grewia occidentalis	0.00	4.10	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.71	0.0000	-	Avoided
Tarchonanthus camphoratus	0.00	16.02	0.0000	-	Avoided
Other tree and shrub species	0.04	1.46	0.0274	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	72.32	29.02	2.4921	1	**Preferred**
Evergreen trees and shrubs	27.67	70.98	0.3898	2	Neglected
Total	**100**	**100**			

Table 5.24 Food preference of socially mature bulls during the dry phase of 2014 (Jun - Aug)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Searsia burchellii	63.50	34.59	1.8358	3	**Preferred**
Searsia ciliata	14.76	3.37	4.3798	1	**Preferred**
Olea europaea subsp. *africana*	5.69	14.06	0.4047	7	Neglected
Buddleja saligna	4.68	9.48	0.4937	6	Neglected
Ehretia alba	4.44	1.29	3.4419	2	**Preferred**
Tarchonanthus camphoratus	3.99	17.60	0.2267	8	Neglected
Ziziphus mucronata	1.88	1.63	1.1534	4	**Preferred**
Searsia lancea	0.91	1.45	0.6276	5	Neglected
Asparagus suaveolens	0.10	0.54	0.1852	9	Neglected
Asparagus laricinus	0.03	1.05	0.0286	10	Neglected
Diospyros lycioides	0.00	1.40	0.0000	-	Avoided
Grewia occidentalis	0.00	4.34	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.21	0.0000	-	Avoided
Vachellia karroo	0.00	5.67	0.0000	-	Avoided
Other tree and shrub species	0.00	1.31	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	21.21	22.01	0.9637	2	Neglected
Evergreen trees and shrubs	78.77	77.98	1.0101	1	**Preferred**
Total	**100**	**100**			

Table 5.25 Food preference of socially mature bulls during the flush phase of 2014 (Sep)

COMMON TREE AND SHRUB SPECIES	A % of tree and shrub feeding time	B % DM of trees and shrubs available below 2m	(A/B) Preference rating	Rank of rating	Preference
Vachellia karroo	67.28	7.97	8.4417	2	**Preferred**
Searsia lancea	32.58	1.56	20.8846	1	**Preferred**
Searsia burchellii	0.13	37.20	0.0035	3	Neglected
Asparagus laricinus	0.00	0.61	0.0000	-	Avoided
Asparagus suaveolens	0.00	0.42	0.0000	-	Avoided
Buddleja saligna	0.00	10.20	0.0000	-	Avoided
Diospyros lycioides	0.00	1.50	0.0000	-	Avoided
Ehretia alba	0.00	0.86	0.0000	-	Avoided
Grewia occidentalis	0.00	4.50	0.0000	-	Avoided
Olea europaea subsp. *africana*	0.00	15.13	0.0000	-	Avoided
Rhigozum obovatum	0.00	2.21	0.0000	-	Avoided
Searsia ciliata	0.00	2.49	0.0000	-	Avoided
Tarchonanthus camphoratus	0.00	12.81	0.0000	-	Avoided
Ziziphus mucronata	0.00	1.10	0.0000	-	Avoided
Other tree and shrub species	0.00	1.43	0.0000	-	Uncategorised
Total	**100**	**100**			
Deciduous trees and shrubs	67.28	22.22	3.0279	1	**Preferred**
Evergreen trees and shrubs	32.71	77.77	0.4206	2	Neglected
Total	**100**	**100**			

As was the case in the mature phase, socially mature bulls only utilised deciduous species in the senescent phase although the species preferred and their preference rankings changed (Table 5.23). At this time *Z. mucronata* had the highest ranking followed by *E. alba, V. karroo, S. ciliata* and *D. lycioides.* All of the following species were utilised by socially mature bulls in smaller proportions to their relative availability in the senescent phase: *S. burchellii, A. laricinus, A. suaveolens, O. europaea* subsp. *africana, S. lancea* and *B. saligna.* Socially mature bulls preferred to utilise *S. ciliata, E. alba, S. burchellii* and *Z. mucronata* during the dry phase of 2014, with two deciduous species ranking first and second (Table 5.24). All the other woody species were either neglected or avoided. The evergreen species *S. lancea* was the most preferred species by socially mature bulls in the flush phase of 2014, with *V. karroo* also receiving high preference during this time (Table 5.25). The only other woody species utilised by socially mature bulls during the flush phase of 2014 was *S. burchellii* although this species was considered to be neglected.

5.4   DISCUSSION

Even during periods when dry feed was supplied to wildlife in the study area, kudu still spent most of their feeding time utilising natural vegetation. The only exception was during the dry phase of 2013 when a delay in the leaf flush of woody species occurred, extending the critical period of food shortage. This could have also resulted from more dry feed being supplied in 2013, which probably reduced competition at the feeding troughs and allowed kudu to utilise more dry feed. Kudu's utilisation of dry feed decreased significantly from the dry to the flush phases, indicating that dry feed was not of critical importance to browsers after deciduous species produced immature leaves. This highlights the importance of natural vegetation as a food source to wildlife, even when dry feed is supplied.

Kudu in the study area were predominantly browsers, which is in accordance with other studies (Wilson, 1965; Wilson, 1970; Conybeare, 1975; Giesecke & Van Gylswyk, 1975; Owen-Smith, 1979; Novellie, 1983; Owen-Smith *et al.*, 1983; Owen-Smith & Cooper 1985; du Toit, 1988; Owen-Smith & Cooper, 1989; Breebaart, 2000; Cerling *et al.*, 2003; Codron *et al.*, 2005a & b; Hooimeijer *et al.*, 2005; Codron *et al.*, 2007; Curlewis, 2014; Makhado *et al.*, 2016a & b). However, kudu spent 49% of their feeding time grazing during the immature phase from November to December. This was even more pronounced in cows that spent 61% of their feeding time grazing during this period.

Some authors noted the difficulty in determining whether kudu were utilising grass or forbs when they were feeding at ground level (Conybeare, 1975; Owen-Smith, 1979; Novellie, 1983). Conybeare (1975) consequently grouped grass and forbs together. However, both Owen-Smith (1979) and Novellie (1983) concluded from feeding observations and limited feeding site inspections that little or no grass was being utilised by kudu in Kruger National Park. Consequently, all ground level feeding, that potentially included grasses, were lumped together in a single forbs category by these authors.

Grass consumption by kudu in the study area on Amanzi Private Game Reserve was almost entirely limited to the planted pastures (*Digitaria eriantha - Cynodon dactylon* Community). Grazing could therefore not have been mistaken for browsing on forbs or dwarf shrubs as they were rarely encountered in this plant community, with the herbaceous layer consisting of 99.83% grass as determined from point observations (see Chapter 4). These results stand in stark contrast to most studies that reported very little to no grass in the diets of kudu (Wilson, 1965; Giesecke & Van Gylswyk, 1975; Owen-Smith, 1979; Owen-Smith *et al.*, 1983; du Toit, 1988; Owen-Smith & Cooper, 1989; Breebaart, 2000; Cerling *et al.*, 2003; Codron *et al.*, 2005a & b; Hooimeijer *et al.*, 2005; Codron *et al.*, 2007; Curlewis, 2014; Makhado *et al.*, 2016a & b). However, the fact that kudu almost exclusively grazed in the *Digitaria eriantha - Cynodon dactylon* Community begs the question whether grass would have contributed to their diet to the same extent under more natural conditions without any planted pastures available.

Conybeare (1975) alluded to the fact that grass may be an important food source to kudu in some areas depending on local conditions. Although kudu mostly browsed in the Hwange National Park (Zimbabwe), one kudu stomach contained 80% grass. This individual was shot in a vlei margin with abundant grass and very little forbs (Conybeare, 1975). Varying amounts of grass were also recorded in the stomachs of kudu after culling operations in May 1968 in the Kyle National Park, Zimbabwe. For example, in the *Brachystegia* Woodland, kudu utilised no more than three percent grass, while they utilised 18% grass in the Grassland with *Combretum* trees and at least 30% grass in the *Acacia* Tree Savannah (Wilson, 1970). The highest grass utilisation by kudu in the Nylsvley Nature Reserve occurred in October when most woody species still had to produce new growth. During this time kudu grazed on firebreaks, with one kudu observed dedicating as much as 58% of its daily feeding time to grass (Owen-Smith & Cooper, 1985).

Kudu in the Tshokwane area of Kruger National Park were also observed to utilise large quantities of new grass during November 1976 after burns occurred in the area the previous month. By December of that year kudu were no longer eating grass, but rather feeding extensively on forbs that increased noticeably in abundance (Novellie, 1983). Kudu in the Tshokwane area of Kruger National Park also spent most of their feeding time during the late wet season (January to March) utilising plants in the herbaceous layer (Owen-Smith, 1979; Novellie, 1983; du Toit, 1988). However, Owen-Smith (1979) and du Toit (1988) found that the herbaceous component in their diet declined from the wet to the dry season, with kudu spending most of their feeding time utilising woody browse. From May to July in Hwange National Park, the proportion of grass and forbs in kudu stomachs also decreased dramatically to well below that comprised of woody browse (Conybeare, 1975).

The proportion of time kudu spent grazing on Amanzi Private Game Reserve decreased significantly from the immature phase (November to December) to the mature phase (January to March). This reduction in grass consumption coincided with rapid growth of the herbaceous layer in February. Kudu avoided the tall grass in the *Digitaria eriantha - Cynodon dactylon* Community from middle February, but continued to graze on the edges of this plant community. They were also observed spending more time utilising the creeping grass *Cynodon hirsutus* during March. Kudu's preference for short grass may be related to their feeding method of plucking grass with their teeth instead of using their tongues to gather grass. However, the *Digitaria eriantha - Cynodon dactylon* Community may also have been avoided by kudu due to very limited visibility in this plant community as the grass height was in excess of 2 meters from middle February. Grass again decreased significantly in the diets of kudu from the mature to the senescent phase (April to May), with grass probably containing lower protein and higher fibre contents when it changed colour (Jarman, 1974).

The browse proportion in the diets of kudu on Amanzi Private Game Reserve consisted of mostly woody species, with very little forbs utilised. Even if all unidentified feeding observations at ground level consisted of forbs, their contribution to the kudu diet would still have amounted to less than 5% at any time of the year. The reason for kudu rarely utilising forbs is probably due to their low availability in the study area on Amanzi Private Game Reserve. Similar results were found by Hooimeijer *et al.*, (2005) who recorded only 1.6% forbs in the annual diet of kudu on the Musina Experimental Farm in Limpopo province.

Woody browse also made up over 50% of the kudu diet throughout the year in the Nylsvley Nature Reserve (Limpopo province), with an annual mean of 62% recorded for this vegetation component (Owen-Smith & Cooper, 1985). Similarly the diet of kudu in the Weenen Nature Reserve (KwaZulu-Natal) consisted of mostly woody browse throughout the year (Breebaart, 2000). Owen-Smith (1979) and du Toit (1988) also found that the bulk of kudu's annual diet in the Tshokwane area of Kruger National Park consisted of woody browse. However, they did report that forbs formed the bulk of their diet during the wet season. In contrast, Novellie (1983) reported that kudu in the Tshokwane area of Kruger National Park showed a higher preference for forbs over woody species during all seasons, except the pre-rain flush. According to Novellie (1983) kudu's preference for forbs seems to be related to their relatively high nutrient content and less fibrous stems compared to woody species. However, woody browse were preferred by kudu during the pre-rain flush when their new shoots were still soft and when forbs were least available. Novellie (1983) attributed kudu's higher proportional consumption of forbs in the same study area used by Owen-Smith (1979) to higher seasonal rainfall that probably corresponded with more forbs being available. Kudu's utilisation of forbs thus seems dependant on local conditions that can vary considerably from one area to the next and from year to year.

The kudu in the study area on Amanzi Private Game Reserve utilised mainly deciduous trees and shrubs from the flush phase in 2013 to the senescent phase in 2014. However they changed their diet during the following dry phase to include proportionally more evergreen species compared to deciduous species. This change in their diet occurred at the same time that *V. karroo* trees shed most of their leaves (see Chapter 4).

According to Owen-Smith *et al*. (1983) the most critical period for kudu occurs at the end of the dry season when food availability is at a low due to leaf fall in deciduous species. Evergreen shrubs, along with succulents, dry forbs and leaf litter provide important food reserves to sustain kudu through these hard times (Owen-Smith *et al*., 1983). However, evergreen species only form a minor vegetation component in most savanna regions and were thus still utilised by kudu to a lesser extent compared to deciduous species in the late dry season (Owen-Smith & Cooper, 1985). In contrast, evergreen species in the study area on Amanzi Private Game Reserve provided the highest dry mass available to kudu throughout the year (see Chapter 4). This probably contributed to the fact that, during the dry phases, evergreen species made up a larger proportion of the kudu diet compared to deciduous species. Giraffe in the Willem Pretorius Nature Reserve (situated in the central Free State) also changed their diet from mainly deciduous to mainly evergreen species during the winter (Kok & Opperman, 1980).

A shift in kudu diet composition occurred again during the flush phase of 2014 when kudu spent most of their feeding time utilising deciduous species. On this occasion, the shift in their diet coincided with *V. karroo* trees producing immature leaves. At this time, kudu spent 76% of their feeding time browsing on *V. karroo* trees as most other deciduous species in the study area were leafless (see Chapter 4).

When comparing the diets of kudu between September 2013 and September 2014, it was clear that the timing of leaf emergence in early flushing species, especially *V. karroo*, had a profound effect on their diet selection. The delay in leaf emergence that occurred in deciduous species during September 2013 resulted in kudu spending most of their feeding time utilising evergreen species during that month. However, when leaves of early flushing deciduous species emerged during September 2014, kudu changed their diet selection to include proportionally more deciduous than evergreen species. According to Owen-Smith & Cooper (1989), the timing of leaf flush can vary by several weeks from one year to the next, with early flushing species only producing new leaves by late October in some years. This lengthens the critical period during which kudu experiences a shortage of energy. Kudu is also very susceptible to cold spells persisting in the critical period of September/October, further draining their dwindling body reserves that could lead to die-offs (Owen-Smith & Cooper, 1989; Van der Waal, 2001).

The diets of cows and socially mature bulls were remarkably similar, although socially mature bulls utilised proportionally more evergreen species compared to cows throughout the year. This was especially evident in the dry phase of 2014 when cows utilised proportionally more deciduous species compared to evergreen species, while bulls utilised proportionally more evergreen species compared to deciduous species. The reason for cows utilising more deciduous species could possibly be related to increased energy demands during pregnancy and lactation (Owen-Smith & Cooper, 1989).

Although kudu in the study area utilised a wide variety of plant species, only five of those species namely, *V. karroo, S. burchellii, Z. mucronata, S. ciliata* and *E. alba* formed the bulk of their annual diet. Similar results are reported by various authors, with only a small number of plant species usually contributing the bulk of kudu diets during any given time of the year (Wilson, 1965; Wilson, 1970; Conybeare, 1975; Owen-Smith, 1979; Novellie, 1983; Owen-Smith *et al.,* 1983; Owen-Smith & Cooper, 1985; du Toit, 1988; Owen-Smith & Cooper, 1989; Breebaart, 2000; Hooimeijer *et al.*, 2005; Curlewis, 2014; Makhado *et al.*, 2016a & b).

Vachellia karroo contributed the largest proportion of all the woody species in the kudu diet from the flush to the senescent phase. This, however, changed in the dry phase as *S. burchellii* was utilised in the greatest proportion. Both *S. burchellii* and *V. karroo* can accordingly be considered as the most important woody species in the study area. Kok & Opperman (1980) also considered *V. karroo* and *S. burchellii* (referred to as *Searsia undulata*) to be the two most important food sources available to giraffe in the Willem Pretorius Nature Reserve.

Kudu preferred deciduous species and neglected evergreen species throughout the study period, although they utilised proportionally more evergreen species compared to deciduous species during the dry phases. In contrast, socially mature bulls preferred evergreen species during the dry phases, while neglecting deciduous species at the same time.

Kudu's food preferences changed dramatically from the dry to the flush phases with the emergence of immature leaves in the early flushing species. During these periods kudu showed the highest preference for *V. karroo* trees, utilising them up to 10 times more than their proportional availability. This temporarily changed during the immature phase as kudu showed a higher preference for *E. alba*. The change in preference was probably due to *E. alba* being a late-deciduous species that only produced new leaves at the start of the immature phase.

As the leaves of all deciduous species matured, kudu again showed the highest preference for *V. karroo*. However, a shift in preference occurred from the mature to the senescent phases with kudu showing the highest preference for *Z. mucronata*, although *V. karroo* still ranked second in preference. *V. karroo* trees were then neglected during the dry phase as they lost most of their leaves. During this time kudu showed the highest preference for *E. alba*, with *Z. mucronata* and *S. ciliata* ranking second and third, respectively. The evergreen shrub *S. burchellii* ranked a lowly 6th place during the dry phases, although contributing the most to the kudu diets during these periods.

5.5   CONCLUSION

The diet composition of kudu in the study area varied according to food quality and availability. The critical period of lowest food availability ended as pre-rain flush occurred in some deciduous species. During the flush phase kudu spent most of their feeding time utilising deciduous trees and shrubs. After the first good rains newly sprouted grass contributed the bulk of food consumed by kudu. However, kudu reverted back to utilising mostly deciduous trees and shrubs after leaf senescence occurred in the herbaceous layer. Kudu then changed their diet from mainly deciduous to mainly evergreen trees and shrubs after the most abundant deciduous species in the study area shed the majority of its leaves.

Based on the diet composition and food preferences of kudu the following species were regarded as the most important in the study area: *V. karroo, S. burchellii, Z. mucronata, S. ciliata* and *E. alba*. The deciduous species *V. karroo* and the evergreen species *S. burchellii* formed the bulk of the kudu diet during different phases of food availability. The late flushing deciduous species, *E. alba*, *Z. mucronata* and *S. ciliata* were also considered important food reserves for kudu, as they usually retained some of their leaves during the critical period stretching from August to September or middle October. Kudu at the correct stocking densities could thus survive the critical period in the study area, without the need for supplementary feeding, due to an abundance of late-deciduous and palatable evergreen species. These species served as a nutritional "stepping stone" before early-flushing trees and shrubs brought an end to the critical period.

CHAPTER 6: SPATIAL ECOLOGY AND HABITAT PREFERENCES OF KUDU

6.1 INTRODUCTION

The size of an animal's home range is mainly determined by the spatial arrangement of available resources (Fabricius, 1994), with the home range expanding until all the animal's requirements have been met (Carr & MacDonald, 1986). The distribution of animal populations is thus important to determine the basic requirements of a species (Simpson, 1972b). However, the factors that govern animal distribution are complex, with various interacting needs resulting in the dispersion of a species over its natural range. Any attempt to determine the importance of one factor must thus allow for the influence of others (Simpson & Cowie, 1967).

Factors mostly affecting the habitat preferences of large mammalian herbivores include vegetation, water, topography (Simpson & Cowie, 1967; Simpson, 1972b; Pienaar, 1974; Dekker *et al.*, 1996) and predation risk (Simpson, 1972b; Pienaar, 1974; Dekker *et al.*, 1996). However, behavioural aspects such as sexual segregation (Simpson & Cowie, 1967; Underwood, 1978), territoriality, reproduction and tolerance of other herbivores (Pienaar, 1974) might also play a role in the habitat selection of certain individuals or groups.

Herbivore movements are influenced by the available vegetation in two ways. Firstly, plants can provide herbivores with a food source and secondly plants can provide cover to escape predators and extreme temperatures (Simpson & Cowie, 1967; Simpson, 1972b; Pienaar, 1974; Underwood, 1978; Fabricius, 1989; Dekker *et al.*, 1996; Dörgeloh, 2001). Phenological changes in the vegetation are thus of critical importance to understand herbivore movements, as it affects both the availability of food and cover to these animals (Simpson, 1972b).

However, habitat selection by herbivores is often a balancing act between food availability and predation risk, with the decision to forage in the most rewarding habitats often complicated by a higher predation risk. Lions appear to have a higher success rate at killing several herbivore species in dense woody vegetation with tall grass cover. Most herbivores thus avoid these areas, especially at night, trading food for safety (Burkepile *et al.*, 2013). The absence of large predators on most game ranches might thus affect the habitat selection of herbivores (Dekker *et al.*, 1996).

Water is another important factor to take into account when analysing the movement patterns of herbivores (Simpson & Cowie, 1967; Simpson, 1972b; Pienaar, 1974; Dekker *et al.*, 1996). Kudu are considered to be water dependent (Simpson & Cowie, 1967; Simpson, 1972b) and thus need to stay within relatively close proximity of water. For example, in Chobe National Park (Botswana), the river was the only source of water to kudu from mid-September. This resulted in kudu concentrating along the river from September until the start of the rainy season. However, most kudu moved away from the river as soon as the rains arrived and water was widely available from pans and temporary pools (Simpson, 1972b).

Kudu are also known to be sensitive to cold spells, with high mortalities occurring during these periods. In this regard, topography plays an important role in kudu habitat selection, as seen in the Chobe area where kudu moved to higher ground in an attempt to escape the worst cold (Simpson, 1972b).

Artificial introduction of game species without prior knowledge of their habitat requirements can have disastrous consequences, leading to starvation and death of animals (Pienaar, 1974). Knowledge of the habitat preferences and other ecological requirements of animals are thus essential to managing wildlife (Dekker *et al.*, 1996; Dörgeloh, 2001). This is especially important on game ranches where animal movements are often restricted by fences (Dekker *et al.*, 1996).

The specific objectives of this chapter were:

1. To determine the range use, distance travelled and habitat preferences of kudu during each phase of food availability; and

2. To determine the percentage woody canopy cover present in each of the plant communities.

6.2   METHODOLOGY

6.2.1 Range use, distance travelled and habitat preferences of kudu

An adult kudu cow in the study area was fitted with a GPS collar during February 2013. Hourly GPS locations were recorded by the collar and uploaded to a secure database via satellite. All GPS locations recorded during the period from September 2013 to September 2014 were used in the current study.

Scan sampling, as described by Altmann (1974), was used to determine the average group size associated with the collared cow throughout the study period. This was done to determine if the location data represented more than one individual's movement patterns. Kudu were observed from sunrise to sunset for five days each month from September 2013 to September 2014. Observations were carried out on foot from slopes in the study area and made through 16x50 binoculars. The number of kudu associated with the collared cow was recorded every 15 minutes.

The recorded data from the GPS collar was divided into phases of food availability rather than seasons based on long term rainfall and temperature. This was done as rainfall and temperature does not always accurately reflect food availability to browsers. The following phases of food availability were accordingly recognised:

Dry phase: Mostly dry grass available, with predominantly yellow, dry or no leaves retained on deciduous trees and shrubs;

Flush phase: Mostly dry grass available, with predominantly green budding and immature leaves available on deciduous trees and shrubs;

Immature phase: Mostly green grass available, with predominantly green immature leaves available on deciduous trees and shrubs;

Mature phase: Mostly green grass available, with predominantly mature green leaves available on deciduous trees and shrubs; and

Senescent phase: Mostly yellow senescing grass available, with predominantly mature green and yellow senescing leaves retained on deciduous trees and shrubs.

Data was also divided into day (sunrise to sunset) and night (sunset to sunrise) locations, by using a Garmin Colorado 3300 GPS to determine the sunrise and sunset times in the study area for each date.

Kudu home ranges (95%) and core areas (50%) were estimated with the fixed kernel density method (Silverman, 1986) using the Geospatial Modelling Environment (Version 0.7.4.4) in conjunction with statistical software R (Version 3.2.0). Least squares cross validation was used to select the smoothing parameter (Seaman & Powell, 1996). The home ranges and core areas were then overlaid on a vegetation map of the study area using ArcMap (Version 10.4).

The difference in linear distance between consecutive hourly GPS locations was used to determine the distances travelled by kudu. The average linear distance travelled over 24 hours and per hour during the day and night was calculated for each phase of food availability. Dates where less than 24 locations were recorded were omitted from these calculations.

A chi-square goodness-of-fit test of the null hypothesis that kudu utilised plant communities in proportion to their availability was also carried out (Neu *et al.*, 1974; Byers *et al.*, 1984). If a significant ($p < 0.05$) difference between the observed and expected utilisation occurred, the null hypothesis was rejected. The chi-square test, however, does not determine preference or avoidance of individual plant communities. Therefore, if a statistically significant difference was found between the observed and expected utilisation of plant communities, the data was further analysed by calculating Bonferroni confidence intervals to determine which plant communities were significantly ($p < 0.05$) preferred or avoided. For both the chi-square and Bonferroni procedures, count data from the GPS collar was used to calculate the number of observed locations in each plant community and the expected utilisation was based on the relative size of plant communities (Neu *et al.*, 1974; Byers *et al.*, 1984). The *Buddleja saligna - Searsia burchellii* Community was further divided into sub-communities even though the vegetation in these two sub-communities was relatively homogenous. This was done due to topographical differences between the two sub-communities that could have affected habitat preferences.

6.2.2 Woody canopy cover

The percentage of woody canopy cover was measured with the line intercept method (Shukla & Srivastava, 1992). The distance of canopy intercept for all woody plants > 0.5 m tall was accordingly measured along a 100 m line situated along the border of each belt transect used in the quantification of the woody layer (see Chapter 4). The measured canopy intercepts were summed for each line transect and allocated to one of the plant communities as described in Chapter 3. Average woody canopy cover was subsequently calculated and expressed as a percentage for each plant community.

6.3 RESULTS

6.3.1 Range use, distance travelled and habitat preferences of kudu

The collared cow spent 90% of the time from September 2013 to September 2014 as part of groups consisting of five or more individuals and only 4% of the time alone. The average group size associated with the cow was 15.47 and the maximum group size 32. The location data can thus be considered representative of kudu breeding herds in the study area. The home range of kudu covered an area of 55.92 ha in the dry phase of 2013, with kudu only utilising 20% of the total area available to them (Figure 6.1). The core areas of their home range covered less than 2 ha and were situated around the two water troughs. Kudu only had a slightly larger home range during the night (64.63 ha) when compared to the day (48.11 ha) (Figures 6.2 – 6.3). However, a shift in their habitat utilisation did occur from day to night-time. This shift is clearly illustrated with kudu core areas also situated on the slopes of the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community at night (Figure 6.3). Kudu travelled an average distance of 3 478 m (SE ± 181.771) per 24 hours in the dry phase of 2013. Although kudu had a smaller home range during the day, they covered greater distances during the day compared to the night, with an average distance of 169 m (SE ± 9.238) covered per hour during the day and an average of 121 m covered per hour (SE ± 7.568) at night.

Statistically significant ($p < 0.05$) differences were found with the chi-square test when comparing the availability of plant communities and their utilisation during the dry phase of 2013 (Table 6.1). Bonferroni confidence intervals were subsequently calculated to determine which plant communities were significantly preferred or avoided. During the dry phase of 2013 kudu showed an overall preference for both the *Buddleja saligna - Searsia burchellii - Vachellia karroo* and the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-communities, while avoiding the *Themeda triandra - Digitaria eriantha* and the *Digitaria eriantha - Cynodon dactylon* Communities ($p < 0.05$) (Table 6.2). However, kudu only preferred the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community during the day, while preferring both the *Buddleja saligna - Searsia burchellii - Vachellia karroo* and the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-communities at night ($p < 0.05$). The *Persicaria lapathifolia - Panicum coloratum* Community was utilised in the same proportion to its availability during the day ($p > 0.05$), but avoided during the night ($p < 0.05$). The other plant communities were avoided during the day and the night ($p < 0.05$).

Figure 6.1 Kudu range use calculated from all recorded locations (day + night) during the dry phase (September 2013)

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Figure 6.2 Kudu range use calculated from recorded day locations during the dry phase (September 2013)

Figure 6.3 Kudu range use calculated from recorded night locations during the dry phase
(September 2013)

Table 6.1 Chi-square goodness-of-fit test results for the dry phase (September 2013). The null hypothesis tested was that kudu utilised plant communities in proportion to their availability

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE	OBSERVED USAGE	OBSERVED RELATIVE USAGE	X^2 (a)	DF (b)	P value (c)	H0 (d)
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	177	0.252				
Day +	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	408	0.580				
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	2	0.003	408.364	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	3	0.004				
	Themeda triandra - Digitaria eriantha	95.74	0.349	113	0.161				
Total		274.08	1	703	1				
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	70	0.202				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	211	0.608				
Day	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	1	0.003	208.600	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	2	0.006				
	Themeda triandra - Digitaria eriantha	95.74	0.349	63	0.182				
Total		274.08	1	347	1				
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	107	0.301				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	197	0.553				
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	1	0.003	211.530	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.003				
	Themeda triandra - Digitaria eriantha	95.74	0.349	50	0.140				
Total		274.08	1	356	1				

(a) Chi-squared value; (b) Degrees of freedom (n-1); (c) Two-tailed P value (d) Ho hypothesis is rejected or accepted

Table 6.2 Bonferronni confidence intervals for utilisation of plant communities during the dry phase (September 2013)

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE (P_{io})	OBSERVED USAGE	OBSERVED RELATIVE USAGE (P_i)	CONFIDENCE INTERVALS For P_i	PREFERENCE
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	177	0.252	$0.210 \leq p \leq 0.294$	+
Day +	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	408	0.580	$0.532 \leq p \leq 0.628$	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	2	0.003	$0.000 \leq p \leq 0.008$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	3	0.004	$0.000 \leq p \leq 0.010$	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	113	0.161	$0.125 \leq p \leq 0.197$	-
Total		274.08	1	703	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	70	0.202	$0.146 \leq p \leq 0.258$	=
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	211	0.608	$0.538 \leq p \leq 0.675$	+
Day	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	1	0.003	$0.000 \leq p \leq 0.011$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	2	0.006	$0.000 \leq p \leq 0.017$	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	63	0.182	$0.129 \leq p \leq 0.235$	-
Total		274.08	1	347	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	107	0.301	$0.239 \leq p \leq 0.363$	+
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	197	0.553	$0.485 \leq p \leq 0.621$	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	1	0.003	$0.000 \leq p \leq 0.010$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.003	$0.000 \leq p \leq 0.010$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	50	0.140	$0.093 \leq p \leq 0.187$	-
Total		274.08	1	356	1		

+ Indicates the plant community was significantly preferred (0.05 level of significance)

- Indicates the plant community was significantly avoided (0.05 level of significance)

= Indicates no significant difference was found between observed and expected utilisation (0.05 level of significance)

The home range of kudu increased somewhat from the dry phase to the flush phase in 2013, covering an area of 79.37 ha (Figure 6.4). Only one core area was utilised by kudu during this flush phase, covering an area of 2.71 ha around the water trough situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community. When comparing the kernel density estimates between day and night, the home range of kudu covered almost twice the size during the night (126.47 ha) compared to the day (69.57 ha) (Figures 6.5 – 6.6). Similar to the dry phase of 2013, kudu utilised more of the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community during the night, with their core areas extending to the slopes of this plant community. As their home range increased, kudu travelled further on average over 24 hours, with 4 089 m (SE ± 267.213) calculated for the flush phase of 2013. The difference between the daytime and night time average distance travelled per hour was also greater, with 203 m (SE ± 11.392), and 132 m (SE ± 10.436) calculated, respectively. This was despite the fact that kudu utilised a home range much larger during the night.

Statistically significant ($p < 0.05$) differences were found with the chi-square test when comparing the availability of plant communities and their utilisation by kudu during the flush phase of 2013 (Table 6.3). The null hypothesis, that kudu utilised plant communities in proportion to their availability, was thus rejected and Bonferroni confidence intervals were subsequently calculated to determine which plant communities were significantly preferred or avoided. When considering all location data during the flush phase of 2013, kudu only showed preference ($p < 0.05$) for the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, while utilising the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community in the same proportion to its availability ($p > 0.05$) (Table 6.4). The other plant communities were all avoided during this time ($p < 0.05$).

Very few differences occurred in habitat preferences of kudu between day and night in this phase. The only plant community preferred by kudu during both day and night-time was the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, while the *Digitaria eriantha - Cynodon dactylon*, *Persicaria lapathifolia - Panicum coloratum* and *Themeda triandra - Digitaria eriantha* Communities were avoided ($p < 0.05$). However, the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community was avoided during the day ($p < 0.05$) and utilised in the same proportion to its availability during the night ($p > 0.05$) (Table 6.4).
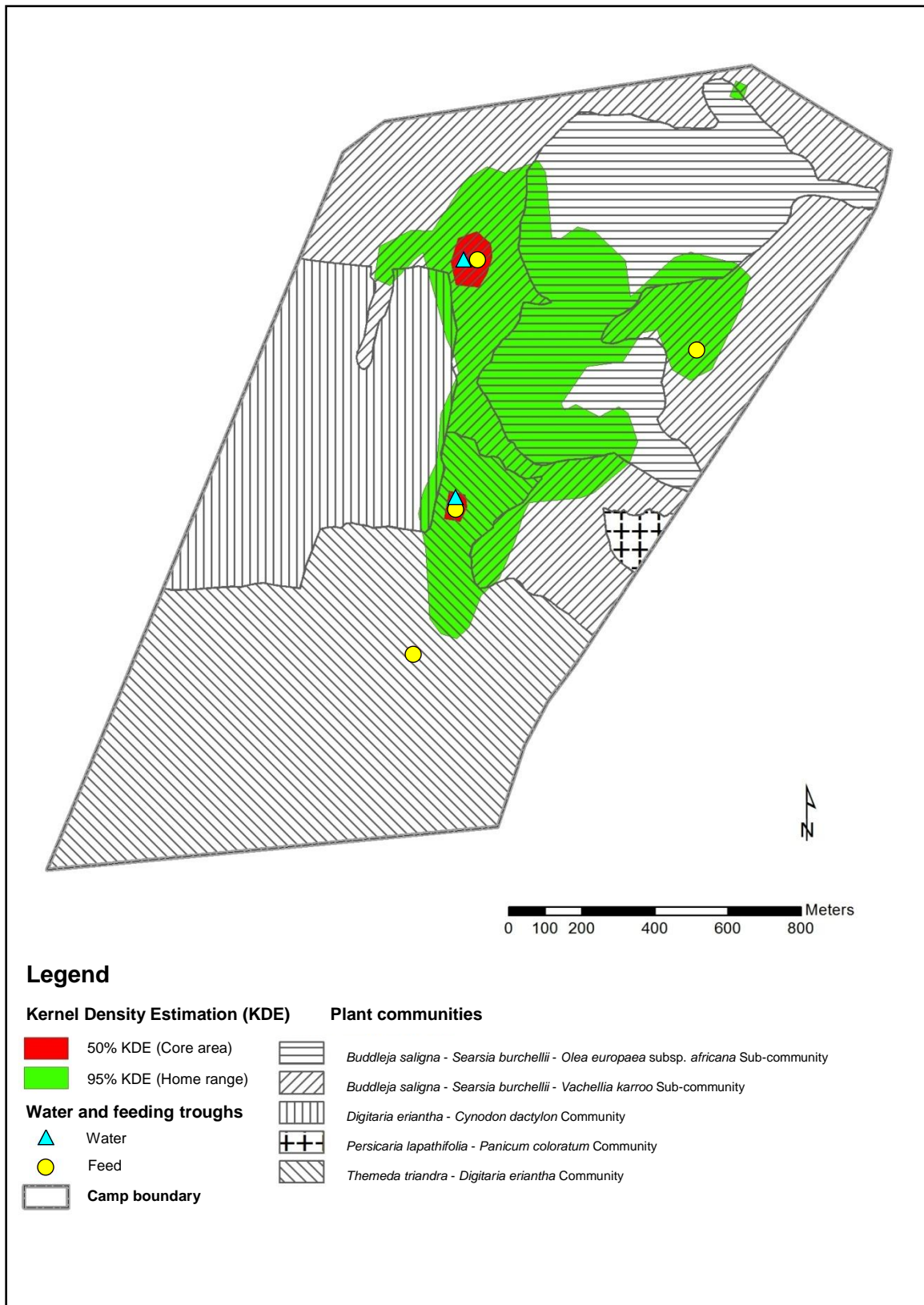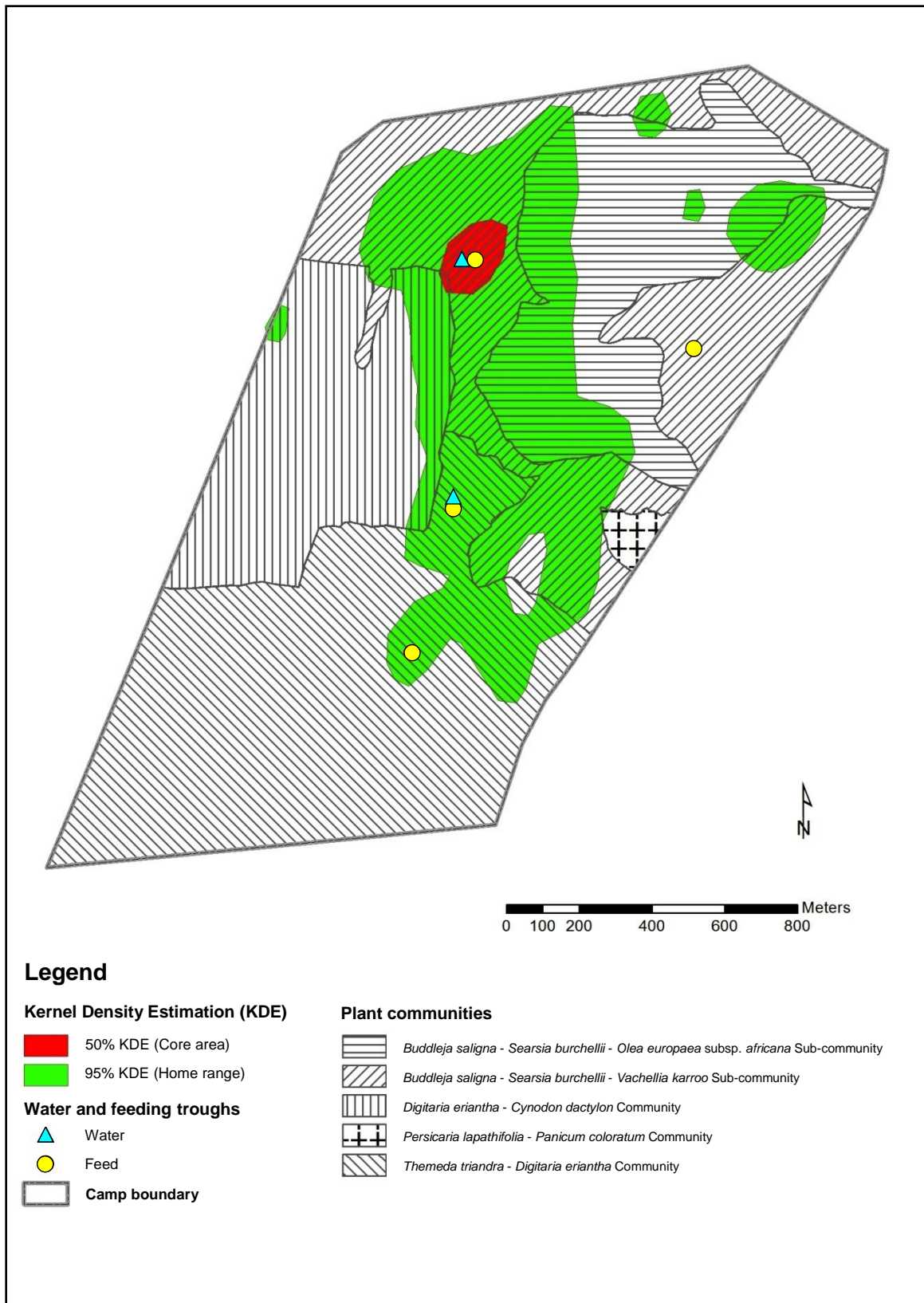
Figure 6.4 Kudu range use calculated from all recorded locations (day + night) during the flush phase (October 2013)
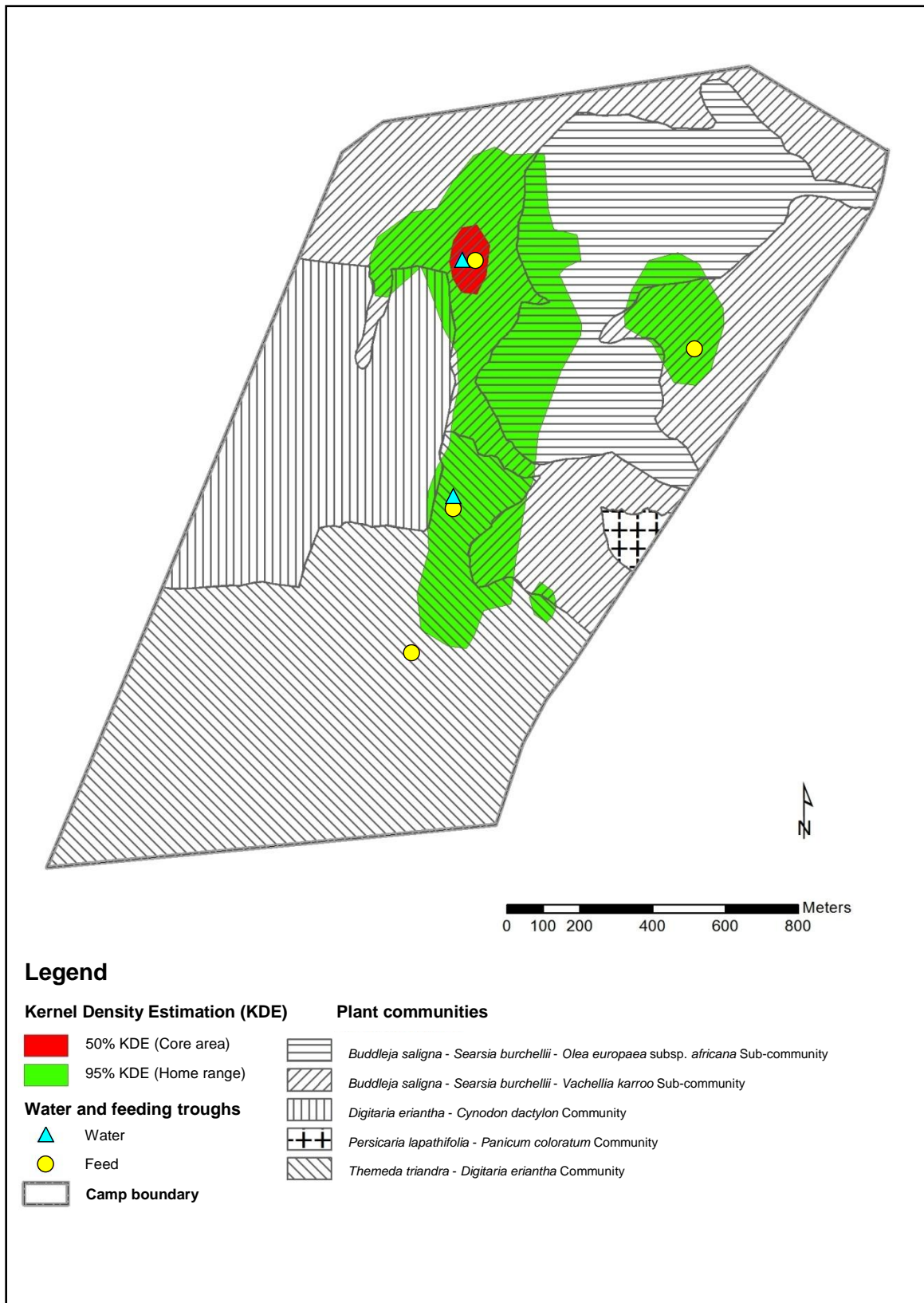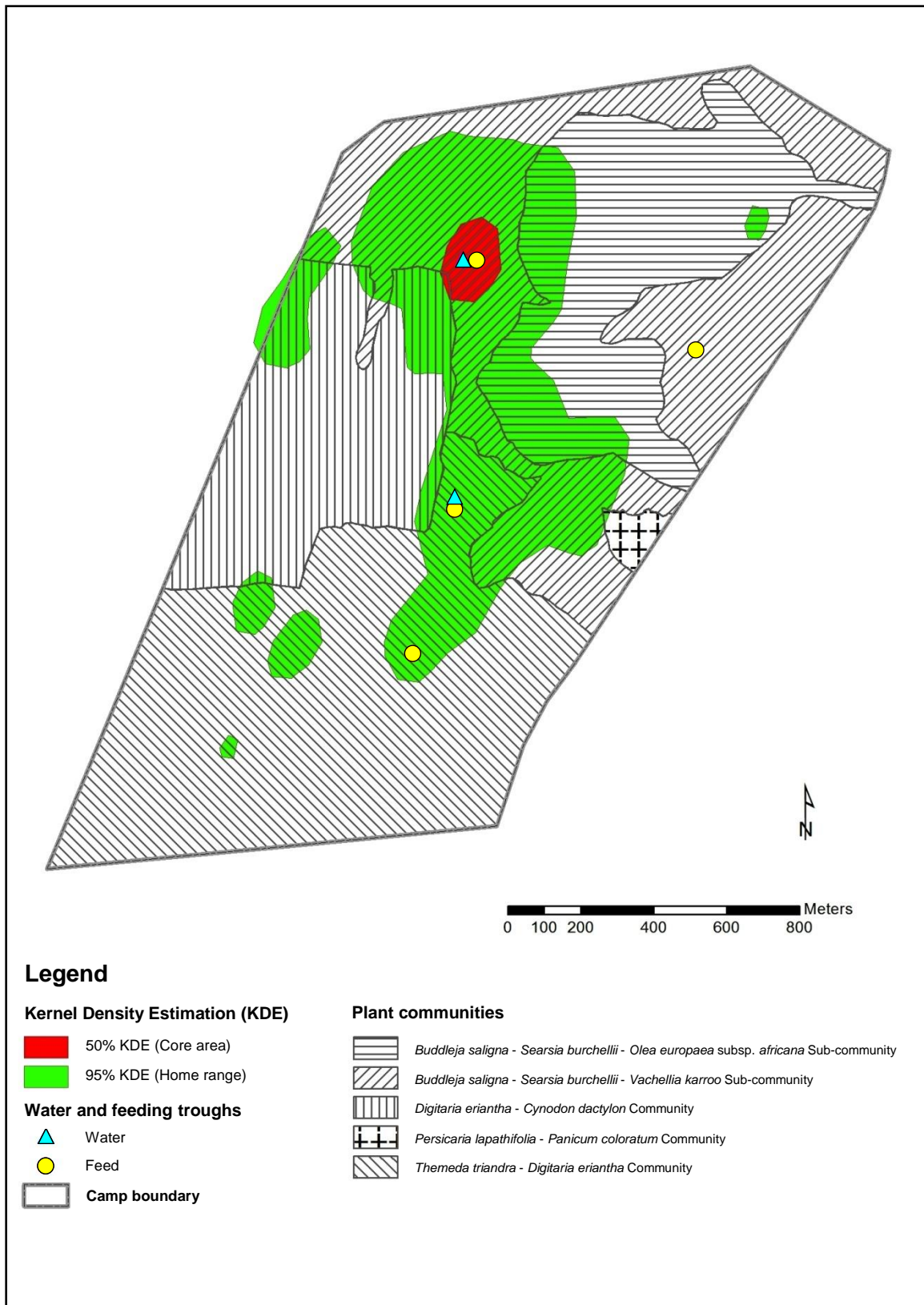
Figure 6.5 Kudu range use calculated from recorded day locations during the flush
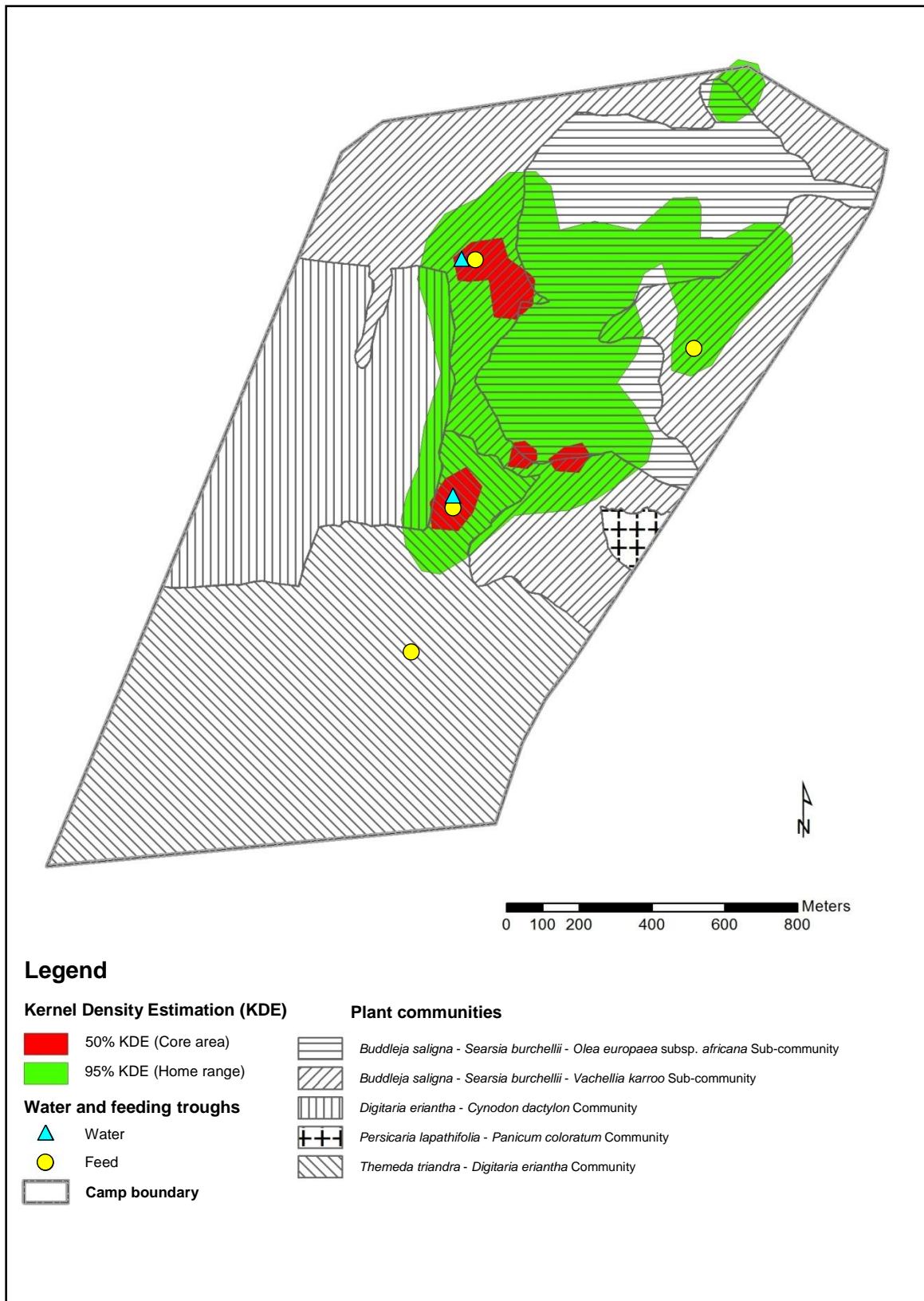phase (October 2013)
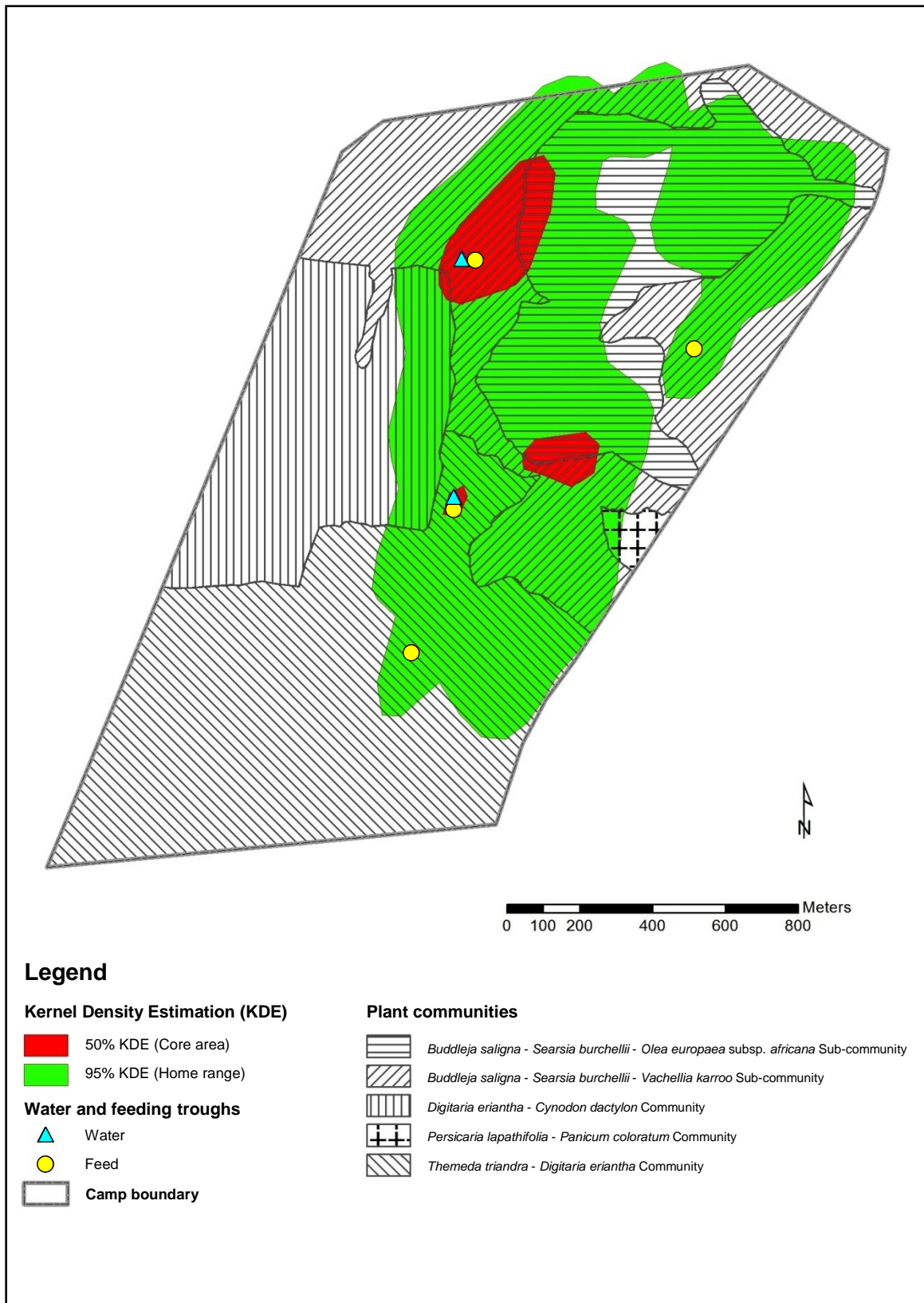
Figure 6.6 Kudu range use calculated from recorded night locations during the flush phase (October 2013)

Table 6.3 Chi-square goodness-of-fit test results for the flush phase (October 2013). The null hypothesis tested was that kudu utilised plant communities in proportion to their availability

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE	OBSERVED USAGE	OBSERVED RELATIVE USAGE	X^2 (a)	DF (b)	P value (c)	H0 (d)
Day + Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	88	0.187				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	284	0.604				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	21	0.045	256.563	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	77	0.164				
Total		274.08	1	470	1				
Day	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	30	0.118				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	168	0.659				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	15	0.059	175.156	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	42	0.165				
Total		274.08	1	255	1				
Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	58	0.270				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	116	0.540				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	6	0.028	101.833	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	35	0.163				
Total		274.08	1	215	1				

(a) Chi-squared value; (b) Degrees of freedom (n-1); (c) Two-tailed P value (d) Ho hypothesis is rejected or accepted

Table 6.4 Bonferronni confidence intervals for utilisation of plant communities during the flush phase (October 2013)

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE (P_{io})	OBSERVED USAGE	OBSERVED RELATIVE USAGE (P_i)	CONFIDENCE INTERVALS For P_i	PREFERENCE
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	88	0.187	$0.141 \leq p \leq 0.233$	=
Day +	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	284	0.604	$0.546 \leq p \leq 0.662$	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	21	0.045	$0.020 \leq p \leq 0.070$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	$0.000 \leq p \leq 0.000$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	77	0.164	$0.120 \leq p \leq 0.208$	-
Total		274.08	1	470	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	30	0.118	$0.066 \leq p \leq 0.170$	-
Day	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	168	0.659	$0.583 \leq p \leq 0.735$	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	15	0.059	$0.021 \leq p \leq 0.097$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	$0.000 \leq p \leq 0.000$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	42	0.165	$0.105 \leq p \leq 0.225$	-
Total		274.08	1	255	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	58	0.270	$0.192 \leq p \leq 0.348$	=
Night	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	116	0.540	$0.453 \leq p \leq 0.627$	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	6	0.028	$0.000 \leq p \leq 0.057$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	$0.000 \leq p \leq 0.000$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	35	0.163	$0.098 \leq p \leq 0.228$	-
Total		274.08	1	215	1		

+ Indicates the plant community was significantly preferred (0.05 level of significance)

- Indicates the plant community was significantly avoided (0.05 level of significance)

= Indicates no significant difference was found between observed and expected utilisation (0.05 level of significance)

The home range of kudu increased dramatically from 79.37 ha in the flush phase of 2013 to 237.81 ha in the immature phase (Figure 6.7). During this time the kudus' home range covered 87% of the total area available. The core area utilised by kudu also increased substantially from 2.71 ha in the flush phase of 2013 to 22.06 ha in the immature phase. The largest part of their core area was situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, followed by the *Themeda triandra - Digitaria eriantha* Community, the *Digitaria eriantha - Cynodon dactylon* Community and lastly the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community. Striking differences in the habitat utilisation of kudu occurred between day and night-time in the immature phase (Figures 6.8 – 6.9). Firstly, the kudu home range was much larger during the day (226.52 ha) than the night (154.23) and secondly, kudu utilised different core areas. During the day the largest part of their core area was situated in the *Digitaria eriantha - Cynodon dactylon* Community, while the largest part of their core area was situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community at night. The average distance travelled by kudu over 24 hours increased again from 4 089 m (SE ± 267.213) to 4 404 m (SE ± 127.226). The difference between the average distance travelled per hour during the day and night also increased to 229 m (SE ± 9.202) during the day and 129 m (SE ± 8.607) at night.

Statistically significant (p < 0.05) differences were found with the chi-square test when comparing the availability of plant communities and their utilisation by kudu during the immature phase (Table 6.5). The null hypothesis, that kudu utilised plant communities in proportion to their availability, was thus rejected and Bonferroni confidence intervals were subsequently calculated to determine which plant communities were significantly preferred or avoided. Kudu only showed preference for the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community (p < 0.05) when considering all location data during the immature phase (Table 6.6). However, the *Digitaria eriantha - Cynodon dactylon* and the *Persicaria lapathifolia - Panicum coloratum* Communities were utilised in the same proportion to their availability (p > 0.05), while the *Themeda triandra - Digitaria eriantha* Community and the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community were avoided (p < 0.05). The only difference when comparing day and night habitat preferences of kudu in the immature phase was that kudu preferred the *Digitaria eriantha - Cynodon dactylon* Community during the day and avoided the same plant community at night (p < 0.05).

Legend

Kernel Density Estimation (KDE)

- 50% KDE (Core area)
- 95% KDE (Home range)

Water and feeding troughs

- Water
- Feed
- Camp boundary

Plant communities

- *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community
- *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community
- *Digitaria eriantha - Cynodon dactylon* Community
- *Persicaria lapathifolia - Panicum coloratum* Community
- *Themeda triandra - Digitaria eriantha* Community
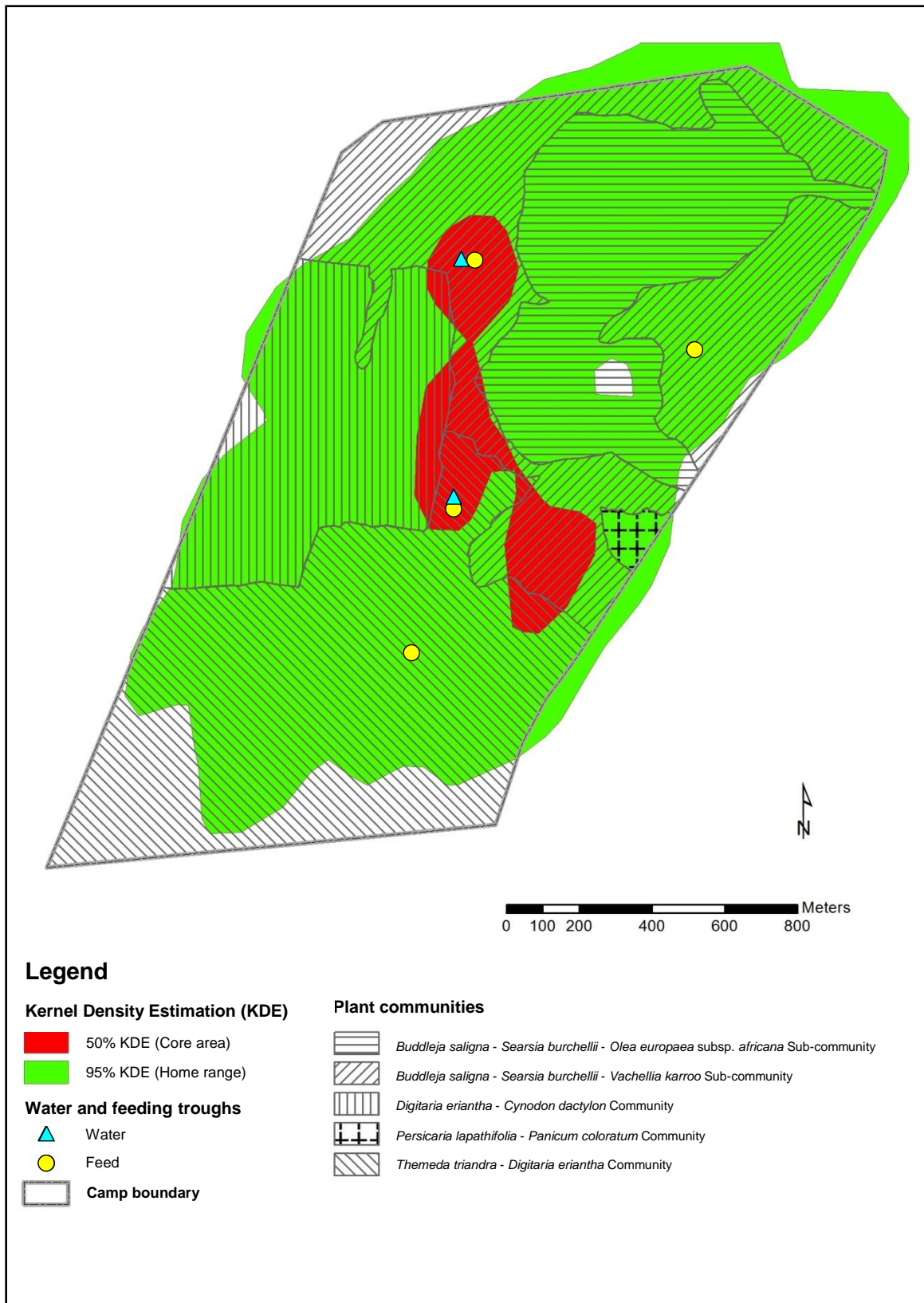
Figure 6.7 Kudu range use calculated from all recorded locations (day + night) during the immature phase (November to December 2013)

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Legend

Kernel Density Estimation (KDE)

- 50% KDE (Core area)
- 95% KDE (Home range)

Water and feeding troughs

- △ Water
- ○ Feed
- ▭ Camp boundary

Plant communities

- *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community
- *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community
- *Digitaria eriantha - Cynodon dactylon* Community
- *Persicaria lapathifolia - Panicum coloratum* Community
- *Themeda triandra - Digitaria eriantha* Community

Figure 6.8 Kudu range use calculated from recorded day locations during the immature phase (November to December 2013)

Legend

Kernel Density Estimation (KDE)

■ 50% KDE (Core area)

■ 95% KDE (Home range)

Water and feeding troughs

▲ Water

● Feed

▭ Camp boundary

Plant communities

Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana* Sub-community

Buddleja saligna - Searsia burchellii - Vachellia karroo Sub-community

Digitaria eriantha - Cynodon dactylon Community

Persicaria lapathifolia - Panicum coloratum Community

Themeda triandra - Digitaria eriantha Community
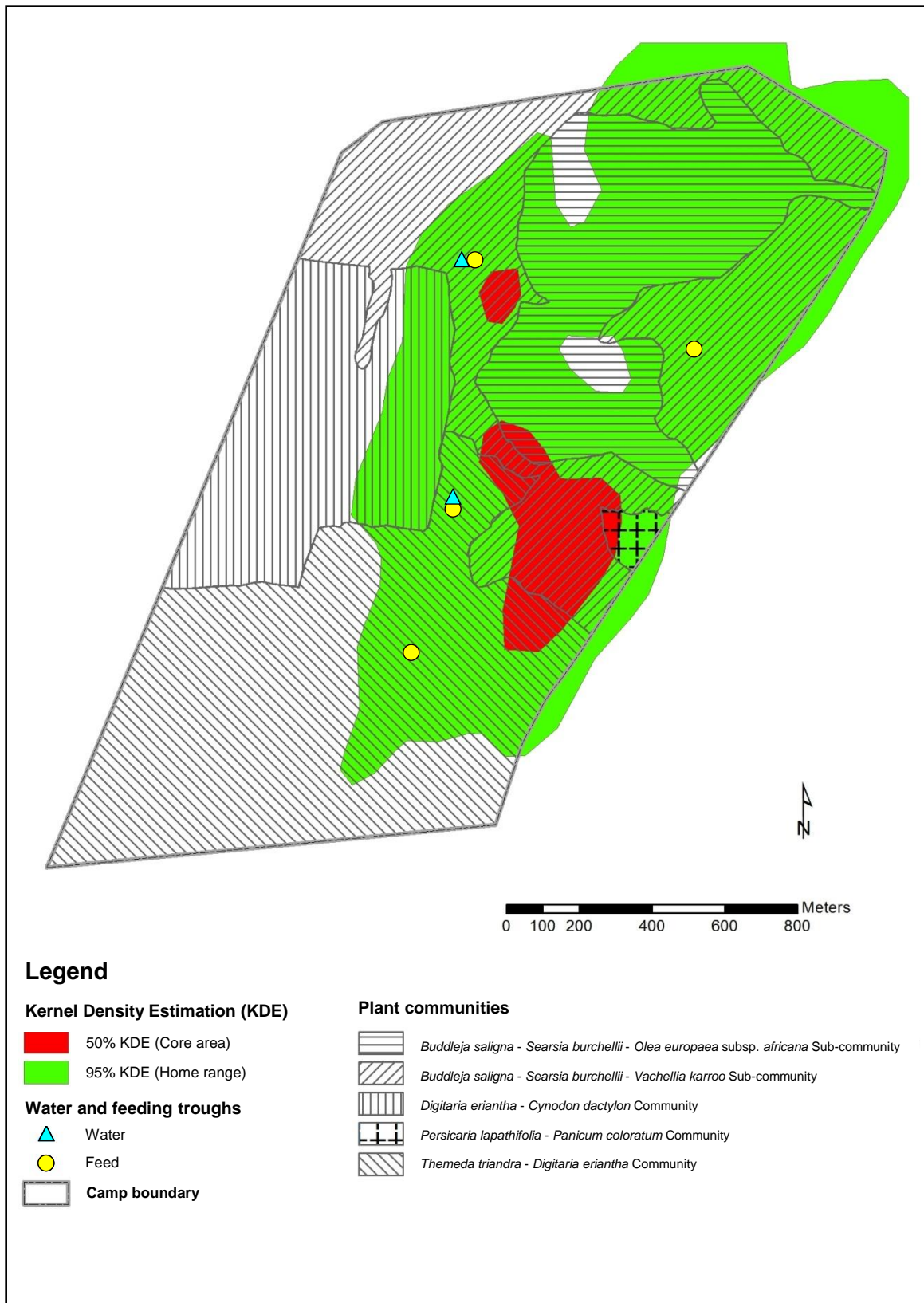
Figure 6.9 Kudu range use calculated from recorded night locations during the immature phase (November to December 2013)

Table 6.5 Chi-square goodness-of-fit test results for the immature phase (November to December 2013). The null hypothesis tested was that kudu utilised plant communities in proportion to their availability

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE	OBSERVED USAGE	OBSERVED RELATIVE USAGE	X² (a)	DF (b)	P value (c)	H0 (d)
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	182	0.130				
Day + Night	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	670	0.478				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	228	0.163	277.937	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	13	0.009				
	Themeda triandra - Digitaria eriantha	95.74	0.349	308	0.220				
Total		274.08	1	1401	1				
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	111	0.141				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	278	0.352				
Day	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	199	0.252	84.137	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	6	0.008				
	Themeda triandra - Digitaria eriantha	95.74	0.349	196	0.248				
Total		274.08	1	790	1				
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	71	0.116				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	392	0.642				
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	29	0.047	388.680	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	7	0.011				
	Themeda triandra - Digitaria eriantha	95.74	0.349	112	0.183				
Total		274.08	1	611	1				

(a) Chi-squared value; (b) Degrees of freedom (n-1); (c) Two-tailed P value (d) Ho hypothesis is rejected or accepted

Table 6.6 Bonferronni confidence intervals for utilisation of plant communities during the immature phase (November to December 2013)

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE (P_{io})	OBSERVED USAGE	OBSERVED RELATIVE USAGE (P_i)	CONFIDENCE INTERVALS For P_i	PREFERENCE
Day + Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	182	0.130	0.107 ≤ p ≤ 0.153	-
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	670	0.478	0.444 ≤ p ≤ 0.512	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	228	0.163	0.138 ≤ p ≤ 0.188	=
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	13	0.009	0.003 ≤ p ≤ 0.015	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	308	0.220	0.192 ≤ p ≤ 0.248	-
Total		274.08	1	1401	1		
Day	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	111	0.141	0.109 ≤ p ≤ 0.173	-
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	278	0.352	0.308 ≤ p ≤ 0.396	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	199	0.252	0.212 ≤ p ≤ 0.292	+
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	6	0.008	0.000 ≤ p ≤ 0.016	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	196	0.248	0.209 ≤ p ≤ 0.287	-
Total		274.08	1	790	1		
Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	71	0.116	0.083 ≤ p ≤ 0.149	-
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	392	0.642	0.592 ≤ p ≤ 0.692	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	29	0.047	0.025 ≤ p ≤ 0.069	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	7	0.011	0.000 ≤ p ≤ 0.022	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	112	0.183	0.143 ≤ p ≤ 0.223	-
Total		274.08	1	611	1		

+ Indicates the plant community was significantly preferred (0.05 level of significance)

- Indicates the plant community was significantly avoided (0.05 level of significance)

= Indicates no significant difference was found between observed and expected utilisation (0.05 level of significance)

The home range of kudu covered an area of 249.94 ha during the mature phase, amounting to 91% of the available area (Figure 6.10). However, their core area was relatively small (19.97 ha), with the largest part situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community. When comparing the day to the night kernel density estimates, the home range of kudu was less than half the size during the night, with an area of 270.92 ha covered during the day and 126.37 ha covered during the night (Figures 6.11 – 6.12). The locations and sizes of core areas were also vastly different between day and night. During the day the core area utilised by kudu covered 99.01 ha and was situated in close to equal proportions over four of the five plant communities. However, the core area utilised at night was much smaller (8.52 ha) and situated mostly in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community. The average distances travelled by kudu per 24 hours decreased somewhat during the mature phase to 3 877 m (SE ± 236.044). This decrease occurred even though their home range increased slightly. During the same period, kudu travelled shorter distances per hour on average, with 214 m (SE ± 10.512) travelled during the day and 109 m (SE ± 8.476) travelled during the night.

The chi-square test was only significant (p < 0.05) for overall and night locations during the mature phase, with the null hypothesis that kudu utilised plant communities in proportion to their availability rejected for these periods (Table 6.7). However, the chi-square test was not significant (p > 0.05) for daytime locations, resulting in the null hypothesis being accepted. Bonferroni confidence intervals, used to determine which plant communities were significantly preferred or avoided, were subsequently only calculated for the overall and night locations. Kudu showed an overall preference for the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community during the mature phase (p < 0.05), while utilising the *Digitaria eriantha - Cynodon dactylon* Community, the *Persicaria lapathifolia - Panicum coloratum* Community and the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community in equal proportions to their availability (p > 0.05) (Table 6.8). The only plant community avoided was the *Themeda triandra - Digitaria eriantha* Community (p < 0.05). The *Themeda triandra - Digitaria eriantha* Community, the *Digitaria eriantha - Cynodon dactylon* Community and the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community were avoided during the night (p < 0.05). Only the *Persicaria lapathifolia - Panicum coloratum* Community was utilised in the same proportion to its availability (p > 0.05), while the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community was preferred (p < 0.05).

Legend

Kernel Density Estimation (KDE)

- 50% KDE (Core area)
- 95% KDE (Home range)

Water and feeding troughs

- ▲ Water
- ● Feed
- Camp boundary

Plant communities

- *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community
- *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community
- *Digitaria eriantha - Cynodon dactylon* Community
- *Persicaria lapathifolia - Panicum coloratum* Community
- *Themeda triandra - Digitaria eriantha* Community

Figure 6.10 Kudu range use calculated from all recorded locations (day + night) during the mature phase (January to March 2014)

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Legend

Kernel Density Estimation (KDE)

🟥	50% KDE (Core area)
🟩	95% KDE (Home range)

Water and feeding troughs

🔺	Water
🟡	Feed
▭	Camp boundary

Plant communities

▤	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community
▨	*Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community
▥	*Digitaria eriantha - Cynodon dactylon* Community
⊞	*Persicaria lapathifolia - Panicum coloratum* Community
▨	*Themeda triandra - Digitaria eriantha* Community

Figure 6.11 Kudu range use calculated from recorded day locations during the mature phase (January to March 2014)

Legend

Kernel Density Estimation (KDE)

■ 50% KDE (Core area)

■ 95% KDE (Home range)

Water and feeding troughs

▲ Water

● Feed

▢ Camp boundary

Plant communities

▤ *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-

▨ *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community

▥ *Digitaria eriantha - Cynodon dactylon* Community

▦ *Persicaria lapathifolia - Panicum coloratum* Community

▧ *Themeda triandra - Digitaria eriantha* Community
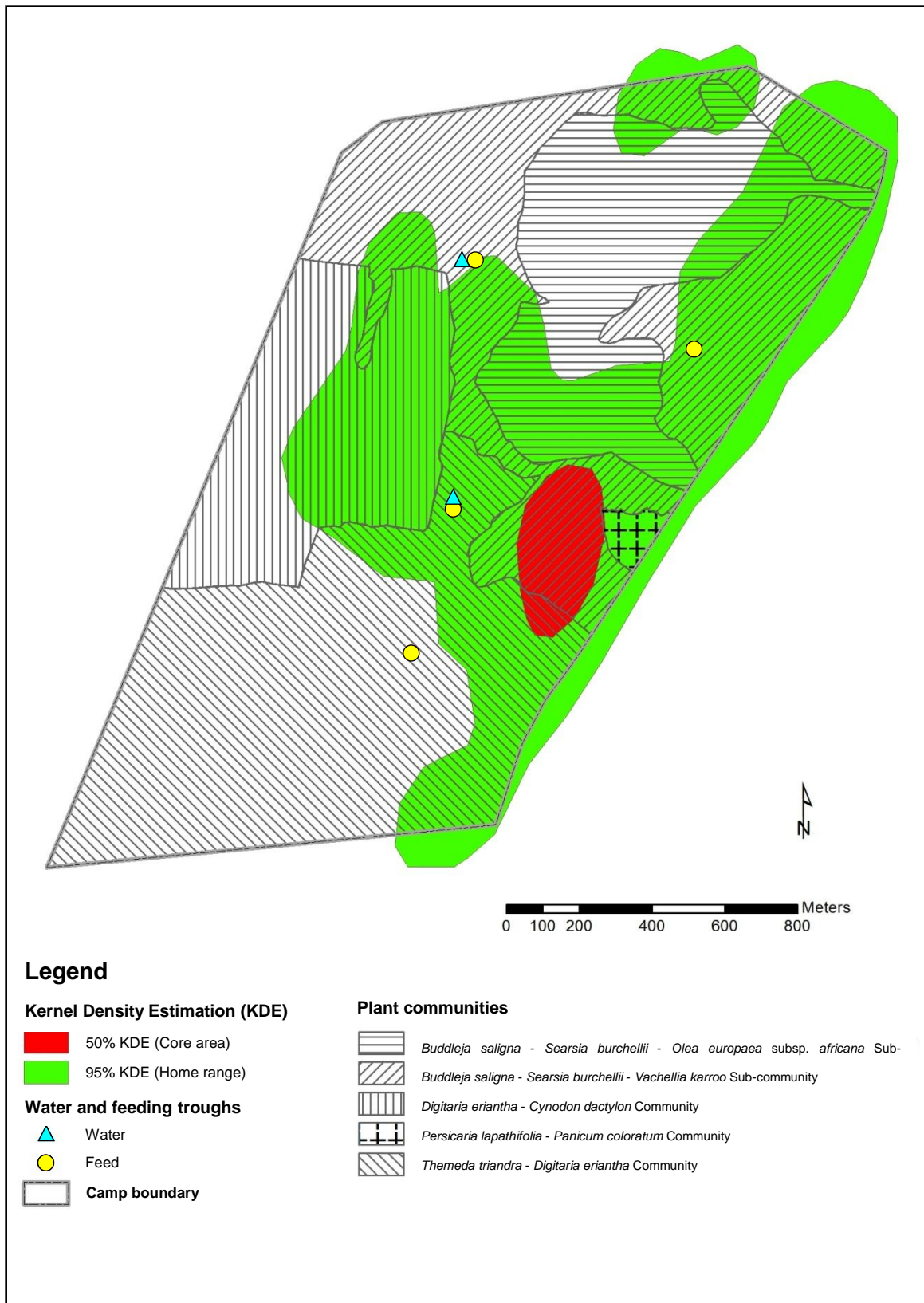
Figure 6.12 Kudu range use calculated from recorded night locations during the mature phase (January to March 2014)

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Table 6.7 Chi-square goodness-of-fit test results for the mature phase (January to March 2014). The null hypothesis tested was that kudu utilised plant communities in proportion to their availability

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE	OBSERVED USAGE	OBSERVED RELATIVE USAGE	X^2 (a)	DF (b)	P value (c)	H0 (d)
Day + Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	131	0.168				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	349	0.446				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	120	0.153	107.856	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	6	0.008				
	Themeda triandra - Digitaria eriantha	95.74	0.349	176	0.225				
Total		274.08	1	782	1				
Day	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	94	0.213				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	128	0.290				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	85	0.193	7.533	4	0.110	Accepted
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.002				
	Themeda triandra - Digitaria eriantha	95.74	0.349	133	0.302				
Total		274.08	1	441	1				
Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	37	0.109				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	221	0.648				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	35	0.103	227.837	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	5	0.015				
	Themeda triandra - Digitaria eriantha	95.74	0.349	43	0.126				
Total		274.08	1	341	1				

(a) Chi-squared value; (b) Degrees of freedom (n-1); (c) Two-tailed P value (d) Ho hypothesis is rejected or accepted

Table 6.8 Bonferronni confidence intervals for utilisation of plant communities during the mature phase (January to March 2014)

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE (P_{io})	OBSERVED USAGE	OBSERVED RELATIVE USAGE (P_i)	CONFIDENCE INTERVALS For P_i	PREFERENCE
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	131	0.168	0.134 ≤ p ≤ 0.202	=
Day +	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	349	0.446	0.399 ≤ p ≤ 0.493	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	120	0.153	0.120 ≤ p ≤ 0.186	=
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	6	0.008	0.000 ≤ p ≤ 0.016	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	176	0.225	0.187 ≤ p ≤ 0.263	-
Total		274.08	1	782	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	94	0.213		
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	128	0.290		
Day	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	85	0.193	(a)	
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.002		
	Themeda triandra - Digitaria eriantha	95.74	0.349	133	0.302		
Total		274.08	1	441	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	37	0.109	0.066 ≤ p ≤ 0.152	-
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	221	0.648	0.582 ≤ p ≤ 0.714	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	35	0.103	0.061 ≤ p ≤ 0.145	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	5	0.015	0.000 ≤ p ≤ 0.032	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	43	0.126	0.080 ≤ p ≤ 0.172	-
Total		274.08	1	341	1		

+ Indicates the plant community was significantly preferred (0.05 level of significance)

- Indicates the plant community was significantly avoided (0.05 level of significance)

= Indicates no significant difference was found between observed and expected utilisation (0.05 level of significance)

(a) Hypothesis that kudu utilised plant communities in proportion to their availability accepted from chi-square test results

During the senescent phase kudu continued to utilise most of the study area, with their home range covering 263.45 ha or 96% of the available area (Figure 6.13). Kudu also utilised a relatively large core area covering 46.27 ha, situated mainly in the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* and *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-communities. As was the case during the immature and mature phases, kudu home range sizes and habitat utilisation changed dramatically from day to night-time during the senescent phase (Figures 6.14 – 6.15). The kudus' home range was much larger during the day compared to the night, with 271.98 ha and 97.34 ha covered by their home ranges, respectively. Core areas utilised by kudu also shifted from day to night. During the day the largest part of their core area was situated in the *Themeda triandra - Digitaria eriantha* Community. However, this plant community was hardly utilised during the night, with the majority of their core area situated in the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* and *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-communities. The average distance travelled by kudu over 24 hours increased slightly to 4 081 m (SE ± 239.629) as their home range increased. Average distance travelled by kudu per hour also increased for both night and day to 241 m (SE ± 13.860) and 134 m (SE ± 11.718), respectively.

Statistically significant ($p < 0.05$) differences were found with the chi-square test when comparing the availability of plant communities and their utilisation by kudu during the senescent phase (Table 6.9). The null hypothesis that kudu utilised plant communities in proportion to their availability was thus rejected and Bonferroni confidence intervals were subsequently calculated. Kudu showed an overall preference for the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community during the senescent phase, while avoiding the *Themeda triandra - Digitaria eriantha* and *Digitaria eriantha - Cynodon dactylon* Communities ($p < 0.05$) (Table 6.10). Both the *Persicaria lapathifolia - Panicum coloratum* Community and the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community were utilised in proportions similar to their availability ($p > 0.05$). However, during the day kudu preferred both the *Themeda triandra - Digitaria eriantha* Community and the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, while avoiding all the other plant communities ($p < 0.05$). Kudu habitat preferences changed from day to night time, with the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* and *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-communities preferred ($p < 0.05$). At the same time the *Themeda triandra - Digitaria eriantha* and *Digitaria eriantha - Cynodon dactylon* Communities were avoided ($p < 0.05$).
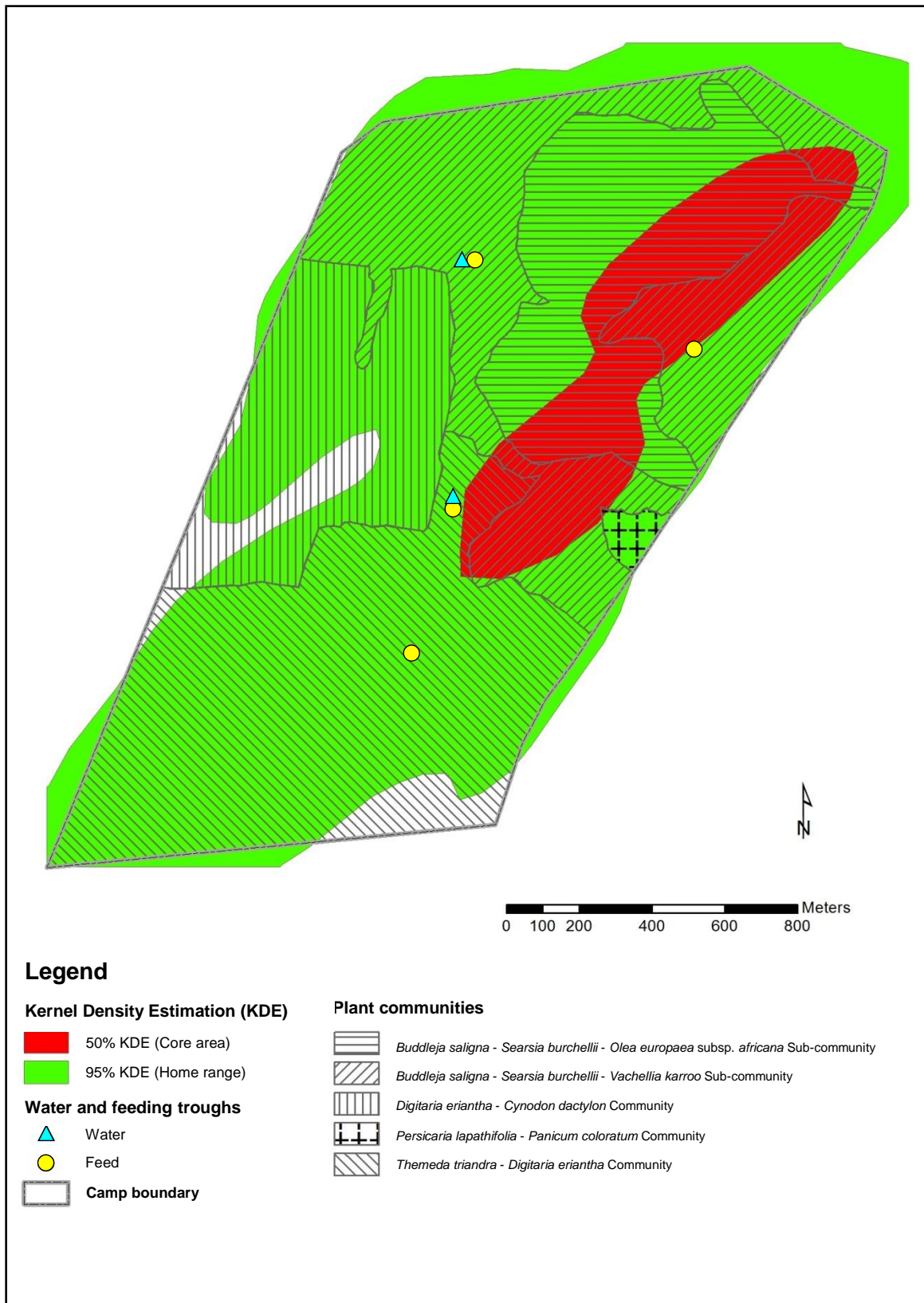
Figure 6.13 Kudu range use calculated from all recorded locations (day + night) during the senescent phase (April to May 2014)
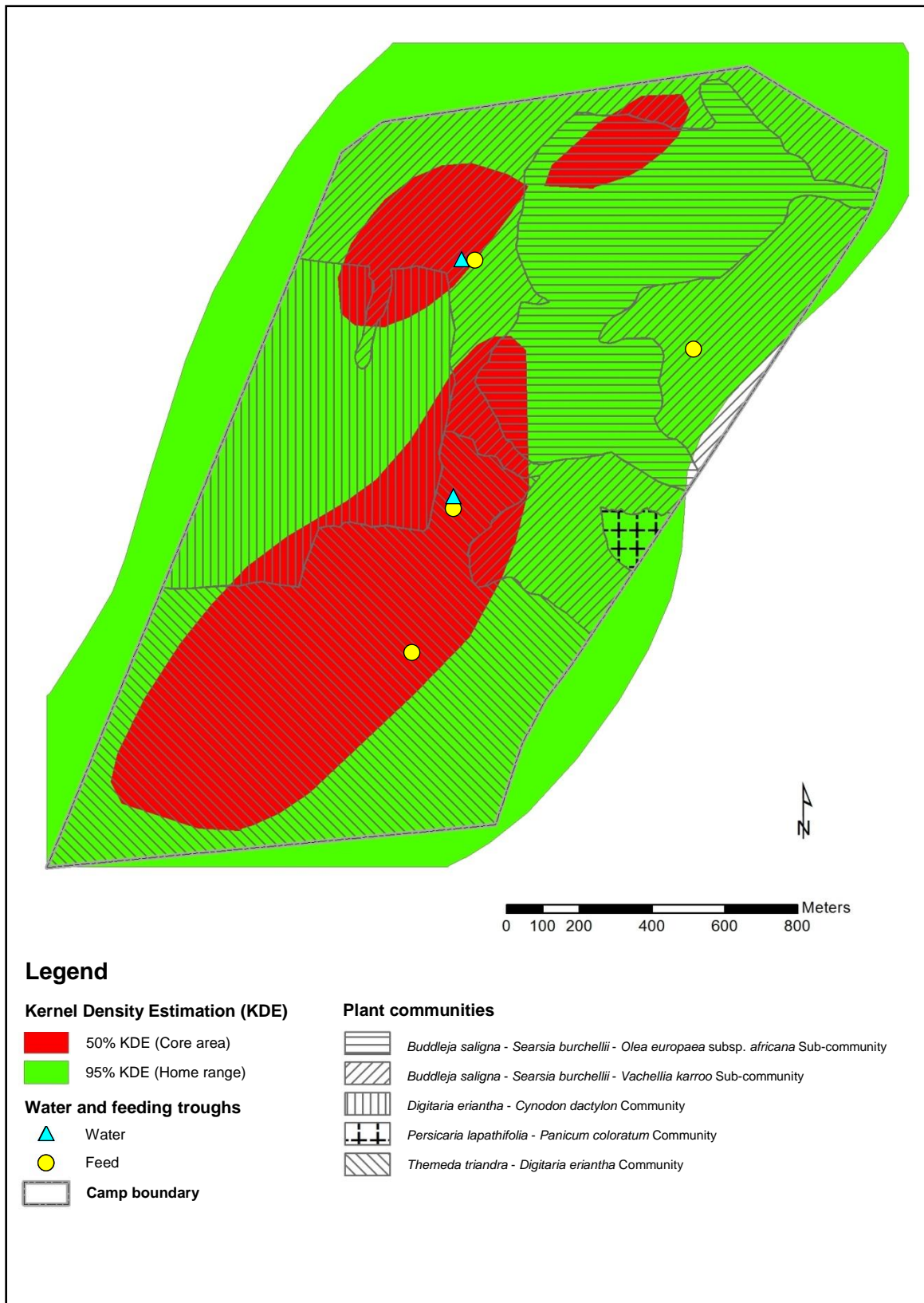
Figure 6.14 Kudu range use calculated from recorded day locations during the senescent phase (April to May 2014)

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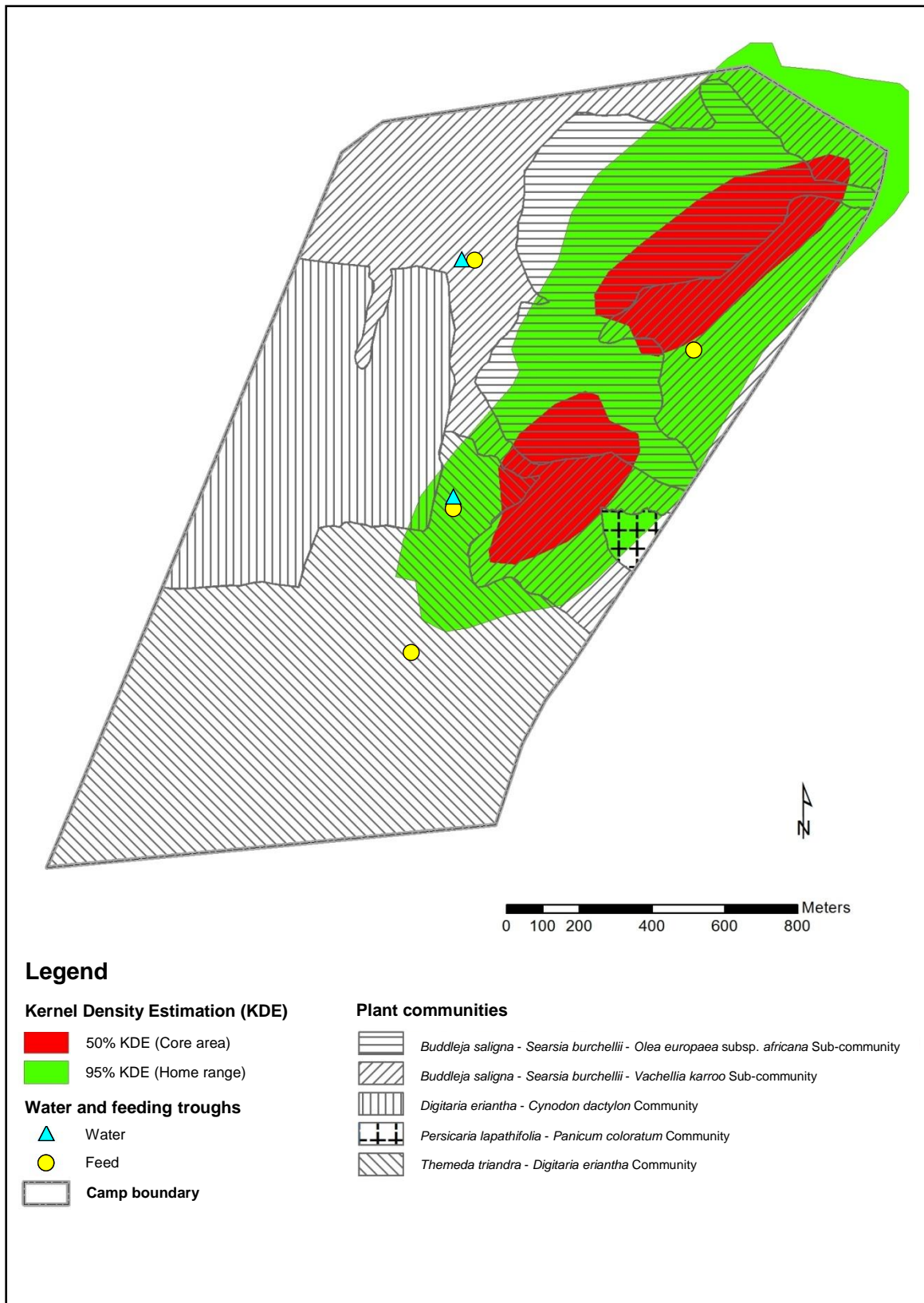
Figure 6.15 Kudu range use calculated from recorded night locations during the senescent phase (April to May 2014)

Table 6.9 Chi-square goodness-of-fit test results for the dry phase (April to May 2014). The null hypothesis tested was that kudu utilised plant communities in proportion to their availability

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE	OBSERVED USAGE	OBSERVED RELATIVE USAGE	X² (a)	DF (b)	P value (c)	H0 (d)
Day + Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	97	0.185				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	291	0.556				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	14	0.027	217.042	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.002				
	Themeda triandra - Digitaria eriantha	95.74	0.349	120	0.229				
Total		274.08	1	523	1				
Day	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	18	0.079				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	84	0.370				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	14	0.062	49.645	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	111	0.489				
Total		274.08	1	227	1				
Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	79	0.267				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	207	0.699				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	0	0.000	319.961	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.003				
	Themeda triandra - Digitaria eriantha	95.74	0.349	9	0.030				
Total		274.08	1	296	1				

(a) Chi-squared value; (b) Degrees of freedom (n-1); (c) Two-tailed P value (d) Ho hypothesis is rejected or accepted

Table 6.10 Bonferronni confidence intervals for utilisation of plant communities during the senescent phase (April to May 2014)

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE (P_{io})	OBSERVED USAGE	OBSERVED RELATIVE USAGE (P_i)	CONFIDENCE INTERVALS For P_i	PREFERENCE
Day + Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	97	0.185	$0.141 \le p \le 0.229$	=
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	291	0.556	$0.500 \le p \le 0.612$	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	14	0.027	$0.009 \le p \le 0.045$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.002	$0.000 \le p \le 0.007$	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	120	0.229	$0.182 \le p \le 0.276$	-
Total		274.08	1	523	1		
Day	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	18	0.079	$0.033 \le p \le 0.125$	-
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	84	0.370	$0.288 \le p \le 0.452$	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	14	0.062	$0.021 \le p \le 0.083$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	$0.000 \le p \le 0.000$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	111	0.489	$0.404 \le p \le 0.574$	+
Total		274.08	1	227	1		
Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	79	0.267	$0.241 \le p \le 0.293$	+
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	207	0.699	$0.630 \le p \le 0.768$	+
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	0	0.000	$0.000 \le p \le 0.000$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	1	0.003	$0.000 \le p \le 0.011$	=
	Themeda triandra - Digitaria eriantha	95.74	0.349	9	0.030	$0.005 \le p \le 0.055$	-
Total		274.08	1	296	1		

+ Indicates the plant community was significantly preferred (0.05 level of significance)

- Indicates the plant community was significantly avoided (0.05 level of significance)

= Indicates no significant difference was found between observed and expected utilisation (0.05 level of significance)

The kudu home range decreased by more than half its size from the senescent to the dry phase of 2014, with their home range covering an area of 263.45 ha during the senescent phase and an area of 126.36 ha during the dry phase of 2014 (Figure 6.16). Consequently, kudu only utilised 46% of the area available to them in the dry phase of 2014. Kudu core areas were also much smaller, only covering 7.46 ha, and situated mostly in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* and *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-communities during this phase. However, a shift in kudu habitat utilisation occurred from the day to the night. The kudus' core area was mostly situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community during the day and did not stretch into the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community (Figure 6.17). However, kudu core areas shifted towards the hills at night to include both the *Buddleja saligna - Searsia burchellii - Vachellia karroo* and *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-communities (Figure 6.18). Kudu home ranges were also slightly larger during the night (106.24 ha) as compared to the day (89.08 ha). As the kudu home range decreased during the dry phase of 2014, so did the average distance travelled by kudu in 24 hours, from 4 081 m (SE ± 239.629) in the senescent phase to 3 701 m (SE ± 168.365) in the dry phase. This was also the only phase during which kudu travelled further on average per hour at night, with 217 m (SE ± 10.362) covered during the day and 123 m (SE ± 8.746) covered during the night.

Statistically significant (p < 0.05) differences were found with the chi-square test when comparing the availability of plant communities and their utilisation by kudu during the dry phase of 2014 (Table 6.11). The null hypothesis that kudu utilised plant communities in proportion to their availability was thus rejected and Bonferroni confidence intervals were subsequently calculated to determine which plant communities were significantly preferred or avoided.

When considering all location data, kudu showed preference for both the *Buddleja saligna - Searsia burchellii - Vachellia karroo* and *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-communities during the dry phase of 2014 (p < 0.05) (Table 6.12). All the other plant communities were avoided at the same time (p < 0.05). The only difference between day and night locations was that kudu avoided the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community during the day, while preferring the same plant community at night (p < 0.05). The *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community was preferred and all other plant communities avoided during both the day and the night (p < 0.05).

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Legend

Kernel Density Estimation (KDE)

🟥 50% KDE (Core area)

🟩 95% KDE (Home range)

Water and feeding troughs

🔺 Water

🟡 Feed

▭ Camp boundary

Plant communities

▭ *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community

▭ *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community

▭ *Digitaria eriantha - Cynodon dactylon* Community

▭ *Persicaria lapathifolia - Panicum coloratum* Community

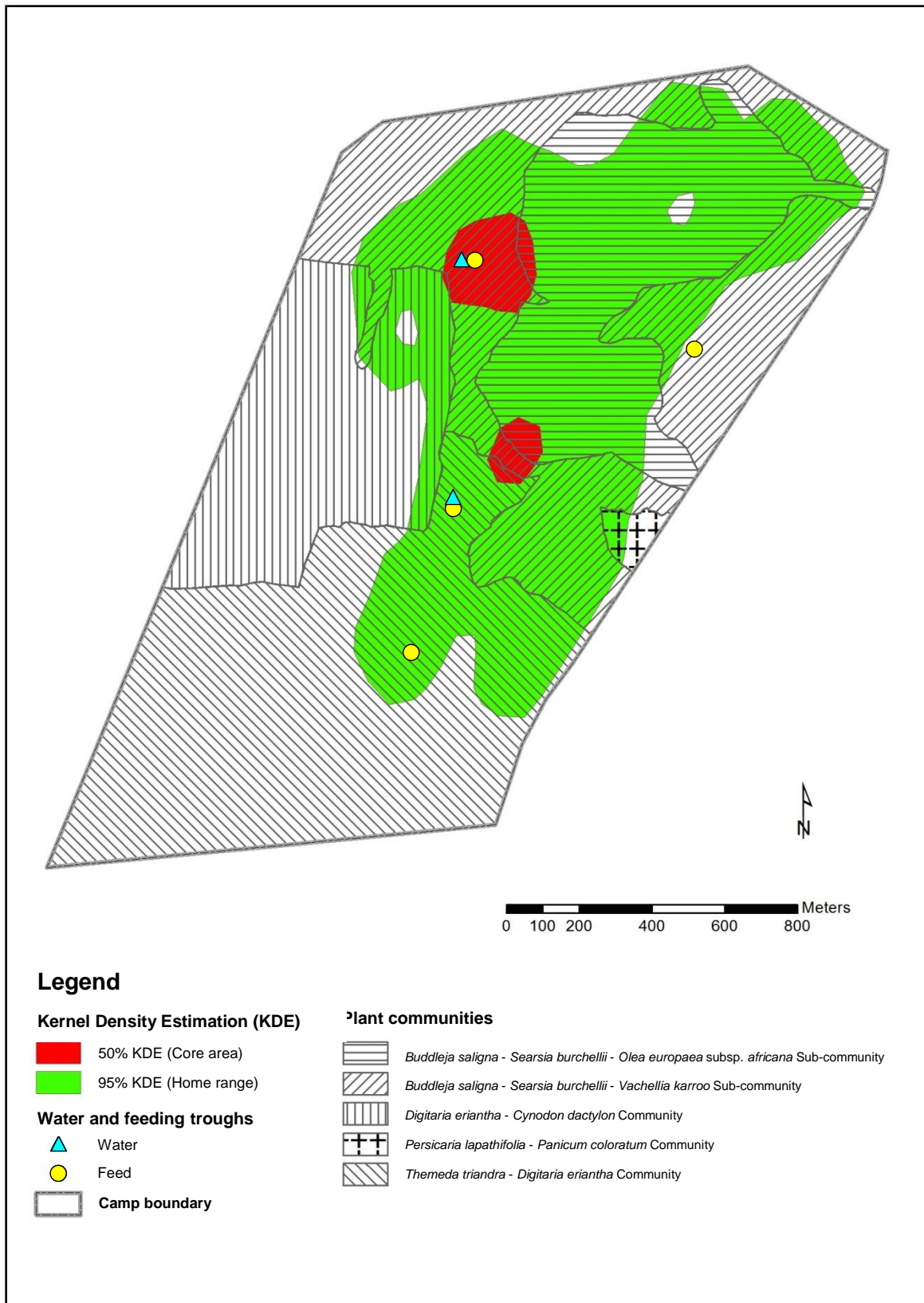▭ *Themeda triandra - Digitaria eriantha* Community

Figure 6.16 Kudu range use calculated from all recorded locations (day + night) during the dry phase (June to August 2014)
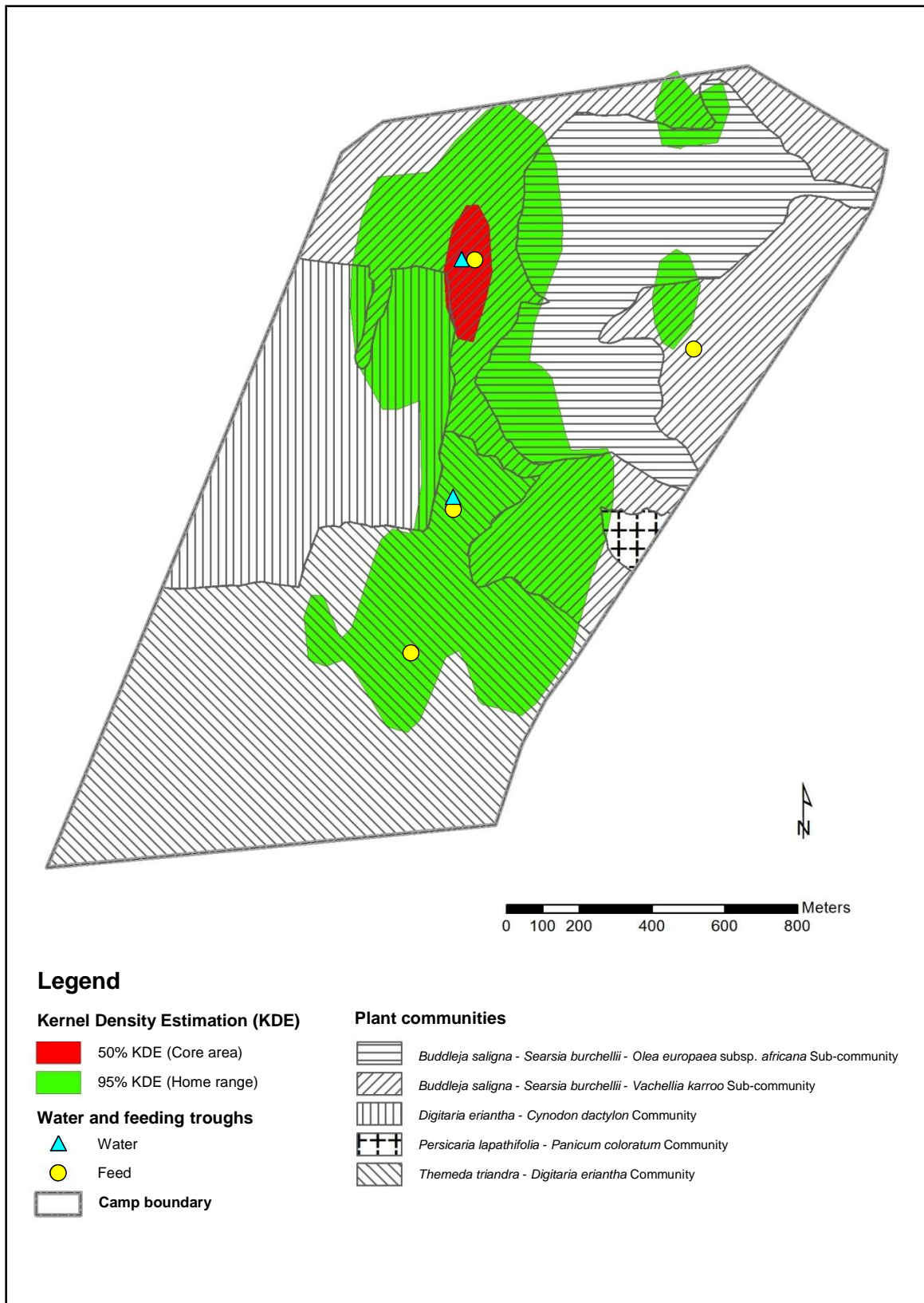
Figure 6.17 Kudu range use calculated from recorded day locations during the dry phase (June to August 2014)
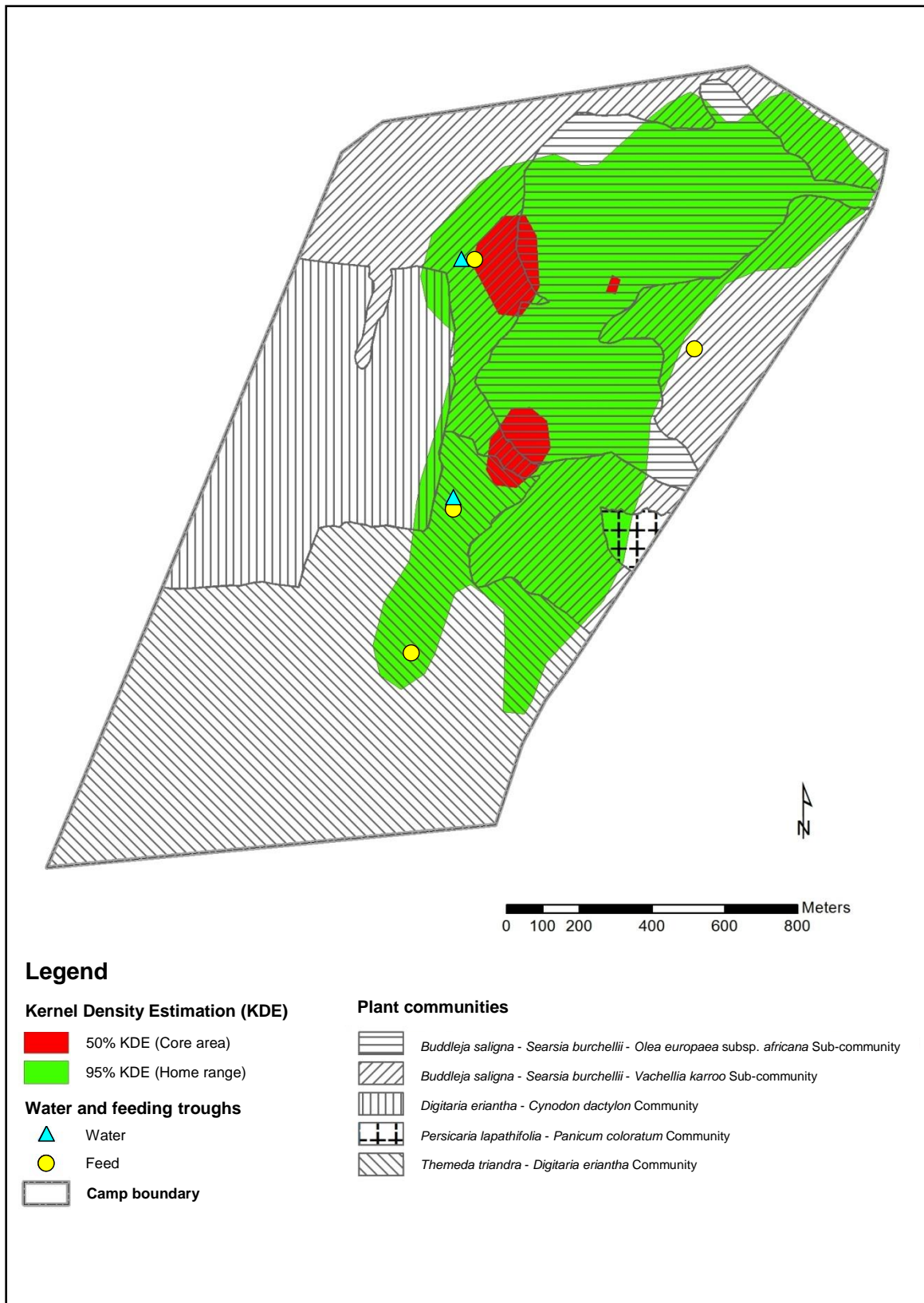
Figure 6.18 Kudu range use calculated from recorded night locations during the dry phase (June to August 2014)

Table 6.11 Chi-square goodness-of-fit test results for the dry phase (June to August 2014). The null hypothesis tested was that kudu utilised plant communities in proportion to their availability

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE	OBSERVED USAGE	OBSERVED RELATIVE USAGE	X² (a)	DF (b)	P value (c)	H0 (d)
Day + Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	266	0.292				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	488	0.536				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	10	0.011	472.139	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	147	0.161				
Total		274.08	1	911	1				
Day	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	34	0.099				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	216	0.632				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	9	0.026	211.237	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	83	0.243				
Total		274.08	1	342	1				
Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	232	0.408				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	272	0.478				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	1	0.002	410.183	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	64	0.112				
Total		274.08	1	569	1				

(a) Chi-squared value; (b) Degrees of freedom (n-1); (c) Two-tailed P value (d) Ho hypothesis is rejected or accepted

Table 6.12 Bonferronni confidence intervals for utilisation of plant communities during the dry phase (June to August 2014)

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE (P_{io})	OBSERVED USAGE	OBSERVED RELATIVE USAGE (P_i)	CONFIDENCE INTERVALS For P_i	PREFERENCE
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	266	0.292	0.253 ≤ p ≤ 0.331	+
Day +	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	488	0.536	0.494 ≤ p ≤ 0.578	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	10	0.011	0.002 ≤ p ≤ 0.020	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	0.000 ≤ p ≤ 0.000	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	147	0.161	0.130 ≤ p ≤ 0.192	-
Total		274.08	1	911	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	34	0.099	0.057 ≤ p ≤ 0.141	-
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	216	0.632	0.565 ≤ p ≤ 0.699	+
Day	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	9	0.026	0.004 ≤ p ≤ 0.048	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	0.000 ≤ p ≤ 0.000	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	83	0.243	0.183 ≤ p ≤ 0.303	-
Total		274.08	1	342	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	232	0.408	0.355 ≤ p ≤ 0.461	+
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	272	0.478	0.424 ≤ p ≤ 0.532	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	1	0.002	0.000 ≤ p ≤ 0.007	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	0.000 ≤ p ≤ 0.000	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	64	0.112	0.078 ≤ p ≤ 0.146	-
Total		274.08	1	569	1		

+ Indicates the plant community was significantly preferred (0.05 level of significance)

- Indicates the plant community was significantly avoided (0.05 level of significance)

= Indicates no significant difference was found between observed and expected utilisation (0.05 level of significance)

The home range utilised by kudu during the flush phase of 2014 only increased by 4.81 ha from the dry phase of that year (Figure 6.19). However, the kudu home range calculated for the daytime increased considerably, from 89.08 ha in the dry phase of 2014 to 182.59 ha in the flush phase of 2014 (Figure 6.20). In contrast, the home range of kudu decreased during the night, from 106.24 ha in the dry phase of 2014 to 72.97 ha in the flush phase of 2014 (Figure 6.21).

Two of the kudu core areas, calculated from all location data, were situated around water troughs with feeding troughs in close proximity and covered an area of 3.62 ha (Figure 6.19). However, a larger third core area (4.79 ha) was situated away from any water or feeding troughs in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community. When day and night time locations were separated, a much clearer picture emerged that better explained kudu habitat utilisation during the flush phase of 2014. Kudu core areas were situated around water and feeding troughs during the day, but also stretched towards the *Themeda triandra - Digitaria eriantha* and *Digitaria eriantha - Cynodon dactylon* Communities (Figure 6.20). At night, only one core area was situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, away from any water or feeding troughs (Figure 6.21).

Although the home range of kudu increased in the flush phase of 2014, a decrease in the average distance travelled per 24 hours was recorded from 3 701 m (SE ± 168.365) in the dry phase to 3 563 m (SE ± 360.769) in the flush phase of 2014. A decrease in both the average distances travelled per hour during the night and day was also recorded. Kudu covered 207 m (SE ± 12.357) on average per hour during the day and 97 m (SE ± 9.801) per hour at night.

Statistically significant ($p < 0.05$) differences were found with the chi-square test when comparing the availability of plant communities and their utilisation during the flush phase of 2014 (Table 6.13). The null hypothesis that kudu utilised plant communities in proportion to their availability was thus rejected and Bonferroni confidence intervals were subsequently calculated to determine which plant communities were significantly preferred or avoided. From all location data, kudu showed preference for the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, while utilising the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community in equal proportion to its availability (Table 6.14). All other plant communities were avoided.

Legend

Kernel Density Estimation (KDE)

🟥	50% KDE (Core area)
🟩	95% KDE (Home range)

Water and feeding troughs

🔺	Water
🟡	Feed
⬚	**Camp boundary**

Plant communities

	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana* Sub-community
	Buddleja saligna - Searsia burchellii - Vachellia karroo Sub-community
	Digitaria eriantha - Cynodon dactylon Community
	Persicaria lapathifolia - Panicum coloratum Community
	Themeda triandra - Digitaria eriantha Community

Figure 6.19 Kudu range use calculated from all recorded locations (day + night) during the flush phase (September 2014)

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Legend

Kernel Density Estimation (KDE)

- 🟥 50% KDE (Core area)
- 🟩 95% KDE (Home range)

Water and feeding troughs

- 🔺 Water
- 🟡 Feed
- ▭ Camp boundary

Plant communities

- *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community
- *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community
- *Digitaria eriantha - Cynodon dactylon* Community
- *Persicaria lapathifolia - Panicum coloratum* Community
- *Themeda triandra - Digitaria eriantha* Community
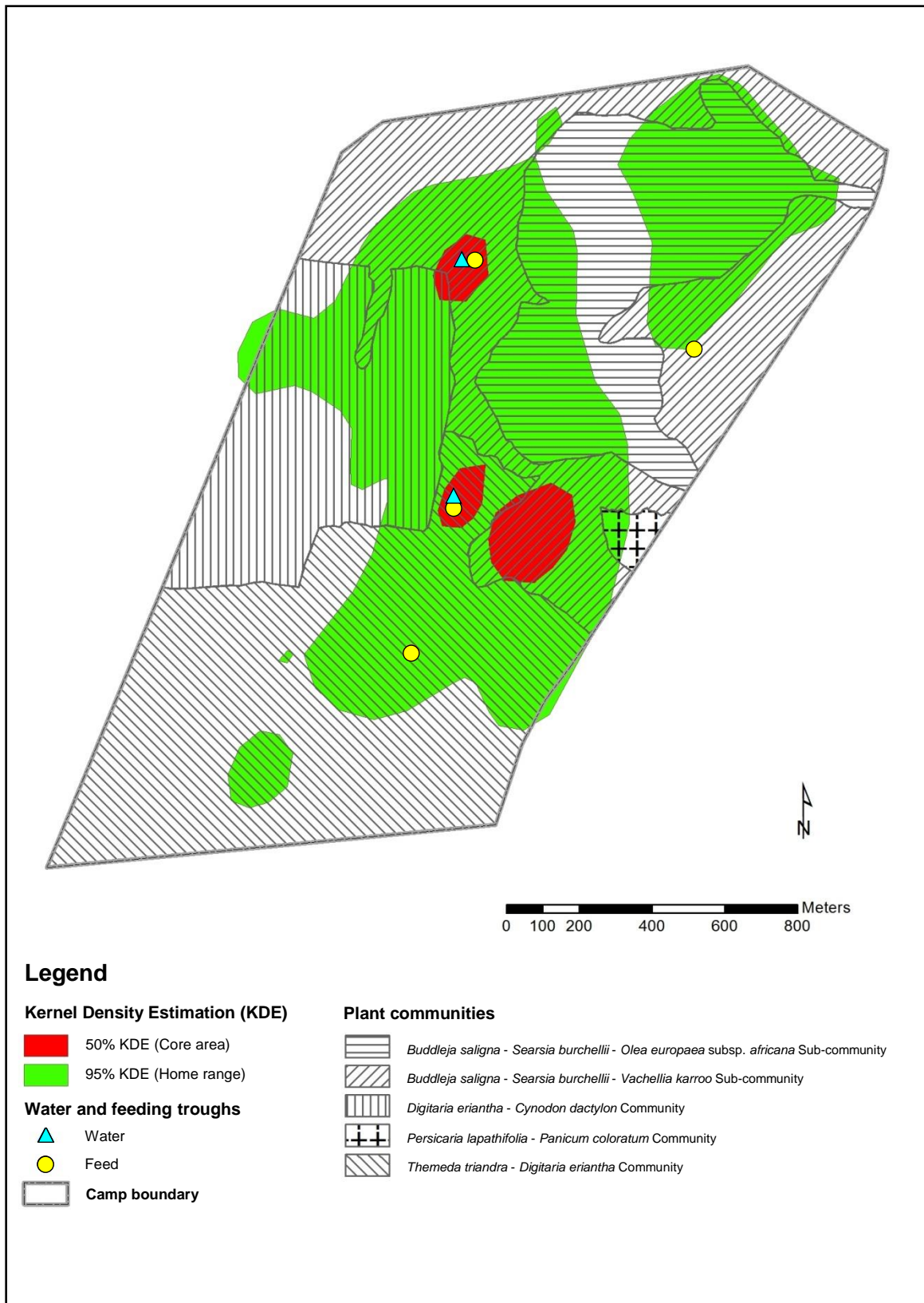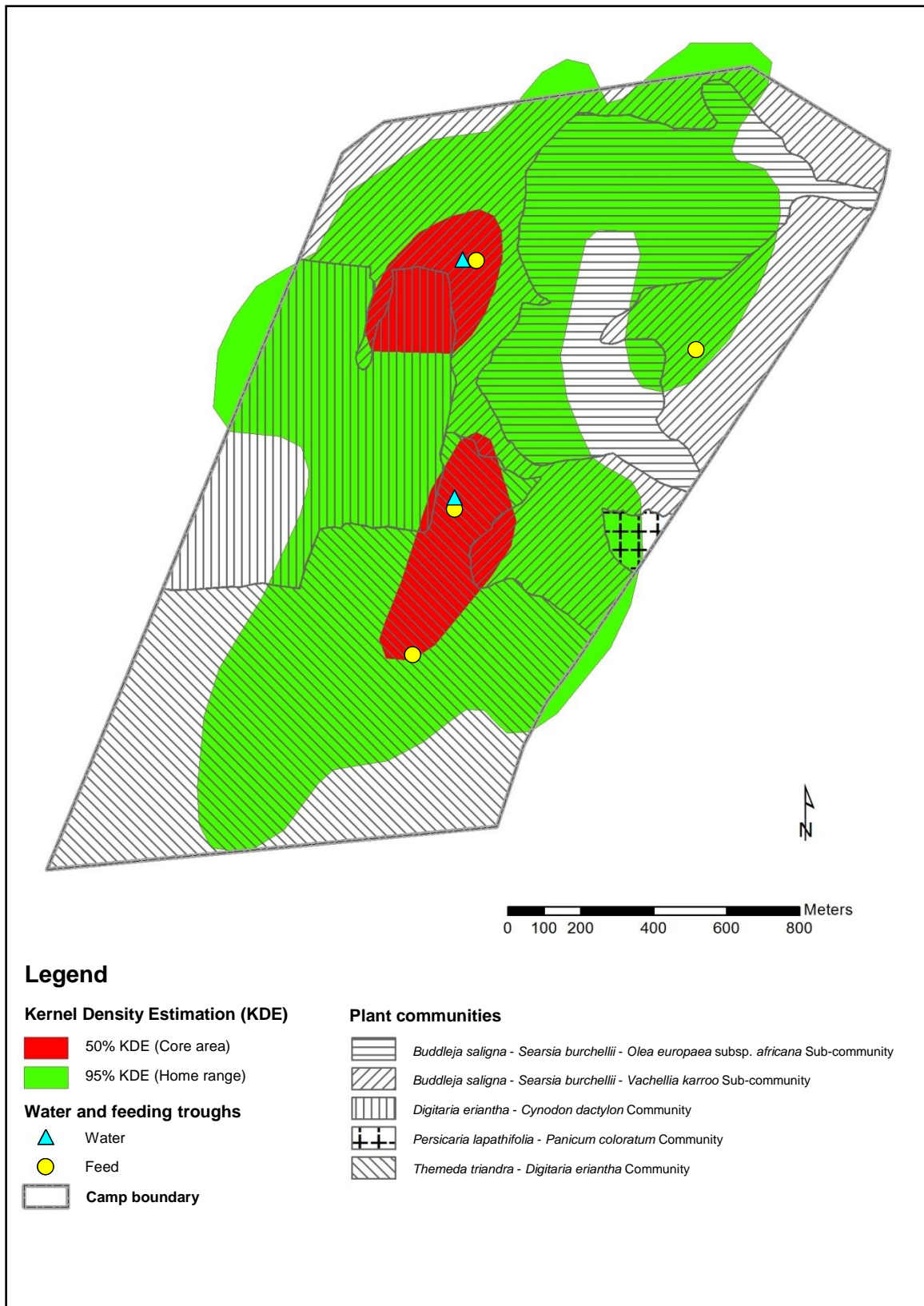
Figure 6.20 Kudu range use calculated from recorded day locations during the flush phase (September 2014)
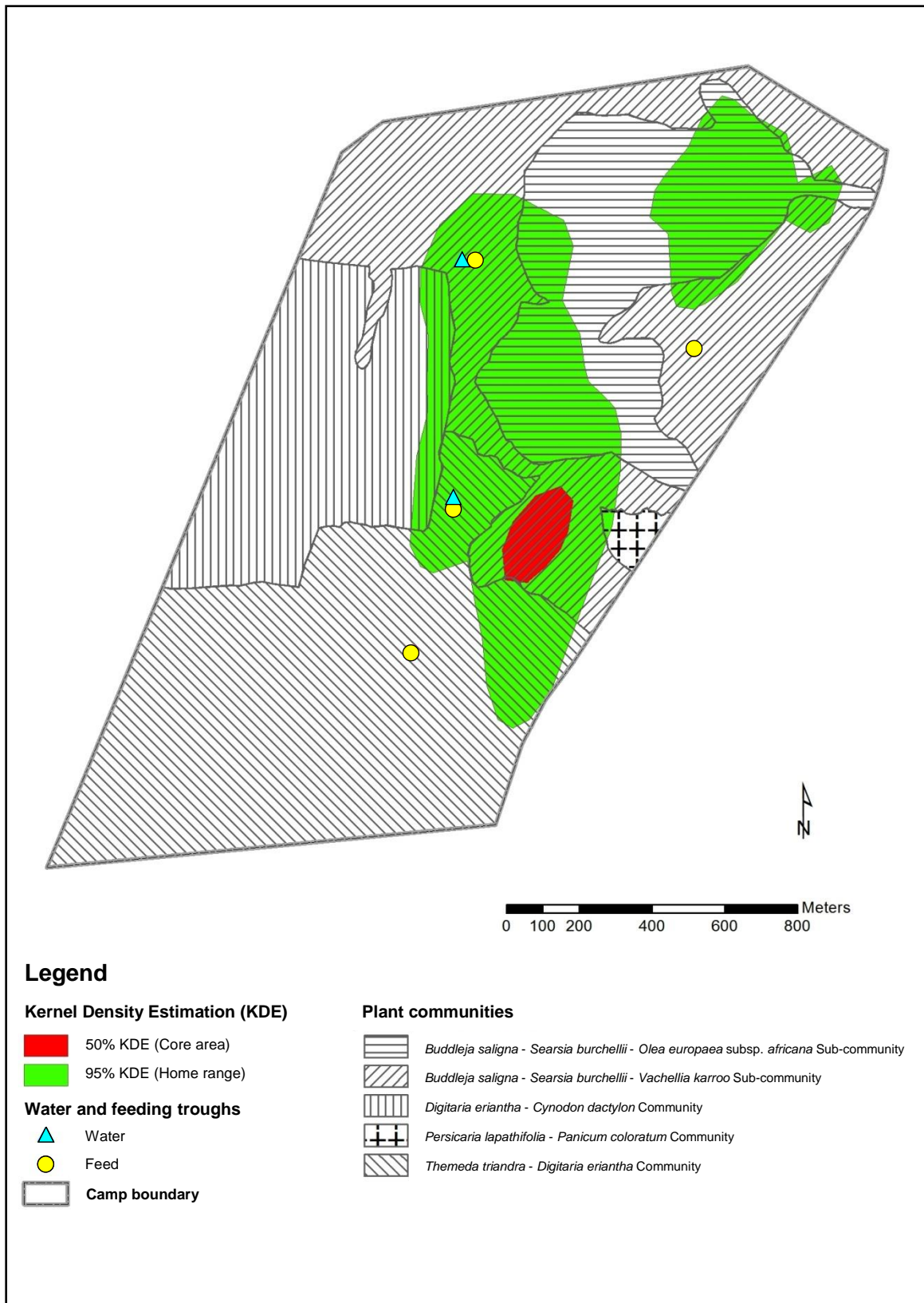
Figure 6.21 Kudu range use calculated from recorded night locations during the flush phase (September 2014)

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Table 6.13 Chi-square goodness-of-fit test results for the flush phase (September 2014). The null hypothesis tested was that kudu utilised plant communities in proportion to their availability

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE	OBSERVED USAGE	OBSERVED RELATIVE USAGE	X² (a)	DF (b)	P value (c)	H0 (d)
Day + Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	80	0.194				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	199	0.482				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	34	0.082	78.829	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	100	0.242				
Total		274.08	1	413	1				
Day	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	14	0.070				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	85	0.427				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	30	0.151	31.065	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	70	0.352				
Total		274.08	1	199	1				
Night	*Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana*	53.06	0.194	66	0.308				
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	114	0.533				
	Digitaria eriantha - Cynodon dactylon	44.87	0.164	4	0.019	115.828	4	0.001	Rejected
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000				
	Themeda triandra - Digitaria eriantha	95.74	0.349	30	0.140				
Total		274.08	1	214	1				

(a) Chi-squared value; (b) Degrees of freedom (n-1); (c) Two-tailed P value (d) Ho hypothesis is rejected or accepted

Table 6.14 Bonferronni confidence intervals for utilisation of plant communities during the flush phase (September 2014)

PERIOD	PLANT COMMUNITY	TOTAL AREA (ha)	EXPECTED RELATIVE USAGE (P_{io})	OBSERVED USAGE	OBSERVED RELATIVE USAGE (P_i)	CONFIDENCE INTERVALS For P_i	PREFERENCE
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	80	0.194	$0.144 \leq p \leq 0.244$	=
Day +	*Buddleja saligna - Searsia burchellii - Vachellia karroo*	78.43	0.286	199	0.482	$0.419 \leq p \leq 0.545$	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	34	0.082	$0.047 \leq p \leq 0.117$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	$0.000 \leq p \leq 0.000$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	100	0.242	$0.188 \leq p \leq 0.296$	-
Total		274.08	1	413	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	14	0.070	$0.024 \leq p \leq 0.094$	-
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	85	0.427	$0.337 \leq p \leq 0.517$	+
Day	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	30	0.151	$0.086 \leq p \leq 0.216$	=
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	$0.000 \leq p \leq 0.000$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	70	0.352	$0.265 \leq p \leq 0.439$	=
Total		274.08	1	199	1		
	Buddleja saligna - Searsia burchellii - Olea europaea subsp. *africana*	53.06	0.194	66	0.308	$0.227 \leq p \leq 0.389$	+
	Buddleja saligna - Searsia burchellii - Vachellia karroo	78.43	0.286	114	0.533	$0.445 \leq p \leq 0.621$	+
Night	*Digitaria eriantha - Cynodon dactylon*	44.87	0.164	4	0.019	$0.000 \leq p \leq 0.043$	-
	Persicaria lapathifolia - Panicum coloratum	1.98	0.007	0	0.000	$0.000 \leq p \leq 0.000$	-
	Themeda triandra - Digitaria eriantha	95.74	0.349	30	0.140	$0.079 \leq p \leq 0.201$	-
Total		274.08	1	214	1		

+ Indicates the plant community was significantly preferred (0.05 level of significance)

- Indicates the plant community was significantly avoided (0.05 level of significance)

= Indicates no significant difference was found between observed and expected utilisation (0.05 level of significance)

A slightly different picture emerged from daytime locations, where kudu preferred the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, but avoided the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community. The *Themeda triandra - Digitaria eriantha* and the *Digitaria eriantha - Cynodon dactylon* Communities were also utilised in the same proportions to their availability. However, kudu preferred the *Buddleja saligna - Searsia burchellii - Vachellia karroo* and *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-communities during the night, while avoiding all the other plant communities (Table 6.14). The range use and distances travelled by kudu throughout the study period were summarised in Table 6.15.

6.3.2 Woody canopy cover

A total of 122 line transects were conducted to determine the available canopy cover of woody species in the study area. Of these transects, 42 were situated in the *Themeda triandra - Digitaria eriantha* Community*,* 32 in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, 25 in the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community, 21 in the *Digitaria eriantha - Cynodon dactylon* Community and two in the *Persicaria lapathifolia - Panicum coloratum* Community. The *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community had the highest woody canopy cover (47.18%), followed by the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community (30.52%), the *Themeda triandra - Digitaria eriantha* Community (17.32%) and the *Digitaria eriantha - Cynodon dactylon* Community (3.05%). Due to a lack of woody plants, no woody canopy cover was available in the *Persicaria lapathifolia - Panicum coloratum* Community.

Table 6.15 Range use and distances travelled by kudu during each phase of food availability from September 2013 to September 2014

Phase	Home range size (ha)			Core area size (ha)			Average distance travelled per 24 hours (m)	Average Distance travelled per hour (m)	
	All locations	Day locations	Night locations	All locations	Day locations	Night locations	All locations	Day locations	Night locations
Dry phase (Sep 2013)	55.92	48.11	64.63	1.69	1.59	5.56	3478	169	121
Flush phase (Oct 2013)	79.37	69.57	126.47	2.71	2.88	10.32	4089	203	132
Immature phase (Nov – Dec 2013)	237.81	226.52	154.23	22.06	15.92	15.36	4404	229	129
Mature phase (Jan – Mar 2014)	249.94	270.92	126.37	19.97	99.01	8.52	3877	214	109
Senescent phase (Apr – May 2014)	263.45	271.98	97.34	46.27	91.16	30.71	4081	241	134
Dry phase (June to August 2014)	126.36	89.08	106.24	7.46	3.66	6.66	3701	217	123
Flush phase (Sep 2014)	131.17	182.59	72.97	8.41	22.78	3.26	3563	207	97

6.4 DISCUSSION

Home ranges utilised by kudu were the smallest during the dry phases and were situated mostly in the *Buddleja saligna* - *Searsia burchellii* - *Olea europaea* subsp. *africana* Sub-community on the hills and the *Buddleja saligna* - *Searsia burchellii* - *Vachellia karroo* Sub-community in the surrounding flats. Both of these sub-communities were dominated by evergreen trees and shrubs, unlike the *Themeda triandra* - *Digitaria eriantha* and *Digitaria eriantha* - *Cynodon dactylon* Communities, which were dominated by deciduous species. Kudu home ranges increased in size during each consecutive phase of food availability from the dry phase of 2013 to the senescent phase of 2014. This coincided with an increase in food availability in the plant communities dominated by deciduous species (see Chapter 4). The kudu home range then decreased dramatically as leaf fall occurred in most deciduous species from the senescent to the dry phase of 2014. This forced kudu to concentrate in the hills and surrounding areas where evergreen trees and shrubs dominated. Water was not considered as an important determinant of the changes in kudu range use, as water was available throughout the year in two water troughs that could quickly and easily be accessed from any of the plant communities. When dry feed was supplied, it was also distributed evenly throughout the study area, not limiting kudu habitat selection to one plant community.

Similar results were reported by Simpson & Cowie (1967) on the adjoining Doddieburn and Manyoli game ranches in Zimbabwe. Kudu were widely dispersed over both ranches during the wet season, with an abundance of browse providing both food and shelter. However, after leaf fall occurred in most trees and shrubs, kudu concentrated along the river, as most of the remaining browse was available in that area. According to Simpson & Cowie (1967), water could not have been the major driving force in habitat selection as enough water was still available throughout the study area in artificial dams and water troughs.

Kudu in Chobe National Park were also distributed over most of their range during the rainy season (Simpson, 1972b). According to Simpson (1972b), this wide dispersal indicated that habitat conditions were optimal, with an abundance of food and cover available as most of the vegetation were in full foliage. Water was also plentiful and widely available from pans and temporary pools during this time. This changed as winter approached, with leaf fall resulting in a reduction of the available food and cover, especially on the hills. Temporary pools of water also dried up, forcing kudu to move to the few remaining water sources (Simpson, 1972b).

Contrary to these findings, kudu breeding herds in the Nylsvley Nature Reserve (Limpopo province) were more widely distributed during the dry, cold season (Dörgeloh, 2001). According to Owen-Smith & Cooper (1989), kudu in Nylsvley Nature Reserve utilised mainly evergreen species at the time. This would have forced kudu to search for food over a greater area (Dörgeloh, 2001). Allen-Rowlandson (1980) also reported that kudu utilised more of their range during autumn and winter months in the Andries Vosloo Kudu Reserve (Eastern Cape). However, no extensive seasonal movements occurred in their study area, indicating that conditions remained optimal throughout the year (Allen-Rowlandson, 1980).

The home ranges calculated for kudu in the study area on Amanzi Private Game Reserve were relatively small, ranging from only 55.92 ha in the dry phase of 2013 to 263.45 ha in the senescent phase of 2014. Kudu home ranges calculated in previous studies varied greatly between individual animals or herds as well as between different habitats. For example, Owen-Smith (1979) calculated home range sizes of 620 ha and 1 120 ha for two kudu groups observed in the central part of Kruger National Park. Du Toit (1990b) also determined home range sizes of kudu in the same study area that ranged from 790 ha to 3 240 ha, with a mean home range size of 2 190 ha. In contrast, the mean home range sizes calculated for kudu bulls and cows in the Andries Vosloo Kudu Reserve were only 125 ha and 96.3 ha, respectively (Allen-Rowlandson, 1980).

It must, however, be taken into account that kudu in the study area on Amanzi Private Game Reserve were limited in their home range selection due to the relatively small size of the camp (274.08 ha). It was thus possible that kudu would have utilised larger areas if not restricted by fences. However, with evergreen trees and shrubs mostly occurring on hills in the central Free State, kudu would still have been restricted to these habitats during dry phases when leaf fall in deciduous species reduces food availability. Kok & Opperman (1980) also reported that giraffe in the Willem Pretorius Game Reserve (central Free State), concentrated on the hills in the dry season where most evergreen plant species occurred and only moved down to the flats when deciduous species produced new leaves.

The core areas utilised by kudu were also the smallest in the dry phases of each year, with these areas mostly situated around the feeding troughs with water available in close proximity. Kudu regularly visited the feeding troughs in the dry phases, especially the one situated in the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community to the north of the study area. During these periods, kudu stayed in the vicinity of this feeding trough for most of the day, browsing on natural vegetation. However, kudu quickly moved towards the feeding trough after new dry feed was supplied.

Kudu core areas increased only slightly from the dry phase of 2013 to the flush phase of the same year. This was probably due to most of the early flushing deciduous species, such as *Vachellia karroo*, only producing new leaves by middle October (see Chapter 4), with kudu still having to rely on dry feed for the first part of the month. However, kudu core areas increased considerably in size from the flush phase of 2013 to the immature phase of the same year. This coincided with kudu being less reliant on dry feed as a food source (see Chapter 5). The core areas utilised by kudu then increased again from the immature phase to the senescent phase as food availability increased.

The average distance travelled by kudu over a 24 hour period was the lowest during the dry phase of 2013, with kudu food resources mostly limited to the *Buddleja saligna* - *Searsia burchellii* - *Olea europaea* subsp. *africana* and the *Buddleja saligna* - *Searsia burchellii* - *Vachellia karroo* Sub-communities and kudu relying heavily on dry feed during this period. The average distance travelled by kudu over 24 hours then increased during the following flush phase as food was more widely distributed over the study area and kudu relied less on dry feed. On average, kudu also travelled further over 24 hour periods when comparing the immature, mature and senescent phases to the dry phases.

When considering all the location data, kudu showed a significant preference for the *Buddleja saligna* - *Searsia burchellii* - *Vachellia karroo* Sub-community in each phase of food availability. Kudu also showed a significant preference for the *Buddleja saligna* - *Searsia burchellii* - *Olea europaea* subsp. *africana* Sub-community, although only during the dry phases. All the other plant communities were either utilised in equal proportions to their availability or significantly avoided. The preference kudu showed for the *Buddleja saligna* - *Searsia burchellii* - *Vachellia karroo* and the *Buddleja saligna* - *Searsia burchellii* - *Olea europaea* subsp. *africana* Sub-communities during the dry phases could be expected, as almost all the food available to kudu occurred in these plant communities during these periods.

It was, however, unclear why kudu would still prefer the *Buddleja saligna* - *Searsia burchellii* - *Vachellia karroo* Sub-community and avoid the *Themeda triandra* - *Digitaria eriantha* Community during the flush phases, as the *Themeda triandra* - *Digitaria eriantha* Community was dominated by *V. karroo* that contributed most of their diet during these periods. Furthermore, the *Buddleja saligna* - *Searsia burchellii* - *Vachellia karroo* Sub-community was dominated by evergreen species, with *V. karroo* only occurring at low densities.

As water was available in both these plant communities, the only explanation could be that woody canopy cover played an important role in their habitat selection, with kudu trading food for more cover provided by the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community. Kudu's preference for dense vegetation was in accordance with most other studies (Underwood, 1978; Fabricius, 1989; Dekker *et al.*, 1996; Dörgeloh, 2001). Although no large predators were present in the study area, kudu were clearly still dependant on cover as they dashed off to areas with higher canopy cover whenever disturbed by humans.

Even when keeping the need for cover in mind, it was still surprising that, when considering all location data, kudu did not prefer the *Digitaria eriantha - Cynodon dactylon* Community in the immature phase as the diet of kudu cows consisted of 65.16% grass and kudu almost exclusively grazed in this plant community. However, when the location data was divided into day and night time categories a much clearer picture emerged, with kudu selecting feeding areas during the day and resting areas at night. For example, kudu preferred the *Digitaria eriantha - Cynodon dactylon* Community during the day in the immature phase, while avoiding the same plant community at night. Furthermore, kudu only preferred the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community at night, with most of their core area situated in an area dominated by *Tarchonanthus camphoratus*, a species rarely utilised by kudu in the study area. It was thus apparent that selecting areas with more cover was more important at night than selecting areas with their preferred food items.

The selection of areas predominantly utilised for feeding or resting was further confirmed by the fact that kudu were less active at night, as they always travelled shorter distances during the night compared to the day. Kudu home ranges were also much larger during the day as opposed to the night, with day-time home ranges increasing in each consecutive phase from the dry phase of 2013 to the senescent phase of 2014. These increases coincided with an increase in food availability in plant communities dominated by deciduous woody species. The only exception occurred during the dry phases when kudu home ranges were slightly larger at night. This could possibly be attributed to kudu concentrating around feeding troughs during the day, waiting for new feed to be supplied.

The pattern of selecting feeding areas during the day and resting areas at night continued into the mature phase as kudu utilised the *Digitaria eriantha - Cynodon dactylon* and *Themeda triandra - Digitaria eriantha* Communities in the same proportion to their availability during the day and avoided the same plant communities at night. Again the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, which provided more cover, but less of their preferred food items was preferred by kudu at night. Likewise, the *Themeda triandra - Digitaria eriantha* Community was preferred during the day and avoided at night during the senescent phase. This occurred even though this plant community had most of their preferred food items available at the time. Both the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community and the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community was preferred at night during the same period, again providing more cover but less of the kudus preferred food items.

The shift in kudu habitat preferences was also evident between day and night locations in the dry and flush phases. Kudu mostly avoided the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community during daytime, while preferring the same plant community at night. This plant community was situated on the hills in the study area and also had the highest woody canopy cover. Selection for more cover and warmer temperatures with increased elevation probably played a role in their preference of this plant community at night. Warmer temperatures on the slopes were confirmed by frost only being visible on the flats in the study area, but never on the slopes.

Kudu in Chobe National Park were also observed to move up slopes in the cold season (Simpson, 1972b). According to Simpson (1972b) this was probably directly influenced by temperature as the most food, cover and water was available at the bottom of the slopes during this time. Temperatures in the area dropped, especially at night, with cold air draining down to the lower lying areas. This was confirmed with temperatures measured just five meters up a slope in the Chobe area being as much as 10°C warmer than lower down (Simpson, 1972b).

6.5 CONCLUSION

The importance of plant communities dominated by evergreen woody species cannot be emphasised enough. These plant communities proved to be critical resource areas for kudu during periods when leaf fall occurred in most deciduous woody species. Topography also became important in the habitat selection of kudu during the coldest part of the year, with kudu escaping the worst cold by moving up the slopes, especially at night when temperatures dropped to well below freezing point. Kudu also showed a definite preference for areas with high woody canopy cover throughout the year, often trading food for more cover, especially at night. According to Burkepile *et al.* (2013), diurnal vs. nocturnal patterns in habitat selection are often overlooked, but are essential to understand the factors that shape the distribution of animals. This statement was clearly illustrated in the current study where kudu selected definite feeding areas during the day and resting areas at night. Without the division of data into day and night locations, the importance of some plant communities to the survival of kudu may have been overlooked. Proper habitat analysis thus plays a crucial role in determining the suitability of fenced areas for wildlife, especially for kudu, as the availability of sufficient cover is just as important as the food available to these animals.

CHAPTER 7: MANAGEMENT IMPLICATIONS AND RECOMMENDATIONS FOR KUDU IN THE CENTRAL FREE STATE

7.1 INTRODUCTION

Population growth is determined by birth and survival rates of animals. However, population growth is seldom constant and depends to a large degree on environmental factors such as rainfall, temperature and competition. Yearly variations in these factors are critically important to wildlife managers and will affect their decision making in terms of the number of animals that can be sustained on the specific ranch or reserve (Starfield *et al.*, 1985).

According to Owen-Smith (1990), kudu populations in Kruger National Park were mainly controlled by resources and not predation. Rainfall indirectly affects kudu through its influence on the quantity and quality of their food supply. The availability and abundance of high quality food could presumably affect the milk supply of cows and also affects the building up of fat reserves in adults. Rainfall can also influence the leaf retention time of deciduous woody species and thus affects the duration of the critical period when kudu have to rely on evergreen species for their survival (Rutherford, 1984; Starfield *et al.*, 1985).

The survival rates of juvenile, yearling and old female kudu were significantly correlated with annual rainfall in Kruger National Park. However, the correlation was insignificant for females in their prime (Owen-Smith, 1990). Mortalities resulting from malnutrition could also be escalated due to cold weather conditions, which might bring about hypothermia when an animal's fat reserves have been depleted (Starfield *et al.*, 1985). For example, during 1981 the survival rates of all kudu age classes in Kruger National Park were relatively low despite the preceding above average rainfall. A severe cold spell, coupled with rain, hit the park during September that year when kudus' body reserves were already low. Late dry season mortalities were thus probably the direct result of cold stress (Owen-Smith, 1990).

Intra- and interspecies competition, in addition to below average rainfall, can also reduce the food available to kudu. It is thus important for wildlife managers to realise when animal populations are overstocked and depleting the future food supply. Wildlife managers also need to anticipate possible population changes and assign annual quotas for culling, hunting or selling of surplus animals (Starfield *et al.*, 1985).

The critical period for kudu is at or shortly after the end of the dry season when food abundance is at a yearly low due to leaf fall occurring in deciduous woody species (Owen-Smith, 1979; Owen-Smith *et al.*, 1983; Starfield *et al.*, 1985; Theron, 2005; Janecke & Smit, 2011; Janecke & Smit, 2015). However, the nutritional status of herbivores is probably influenced more by the quality of their diet than by the actual food abundance in the area (Owen-Smith, 1990). During the critical period, kudu depend on the availability of certain evergreen trees and shrubs for their survival (Owen-Smith *et al.*, 1983; Owen-Smith, 1985).

Kudu densities are thus limited by food abundance during the dry season bottleneck and the availability of high quality food during the wet season for cows to produce enough milk for nursing calves and for adults to build up sufficient fat reserves for the dry season. However, the stocking densities of kudu could be greatly increased by supplying them with additional food (Owen-Smith, 1985). To get a good indication of when to supply kudu with additional food or when to reduce their numbers, faecal nitrogen concentrations can be used as a measure of their nutritional status (Van der Waal *et al.*, 2003; Janecke & Smit, 2015).

Kudu are, however, rarely managed in isolation, as the objective of most wildlife ranches is to accommodate a diversity of animal species to satisfy the need for ecotourism, hunting and live sales (Van Rooyen, 2010a). A key component in the managing of free-ranging wildlife populations is correct habitat management. It is thus essential to keep wildlife population numbers in balance with the available food resources (Bothma *et al.*, 2004).

During plant ecological surveys to determine wildlife stocking densities, the quantity and quality of food resources must be calculated in both the woody and the herbaceous layer of each represented plant community. This is important as each plant community has its own unique food resources. However, the use of long term stocking densities is only applicable to large, open environments where wildlife movements are not restricted, allowing them to utilise localised patches containing higher quantity and/or quality food resources. In contrast, stocking densities on relatively small enclosed wildlife ranches and nature reserves must be adapted according to the quantity and quality of food resources available each year. This, therefore, requires the constant monitoring of rainfall, fire and vegetation (Bothma *et al.*, 2004).

Overstocking of wildlife, that could potentially have a negative impact on the food resources, can be avoided by harvesting excess animals at the end of each growing season. In addition to food resources, the minimum herd size, sex ratio, home range size and territoriality of different species also need to be considered when setting stocking densities for wildlife (Bothma *et al.*, 2004).

To effectively manage a wildlife ranch the first step would thus be to identify, describe and map homogenous plant communities. After this the grazing and browsing capacity of the different plant communities can be determined. This will subsequently allow wildlife managers to make informed decisions on the appropriate species that can be accommodated, as well as the stocking densities of each species (Van Rooyen, 2010a).

The specific objectives of this chapter were:

1. To determine the faecal nitrogen levels of kudu in the study area;

2. To recommend stocking densities for the study area; and

3. To make recommendations concerning the management of kudu in both the study area and the central Free State.

7.2 METHODOLOGY

7.2.1 Faecal analysis

Kudu were followed on foot for two days each month from June 2013 to September 2014 in order to collect faecal samples. Between three and five faecal samples of 10 pellets each were collected per month for both adult cows and socially mature bulls. It was possible to distinguish between sexes due to distinct sexual dimorphism of greater kudu (Jarman, 1974). Bulls from the age of four were considered socially mature (Furstenburg, 2005), with the age of bulls determined by their horn shape according to the classification of Allen-Rowlandson (1980). The age of females was determined based on their body size. They were accordingly separated into heifers between one and two years of age and adult cows from two years and older (Allen-Rowlandson, 1980). Adult cows and/or socially mature bulls were continuously observed until one of them defecated. A photograph was then taken of the kudu defecating and used as a reference for locating the faecal sample. Only fresh faecal samples were accordingly collected, following Grant *et al.* (1995), Wrench *et al.* (1996), Grant *et al.* (2000); Van der Waal *et al.* (2003) and Janecke & Smit (2015). After collection, faecal samples were stored at room temperature to dry out (Grant *et al.*, 1995; Wrench *et al.*, 1996; Grant *et al.*, 2000; Van der Waal *et al.*, 2003; Janecke & Smit, 2015). According to Wrench *et al.* (1996), dried samples can be stored for up to one year before analysis. The samples were further dried in an oven at 70°C for 48 hours before being ground into a powder using a Tecator mill with a 1 mm mesh screen (Wrench *et al.*, 1996; Van der Waal *et al.*, 2003; Janecke & Smit, 2015). The powder of each sample was mixed and divided into two subsamples of similar weight. The nitrogen concentration (g N/kg DM) in each subsample was determined with a Leco FP 528 Nitrogen Analyser (Janecke & Smit, 2015). The average nitrogen concentration between the two subsamples was then calculated.

7.2.2 Recommended stocking densities

The ecological grazing and browsing capacity is considered to be the maximum number of grazers and browsers that a certain area can sustain based on the food resources available, while the economic grazing and browsing capacity is considered to be lower than the ecological capacity (Bothma *et al.*, 2004). An economic grazing capacity of between 70% and 80% of the ecological grazing capacity is recommended for sustainable wildlife production (Van Rooyen, 2010b).

The grazing and browsing capacity of the study area was calculated to help determine the number of animals that could be stocked (see Chapter 4). An economic grazing capacity was then calculated for the study area, set at 70% of the calculated ecological grazing capacity. The calculated browsing capacity was, however, already considered an economic browsing capacity due to the low utilisation factors assigned to woody species (see Chapter 4). This browsing capacity used for recommending stocking densities was also calculated when food availability was at a yearly low due to leaf fall occurring in most deciduous woody species. A total of 132 grazer units and 26 browser units were accordingly calculated to be available in the study area by using the mentioned economic grazing and browsing capacities, with stocking densities set based on these calculations. The objectives of the ranch were also considered when determining the animal species to be stocked. These included accommodating a wide diversity of animal species for ecotourism, hunting and live sales. Hartmann's mountain zebra, blue wildebeest, bontebok and nyala were therefore retained in the study area, as this was the only enclosure where they occurred on Amanzi Private Game Reserve. Browsers and mixed-feeders were also given preference when recommending stocking densities due to browser units being limited in the study area.

Substitution values for the different species to be stocked were first calculated according to Smit (2006) and are presented in Table 7.1. The following norms were used in these calculations:

A grazer unit (GU) is defined as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean body mass of 180 kg and a browser unit (BU) defined as the metabolic equivalent of a kudu (100% browser) with a mean body mass of 140 kg (Dekker, 1997). The daily food requirements of a GU was calculated as 4.5 kg (2.5% of body mass for a blue wildebeest) and the daily food requirements of a BU calculated as 3.5 kg (2.5% of body mass for a kudu) (Owen-Smith, 1988; Owen-Smith, 1999). The following is an example of how to calculate the substitution values for impala with a mean body mass of 41 kg, a diet consisting of 45% grass and 55% browse and daily food intake of 1.11 kg (2.7% of its body mass):

(Daily food intake of an impala x grass in diet) / Daily food intake of a blue wildebeest)

(1.11 x 0.45) / 4.5 = 0.11 GU equivalents

(Daily food intake of an impala x browse in diet) / Daily food intake of a kudu)

(1.11 x 0.55) / 3.5 = 0.17 BU equivalents

Stocking densities were carefully selected to accommodate the maximum number of animals without exceeding the calculated grazing or browsing capacity of the study area. These numbers were adjusted until most of the available browser and grazer units in the study area were utilised.

Table 7.1 Substitution values calculated for the different game species to be stocked in terms of grazer units and browser units

GAME SPECIES	Mean body mass (kg)	Daily food intake (% of mass)	% grass in diet	% browse in diet	Grazer unit equivalents	Browser unit equivalents
Blue wildebeest	180	2.5	87	13	0.87	0.17
Bontebok	60	2.8	90	10	0.34	0.05
Greater kudu	140	2.5	15	85	0.12	0.85
Hartmann's mountain zebra	240	4.1	95	5	2.08	0.14
Impala	41	2.7	45	55	0.11	0.17
Nyala	73	2.6	20	80	0.08	0.43

* A grazer unit (GU) is defined as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean body mass of 180 kg (Dekker, 1997).

* A browser unit (BU) is defined as the metabolic equivalent of a kudu (100 % browser) with a mean body mass of 140 kg (Dekker, 1997).

* The mean body mass of game species represents all ages and sexes in the population (Van Rooyen, 2010b).

* The diets are the same as used in Van Rooyen (2010b).

7.3   RESULTS

7.3.1 Faecal analysis

Seasonal trends were visible when comparing monthly faecal nitrogen (N_f) concentrations of both socially mature bulls and adult cows (Figure 7.1). The faecal nitrogen (N_f) concentration of adult cows ranged from a high of 32.59 g N/kg DM in February 2014 to a low of 17.84 g N/kg DM in July 2014, while the N_f concentration of socially mature bulls ranged from a high of 27.87 g N/kg DM in March 2014 to a low of 11.81 g N/kg DM in August 2014.

The N_f concentrations of adult cows decreased steadily from 23.16 g N/kg DM in June 2013 to 18.7 g N/kg DM in October 2013. However, a noticeable increase in the N_f concentration of cows occurred from October to November in 2013, with 30.42 g N/kg DM recorded in November. From November 2013 to April 2014 the N_f concentrations of cows fluctuated between 32.59 and 23.57 g N/kg DM, except for December when a N_f concentration of 19.14 g N/kg DM was recorded. The N_f concentrations measured for cows then decreased from 24.43 g N/kg DM in April 2014 to a low of 17.84 g N/kg DM in July 2014. A visible increase in the N_f concentrations of cows was only noticed again in September, increasing from 18.36 g N/kg DM in August 2014 to 20.98 g N/kg DM in September 2014. The N_f concentration measured for cows continued to increase, with 22.61 g N/kg DM measured in October 2014.

The N_f concentrations of socially mature bulls fluctuated between 21.23 and 22.83 g N/kg DM from June to August in 2013 and reached a low of 19.85 g N/kg DM in September of that year. A noticeable increase then occurred in October 2013, with 24.76 g N/kg DM measured. The N_f concentrations of socially mature bulls remained above 23 g N/kg DM from October 2013 to April 2014. However, a steady decrease in the N_f concentrations occurred from March to August in 2014, reaching a very low level of 11.81 g N/kg DM in August 2014. Although the N_f concentration of socially mature bulls increased in September 2014, it remained relatively low. However, it continued to increase, with 19.98 g N/kg DM measured in October 2014.

7.3.2 Recommended stocking densities

The recommended stocking densities for the study area, with the number of grazer and browser units utilised, are presented in Table 7.2. All the available browser units in the study area were utilised, but only 117 of the 132 available grazer units were stocked.
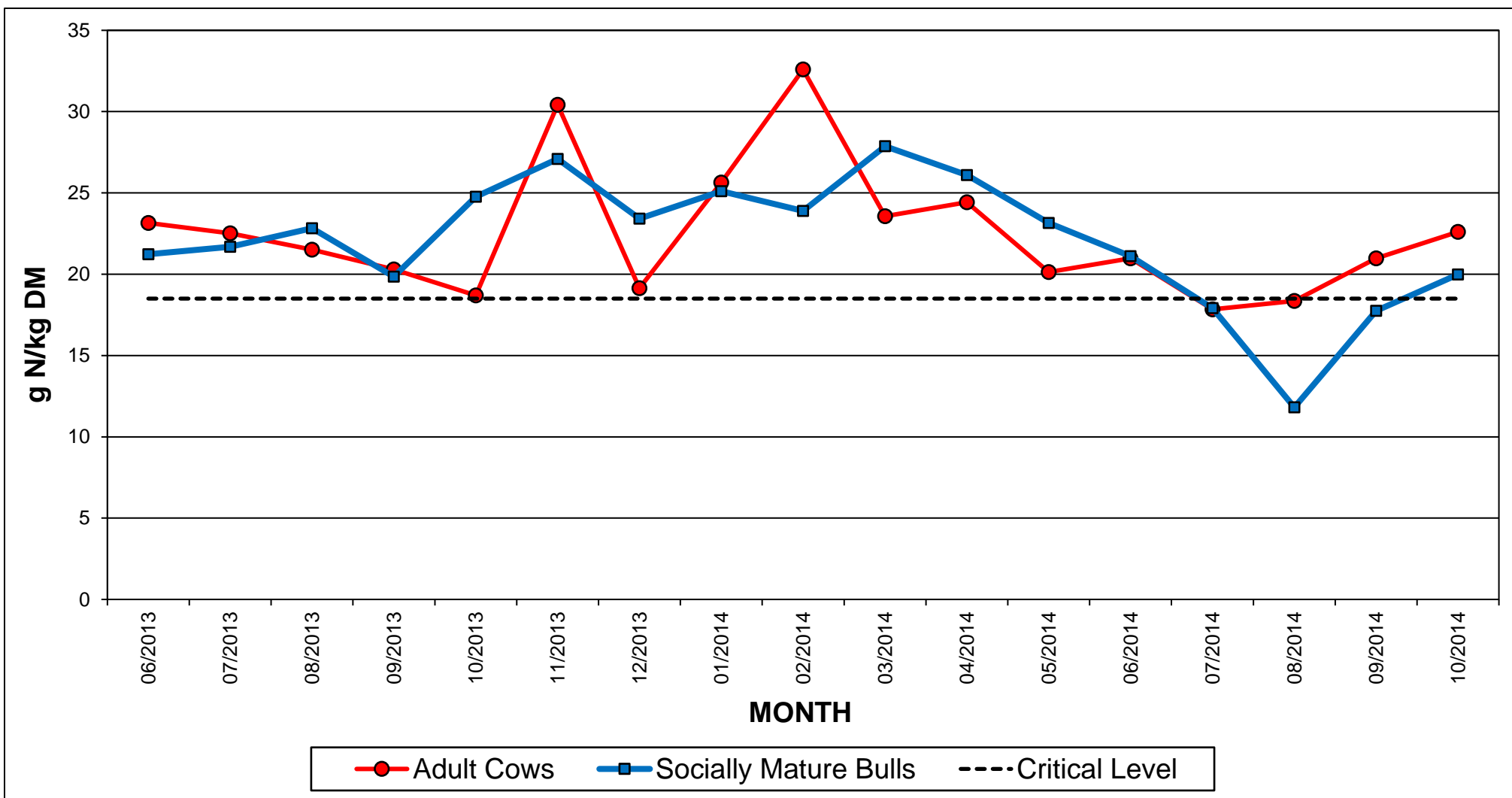
271

Figure 7.1 Faecal nitrogen values of kudu compared over a period of 17 months

Table 7.2 Recommended stocking densities for the study area, based on the available grazer and browser units during August 2014

GAME SPECIES	Total number of animals stocked	Total number of animals recommended	Grazer Units	Browser Units
Blue wildebeest	7	26	23	4
Bontebok	43	68	23	3
Fallow deer	6	0	0	0
Greater kudu	35	11	1	9
Hartmann's mountain zebra	30	32	67	4
Impala	40	14	2	2
Nyala	10	10	1	4
Waterbuck	4	0	0	0
Total	**175**	**161**	**117**	**26**

* A grazer unit (GU) is defined as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean body mass of 180 kg (Dekker, 1997).

* A browser unit (BU) is defined as the metabolic equivalent of a kudu (100 % browser) with a mean body mass of 140 kg (Dekker, 1997).

7.4 DISCUSSION

The faecal nitrogen concentrations of both adult cows and socially mature bulls were generally much higher during the growing season and decreased as the dry season approached. The lowest N_f concentrations were usually recorded at the end of the dry season between July and September each year. However, a noticeable increase in N_f concentrations was recorded for both adult cows and socially mature bulls during September 2014. This increase coincided with the emergence of immature leaves in *Vachellia karroo* trees. A marked increase in the N_f concentration of socially mature bulls also occurred in October 2013, during the same time that *Vachellia karroo* trees produced immature leaves. This does, however, not explain why the N_f concentration of adult cows decreased from September to October 2013.

Faecal nitrogen values nevertheless provided a good indication of when kudu might have experienced nutritional stress. According to Van der Waal *et al.* (2003), some kudu in Limpopo Province were in visibly poor condition from May to June. These animals had N_f concentrations ranging between 18.0 and 17.7 g N/kg DM. At the same time, kudu in good condition had N_f concentrations of between 19.3 and 19.8 g N/kg DM. However, during August and September kudu in poor condition had N_f concentrations ranging between 13.9 and 14.0 g N/kg DM, while kudu in good condition had N_f concentrations ranging between 16.7 and 16.3 g N/kg DM. Grant *et al.* (1995) also determined that kudu in Kruger National Park with an average N_f concentration of 18.1 g N/kg DM were in relatively poor condition, while kudu with an average N_f concentration of 25.1 g N/kg DM were good condition. According to Janecke & Smit (2015), kudu in the Wag-'n-Bietjie Private Nature Reserve (central Free State) were considered in poor physical condition from July to August/September. During these times kudu had N_f concentrations ranging between 13.6 and 18.0 g N/kg DM (Janecke & Smit, 2015).

The highest known N_f value for kudu in poor condition was thus the one reported by Grant *et al.* (1995) of 18.1 g N/kg DM. However, Van der Waal *et al.* (2003) suggested N_f concentrations for kudu lower than 18.5 g N/kg DM in the cool-dry season and lower than 15.0 g N/kg DM in the dry-hot season could result in nutritional stress that is associated with a loss in body condition and increased mortalities. The N_f value of 18.5 g N/kg DM was thus considered to be the critical level under which kudu in the study area might experience nutritional stress.

The minimum N_f concentrations recorded for adult cows and socially mature bulls during 2013 were above the critical level of 18.5 g N/kg DM suggested for kudu. However, during 2014 N_f concentrations measured for adult cows during July and August were below this level. Faecal nitrogen concentrations below the critical level were also measured for socially mature bulls from July to September in 2014. This suggests that kudu in the study area were under nutritional stress from July to September in 2014, but not during the same time the previous year.

The longer leaf retention times of deciduous woody species during 2013 could explain why N_f concentrations of kudu did not drop below the critical level during these months in 2013. Another possible reason could be the fact that the diet of kudu was comprised of significantly ($p < 0.05$) more dry feed during the dry phase of 2013 compared to the dry phase of 2014 (see Chapter 5). This probably resulted from less competition at the feeding troughs, with more dry feed being supplied during 2013 compared to 2014 (see Chapter 4). As more dry feed was supplied it became less of a limited resource, reducing competition at the feeding troughs and allowing kudu to make more use of dry feed as a food source. According to Van der Waal *et al*. (2003), supplementary forage supplied to kudu significantly increased N_f concentrations. In addition the study area was also more severely overstocked during 2014, which could have had a negative effect on the N_f concentrations of kudu.

However, not all kudu seemed in poor physical condition from July to September in 2014. On the contrary, individuals in their prime seemed in relatively good condition during this period (Figure 7.2). It was only older individuals that were in visibly poor condition (Figure 7.3). In this regard, Owen-Smith (1990) found that, while the survival rates of juvenile, yearling and old female kudu were significantly correlated to annual rainfall (which influences the quantity and quality of their food supply), this was not the case for females in their prime. This could explain to some degree why kudu in their prime did not display any signs of nutritional stress in the study area. These results nevertheless concur with those of Janecke & Smit (2015) that considered kudu in the Wag-'n-Bietjie Private Nature Reserve to be in poor physical condition from July to August/September. Only one kudu cow died during the current study in July 2014. The reason for the death is unknown, but may also have been due to illness or old age, not necessarily food shortages.

Figure 7.2 Socially mature kudu bull and adult kudu cow in relatively good condition (photo taken on 31 July 2014)

Figure 7.3 Adult kudu cow in poor condition (photo taken on 31 July 2014)

Due to the study area being overstocked, new stocking densities for the study area were recommended. However, these stocking densities were not only based on the ecological capacity of the study area to support grazers and browsers, but also on the objectives of the ranch. These included accommodating a wide diversity of animal species for the purposes of ecotourism, hunting and live sales. The following species were thus retained in the study area when considering stocking densities, as it was the only enclosure where they occurred on the ranch: Hartmann's mountain zebra, blue wildebeest, bontebok and nyala. All these species were also considered medium to high value species at the time. It is, however, recommended to remove the fallow deer in the study area, as this is an exotic species which is not aesthetically pleasing for either ecotourism or hunting. It is also recommended to remove the waterbuck as they were very abundant in other areas of the ranch.

Browsers were first considered for stocking the study area as the most food available in the woody layer was provided by evergreen species that could support browsers throughout the dry season. This is not the case on most wildlife ranches in the Free State that are dominated by deciduous woody species. After browsers, mixed-feeders were considered. However, some browser units also had to be allocated to predominantly grazing animals that made some use of the browsing component. Consequently, in trying to stock the area with a variety of game species, all the grazer units could not be utilised, as browser units were ultimately the limiting factor preventing more grazers from being stocked. It must, however, be kept in mind that these stocking densities are only an approximation and that the veld condition and physical condition of the animals need to be constantly monitored to make final adjustments. The grazing and browsing capacity of the study area also needs to be determined on a yearly basis, with the available browser units representing those that can sustain animals through the dry season when leaf fall occurs in deciduous species.

If, in future, the stocking density exceeds the carrying capacity of the study area, it would be recommended to remove the surplus animals for either relocation to other parts of the ranch or to sell the animals. Another option would be to supply the animals with dry feed. However, the current feeding programme should be adjusted to reduce competition at the feeding troughs. Firstly, the locations of feeding sites need to be re-evaluated, as both grazers and browsers compete at the same feeding troughs. This is largely avoidable by placing feeding sites deeper within the plant communities preferred by either grazers or browsers during the dry season (Figure 7.4). Currently, most feeding sites are located at or close to the edge of plant communities, allowing quick access to both grazers and browsers after feed has been supplied.
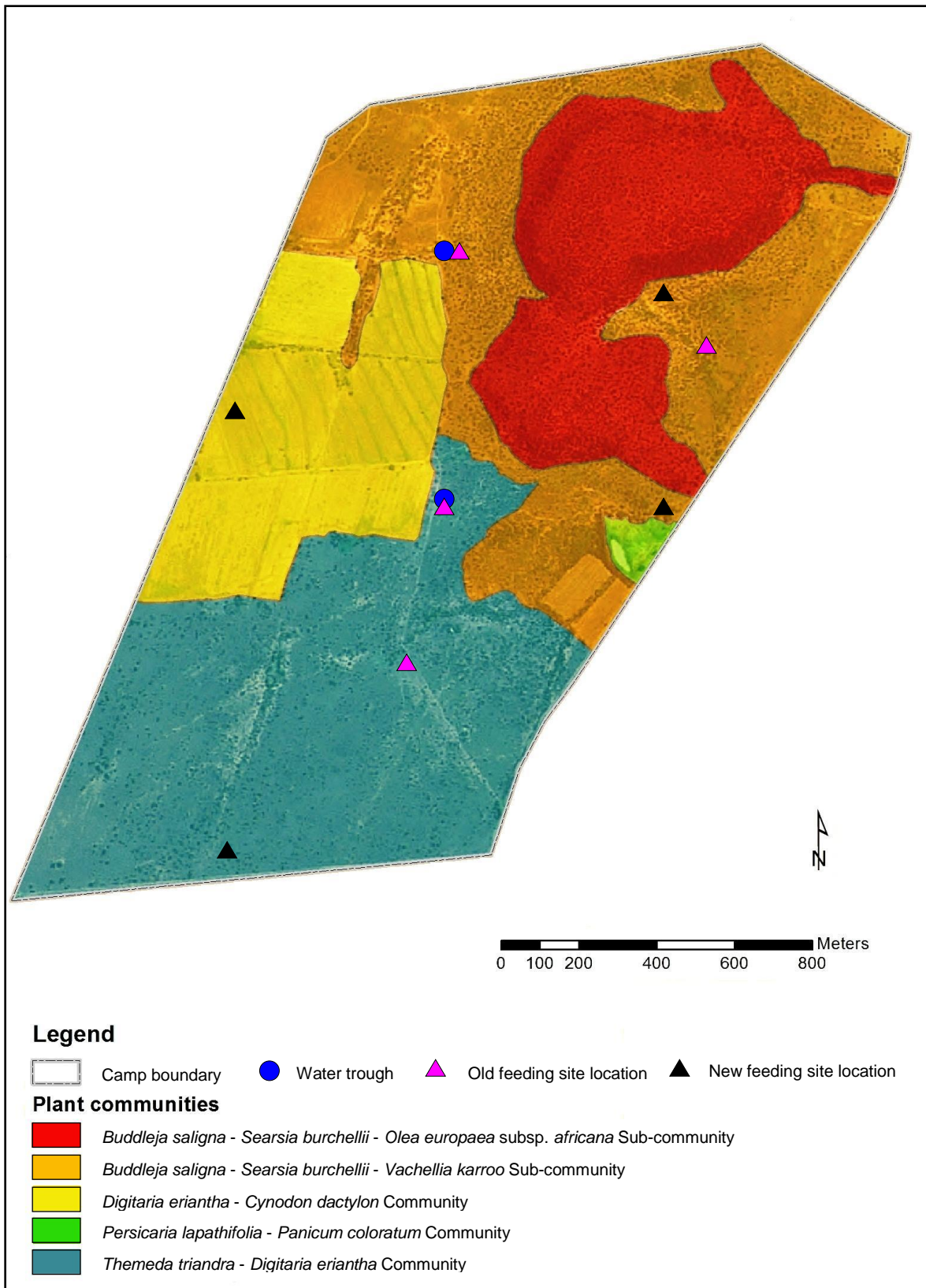
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Figure 7.4 Vegetation map of the study area indicating the newly proposed feeding site locations

This often resulted in grazers, especially Hartmann's mountain zebra, dominating most of the feeding troughs and preventing some species from utilising the dry feed (Figures 7.5 – 7.6). By placing one feeding site deep within the *Digitaria eriantha - Cynodon dactylon* Community and another deep within the *Themeda triandra - Digitaria eriantha* Community, grazers should firstly utilise these feeding sites as they are in close proximity of the habitat they mostly occupy. The other two feeding sites should be placed deep within the *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community, which is mostly preferred by browsers during the dry season. This would allow browsers quick access to these feeding sites after dry feed has been supplied and allow them to utilise the feed without being displaced by aggressive grazers, such as the Hartmann's mountain zebra. This theory was already tested to a degree, with the feeding trough currently placed to the east of the *Buddleja saligna - Searsia burchellii - Olea europaea* subsp. *africana* Sub-community rarely visited by grazers.

Another adjustment to the current feeding program is recommended by replacing each of the four rectangular feeding troughs (Figure 7.7) with 10 round feeding troughs (tyre troughs) spaced 3 m apart at each feeding site (Figure 7.8). This should reduce the competition at feeding sites and allow more of the subordinate individuals to acquire sufficient supplementary feed. It is also recommended that the period when dry feed is provided be adjusted from year to year by taking leaf phenology and faecal nitrogen concentrations of different game species into account.

By feeding game in the study area it would be possible to accommodate more animals. It is however, not recommended to stock more than the 33 available browser units calculated for the study area when most woody species were at full leaf cover or to exceed the economical grazing capacity. The veld condition, as well as the condition of animals, should also be monitored continuously to prevent veld degradation or increased animal mortalities. The *Buddleja saligna - Searsia burchellii - Vachellia karroo* Sub-community and a part of the *Themeda triandra - Digitaria eriantha* Community already showed signs of historical overgrazing based on the pioneer species *Aristida adscensionis* dominating the herbaceous layer. Bush encroachment by *V. karroo* and *Tarchonanthus camphoratus* also started to occur in these disturbed areas. Further bush encroachment can, however, be avoid by preventing overgrazing of the herbaceous layer.

Figure 7.5 A Hartmann's mountain zebra approaching a breeding herd of kudu feeding at one of the feeding troughs

Figure 7.6 Kudu stopped feeding and are moving away from the feeding trough. All kudu including socially mature bulls were intimidated by this single zebra stallion

Figure 7.7 Rectangular feeding trough (3 x 0.5 x 0.5 m) currently used to supply game with dry feed

Figure 7.8 Sable antelope feeding in round feedings troughs (tyre troughs)

7.5 CONCLUSION

A proper habitat evaluation is important before stocking kudu in the central Free State. A sufficient amount of evergreen woody species should be available for kudu to survive the critical period, from July to August/September, when deciduous species lose most of their leaves. *Searsia burchellii* is considered the most important evergreen species occurring in the area, with the kudu diet in the study area dominated by this species during dry phases. The fact that kudu also showed preference for this species during the dry phase of 2014 indicates that it is a highly palatable species (see Chapter 5). As most evergreen species grow on or in the vicinity of hills in the central Free State, the inclusion of these critical resource habitats in areas where kudu are to be stocked is vital for their survival. Hills also provide an escape from the worst cold during the winter and could possibly reduce mortalities of kudu already in weak physical condition. Some late deciduous species are also considered important to the survival of kudu as they retained some of their leaves until the early flushing deciduous species, like *V. karroo*, produced new immature leaves. These species included *Searsia ciliata*, *Ziziphus mucronata* and *Ehretia alba*. All three species were also preferred by kudu during the dry phase of 2014. *Vachellia karoo* is considered the most important deciduous species in the area as this species usually produces new immature leaves before the first good rains. This helps to alleviate nutritional stress that kudu might experience during the late dry season. This species also dominated the kudus' diet from the flush to the senescent phases and were either the most or second most preferred woody species for most of the year (see Chapter 5). If the desired woody species are absent in the area, the only option to stock browsers would be to transform the vegetation by establishing these woody species first. The area could, in the meantime, still be stocked with grazers, but care should be taken to protect saplings from possible damage by fencing them off.

Sufficient woody canopy cover is another factor to consider when stocking an area with kudu. Kudu showed a significant ($p < 0.05$) preference for areas with higher canopy cover in the study area, often trading food for more cover (see Chapter 6). The availability of *Digitaria eriantha* planted pastures should also not be underestimated, as the kudus' diet consisted of 49.11% grass in the immature phase (November to December 2013) and 30.49% grass in the mature phase (January to March 2014). Almost all grass consumed by kudu occurred in the *D. eriantha* planted pastures, and thus, in all likelihood, consisted of mostly *D. eriantha*. Although not considered essential, this palatable grass species probably helped to satisfy the increased energy demands experienced by cows during pregnancy and lactation (Owen-Smith & Cooper, 1989).

However, before even considering stocking any wildlife on a game ranch or a nature reserve a proper management plan is needed for the sustainable utilisation and conservation of the ecosystem. This starts with the identification, description and mapping of homogenous plant communities. Then based on the available plant communities, palatability of plant species, grazing and browsing capacity and veld condition, it is possible to make informed decisions regarding the most appropriate wildlife species and optimum numbers of each species that can be accommodated on the specific ranch (Van Rooyen, 2010a).

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EXTENDED ABSTRACT

FEEDING ECOLOGY OF THE GREATER KUDU (<u>TRAGELAPHUS STREPSICEROS</u>) IN THE CENTRAL FREE STATE

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The objective on most wildlife ranches is to accommodate a diversity of wildlife species to satisfy the need for ecotourism, hunting and live sales. However, the small size of many wildlife ranches presents its own unique challenges. One of these is fencing that prevents animals from moving to more favourable areas during times of food shortages. Intensive management is thus required to prevent overstocking that can lead to the deterioration of natural resources or even total habitat destruction in the long term, or alternatively requires the provision of supplementary feed at a high cost over an extended period of time.

The feeding habits of herbivores are largely determined by their food preferences and the availability of their preferred food plants, with food considered the most important resource that limits animal populations. It is thus important that an animal's diet provides all the essential nutrients needed for survival, growth and reproduction. However, the quality and quantity of food available to herbivores can vary considerably from one season to the next or from year to year. A proper management plan is therefore essential for the sustainable utilisation and conservation of the ecosystem on these small fenced wildlife ranches.

The main objectives of this study were to identify, describe and map different plant communities present in the study area; determine the abundance of potential food in the study area; determine the diet composition and food preferences of kudu in the study area; determine if potential food abundance, food preferences, woody canopy cover and topography affected habitat selection by kudu and to make recommendations concerning the management of kudu in the central Free State based on this study.

The study was conducted in a section of the Amanzi Private Game Reserve, situated in the central region of the Free State Province of South Africa. The study area was approximately 274 ha in size, enclosed by a three metre high game-proof fence. The vegetation in the study area consisted of a combination of natural vegetation and *Digitaria eriantha* planted pastures. The dominant woody species present in the study area were *Searsia ciliata*, *Vachellia karroo, Searsia burchellii, Tarchonanthus camphoratus, Olea europaea* subsp. *africana* and *Buddleja saligna*, while the dominant grass species were *Themeda triandra, Digitaria eriantha*, *Sporobolus fimbriatus*, *Panicum stapfianum, Aristida adscensionis, Aristida canescens, Panicum maximum, Cynodon hirsutus* and *Cynodon dactylon*.

A total of four plant communities, one of which was subdivided into two sub-communities, were identified and described. The potential food available to kudu was determined in each of the identified plant communities and then in the study area as a whole. As kudu are predominantly browsers, only the woody browse (leaves + shoots < 0.5 cm) up to a feeding height of 2.0 m was considered to be available to kudu in the current study. Forbs were not included as they were rarely encountered in the study area, contributing an insignificant proportion of the herbaceous layer. Leaf phenology of woody species was also taken into account in these calculations due to the winter deciduous nature of several woody species in the study area.

Most deciduous species produced immature leaves after the first good rains, while *V. karroo* and *Diospyros lycioides* produced immature leaves before the onset of the rainy season. However, full leaf cover was reached by most deciduous species during January, with leaf senescence usually starting in April and the first leaf fall occurring a month later. The early flushing species retained very little leaves during July and were mostly leafless by August. In contrast, most other deciduous species retained some yellow leaves until the end of August.

Results of the present study indicated that the critical period with the lowest browse availability was from July to August/September, when deciduous species lost most of their leaves. The deciduous species *S. ciliata*, *Ziziphus mucronata*, *Asparagus laricinus*, *Asparagus suaveolens* and *Ehretia alba* were considered to be important to the food supply of kudu in the study area during the critical period as these retained some leaves until the time when *V. karroo* trees produced immature leaves. The critical period for browsers ended with the emergence of immature leaves on most *V. karroo* trees.

The diet composition and food preferences of kudu varied according to food quality and availability. Although the kudu population's annual diet consisted of mostly woody browse, a considerable amount of grass was consumed from November to March. Kudu also changed their diet selection from mostly deciduous woody species during the growing season to mostly evergreen species during the dry season. In addition to this, kudus' food preferences changed throughout the year due to the timing of leaf emergence and leaf fall in woody species. Significant differences were also observed between the diets of cows and socially mature bulls, especially during the dry phases. The tree and shrubs species mostly utilised by kudu were *V. karroo, S. burchellii, Z. mucronata, S. ciliata* and *E. alba,* comprising 55.75% of the kudu population's annual diet.

Kudu home ranges were the smallest during the critical period of lowest food availability, with kudu concentrating in the areas close to or on the hills where most of the remaining food was available in the form of evergreen woody species. After the critical period, kudu home ranges increased with increased food availability. Although the habitat selection of kudu was affected by food availability, cover also played an important role in determining their habitat preferences. Kudu showed a definite preference for areas with high woody canopy cover throughout the year, often trading food for more cover. Kudu habitat selection also changed markedly between day and night time, with kudu selecting areas dominated by their preferred food items during the day and areas with more cover, but less of their preferred food items at night. The selection of areas predominantly for feeding or resting was further confirmed by the fact that kudu were less active at night, as they travelled shorter distances during the night compared to the day. Topography also became important in the habitat selection of kudu during the coldest part of the year, with kudu escaping the worst cold by moving to the hills, especially at night when temperatures dropped to well below freezing point.

Faecal nitrogen values of monthly collected fresh faecal samples of both adult kudu cows and socially mature kudu bulls provided a good indication of when kudu might have experienced nutritional stress. The faecal nitrogen (N_f) concentrations of both adult cows and socially mature bulls were generally much higher during the growing season and decreased as the dry season approached. The lowest N_f concentrations were mostly recorded during the critical period between July and September each year.

Based to the calculated browsing capacity, the study area was overstocked in terms of browsers during 2014. The number of browsers should thus have been reduced to avoid damage to the browse resource and possible game losses. The alternative option would have been to supply animals with enough feed to sustain them through the critical period. However, the current feeding programme should be adjusted to reduce competition at the feeding troughs.

A proper habitat evaluation is important to determine the suitability of fenced areas for kudu in the central Free State. A sufficient amount of evergreen woody species should be available for kudu to survive the critical period, with most evergreen species growing on or in the vicinity of hills in the central Free State. Hills also provide an escape from the worst cold during the winter and could possibly reduce mortalities of kudu already in weak physical condition. Woody canopy cover is also important to consider, as kudu showed preference for areas with higher cover throughout the year. However, before stocking an area with kudu it is important to first determine the grazing and browsing capacity of each available plant community. Palatability of woody species, the minimum herd size of kudu, kudu sex ratio, home range size of kudu and other game species already stocked should also be considered. It must, however, be kept in mind that the grazing and browsing capacity of an area is only an approximation and that the physical condition of the animals need to be constantly monitored to make final adjustments.