THE MANAGEMENT OF EXTRALIMITAL GIRAFFE (*GIRAFFA CAMELOPARDALIS*) IN THE MOSAIC THICKET OF THE SOUTHERN CAPE, SOUTH AFRICA

Andri Judith Cornelius

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Supervisor: Dr. L.H. Watson
Co-Supervisor: Mr. A.G. Schmidt

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ABSTRACT

The giraffe at Nyaru were found to be browsers who made little use of graze during the study period. They utilized a diversity of 20 browse species. Two species, *Acacia karroo* and *Acacia cyclops*, formed the bulk of the giraffe diet throughout the year. A definite seasonal dietary shift was evident. *A. karroo* was favoured in summer and autumn and formed the main food species in spring, summer and autumn. *A. cyclops* was favoured throughout the study, but its contribution to the diet increased during winter when less *A. karroo* was consumed. This seasonal shift is related to the deciduous nature of *Acacia karroo*. Although a seasonal shift in species contribution to giraffe diet has been observed in many other giraffe feeding studies, no studies on giraffe feeding have been done in the Mosaic Thicket of the southern Cape.

The ecological browsing capacity for giraffe in thicket was estimated to be between 0.020 BU/ha and 0.095 BU/ha. The browsing capacity for giraffe at Nyaru, based on the available phytomass 2–5 m above the ground, was estimated using those species that formed the bulk of the giraffe diet, and amounted to 0.063 BU/ha. A maximum of three giraffe could thus be stocked on the 157 ha of suitable giraffe habitat on Nyaru. This stocking rate recommendation lies within the range commonly recommended by local consultants for giraffe introductions into the southern Cape. Their recommendations are, however, not based on quantitative assessments such as performed in this study. The recommendation of this study should not be applied as a fixed ecological capacity for giraffe in thicket, but should be seen as a starting point in the adaptive management cycle. Ongoing monitoring of parameters, such as herbaceous composition and phytomass; as well as the condition of key browse species, is strongly advocated.

A. karroo was browsed significantly more and carried significantly fewer pods per tree at a heavily used site compared to a lightly used site. Heavy browsing thus appears to affect the reproductive success of *A. karroo* significantly. Fewer pods are likely to lead to lower regeneration and thus reduced density of *A. karroo.* Whether *A. karroo* will maintain its dominance within the thicket

community in the long run will be related to how individual plants survive and reproduce and if some can escape from herbivory.

Fewer *G. occidentalis* were clumped with other species at the heavily used site compared to the lightly used site. This could possibly be attributed to the fact that intense browsing pressure at the heavily used site caused protective clumps to be eaten away, thus exposing *G. occidentalis* to higher ungulate browsing. Previous studies have found that nurse shrubs protect *G. occidentalis* against ungulate browsing. *G. occidentalis* was browsed significantly more at the heavily used site compared to the lightly used site. There was a general trend of fewer fruits at the heavily used site compared to the lightly used site, while fruits were absent on *G. occidentalis* growing alone at the heavily used site. This suggests a negative effect of heavy browsing on plant reproductive success and emphasizes the importance of nurse plants for the successful recruitment and hence long term prevalence of *G. occidentalis* in Mosaic Thicket.

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DECLARATION

I, Andri Judith Cornelius with student number 207041444, declare that this thesis is my own, original work and that it has not been submitted for a degree to any other university.

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Andri Judith Cornelius

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

Conservation efforts in recent years have shifted from the conservation of specific species to the conservation of biodiversity (Margules and Pressey 2000). Managing the introduction of extalimital species is an important aspect of biodiversity conservation as it is imperative to understand how introduced species impact on ecosystems (Castley *et al.* 2001; Margules and Pressey 2000).

In this thesis, management aspects of extralimital giraffe in Mosaic Thicket of the southern Cape are explored. Previous studies on extralimital giraffe introductions were conducted in the Free State (Theron 2005), KwaZulu Natal (Bond and Loffell 2001), as well as in the Solid Thicket of the Eastern Cape Province (Jacobs 2008; Parker and Bernard 2005; Parker *et al.* 2003). Although there has been a recent trend of increased giraffe introductions into the southern Cape, no work has been done on this. The broad aim of this study is to facilitate the management of giraffe in the southern Cape and has the following objectives: To determine giraffe diet composition and preference in Mosaic Thicket; to estimate the ecological browsing capacity of Mosaic Thicket for giraffe; and to determine the impact of browsing on two palatable thicket species.

This dissertation is structured as follows: Chapter 1 is a general introduction to giraffe taxonomy, giraffe distribution and giraffe introductions into the southern Cape and introduces each of the research chapters (Chapter 2–4), focusing on the objectives given above. Chapter 2–4 are the four research chapters of the thesis. Chapter 5 is a concluding chapter that discusses management implications and potential suggestions for future research.

1.2 GIRAFFE TAXONOMY

The family Giraffidae is represented by two living genera, each with a single species: the okapi (*Okapia johnstoni*), occurring in the lowland forests of East Africa and the Democratic Republic of Congo, and the giraffe (*Giraffa camelopardalis*), which has a wide distribution in sub-Saharan Africa, although it has been eradicated in many parts of its range through over-exploitation (Skinner and Chimimba 2005).

Several species of giraffe were once recognised, but it is generally accepted today that they are all subspecies of *Giraffa camelopardalis* and thus the genus is now considered monospecific (Dagg 1971). According to Skinner and Smithers (1990), two sub-species occur in southern Africa, namely *Giraffa camelopardalis capensis* which occurs in the Mpumalanga Province of South Africa, southwestern Mozambique and southern and south-eastern Zimbabwe, and *Giraffa camelopardalis angolensis* from northwestern Zimbabwe, northern Botswana and northern Namibië. However, Skinner and Chimimba (2005) indicated that the subspecies are regional polymorphisms since the variants are not isolated reproductively.

1.3 GIRAFFE DISTRIBUTION

Giraffe were once widespread throughout Africa, but presently their distribution is discontinuous from South Africa to West Africa (Skinner and Chimimba 2005). Poaching, settlement and diseases such as rinderpest, have contributed substantially to their local disappearance (Skinner and Chimimba 2005).

In southern Africa, populations of giraffe are naturally distributed through savanna and open grassland areas in the northern parts of South Africa, Namibia, Botswana, Mozambique and Angola (Skinner and Chimimba 2005; Dagg and Foster 1976). They favor open or dry savanna habitats where visibility is good and where they are less prone to predation (Skinner and

Chimimba 2005). Giraffe do not occur in forests and are not commonly associated with open plains (Skinner and Chimimba 2005). Their occurrence depends on the availability of the range of food plants that are necessary to sustain them seasonally (Skinner and Chimimba 2005).

Skead (1987) claims that Namaqualand in the north-western Cape is the most southern district in which giraffe have been known to occur in historical times. However, according to Skinner and Chimimba (2005), it is doubtful whether giraffe ever occurred south of the Komati River. In South Africa, giraffe occurring in areas outside of the Kruger National Park are most likely the result of introductions after they became locally extinct (Owen-Smith 1988). Despite fossil records from the Western Cape Province (of which the given locality is doubtful), giraffe were not recorded along the southern seaboard of South Africa (Skead 1987; Boshoff *et al.* 2007). There is no earlier physical evidence of giraffe in the southern Cape and the species can thus be regarded as extralimital in the region. Today, giraffe have however been introduced to several private game farms in the southern Cape.

1.4 GIRAFFE INCIDENCE IN THE SOUTHERN CAPE

Extralimital species are frequently introduced to areas outside of their natural distribution range to artificially increase local diversity and improve the economic viability of wildlife operations (Castley *et al.* 2001; Daehler and Gordon 1997). However, according to Castley *et al.* (2001), it appears as if the ecological, as well as economic costs outweigh the benefits. The introduction of extralimital species may artificially increase local diversity (Angermeier 1994) but it poses an increasing global threat to biodiversity (Castley *et al.* 2001). These species compete with indigenous species for habitat and food resources and can displace local populations (Clavero and Garcia-Berthou 2005). This could lead to the extinction of indigenous species (Clavero and Garcia-Berthou 2005). Species loss within habitats results in less complexity and diversity of natural areas and a resultant loss of biodiversity (Naeem *et al.* 1994).

Giraffe are herbivorous mammals with males exceeding 1000 kg and are thus classified as browsing mega-herbivores with high energy requirements (Owen-Smith 1988). Although giraffe are extralimital to the southern Cape, the species is continuously introduced to the region. Short term commercial benefits are arguably the main driving force behind these introductions as foreign tourists associate giraffe with the "African wildlife experience" (Castley *et al.* 2001). The ecological impact of giraffe needs to be addressed in order to make management decisions on the future of giraffe in the southern Cape and the conservation of the indigenous vegetation. Tourism could potentially increase the income of the region, but must be viewed in terms of ecological sustainability (Castley *et al.* 2001).

Considering the above, it was deemed necessary to determine the current status of extralimital giraffe in the southern Cape, especially in the Gouritz Iniative (GI) planning domain. The GI planning domain (Figure 1.1) is an area of overlap of four sub-regions of southern Africa, each of which has received international funding to develop conservation and sustainable land use plans, namely Cape Action for People and the Environment (CAPE), Succulent Karoo Ecosystem Plan (SKEP), Subtropical Thicket Ecosystem Plan (STEP) and the Garden Route Initiative (GRI) (Lombard and Wolf 2004). Two of these sub regions (the Cape Floristic Kingdom and the Succulent Karoo) have been classified as global biodiversity hotspots, and have thus received international recognition and funding (Lombard and Wolf 2004). The GI planning domain supports a diversity of vegetation types (half of which are endemic to the planning domain), as well as a rich faunal diversity (Lombard and Wolf 2004).

To obtain an overview of giraffe incidence in the GI planning domain, a list of landowners with permits for giraffe was obtained from CapeNature. However,

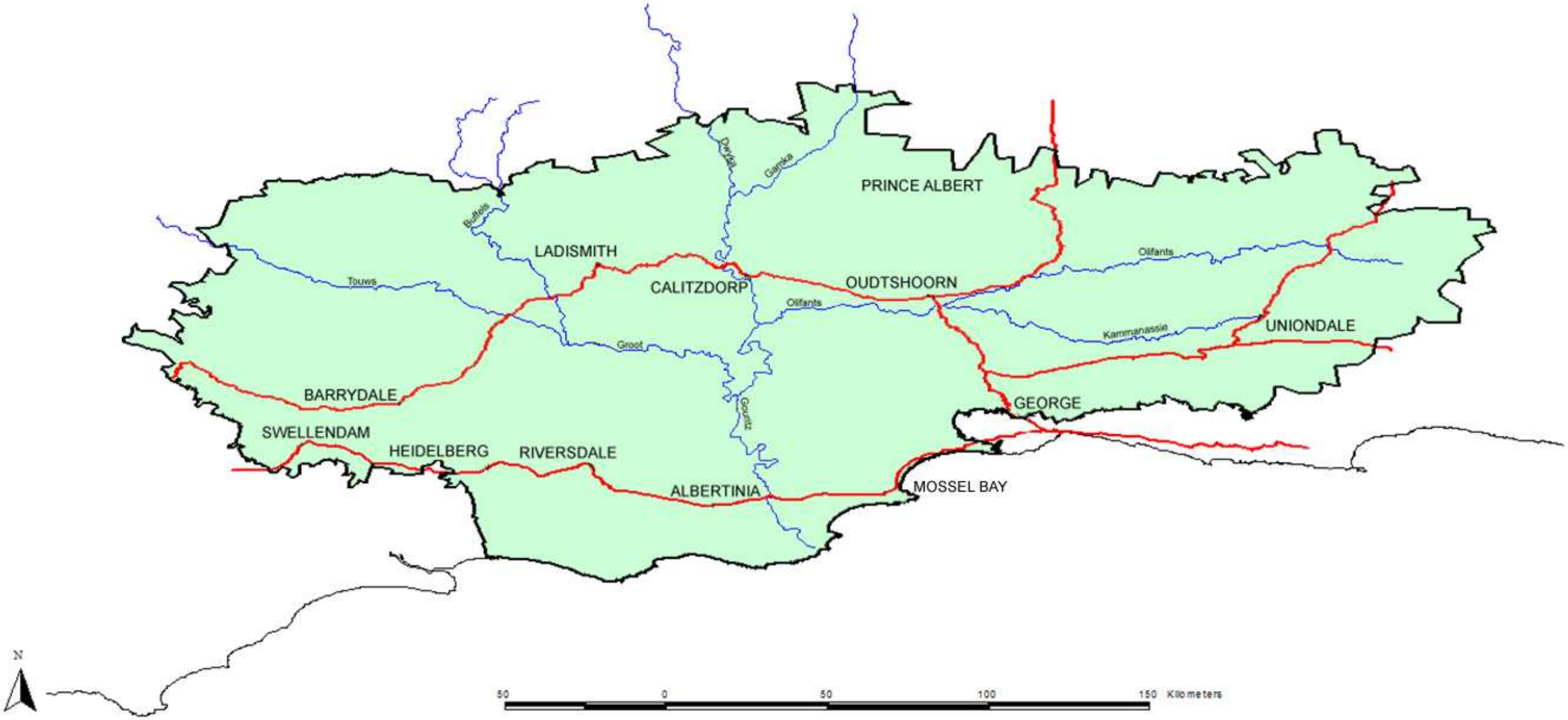

Figure 1.1: The Gouritz Initiative planning domain (adapted from Lombard and Wolf 2004).

not all landowners owning giraffe had valid permits, but it was possible to get hold of owners without permits through other owners, and they were therefore included in the survey. A simple questionnaire was drawn up to be answered by each owner/manager (Appendix 1.1). Each property was visited and the owner/manager interviewed. Details on the properties where giraffes have been introduced were obtained. These include the size and the vegetation composition of the property, the use of supplementary feeding and information on water availability. Information on the giraffe (numbers, sex ratio's and population trends) were also acquired.

In total, 19 properties were surveyed. Tourism was the main objective of most of the properties (73.7 %; Table 1.1), while 21.1 % of the properties had game farming and own enjoyment as objectives (Table 1.1). Conservation and hunting were less popular management objectives at 10.5 % (Table 1.1). Of the properties, 47.4 % made use of supplementary feeding (Table 1.1). Of the properties, 94.8 % had perennial water available all over, while 5.2 % had limited, non-perennial water available (Table 1.1).

On 52.6 % of the properties, giraffe occurred in a mosaic of Southern Cape Valley Thicket and Arid Spekboom veld (Table 1.1). On 36.8 % of the properties giraffe occurred in a mosaic of Southern Cape Valley Thicket, Blanco Fynbos and Herbertsdale Renosterveld (Table 1.1). A single property (5.3 %) consisted of Arid Spekboom veld only. Another property, positioned on the coastline outside the planning domain in the southeast, was also included in the survey. This property consisted of Coastal Fynbos, old farmlands and indigenous forests (5.3%; Table 1.1). Stocking density varied greatly between the properties, ranging from 30 to 1650 ha per giraffe.

There was a total adult sex ratio of 45 males to 47 females (Table 1.1). In total, 25 males were born, while only 12 females were born (Table 1.1). A total of 21 giraffe have died on the properties (Table 1.1). Of this, 81.0 % died of unknown causes, 4.8 % were struck by lightning, 9.5 % fell and broke their backs and 4.8 % drowned (Table 1.1).

Table 1.1: Data regarding objectives, water provision, supplementary feeding, veld types and stocking rates, sex ratios and mortalities of giraffe on Private Game Reserves in the Gouritz Initiative planning domain. Percentages are given in brackets. Percentages do not add up to 100 % due to properties having several objectives. Nomenclature is according to Vlok and Euston Brown (2002).

Objectives	Tourism	Personal enjoyment	Game farming	Conservation	Hunting
	14 (73.7)	4 (21.1)	4 (21.1)	2 (10.5)	2 (10.5)
Water	Abundant	Limited			
	18 (94.8)	1 (5.2)			
Supplement feeding	Yes	No			
	9 (47.4)	10 (52.6)			
Veld types	Arid Spekboom veld	Southern Cape Valley Thicket/ Arid Spekboom veld	Southern Cape Valley Thicket/ Blanco Fynbos	Coastal Fynbos/ Forest margins	
	1 (5.3)	10 (52.6)	7 (36.8)	1 (5.3)	
Stocking rates	Ranged from 30 – 1650 ha/giraffe				
Sex ratios	Male	Female			
Adults	45 (48.9)	47 (51.1)			
Juveniles	24 (67.6)	11 (32.4)			
Number of mortalities	21				
Causes of mortalities	Unknown	Striked by lightning	Drowned	Fell and broke bones	
	17 (81.0)	1 (4.8)	1 (4.8)	2 (9.5)	

1.5 DIET COMPOSITION AND PREFERENCE

1.5.1 DIET COMPOSITION

The diet selection of large mammalian herbivores can be defined as the selection of a diversity of plant species from an abundance of food items in the environment (Pellew 1984a). Large differences occur in the nutritional qualities of available plant species for herbivore consumption between season, between species and between different plant parts (Senft *et al.* 1987; Owen-Smith and Novellie 1982). To compensate for these variations, herbivores adapt certain aspects of their feeding behaviour in order to achieve the daily nutrient and energy requirements that they need for reproduction and maintenance (Pellew 1984a). These aspects include the choice of habitat in which they feed, the plant species and plant parts they feed on and the time allocated to feeding in comparison to other energy consuming activities (Pellew 1984a; Johnson 1980). The combination of these factors that maximizes the nutrient and energy intake of the herbivore can be regard as the optimal foraging strategy (Pellew 1984a).

According to the proportion of browse or grass in the diet, Hofmann and Stewart (1972) and Hofmann (1989) classified African ruminants as grazers, intermediate feeders and browsers. Giraffe are classified as browsers (Hofmann 1989; Hoffman and Stewart 1972) feeding predominantly on leaves and shoots from trees and shrubs (Du Toit 1988; Pellew 1984a; Leuthold and Leuthold 1972).

Giraffe diet composition has been recorded in a wide range of vegetation types within and beyond their natural distribution range (Parker and Bernard 2005; Theron 2005; Parker *et al.* 2003; Du Toit 1988; Pellew 1984a; Sauer *et al.* 1977; Van Aarde and Skinner 1975; Leuthold and Leuthold 1972), but no studies of giraffe diet composition have been done in the Mosaic Thicket of the southern Cape. Mosaic Thicket forms part of the Thicket Biome (Lubke 1996) that can be categorized broadly into Solid Thicket and Mosaic Thicket (Vlok and Euston Brown 2002). Mosaic Thicket is considerably fragmented and displaced by renosterveld, fynbos and Succulent Karroo in the southern Cape (Hoare *et al.* 2006; Vlok and Euston Brown 2002). In Chapter 2, the diet composition of giraffe in Mosaic Thicket is studied at the plant form and plant species levels.

1.5.2 DIET PREFERENCE

Large mammalian browsers are surrounded by a variety of woody species while feeding. Some plant species are however more utilised than others (Owen-Smith 1982). The likelihood of a plant species being eaten when encountered by a herbivore can be defined as the acceptability of that plant species to the herbivore (Owen-Smith and Cooper 1987a; Watson and Owen-Smith 2002). Although the morphology, digestive physiology and body size of a large mammalian herbivore places constraints on the acceptability of plant species to the herbivore (Du Toit and Yetman 2005; Owen-Smith 1982), selection is largely governed by the chemical properties of the plant, such as nutrients and secondary metabolites (Furstenburg and Van Hoven 1994; Cooper *et al.* 1988; Du Toit 1988; Owen-Smith and Cooper 1987a; Cooper and Owen-Smith 1985), and structural properties, such as thorns, spines or toughness of leaves (Wilson and Kerley 2003; Sasaki *et al.* 2001; Cooper and Owen-Smith 1986; Pellew 1984b). The growth stage of the plant, soil nutrients, light availability and previous defoliation history can also play a role (Owen-Smith and Cooper 1987a). The term palatable refers to plant parts readily eaten when accessible, while reduced palatability implies the presence of chemical deterrents affecting smell, taste or texture (Owen-Smith and Cooper 1987a). Forage preference may thus represent an attempt by the browser to restrict their intake of fibre and plant secondary compounds, while maintaining metabolic requirements for energy and protein.

Giraffe utilize a wide variety of woody plants, but prefer high protein shoot tips (Pellew 1984a) and will feed on pods and flowers when available (Du Toit 1988). It is generally accepted that giraffe prefer deciduous species over evergreen species (Kok and Opperman 1985; Sauer *et al.* 1977; Van Aarde and Skinner 1975).

Some measure of comparative preferences is required in order to classify plant species in terms of their value as food resources for a herbivore species (Owen-Smith and Cooper 1987b). Principle food refers to those species that form the bulk of the diet and preferred food refers to plant species that are ingested in a greater proportion than their representation in the community (Grunow 1980; Petrides 1975). Less preferred food may make up the bulk of the diet because those species are the only ones available (Petrides 1975). On the other hand, highly preferred food may form only a small portion of the diet composition because it is difficult to find (Petrides 1975).

A number of methods have been developed to measure herbivore species preference (Caister *et al.* 2003; Owen-Smith and Cooper 1987b; Johnson 1980; Chesson 1978; Ivlev 1961). In Chapter 2 these methods are reviewed and the method of Caister *et al.* 2003 is used to measure giraffe browse species preference in Mosaic Thicket.

1.6 BROWSING CAPACITY

Concepts in wildlife management have advanced from a focus on individual species (before 1950) to an ecosystem management approach, with biodiversity, including structure, composition and function, being focal (Carruthers and Boshoff 2008). In the 1960's, scientists attempted to stabilize, maintain, and engineer the ecosystems managed in South African protected areas (Phillips 1959). This demand-and-control methodology was flawed in that the intention was to maximize production or gain stability, not taking resilience and long-term survival into account (Denison *et al.* 2003).

By the 1970's a new way of thinking emerged as the complexity of systems was acknowledged (Biggs and Rogers 2003). This way of thinking provided for a series of varying stable states that change over time, with vegetation dynamics being difficult to predict, reflecting the realities faced by researchers and management in the field (Carruthers and Boshoff 2008; Walker 1993). Instead of seeking one ultimate stable state towards which an ecosystem would progress, complexity raised the possibility of different outcomes

(Carruthers and Boshoff 2008). Scale and heterogeneity (spatial variation) thus became critical in the management of ecosystems (Biggs and Rogers 2003; Urban *et al.* 1987). This style of decision making for natural resource management deals with complexity and uncertainty by a process of questioning and testing, called adaptive management, and supports the concept of ongoing learning (Carruthers and Boshoff 2008; Biggs and Rogers 2003; Stuart-Hill 1989). This paradigm is characterised by feedback continuously influencing action (Carruthers and Boshoff 2008).

With a shift in focus towards recognizing that ecosystems are complex, heterogeneous and constantly changing in time and space, many ecologists have begun to consider the concept of a long-term stable carrying capacity as being of minimal value (Cowling 2000). An approach to managing animal numbers in accordance with their impact on vegetation through the process of adaptive management is currently advocated (Carruthers and Boshoff 2008).

In Chapter 3, the browsing capacity of the study area for giraffe is estimated with the use of a quantitative approach based on the procedure of Trollope *et al.* (2004). This should however, not be considered a long-term stable estimate for the region. At best the estimate is only a first approximation of what the vegetation in the study area can carry. The estimate will, however, provide decision makers, such as Cape Nature and landowners, with a starting point on which to base initial giraffe stocking rates. Thereafter it is advocated that giraffe numbers be managed through continuous probing, testing and monitoring.

1.7 THE IMPACT OF BROWSING ON *ACACIA KARROO* AND *GREWIA OCCIDENTALIS*

Mosaic Thicket forms part of the Thicket Biome (Lubke 1996), which has been identified as a highly threatened resource (Lubke *et al.* 1986). A number of studies have drawn attention to the widespread degradation of this biome (Lechmere-Oertel *et al.* 2005; Lechmere-Oertel 2003; Lloyd *et al.* 2002; Kerley *et al.* 1995). Kerley and Boshoff (1997) reported that only 4.5 % of the

Thicket Biome is conserved nationally. Transformation of thicket in response to herbivory is widespread and results in a significant loss of plant and functional diversity (Lechmere-Oertel *et al.* 2005). Heavy browsing causes a considerable reduction in the biomass and structural complexity of the vegetation and the canopy tree guild in transformed thicket are unstable due to ongoing adult mortality and little successful recruitment (Lechmere-Oertel *et al.* 2005). Restoration of transformed thicket does not occur spontaneously, even with complete resting from herbivory (Vlok *et al.* 2003). Lechmere-Oertel *et al.* (2005) suggested that the pseudo-savanna typical of transformed thicket is not a stable alternative state to intact thicket, but rather an intermediate stage on the way to a highly desertified state. In a state of extreme transformation, a depleted and dying canopy tree layer is all that remains of the original perennial vegetation (Lechmere-Oertel *et al.* 2005). Large areas of thicket have already suffered extensive degradation (La Cock *et al.* 1990; Lloyd *et al.* 2002), yet many landowners are unconcerned by the transformation perceived by independent experts (Lechmere-Oertel *et al.* 2005; Bothma 1990). According to Bothma (1990), some landowners even believe that transformed thicket is a more productive state than intact thicket. The continuous existence of intact thicket is therefore under constant threat from agriculture and unsustainable game farming (Lechmere-Oertel 2003; Lechmere-Oertel *et al. 2*005).

In Chapter 4, the impact of browsing of two species, *Acacia karroo* and *Grewia occidentalis,* occurring in Mosaic Thicket, are investigated. The proportional utilization and reproductive success of the species are compared between a lightly used site and a heavily used site in similar thicket vegetation. *Acacia* species are prevalent in the diet of giraffe within and beyond their natural distribution range (Parker and Bernard 2005; Theron 2005; Parker et al. 2003; Du Toit 1988; Kok en Opperman 1980; Hall-Martin 1974; Leuthold and Leuthold 1972). *Grewia occidentalis* is classified as a palatable species (Watson and Owen Smith 2002) that commonly occurs in Mosaic Thicket (Hoare *et al.* 2006). This species is unarmed and consequently heavily browsed by ungulates (Watson and Brown 2001;

Watson 1999). The influence of bush clumps on the utilization and reproductive success of *G. occidentalis* in Mosaic Thicket is also investigated.

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CHAPTER 2: DIET COMPOSITION AND PREFERENCE

2.1 INTRODUCTION

Foraging behaviour is an important ecological process that describes the relation between plant communities and herbivores (Spalinger *et al.* 1997). This behaviour is affected by various plant characteristics such as plant availability, plant chemical composition and plant defence; as well as animal factors including body size, digestive physiology, and experience (Bryant *et al.* 1991; Pellew 1984a; Owen-Smith 1982). The feeding strategy of a herbivore is continually modified as the availability and nutritional quality of food items varies seasonally and between and amongst species (Owen-Smith 1994; Senft *et al.* 1987; Pellew 1984a). The diet assessment of herbivores is thus important for the understanding of resource requirements and provides insight into herbivore impacts on an ecosystem (Bookhout 1996). This is an important aspect of managing habitats as well as animal populations (Parker and Bernard 2005; Spalinger *et al.* 1997).

Giraffe are mega-herbivores that are classified as predominantly browsers (Hofmann and Stewart 1972; Hofmann 1989). They almost exclusively browse on leaves and shoots from trees and shrubs (Parker and Bernard 2005; Theron 2005; Parker *et al.* 2003; Hofmann 1989; Du Toit 1988; Pellew 1984a; Leuthold and Leuthold 1972). Seasonal variation in the diet of giraffe is evident within and beyond their natural distribution range (Theron 2005; Parker and Bernard 2005; Du Toit 1988; Kok and Opperman 1985; Pellew 1984a). These seasonal changes in diet are associated with changes in the phenology of the food species (Du Toit 1988; Kok and Opperman 1985; Pellew 1984a). The leaves of deciduous trees and shrubs are mostly utilized in the wet season, while leaves of evergreen species are utilized in the dry season when preferred species decrease in abundance (Theron 2005; Parker and Bernard 2005; Du Toit 1988; Kok en Opperman 1980; Sauer *et al.* 1977; Van Aarde and Skinner 1975; Hall-Martin 1974; Leuthold and Leuthold 1972). Giraffe generally feed on those species with the greatest quantity of new leaf and shoot material in any given month due to their higher protein content (Pellew 1984a; Hall-Martin and Basson 1975). Studies have found *Acacia* species to be prevalent in the diet of giraffe (Parker and Bernard 2005; Theron 2005; Parker *et al.* 2003; Du Toit 1988; Kok en Opperman 1980; Hall-Martin 1974; Leuthold and Leuthold 1972).

Sauer *et al.* (1982) suggested that the acceptability of plant species to giraffe is largely dependent on the crude protein contents of the leaves. Du Toit (1988) and Pellew (1984b) suggest that giraffe have the facultative ability to cope with relatively high doses of plant secondary compounds. Giraffe produce proline-rich salivary proteins which could possibly be effective in deactivating tannins (Du Toit 1988). However, Furstenburg and Van Hoven (1994) suggest that an increase in condensed tannin content may be a means by which some *Acacia* species regulate the duration of giraffe browsing. Levels of condensed tannins in foliage increased markedly shortly after the onset of giraffe browsing and caused the animals to browse an individual tree for only a few minutes before moving on (Fursterburg and Van Hoven 1994). Caister *et al.* (2003) found that giraffe bulls and non-nursing cows prefer food with a high protein and fat content, while nursing cows exhibit an avoidance of tannins. According to Hofmann (1989) giraffe are equipped with a digestive system that is not suited to optimize plant fibre digestion. The fibre contents of plants, including cellulose, hemicelluloses and lignin, thus influence the digestibility of plants species to giraffe (Hofmann 1989). Pellew (1984b) has shown that spinescence has no significant effect on the feeding of giraffe in the Serengeti. Giraffe have a characteristic feeding technique of stripping leaves with their mouth and tongue which minimizes the effect of spinescence on their feeding rate (Sasaki *et al.* 2001; Pellew 1984b).

Some measure of preference is required to assess the relative importance of chemical and structural factors on the acceptability of browse to herbivores (Owen-Smith and Cooper 1987a). To access this preference, the utilization of individual plant species needs to be related to its availability to the animal (Petrides 1975). A number of indices have been developed to measure food preference (Caister *et al.* 2003; Owen-Smith and Cooper 1987a; Johnson

1980; Chesson 1978; Ivlev 1961). The most widely used index is the forage ratio (Petrides 1975). The forage ratio is calculated by dividing the relative abundance of a food in the diet by its relative abundance in the environment. Foods that yield a ratio of higher than 1 are regarded as preferred while those that yield a ratio of lower than 1 are considered as being avoided (Petrides 1975). The forage ratio has several limitations: it varies irregularly between 0 and infinity and conclusions about whether a particular food is preferred or avoided depends on the food species that the researcher regards as being available to the herbivore (Owen-Smith and Cooper 1987a; Johnson 1980). Rare plants can thus commonly be reported as yielding the highest preference ratios, mainly because of statistical errors in estimating species abundance separately from feeding observations (Owen-Smith and Cooper 1987a). Johnson (1980) suggested that rank orders of preference among food types are more meaningful since food may be rated as preferred or avoided depending on the exclusion or inclusion of other food types in the analysis. Owen-Smith and Cooper (1987b) used acceptability indices to measure the preference of woody species to browsing ruminants. Acceptability indices have the advantage that food availability is assessed simultaneously with dietary intake, eliminating sampling errors in estimation of availability (Owen-Smith and Cooper 1987a).

In the present study, the approach of Owen-Smith and Cooper (1987b) was not possible because of the dense, intertwined and spiny nature of thicket vegetation that makes the assessment of food availability problematic (Trollope *et al.* 2004). Parker *et al.* (2003) had success in thicket in the Eastern Cape Province with the use of the strength-of-preference index of Caister *et al.* (2003). The advantage of the strength-of-preference index is that, unlike the forage ratio and variations thereof, it accounts for the variation in the availability of plant species in the habitat and for the proportion of a species in the diet (Caister *et al.* 2003).

Giraffe have recently been introduced onto a number of estates in the southern Cape, mainly where Mosaic Thicket is present. As giraffe are extralimital to the southern Cape (Skead 1987) it can be accepted that giraffe herbivory has not co-evolved with the thicket vegetation. Their diet assessment may therefore be particularly crucial for providing insight into the impact these herbivores have on the system. The objectives of the present study were as follows: (1) To determine giraffe diet composition in Mosaic Thicket. Diet composition was determined through the seasonal cycle at the plant form and species levels. (2) To determine the food preference of giraffe in Mosaic Thicket throughout the seasonal cycle. Since preference can be influenced by what is considered available, two variations, based on a density estimate of availability (Density preference index) and a biomass estimate of availability (Biomass preference index) were used in this study.

2.2 METHODS

2.2.1 STUDY SITE

2.2.1.1 Location and Topography

The study was conducted on a single private estate, Nyaru, in the southern Cape region of South Africa (Figure 2.1). The duration of the study was from June 2008 – May 2009. Nyaru is 429 ha in size and is situated approximately 15 km North-West of Mossel Bay and 55 km South-West of Oudtshoorn at 34˚03´S and 22˚01´E. The properties surrounding Nyaru consist of livestock and game farms.

The topography of the estate is variable, with hills and valleys supporting a variety of vegetation units. The land type of the area has been classified as the Wolwedans land type which is characterized by steep, dominantly southern facing slopes with incised valleys of rivers flowing mainly in a north-south direction (Schafer 1992). No true plains are present on the property. The altitude of the area ranges between 5–170 m above sea level (SA Geoscience 2000).

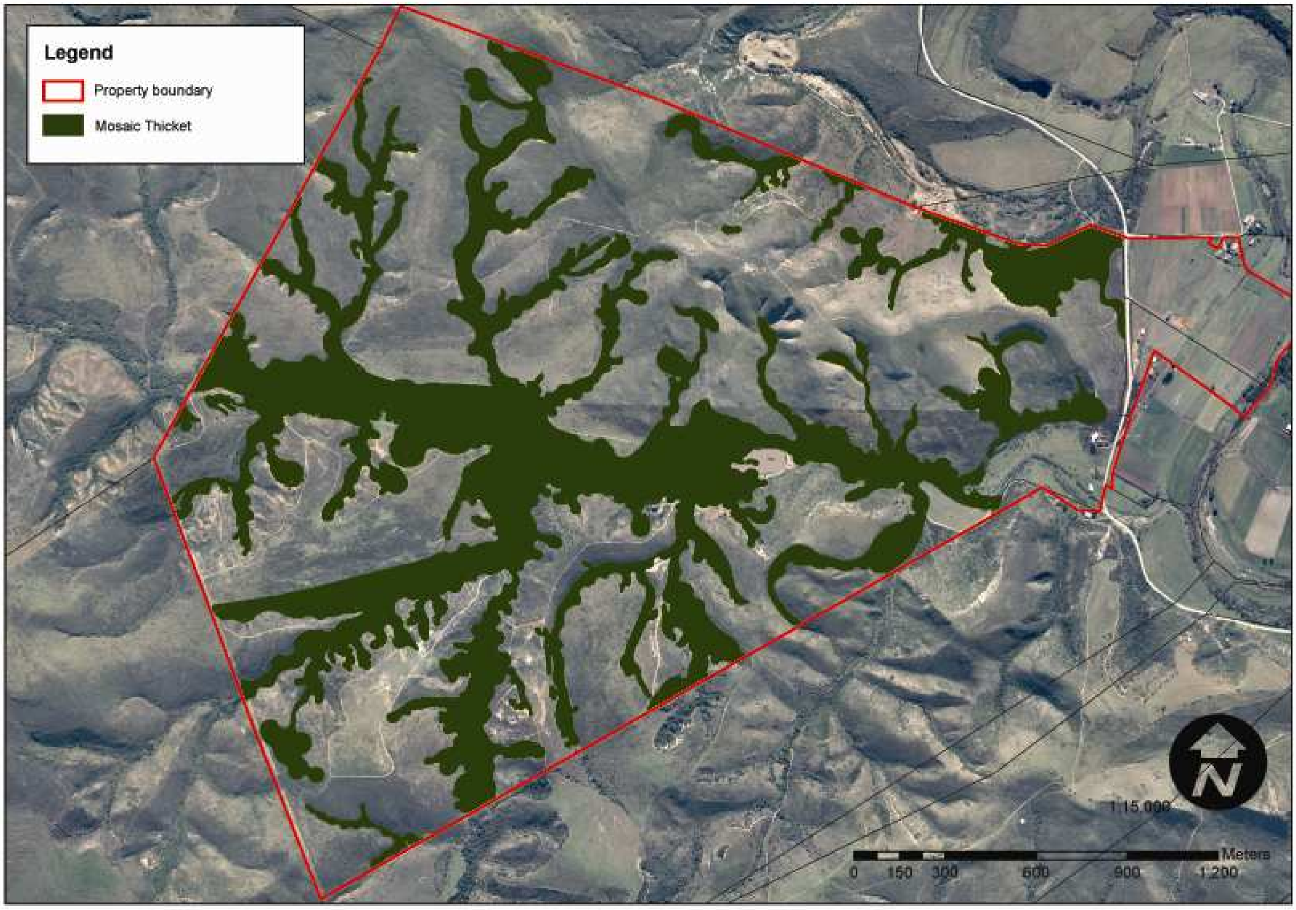

Figure 2.1: An aerial photograph of the private estate, Nyaru, indicating the boundary and the extent of thicket on the property (Google Earth 2007).

2.2.1.2 Geomorphology

The dominant geological formations of the area include Enon Conglomerates, similar younger deposits and clay lenses (SA Geoscience 2000; Deacon *et al.* 1983).

The residual soils in the area consist out of rubified duplex loams with structured clay subsoils of the Valsrivier form (SA Geoscience 2000). These soils are restricted to areas associated with Cretaceous clays and conglomerates or material derived from them (Deacon *et al.* 1983).

2.2.1.3 Climate and water

The proximity of the mountains to the coast in the region contributes to higher orographic rainfall and precipitation occurs in all seasons, although more frequently in winter or spring-autumn months (Hoare *et al.* 2006; Stone *et al.* 1998). The rainfall recorded at the Mossel Bay weather station for the one year study period was 401.2 mm, while the long term mean annual rainfall recorded for the period 1985–2009 was 539.8 mm (Figure 2.2). Rainfall in the southern Cape is not as seasonal as it is for other parts of southern Africa. This is ascribed to the area being a transition zone of climate types (Stone *et al.* 1998). Water is however abundant on the estate and available all year round via man-made dams. There are also non-perennial streams in the valleys that serve as water sources. Most of these streams do however dry up during periods of little or no precipitation.

Temperatures are mild or subtropical (Lubke *et al.* 1986). As the weather station in Mossel Bay only had three years of temperature data on record, long term mean temperature data was obtained from the George weather station. Mean daily temperatures over the period 1981–2009 varied between 11.2℃ and 21.4℃, with an annual mean of 16.3℃. The highest maximum temperature recorded from 1981–2009 was 41.3℃ while the lowest minimum temperature was -0.2℃.

2.2.1.4 Vegetation

Mosaic Thicket forms part of the Thicket Biome of South Africa as defined by Lubke (1996). The Thicket Biome forms the transition between the Nama-Karroo and the subtropical regions of the eastern seaboard of South Africa (Hoare *et al.* 2006). Thicket is by definition a dense growth of shrubs and trees, and clumping of the vegetation is a characteristic feature (Hoare *et al.* 2006). The vegetation is described in general as dense, woody, semi-succulent and thorny, of an average height of 2–3 m (Hoare *et al.* 2006). The Thicket Biome can be categorized broadly into Solid Thicket and Mosaic Thicket (Vlok and Euston Brown 2002) and consists of various major vegetation types, and a wide variety of plant communities with varying structure and species composition (Hoare *et al.* 2006). Mosaic Thicket is considerably fragmented and displaced by renosterveld and fynbos in the winter-rainfall zone and by grassland and savanna in the summer-rainfall zone (Hoare *et al.* 2006; Vlok and Euston Brown 2002). The vegetation incorporates a wide range of growth forms and a high diversity of plant species, including leaf and stem succulents, deciduous and semi-deciduous woody shrubs and dwarf shrubs, geophytes, annuals and grasses (Hoare *et al.* 2006; Cowling 1983). The understory generally consists of a diversity of dwarf succulent shrubs and forbs, of which many are locally endemic and rare (Hoare *et al.* 2006).

The thicket vegetation of the study area has been classified by Hoare *et al.* (2006) as Southern Cape Valley Thicket, here after referred to as thicket. This is the western most thicket type completely surrounded by the Fynbos Biome (Hoare *et al.* 2006). The vegetation on the estate consists of a matrix of Southern Cape Valley Thicket, Herbertsdale Renosterveld, here after referred to as renosterveld, and Blanco Fynbos, here after referred to as fynbos (Vlok and Euston-Brown 2002).

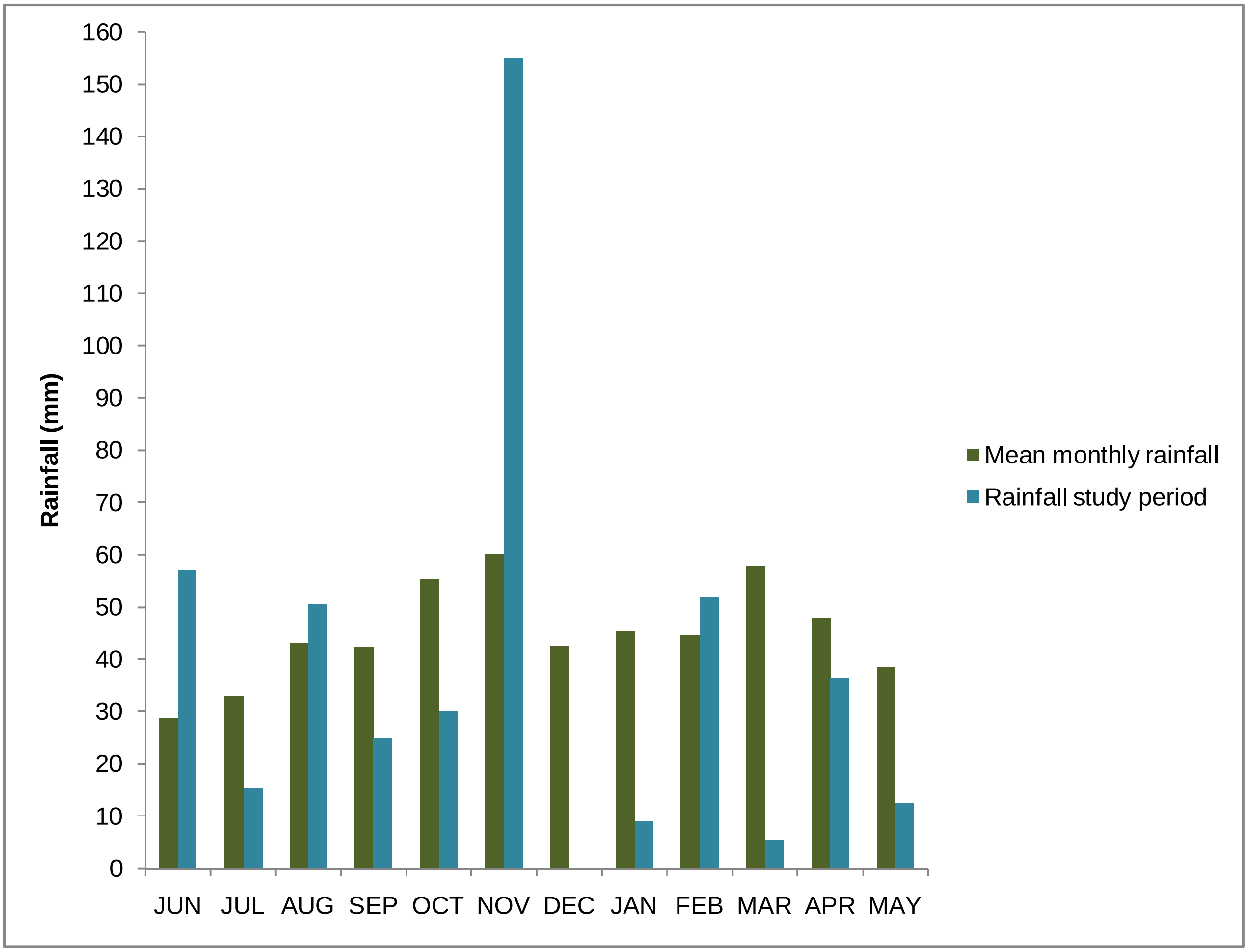

Figure 2.2: The long term mean monthly rainfall (1928–2009) and monthly rainfall for the study period (June 2008–May 2009) for the Mossel Bay area. The long term mean annual rainfall was 539.8 mm while the mean annual rainfall for the study period was 401.2 mm (South African Weather Service 2010).

The steep, rocky slopes, geomorphology and consequently poor soil development on which thicket occurs, create environmental conditions very different from the surrounding renosterveld and fynbos vegetation which typically covers the coastal plateaus of the Southern Cape (Hoare *et al.* 2006).

The vegetation consists of medium sized to tall (3–5 m), dense thicket composed of sclerophyllous (often spinescent) shrubs including *Euclea undulata, Grewia occidentalis, Gymnosporia nemarosa, Gymnosporia buxifolia, Putterlickia pyracantha, Rhus longispina, Rhus lucida, Rhus pyroides, Rhus tomentosa and Sideroxylon inerme* as well as a microphyllous (partly ericoid) shrub element, incuding *Anthanasia dentata, Elytropappus rhinocerotis, Oedera capensis* and *Stoebe plumosa*. The low shrub layer contains a high proportion of succulent shrubs. The grass component is not well developed, which, according to Vlok and Euston Brown (2002) may be an artefact of the present heavy grazing pressure on this vegetation type. Nomenclature is according to Vlok and Euston Brown (2002).

2.2.1.5 Study population

The study population consisted of eight adult giraffe, six females and two males. The group predominantly browsed collectively, but separated into smaller groups from time to time. Two female giraffe were sold during the year of data collection and one male calf was born.

2.2.1.6 Other ungulates

The estate appears to be overstocked by browsing ungulates. These include nyala (*Tragelaphus angasi*), impala (*Aepyceros melampus*), kudu (*Tragelaphus strepsiceros*), bushbuck (*Tragelaphus scriptus*), eland (*Tragelaphus oryx*) and common duiker (*Sylvicapra grimmia*). Grazing ungulates present on the property are black wildebeest (*Connochaetes gnou*), Cape Mountain zebra (*Equus zebra zebra*), bontebok (*Damaliscus pygargus pygargus*) and waterbuck (*Kobus ellipsiprymnus*).

2.2.2 DIETARY COMPOSITION

According to Parker and Bernard (2005) both direct observations and faecal analysis are appropriate techniques to assess the diet of giraffe. In the present study, direct observations of the diet of giraffe were conducted by adapting the interval scan method used by Parker and Bernard (2005). Direct observations requires little equipment; it permits the researcher to gain field experience that provides first-hand knowledge of feeding behaviour that cannot be replaced by laboratory work and literature; it provides information on the diet that would not otherwise be known (such as the consumption of fruit that are completely digested); and several studies have shown that direct observations of giraffe do not disturb their feeding habits or behaviour (Parker and Bernard 2005; Parker *et al.* 2003; Du Toit 1990; Pellew 1984a; Leuthold and Leuthold 1972).

Feeding data were recorded using a pair of 10 x 20 Zeiss binoculars for visual scans and a hand held computer for data input. Scans were made of the activities of all visible giraffe, recording the following: feeding, walking, standing, ruminating, and lying. When feeding, the plant species consumed and the height of feeding was recorded.

Feeding is the principle diurnal activity of giraffes (Theron 2005; Pellew 1984a), with intensity of feeding peaking during three hour periods post-dawn and pre-dusk (Pellew 1984a). A marked decline in feeding occurs during the mid-day period. Ruminating is the dominant nocturnal activity (Theron 2005; Pellew 1984a). On each day, the first group of giraffe encountered was observed to reduce observer bias and the habitat type in which they occurred was recorded. A feeding record is defined as each instance in which one plant species is consumed by one giraffe during a particular scan (Parker *et al.* 2003). Scans were made every minute for a period of six hours a day. The six hours of observations were split into two, three hour observation sessions twice daily; one in the morning and one in the afternoon. Four days of observations were made in each month and the months were grouped into seasons: Winter (June – August), Spring (September – November), Summer

(December – February) and Autumn (March – May). For each season there was thus a total of 72 hours of observations. In this time, 15 292 feeding observations were recorded.

The feeding records for each species consumed during a day of observations were summed and expressed as a percentage of all feeding records for that day. For each species, the seasonal mean percentage was calculated from the 12 days of observations. The non-parametric Kruskal-Wallis ANOVA and multiple comparisons test of mean ranks (Zar 1984) was used to determine if the proportional utilization of species was the same between seasons.

2.2.3 DIETARY PREFERENCE

Trees and shrubs (here after named shrubs) were the only vegetation used for preference calculations as giraffe mainly consumed shrub species (see below). For each season, the strength-of-preference index (Si) of Caister *et al.* (2003) was used to calculate preference indices for shrub species in the diet of giraffe:

$$Si = (di - vi)/100$$

where di is the percentage contribution of shrub species i to the diet and vi is the percentage availability of shrub species i in the field.

A positive value indicates that a plant species was favoured and a negative value indicates that a plant species was avoided (Caister *et al.* 2003).

Shrub species contribution to the diet of giraffe was assessed as described in section 2.2.2. Two variations were used to determine shrub species availability in the field, namely a density estimate of availability and a biomass estimate of availability. Accordingly, giraffe diet preference was assessed in two ways: (a) Density preference index – based on the density estimate of availability. (b) Biomass preference index – based on the biomass estimate of availability.

The density of browse species was obtained from a vegetation composition assessment (Chapter 3). Briefly, using the Point-Centred-Quarter method of Cottam and Curtis (1956), four transects were sampled in two homogenous thicket units. In each transect, 25 points were sampled at 10 m intervals, thus amounting to 100 sample points in each thicket unit. According to Trollope (2004), 25 points per sample site is sufficient to show major differences in the condition of vegetation between sample sites. At each point the closest individual plant in each quarter was sampled. For each shrub sampled, the species and the distance to the shrub (in meters) was recorded. The density of species i (P/ha) is expressed as the number of that species per hectare:

$$P/ha = 10000\ m^2/D^2$$

where D is the mean distance of that species from the recording points.

Biomass estimates were established by using the BECVOL (Biomass Estimates from Canopy Volume) method of Smit (1996). BECVOL calculations were done on the closest individual tree in the right front quadrate at each point. Seven measurements (in meters) were taken of each tree for the application of the BECVOL method (Melville *et al*. 1999): (a) Tree height. (b) Height of maximum canopy diameter. (c) Height of first leaves or leaf-bearing shoots. (d) Maximum canopy diameter on two perpendicular planes. (e) Basal diameter on two perpendicular planes. All measurements were based on living tree parts only. The information was then entered into the BECVOL computer program (Smit 1996) to calculate the phytomass of shrub species on Nyaru.

Species preference was only calculated for thicket shrubs since thicket was the habitat most often utilized by giraffe at Nyaru in any given season (see below). Only thicket shrubs utilized >1 % in the annual diet of giraffe were used for preference calculations (see Table 2.3).

2.3 RESULTS

2.3.1 DIETARY COMPOSITION

Although the sample size was small, on an annual basis thicket was the habitat mainly used (87 %) by giraffe throughout the year (Table 2.1). Renosterveld was used 10.7% and fynbos a mere 2.1% annually. In autumn, giraffe used thicket 98.6 %, while resosterveld was only used 1.4 % and fynbos was not used at all. The giraffe were observed to utilize the deciduous *A. karroo* distributed in the renosterveld while moving from one thicket area to the next and with *A. karroo* losing its leafs in autumn, giraffe utilized less of this species. The occurrence of giraffe in renosterveld increased in summer (17.8 %) when more *A. karroo* were utilized and flowers of *Bobartia orientalis*, also ocuring in renosterveld, were consumed (see below).

Browse contributed 98.5 % to the annual diet of giraffe, while other species formed only 1.5 % of the diet (Table 2.2). A very small proportion of the diet remained unidentified (0.1 %; Table 2.2). Although the recorded diet consisted of 20 browse species, only two species, *Acacia karroo* (60.5 %) and *Acacia cyclops* (27.7 %), formed the bulk of the annual diet of giraffe (> 88 %; Table 2.2). *Rhus lucida* contributed 2.8 %, *Grewia occidentalis* contributed 1.9 %, *Olea europaea* contributed 1.7 % and *Buddleja saligna* contributed 1.2 % to the annual diet (Table 2.2). All the other browse species contributed <1 % to the annual diet of giraffe (Table 2.2). The iris, *Bobartia orientalis,* contributed 1.4 % to the annual diet while unknown grass species contributed <1 % (Table 2.2).

A. karroo formed most of the food eaten during spring (67.1 %), summer (74.0 %), and autumn (73.9 %), but contributed significantly less to the diet during winter (27.0 %; Table 2.2). *A. cyclops* formed less of the food eaten during spring (24.1 %), summer (21.5 %), and autumn (17.3 %), but became significantly more important in winter (48.2 %; Table 2.2). *Rhus lucida* was significantly more important in winter (8.4 %) than in spring (2.2 %), summer (0.6 %) and autumn (0.2 %; Table 2.2). *Olea europaea, Buddleja saligna,* *Grewia occidentalis* and the iris, *Bobartia orientalis,* were consistently eaten throughout the recording period but at low proportions and none of them showing a significant difference in contribution between seasons (Table 2.2).

2.3.2 DIETARY PREFERENCE

With the use of the Density preference index, only two species (*Acacia cyclops* and *Acacia karroo*) were favoured by giraffe. *A. cyclops* was favoured in all seasons (preference ratings ranging from 0.160 to 0.469; Table 2.3), while *A. karroo* was favoured in spring (0.365), summer (0.434) and autumn (0.433; Table 2.3).

With the use of the Biomass preference index, five species (*Acacia cyclops, Acacia karroo, Grewia occidentalis, Rhus glauca* and *Olea europaea*) were favoured by giraffe. *Acacia cyclops* was favoured in all seasons (preference ratings ranging from 0.057 to 0.366; Table 2.3). *A. karroo* was favoured in summer (0.039) and autumn (0.038; Table 2.3). *Grewia occidentalis* was favoured in all seasons (preference ratings ranging from 0.003 to 0.021), and *Rhus lucida* (0.029) *and Olea europaea* (0.012) were favoured in winter (Table 2.3).

2.4 DISCUSSION

Giraffe are classified as predominantly browsers preferring leaves and shoots from trees and shrubs (Hofmann and Stewart 1972; Hofman 1989). Various studies have supported this classification (Parker and Bernard 2005; Theron 2005; Parker *et al.* 2003; Du Toit 1988; Pellew 1984a; Leuthold and Leuthold 1972). At Nyaru, thicket was the habitat mainly used by giraffe throughout all four seasons and browse formed 96.7% of the annual diet of giraffe. The proportion of grass in the diet of giraffe is characteristically low (Sauer *et al.* 1977; Van Aarde and Skinner 1975; Leuthold and Leuthold 1972), and the diet of giraffe on Nyaru was no exception with only 0.1% annually consisting of grasses. Giraffe typically eat a wide range of species (Parker and Bernard

Table 2.1: Seasonal habitat use of giraffe at Nyaru as determined by direct observations. Values are percentages. n = number of days of observations.

Vegetation	**Season**				
	Winter n = 12	Spring n = 12	Summer n = 12	Autumn n = 12	Annual n = 48
Southern Cape Valley Thicket	84.9	86.5	79.1	98.6	87.2
Herbertsdale Renosterveld	11.0	12.5	17.8	1.4	10.7
Blanco Fynbos	4.1	1.0	3.1	0	2.1
Total	100	100	100	100	100

Table 2.2: Seasonal frequency of occurrence of plant species (mean ± SD) in the diet of giraffe as determined by direct observations. Values are percentages. Columns do not add up to 100 due to rounding off. Codes: n = number of days of observations; d = deciduous; e = evergreen.

Species	Plant form	Winter n = 12	Spring n = 12	Summer n = 12	Autumn n = 12	Annual n = 48	Kruskal - Wallis[1] = $H_{3, 48}$
Browse							
Acacia karroo	d	27.0 ± 18.9 [a]	67.1 ± 24 [b]	74.0 ± 32.5 [b]	73.9 ± 16.8 [b]	60.5 ± 30.4	18.8**
Acacia cyclops	e	48.2 ± 20.9 [a]	24.1 ± 21.6 [ab]	21.5 ± 33.1 [b]	17.3 ± 13.8 [b]	27.7 ± 25.7	11.5*
Rhus lucida	e	8.4 ± 7.4 [a]	2.2 ± 2.8 [b]	0.6 ± 1.0 [b]	0.2 ± 0.5 [b]	2.8 ± 5.1	27.3**
Olea europaea	e	3.2 ± 3.9	1.9 ± 3.0	0.8 ± 1.2	0.9 ± 1.4	1.7 ± 2.7	5.9
Buddleja saligna	e	1.8 ± 3.7	0.7 ± 1.3	0.9 ± 0.6	1.2 ± 1.8	1.2 ± 2.2	4.3
Grewia occidentalis	e	1.2 ± 1.8	1.4 ± 1.7	2.0 ± 2.1	3.0 ± 3.9	1.9 ± 2.5	1.5
Scutia myrtina	e	0.1 ± 0.4	1.0 ± 3.3	0.0	0.0	0.3 ± 1.7	-
Gymnosporia nemorosa	e	0.4 ± 0.8	0.4 ± 0.7	0.0	0.0	0.2 ± 0.5	-
Rhus pyroides	e	0.8 ± 1.6	0.02 ± 0.1	0.0	0.6 ± 2.2	0.4 ± 1.4	-
Eriocephalus africanus	e	0.1 ± 0.3	0.1 ± 0.2	0.0	0.0	0.05 ± 0.2	-
Conyza scabrida	e	0.1 ± 0.2	0.0	0.0	0.0	0.02 ± 0.1	-
Opuntia ficus-indica	e	1.5 ± 4.0	0.0	0.0	0.0	0.4 ± 2.1	-
Schotia afra	e	1.2 ± 4.2	0.0	0.0	0.0	0.3 ± 2.1	-
Rhus tomentosa	e	2.4 ± 5.1	0.0	0.0	0.0	0.6 ± 2.7	-
Polygala myrtifolia	e	0.0	0.02 ± 0.1	0.0	0.0	0.01 ± 0.04	-
Clutia daphnoides	e	0.0	0.03 ± 0.1	0.0	0.0	0.01 ± 0.1	-
Sideroxylon inerme	e	0.0	0.02 ± 0.1	0.0	0.0	0.01 ± 0.04	-
Gymnosporia buxifolia	e	0.0	0.5 ± 1.0	0.1 ± 0.3	0.6 ± 2.1	0.3 ± 1.1	-
Carissa bispinosa	e	0.0	0.1 ± 0.2	0.0	0.0	0.03 ± 0.1	-
Rhus longispina	e	0.0	0.0	0.2 ± 0.6	0.4 ± 1.0	0.15 ± 0.6	-
Other							
Bobartia orientalis (Iridaceae)		3.1 ± 3.9	0.5 ± 1.4	0.5 ± 1.0	1.4 ± 3.6	1.4 ± 2.9	10.2
Grass spp.		0.3 ± 0.7	0.04 ± 0.1	0.1 ± 0.7	0.1 ± 0.3	0.1 ± 0.4	0.9
Unidentified		0.2 ± 0.4	0.02 ± 0.1	0.1 ± 0.2	0.3 ± 0.4	0.1 ± 0.3	
Total		**100**	**99.9**	**100.1**	**100.1**	**100**	

[1] Only calculated for species recorded in every season.

* *P < 0.05; ** P < 0.001*

a - means with same letters do not differ significantly

Table 2.3: The seasonal preference indices for thicket species (utilized >1% in each season) in the diet of giraffe as calculated by the Density preference index and the Biomass preference index. A value of 0 indicates that the frequency of a species in the diet is equal to the frequency of that species in the field; a positive value indicates that a species was favoured and a negative value indicates an avoidance of a species. n = number of days of observations.

Species	**Winter n = 12**		**Spring n = 12**		**Summer n = 12**		**Autumn n = 12**	
	Density	**Biomass**	**Density**	**Biomass**	**Density**	**Biomass**	**Density**	**Biomass**
Acacia karroo	-0.036	-0.431	**0.365**	-0.030	**0.434**	**0.039**	**0.433**	**0.038**
Acacia cyclops	**0.469**	**0.366**	**0.228**	**0.125**	**0.202**	**0.099**	**0.160**	**0.057**
Grewia occidentalis	-0.059	**0.003**	-0.057	**0.005**	-0.051	**0.011**	-0.041	**0.021**
Rhus lucida	-0.056	**0.029**	-0.118	-0.033	-0.134	-0.049	-0.138	-0.053
Olea europaea	-0.099	**0.012**	-0.112	-0.001	-0.123	-0.012	-0.122	-0.011
Buddleja saligna	-0.141	-0.050	-0.152	-0.061	-0.150	-0.059	-0.147	-0.056

2005; Du Toit 1988; Sauer *et al.* 1977; Van Aarde en Skinner 1975; Leuthold and Leuthold 1972) and the results of this study conform to such a finding with 20 browse species being utilized at Nyaru.

Although 20 browse species were consumed by giraffe at Nyaru, only two species, *Acacia karroo* and *Acacia cyclops* formed the bulk of the annual diet. *A. karroo* and *A. cyclops* were the two most important species throughout all four seasons. This prevalence of *Acacia* species in the diet of giraffe supports the findings of previous studies within and beyond the natural distribution range of giraffe (Theron 2005; Parker and Bernard 2005; Du Toit 1988; Kok en Opperman 1980; Hall-Martin 1974; Leuthold and Leuthold 1972).

In the present study, there was a seasonal dietary shift from *A. karroo* as the main food species in spring, summer and autumn to the evergreen *A. cyclops* as the most important food species in winter. This dietary switch is attributed to the deciduous nature of *A. karroo.* For most deciduous species, availability declines during winter due to leaf shedding (Du Toit 1988; Sauer 1983; Sauer *et al.* 1977; Hall-Martin and Basson 1975). The winter months are therefore a nutritionally limiting period for giraffe and other browsers due to reduced food availability (Owen-Smith 1994; Hall-Martin and Basson 1975).

In the Willem Pretorius Game reserve in the FreeState, Kok and Opperman (1985) found crude protein content of deciduous plant species increased during early summer after which a gradual decrease took place until winter. Parker *et al*. (2003) found a distinct dietary shift from *A. karroo* in summer to *Rhus longispina* in winter in the Solid Thicket of the Eastern Cape. Parker and Bernard (2005) observed similar giraffe dietary shifts on three game farms in the Eastern Cape. Although Parker *et al*. (2003) and Parker and Bernard (2005) found *A. cyclops* to be present in the giraffe diet, its contribution to the diet was low. In the present study, it appears as if the alien *A. cyclops* acts as an evergreen substitute to the deciduous *A. karroo* in the winter months at Nyaru. In contrast to the findings of Parker *et al.* (2003) and Parker and Bernard (2005), the importance of *R. longispina* in the present study was low, only being utilized in summer and autumn. This is most likely a result of the low abundance of this species in the field (Chapter 3).

Parker and Bernard (2005) found the importance of *Olea europaea* and *Grewia occidentalis* to be low in the diet of giraffe and *Rhus lucida* was not recorded in the giraffe diet in their study. In the present study, the contribution to the diet of *Olea europaea* and *Rhus lucida* was low, but increased somewhat in winter. *Rhus lucida* was significantly more important in winter than in spring, summer and autumn. Unexpectedly, the contribution to the diet of the deciduous, palatable *Grewia occidentalis* remained low during spring and summer. This finding will be further investigated and discussed in Chapter 4.

Giraffe are known to consume flowers and fruit (Du Toit 1990; Van Aarde and Skinner 1975). This could explain the inclusion of the iris, *Bobartia orientalis*, in the diet of giraffe since they were observed consuming the flowers of this species.

Preference ratings are useful in that, of the forage species present in an area, those with highest and lowest ratings act as indicators of herbivore stocking density and range condition (Petrides 1975). When herbivore stocking densities are too high, the favoured forage species tend to be depleted first, while the rejected species tends to increase (Petrides 1975).

A limitation of the approach for determining giraffe diet preference is that usage and availability data were not collected concurrently. Separate sampling of these two parameters at different times and different areas could lead to sampling mistakes (Owen-Smith and Cooper 1987a). However, because the giraffe at Nyaru used thicket vegetation at similar frequencies throughout all four seasons (see Table 2.1), the availability of evergreen species are assumed to have stayed the same, while the availability of deciduous species declined in winter due to leaf shedding.

Estimates obtained from the Biomass preference index differed noticeably from those obtained from the Density preference index. Density data are commonly used to describe tree communities, but are inadequate to quantify biomass accurately (Smit 1989). The Biomass preference index provides a more detailed estimate of the browse availability than when only the density of species is taken into consideration. The results from the Biomass preference index were therefore taken as the most accurate estimate of dietary preference and are referred to in the rest of the discussion.

A. cyclops was favored by giraffe throughout the year. As this species was the second most important species in the diet of giraffe, it can be regarded as a principle and preferred food species. *A. karroo* was favoured in summer and autumn. Du Toit (1988) found giraffe in savanna switched from favouring deciduous *Acacia* species in summer to mature, evergreen species such as *Euclea divinorum* in winter. Although Parker *et al*. (2003) found a dietary shift from *A. karroo* in summer to *Rhus longispina* in winter in the Solid Thicket of the Eastern Cape, they found giraffe continued to prefer *A. karroo* throughout winter. This could possibly be an artefact of their vegetation sampling technique as they made use of density data only. Giraffe favoured *Olea europaea* and *Rhus lucida* in winter. The highly palatable *Grewia occidentalis* was favoured by giraffe throughout all four seasons although its contribution to the diet remained low.

2.5 CONCLUSION

Overall, the results indicate that *A. karroo* and *A. cyclops* were the two most important species utilized by giraffe in thicket throughout the year. The diet was dominated by the deciduous species, *A. karroo,* in spring, summer and autumn, while an increase in the importance of the evergreen species, *A. cyclops,* became more evident in winter. Giraffe preferred *A. cyclops* throughout the year, while *A. karroo* was favoured in summer and autumn. This suggests that thicket is a suitable habitat for giraffe. A preference for species such as *A. karroo* and *G. occidentalis,* which are showing signs of over-utilization (Chapter 4), could however result in increased browsing pressure and therefore careful monitoring of these key species is important. Monitoring in terms of utilization, fruiting and seedlings is required to ensure that the system does not collapse (Lechmere-Oertel 2003).

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CHAPTER 3: BROWSING CAPACITY

3.1 INTRODUCTION

The ability to determine the number of herbivores that a given area can sustain, often referred to as ecological carrying capacity, is an area of much debate in rangeland management (Campbell *et al.* 2006; Peel *et al.* 1999; Roe 1997; Dhont 1988). According to these authors, the term ‘carrying capacity’ is ill-defined and difficult to determine in heterogeneous environments experiencing unpredictable environmental and resource conditions. In addition to this, the concept was originally developed by agriculturalists for domestic grazers only (Meissner 1982), and it consequently does not make provision for the wide variety of diets found in wild African herbivores (Bothma *et al.* 2004; Peel *et al.* 1999). As a result of this many scientists believe the concept of an ecological carrying capacity to be of minimal value, particularly in non-equilibrium environments where herbivore dynamics is said to be uncoupled from vegetation dynamics (Scoones 1994; Behnke *et al*. 1993). This non-equilibrial conception has, however, been challenged by Cowling (2000) and Illius and O’Connor (2000, 1999) who argue that herbivore and vegetation dynamics are coupled to key plant resources during the dry season in semi-arid rangelands. As a consequence of this, these rangelands are likely to be vulnerable to ecological damage due to herbivory during the dry season (Illius and O’Connor 2000). The non-equilibrial view point does not consider the likelihood of degradation and, hence, its economic costs (Cowling 2000).

According to Bothma *et al.* (2004), correct habitat management is a key component of managing wildlife populations in production systems with free-ranging wildlife. With the re-establishment and increase of wildlife populations, it is essential to set limits to their population size in order to ensure sufficient food resources and to provide for their social needs (Bothma *et al.* 2004). It is therefore important to improve estimates of ecological carrying capacity to ensure the sustainable management and utilization of ecosystems (Meissner 1996). This is especially important for megaherbivores as these animals remove large quantities of vegetation and have powerful effects on plant dynamics (Owen-Smith 1988), and hence on the biodiversity of ecosystems (Fritz *et al*. 2002).

In order to make carrying capacity estimates more appropriate to areas carrying wild herbivore populations, Bothma *et al.* (2004) introduced a technique that separately estimates the grazing and browsing capacity of an area. These estimates are expressed in grazer and browser units per hectare per year respectively and not in large stock units per hectare per year, as is traditionally done in areas carrying domestic stock. In addition to this, a grazer unit is defined as a 180 kg blue wildebeest and a browser unit as a 140 kg kudu, after Peel *et al.* (1999). Bothma (2002) also advocates the use of the term ecological capacity, instead of the agriculturally derived term carrying capacity, when referring collectively to the browsing and grazing capacity of a region for wild herbivores. This convention is followed in the rest of the study.

Browsing by large herbivores can alter thicket vegetation irreversibly, having major repercussions for the sustainability of the Thicket Biome (Lechmere-Oertel *et al.* 2005; Lechmere-Oertel, 2003; Kerley *et al.* 1995). The ecological capacity of thicket is often over estimated as the high density of the vegetation creates an impression of a large quantity of fodder when in actual fact only a small portion may be available to herbivores (Aucamp 1976). Over-utilization is therefore frequently invoked as a major cause of rangeland deterioration in the Thicket Biome (Danckwerts and Tainton 1996). According to Lechmere-Oertel *et al.* (2005) transformation of thicket in response to herbivory is widespread and results in a significant loss of plant and functional diversity. Hoffman and Cowling (1990) suggested that thicket vegetation has a low resilience and a long recovery time and that severe defoliation by herbivores is therefore likely to cause irreversible changes to the vegetation. Heavy browsing of thicket vegetation could therefore result in an unstable community that is prone to soil erosion and which will support too few animals to be economically viable (Schmidt 2002; Stuart-Hill and Aucamp 1993). According to Vlok *et al.* (2003), restoration of transformed thicket does not occur spontaneously, even with complete resting from herbivory.

The Thicket Biome can be categorized broadly into Solid Thickets and Thicket Mosaics (Vlok and Euston Brown 2002). According to Parker (2004) certain plant species in the Solid Thicket of the Eastern Cape Province, which have evolved in the absence of giraffe, are threatened by giraffe browsing, even at relatively low giraffe densities. The impact of the introduction of non-native giraffe has not yet been quantified in the Mosaic Thicket of the Southern Cape. Nevertheless, the species is continuously introduced into the region for tourism purposes (Chapter 1). As giraffe are extralimital to the southern Cape (Skead 1987) it can be accepted that giraffe herbivory has not co-evolved with the thicket vegetation and may thus be capable of degrading the system. Therefore, in order to ensure the sustainability of thicket vegetation and its associated browser assemblage, it is imperative that giraffe be appropriately managed. To this end, the objectives of this study were: (1) To estimate the ecological browsing capacity of Mosaic Thicket for giraffe using a quantitative approach similar to that of Bothma *et al.* (2004). (2) To make a stocking rate recommendation for giraffe as a first approximation for the region.

3.2 METHODS

3.2.1 STUDY SITE

A detailed description of the study site is given in Chapter 2. Briefly, the study took place on a 429 ha estate, Nyaru, situated in the Mosaic Thicket of the Southern Cape.

The present study was done during the period June 2008 to May 2009. The mean annual rainfall recorded at the Mossel Bay weather station for the study period was 401.2 mm, while the long term mean annual rainfall recorded for the period 1985-2009 was 539.8 mm.

3.2.2 BROWSING CAPACITY

To determine the browsing capacity of a region it is necessary to quantify the species composition and phytomass of the browse component of the vegetation. In the Thicket Biome various methods have been considered in attempts to develop practical and effective methods for surveying these parameters. The dense, intertwined and spiny nature of the woody component, however, makes effective sampling of individual plants difficult (Trollope *et al*. 2004). In a recent attempt to develop a simplified technique for assessing the condition of thicket vegetation, Trollope *et al.* (2004) assessed the Bush Assessment Method (Teague *et al.* 1981); the Bush Assessment Method for Valley Bushveld (Stuart-Hill 1989) and the Biomass Estimates from Canopy Volume (BECVOL) method (Smit 1996).

From these methods they developed a procedure for assessing the species composition, density, structure, and browsing potential of trees and shrubs which incorporates the Point Centred Quarter method (Cottam and Curtis 1956). A similar approach to this, which also incorporates the BECVOL method of Smit (1996), is used in the present study to assess the density and phytomass of the trees and shrubs in the thicket on the estate.

To determine the area of thicket, an aerial photograph of Nyaru was digitized using Arcview GIS (version 3.2; Figure 3.1). The thicket on the property was divided into two homogenous units - valley bottoms and valley slopes - and 4 x 250 m transects were systematically selected in each unit. In each transect, 25 points were sampled at 10 m intervals, thus amounting to 100 points per sample site.

To determine the density of the tree and shrub species, the Point-Centre-Quarter method (Cottam and Curtis 1956) was applied along each transect in the following way. In each transect, 25 points were sampled at 10 m intervals. The distance to the closest individual plant in each quarter was measured in meters, thus 100 plants in each unit were enumerated. Trees and shrubs (here after named shrubs) were the only vegetation sampled as giraffe mainly consumed shrubs in my study (Chapter 2). For each shrub sampled, the species and the distance to the shrub (in meters) was recorded. The density of a species (P/ha) is expressed as the number of that species per hectare:

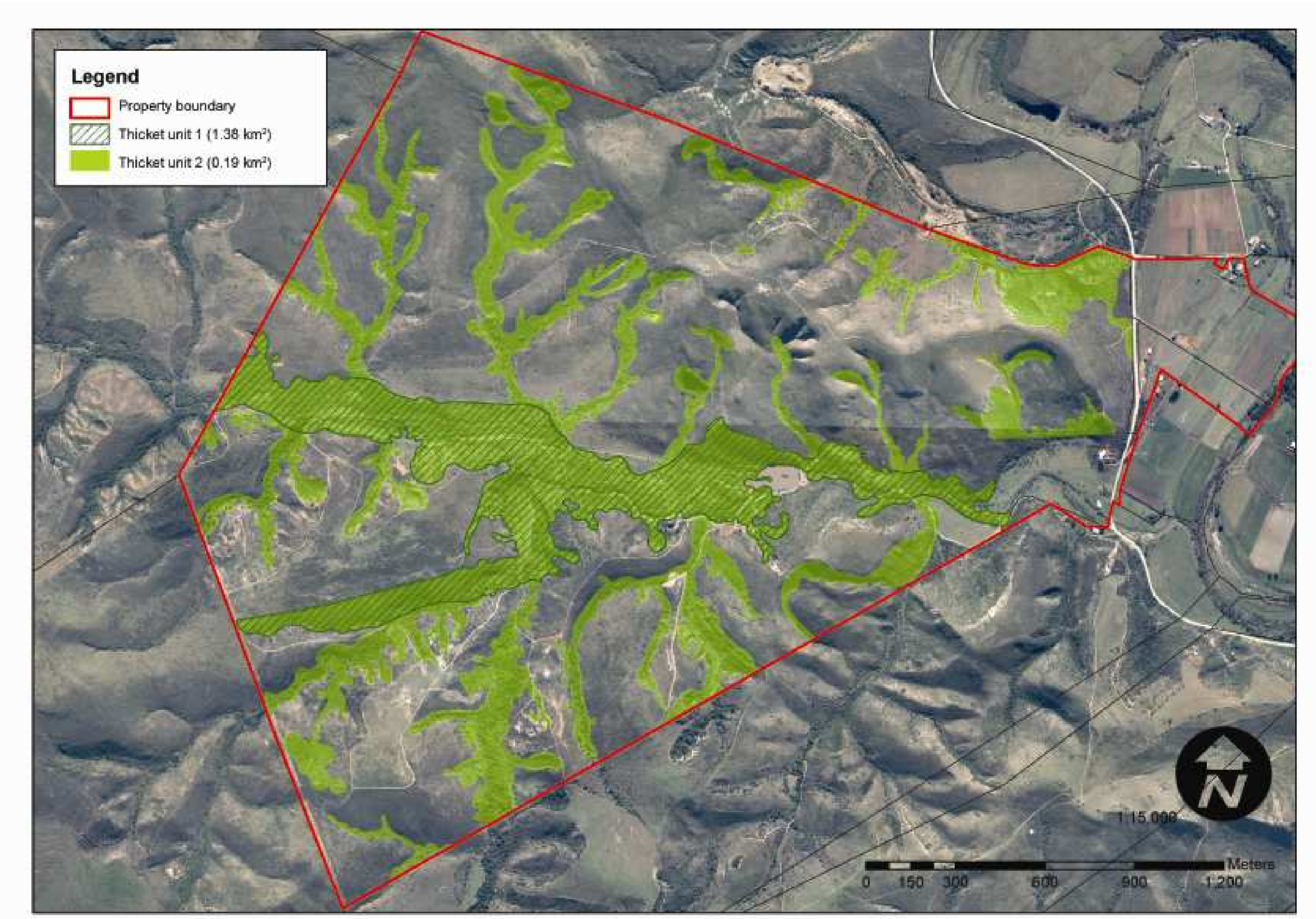

Figure 3.1: An aerial photograph of Nyaru indicating the extent of two homogenous units of thicket on the property (Google Earth 2007; Digital Signature 2010).

$$P/ha = 10000\ m^2/D^2$$

where D is the mean distance of that species from the recording points.

To estimate the above ground phytomass of the shrubs encountered along each transect, the BECVOL method (Smit 1996) was used. Here the closest individual in the right front quarter at each point was sampled and the following measurements taken: (a) Tree height. (b) Height of maximum canopy diameter. (c) Height of first leaves or leaf-bearing shoots. (d) Maximum canopy diameter on two perpendicular planes. (e) Basal diameter of lowest browsable material on two perpendicular planes. All measurements were based on live tree parts only.

The data were entered into the BECVOL computer program (Smit 1996) to calculate the mean phytomass for each species for the following three height classes: 0–1.5 m; 1.5–2 m; 2–5 m. The spatial volume of any tree, regardless of its shape or size, is then calculated from the dimensional measurements by using the volume formulas of an ellipsoid, a right circular cone or a right circular cylinder. The shape of the tree governs which formulas are used for calculations, with two formulas quite often used in conjunction with one another (Smit 1996). The phytomass estimate per species was converted to phytomass per species per hectare by multiplying the mean phytomass per species by the density estimate for each species calculated from the Point-Centre-Quarter method.

To calculate the browsing capacity of the estate for giraffe, the approach of Bothma *et al.* (2004) was used by substituting the phytomass available into the following equation:

$$\text{Browsing capacity (BU/ha/year)} = \frac{\text{Phytomass available (kg/ha)} \times 0.01}{4.2 \times 365}$$

Where 0.01 refers to the amount of standing plant biomass usually utilized by browsers in Africa (Von Holdt 1999); 4.2 refers to the amount of dry leaf matter required per day by 1 browser unit (Peel *et al.* 1999); and 365 refers to the number of days in a year.

To convert the above browsing capacity estimate into an estimate for giraffe, the estimate was divided by 3.8, the browser unit equivalent of one adult giraffe (Van Rooyen 2010).

According to Melville *et al.* (1999) the most important plant species occurring in the diet of an herbivore should be used to determine the browsing capacity for that herbivore. In this study the following categories were used to determine the phytomass available to giraffe when doing the browsing capacity calculations using the above equation: (a) The total phytomass of all species surveyed. (b) The phytomass of species utilized >1 % in the diet of giraffe. (c) The phytomass of those species forming the bulk of the giraffe's diet (> 85%; Chapter 2). (d) The phytomass of those species forming the bulk of the giraffe's diet within its feeding height. (e) The phytomass of species that were preferred in any season (Chapter 2). (f) The phytomass of species preferred in winter (Chapter 2).

The height of feeding by giraffe was recorded according to the method of Theron (2005), where the general feeding height of giraffes was determined by differentiating between the following six levels of feeding: (a) Stretch-height – mouth lifted higher than base of horns. (b) Head-height – normal upright position with the neck at an angle of at least 45° above horizontal level. (c) Neck-height – neck angle less than 45° from horizontal level, but not lower than the start of the neck. (d) Chest-height – neck horizontal or lower but still above the bottom of the abdomen. (e) Knee-height – head lower than the abdomen, with the exception of feeding at ground height. (f) Ground-height – Head lower than knees, including knee-bending position. The height categories were then converted into approximate meters by using height measurements of the body parts of a mounted male giraffe at the Amatole Museum, King William's Town. The average chest height of a giraffe is about 1.8–2 m while the total height of a giraffe varies between 4.3–5.2 m (Skinner and Smithers 1990).

The area (in ha) of available giraffe habitat was recorded separately for valley bottoms and valley slopes and the percentage representation of each unit within the total area covered by thicket was established from this. In order to obtain the total browsing capacity of the thicket on the estate, a weighted representation of the BU/ha for valley bottoms and valley slopes was used to combine the two units.

3.3 RESULTS

The total mean density of trees on the valley slopes (2848.9; Table 3.1) is similar to that on the valley bottom (2892.3; Table 3.2). The total mean phytomass/plant is, however, much higher on the valley slopes (10.3; Table 3.1) than on the valley bottom (1.8; Table 3.2). As a result of this the total mean phytomass/ha is higher on the valley slopes (4905.8; Table 3.1) than on the valley bottom (1069.9; Table 3.2).

Due to the high phytomass/ha on the valley slopes, the browsing capacity estimates for giraffe are higher (ranging from 0.03 to 0.08 giraffe/ha) than on the valley bottom (ranging from 0.002 to 0.018 giraffe/ha; Table 3.3). Although the valley slopes have a much higher browsing capacity/ha than the valley bottom, they cover a much smaller portion (12%) of the Mosaic Thicket in the study area (Table 3.3). Consequently the total estimated browsing capacity for Nyaru (valley slopes and bottom proportionally combined) is relatively low (ranging from 0.005 to 0.026 giraffe/ha or 0.8 to 4.1 giraffe/Nyaru; Table 3.3).

The preferred plant species in any season formed the majority of the phytomass on both the valley slopes (Table 3.1) and valley bottoms (Table 3.2) and therefore contributed most towards the browsing capacity of Nyaru (Table 3.3). Of the preferred species, *Acacia karroo* has the highest phytomass/ha followed by *Acacia cyclops*, *Rhus lucida*, *Olea europaea* and *Grewia occidentalis* on the valley slopes (Table 3.1); and *Olea europaea*, *Rhus lucida* and *Grewia occidentalis* on the valley bottom (Table 3.2).

Other species which contribute substantially to the phyomass/ha, but which are not preferred by giraffe at Nyaru, include *Buddleja saligna* and *Scutia myrtina* on the valley bottom (Table 3.1) and *Euclea undulata*, *Gymnosporia buxifolia* and *Diospyros dichrophylla* on the valley slopes (Table 3.2).

Less than 4 % of giraffe feeding in the study area occurred under the giraffe's chest height while less than 3 % of giraffe feeding occurred at stretch height (Table 3.4). Giraffe therefore predominantly fed on vegetation >2 m and <5 m (93.7 %; Table 3.4).

3.4 DISCUSSION

Bothma *et al.* (2004) emphasized the importance of setting limits to the size of wildlife populations in order to ensure adequate food resources. This study aimed to make a browsing capacity estimate for giraffe in thicket to use as a first approximation in the adaptive management cycle. Appropriate management depends on ecological factors, such as the condition of the veld and the density of giraffe, and human factors, such as the objectives of the land owner and economic considerations (Carruthers and Boshoff 2008; Rogers 2003).

Nyaru currently has nine giraffe or a giraffe stocking density of 0.21 BU/ha. The results from this study indicate that the stocking density for giraffe on Nyaru should lie somewhere between one and four giraffe for the 157 ha of suitable giraffe habitat, or between 0.020 BU/ha and 0.099 BU/ha if other browsers are excluded. This represents an overstocking of the ecological capacity of the ranch of between 125 and 800 %. Since Nyaru is stocked with browsers which mostly browse below a height of 2 m, it is probably more correct to consider the browsing capacity estimate which is based on the available phytomass between 2–5 m above the ground, as being a more appropriate estimate for giraffe. This would mean that no more than three giraffe should be stocked on the 157 ha of available giraffe habitat on Nyaru, or 1 giraffe/78.5 ha.

Table 3.1: The mean density (%), mean phytomass (mean ± SD), and mean phytomass per hectare of various species for valley slopes at Nyaru.

Species	**Density** (plants/ha) n = 100	**Phytomass** (mean kg/plant) n = 25	**Phytomass per hectare (kg/ha)**					
			Total	Species utilized >1%	Bulk (>85%)	Bulk (>85%) >2 m, <5 m	Preferred any season	Preferred in winter
Acacia karroo	626.8 (22.0)	4.4 ± 5.5	2757.7	2757.7	2757.7	2005.8	2757.7	
Acacia cyclops	313.4 (11.0)	4.6 ± 8.3	1441.6	1441.5	1441.5	1316.3	1441.5	1441.5
Rhus lucida	527.1 (18.5)	0.6 ± 0.7	316.2	316.2			316.2	316.2
Euclea undulata	312.2 (11.0)	0.7 ± 0.7	218.6					
Gymnosporia buxifolia	245.0 (8.6)	0.2 ± 0.2	49.0					
Olea europaea	122.5 (4.3)	0.3 ± 0.4	36.8	36.8			36.8	36.8
Grewia occidentalis	153.8 (5.4)	0.2 ± 0.2	30.8	30.8			30.8	30.8
Diospyros dichrophylla	239.3 (8.4)	0.1 ± 0.02	23.9					
Carissa bispinosa	79.8 (2.8)	0.2	15.9					
Polygala myrtifolia	85.5 (3.0)	0.1	8.5					
Rhus longispina	41.7 (1.5)	0.1	4.2					
Buddleja saligna	54.1 (1.9)	0.03	1.6	1.6				
Rhus pyroides	47.7 (1.7)	0.02	0.9					
Total	**2848.9**	**10.3**	**4905.8**	**4584.7**	**4199.3**	**3322.1**	**4583.0**	**1825.3**

Table 3.2: The mean density (%), mean phytomass (mean ± SD), and mean phytomass per hectare of various species for valley bottoms at Nyaru.

Species	Density (plants/ha) n = 100	Phytomass (mean kg/plant) n = 25	Phytomass per hectare (kg/ha)					
			Total	Species utilized >1%	Bulk (>85%)	Bulk (>85%) >2 m, <5 m	Preferred any season	Preferred in winter
Acacia karroo	916.9 (31.7)	0.9 ± 1.1	825.2	825.2	825.2	641.8	825.2	
Buddleja saligna	514.8 (17.8)	0.2 ± 0.3	103.0	103.0				
Olea europaea	412.2 (14.3)	0.1 ± 0.1	41.2	41.2			41.2	41.2
Rhus lucida	388.1 (13.4)	0.1 ± 0.1	38.8	38.8			38.8	38.8
Scutia myrtina	142.3 (4.9)	0.2 ± 0.3	28.5					
Grewia occidentalis	211.1 (7.3)	0.1 ± 0.1	21.1	21.1			21.1	21.1
Rhus pyroides	69.4 (2.4)	0.1 ± 0.2	6.9					
Gymnosporia buxifolia	150.4 (5.2)	0.03 ± 0.02	4.5					
Carissa bispinosa	40.4 (1.4)	0.004	0.2					
Gymnosporia nemarosa	24.9 (0.9)	0.1	0.2					
Diospiros dichrophylla	21.8 (0.8)	0.01	0.2					
Total	**2892.3**	**1.8**	**1069.9**	**1029.3**	**825.2**	**641.8**	**926.3**	**101.1**

Table 3.3: Giraffe browsing capacity estimates of Mosaic Thicket units at Nyaru based on various categories of available phytomass estimates.

Category	BU/ha	Giraffe/ha	Giraffe/ unit area
Valley bottoms - 138 ha			
Total	0.069	0.018	2.5
Species utilized > 1% in the diet	0.067	0.017	2.4
Species forming the bulk (>85%) of the diet	0.054	0.014	1.9
Species >2m; <5m forming the bulk (>85%) of the diet	0.042	0.011	1.5
Species preferred in any given season	0.060	0.016	2.2
Species preferred in winter	0.007	0.002	0.3
Valley slopes - 19 ha			
Total	0.320	0.083	1.6
Species utilized > 1% in the diet	0.299	0.078	1.5
Species forming the bulk (>85%) of the diet	0.274	0.071	1.4
Species >2m; <5m forming the bulk (>85%) of the diet	0.217	0.056	1.1
Species preferred in any given season	0.299	0.078	1.5
Species preferred in winter	0.119	0.031	0.6
Total Mosaic Thicket on Nyaru - 157 ha			
Total	0.099	0.026	4.1
Species utilized > 1% in the diet	0.095	0.025	3.9
Species forming the bulk (>85%) of the diet	0.080	0.021	3.3
Species >2m; <5m forming the bulk (>85%) of the diet	0.063	0.016	2.6
Species preferred in any given season	0.089	0.023	3.6
Species preferred in winter	0.020	0.005	0.8

Table 3.4: The estimated feeding height and the number (percentage are given in brackets) of feeding records per height class for giraffe on Nyaru.

Height category	Height (m)	Feeding records
Ground	0 - 0.5	54 (0.4)
Knee	0.5 - 1.9	517 (3.4)
Chest	2 m - 2.5	4936 (32.3)
Neck	2.5 m - 4.5	6682 (43.7)
Head	4.5 m - 5.0	2707 (17.7)
Stretch	>5	396 (2.6)
Total		**15292**

The giraffe stocking rates of private estates surveyed in the southern Cape varied from 1 giraffe/30 ha to 1 giraffe/1650 ha (Chapter 1). Five of the 19 farms surveyed had higher stocking rates than my recommendation of 1 giraffe/78.5 ha. However, it must be noted that the total size of the properties were used for stocking rate calculations and that the availability of suitable giraffe habitat on each property was therefore not taken into consideration.

The stocking rate recommendation of this study lies within the range commonly recommended by local consultants such as Conservation Management Services[1] when compiling giraffe impact reports. These reports are required by Cape Nature before approving any giraffe introductions onto game ranches in the southern Cape. The stocking density estimates for giraffe in these reports range from 1 giraffe/50 ha to 1 giraffe/100 ha depending on the location and perceived veld condition of the ranch. These recommendations are, however, not based on quantitative assessments such as performed in the present study.

Quantitative browsing capacity estimates do, however, exist for different rainfall regimes and veld condition classes in thicket of the Eastern Cape (Stuart-Hill 1999). For example, for a mean annual rainfall of 400 mm, thicket in a good condition is estimated to have a browsing capacity in the region of 0.117 LSU per ha. For thicket in a poor condition, this estimate is likely to decrease to about 0.065 LSU per ha since much of the browseable vegetation will have been replaced by grasses (Stuart-Hill 1999). If an average giraffe is taken to be the equivalent of 1.59 LSU (Van Rooyen 2010) then the estimate of Stuart-Hill (1999) for the 157 ha in the study area would lie between approximately six and twelve giraffe if no other browsers are stocked on the property. This range is higher than my range of between one and four giraffe. The result is, however, to be expected since Stuart-Hill (1999) worked in the Solid Thicket of Sundays River Valley whereas the current study took place in Mosaic Thicket. In addition to this the current study site has a low phytomass/plant in the valley bottom which makes up

[1] Conservation Management Services, 4 Chestnut Street, Heather Park, George, 6529

88% of the giraffe habitat. This low phytomass is probably due to the high stocking rate of browsers on the ranch in recent times and the tendency for herbivores to concentrate their feeding in low lying areas close to water (Shrader *et al.* 2008; Smet and Ward 2006).

In a desktop study, using quantitative data from various studies, Boshoff *et al.* (2001) estimated the spatial requirements for mammalian herbivores indigenous to various habitat types in the Thicket Biome. They did however not consider extralimital species such as giraffe in their study. To make their findings more comparable to the results of this study, their density estimate for kudu in Succulent Thicket was converted to an equivalent estimate for giraffe using the LSU conversion table for wild southern African herbivores in Van Rooyen (2010). In contrast to the finding of Stuart-Hill (1999), Boshoff *et al.* 2001 estimated that 0.010 kudu, and thus 0.002 giraffe, can be sustained per hectare. This would mean that Nyaru would not even have enough suitable habitat to sustain a single giraffe.

My recommended stocking rate of three giraffe for the study area (or 0.016 giraffe/ha), based on the available phytomass between 2–5 m above the ground, may appear conservative considering the wide range of estimates (one to twelve giraffe) discussed above. However, the findings of my browse impact study (Chapter 5) and the low shrub phytomass in the valley bottom, indicate that there is a perceptible impact on the thicket vegetation in the study area due to an excessively high browser stocking rate. It would consequently make sense to start stocking conservatively and to adjust stocking rates at a later stage in accordance with an adaptive management approach.

It is suggested that monitoring the density, phytomass, utilization, fruiting and seedling recruitment of key browse species be done on an annual basis (Birnie *et al.* 2005; Schmidt 2002; Stuart-Hill 1999; Hurt and Hardy 1989). The phytomass between 2–5 m above the ground on selected individuals of *Acacia karroo* and

Grewia occidentalis could be monitored using the BECVOL method. *Acacia karroo* formed the bulk of the giraffe diet in this study and was preferred in summer and autumn (Chapter 2). The species also contributed significantly to the phytomass in both thicket units studied. *Grewia occidentalis* was preferred by giraffe throughout the year, but did not contribute significantly to the diet of giraffe (Chapter 2). In addition to this, *Grewia* species are widespread throughout the Thicket Biome and Stuart-Hill (1989) has recommended that *Grewia* species be used to monitor browser impacts. Significant changes to the density and phytomass of *Acacia karroo* and *Grewia occidentalis* could be used to prompt adjustments to giraffe stocking rates. Monitoring the degree of utilization and fruiting could also be done as described in Chapter 4. If a negative impact is perceptible, such as an annual drop in the quantity of leaves, fruit and seedlings, browse stocking rates should be re-assessed (Birnie *et al.* 2005).

3.5 CONCLUSION

No one method for determining ecological capacity is foolproof. For example, shortcomings of the approach used in this study include the following. With a Browser Unit, as with a Large Stock Unit, there is an assumption that all browsers consume the same amount of dry matter relative to their body mass (Peel *et al*. 1999). Furthermore a limitation of the BECVOL method is that the program was originally developed for savanna species, thus taking the growth forms of savanna species into account which may differ from thicket species. In this study, generalized equations were also used in the BECVOL programme to determine the phytomass of most broad leaved and fine leaved species, thus reducing the accuracy of the method. Thicket clumps are also so intertwined that it is difficult to measure the plant dimensions required in the BECVOL method.

The results of this study provide an estimated ecological browsing capacity of between 0.020 BU/ha and 0.099 BU/ha for giraffe in thicket. The recommended estimate is based on the available phytomass between 2–5 m above the ground in order to eliminate overestimates, and amounts to 1 giraffe per 78.5 ha. This recommendation should not be seen as a fixed ecological capacity for giraffe in thicket. It should rather be regarded as a starting point for the region which can be adjusted in response to annual changes in the phytomass, fruiting and seedlings of preferred species such as *Acacia karroo* and *Grewia occidentalis*.

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CHAPTER 4: THE IMPACT OF BROWSING ON *ACACIA KARROO* AND *GREWIA OCCIDENTALIS*

4.1 INTRODUCTION

Large mammalian herbivores can have major impacts on the structure and functioning of ecosystems (Bergstrom 1992; Augustine and McNaughton 1998). They use a disproportionately larger share of local resources than smaller mammals and can modify vegetation communities, consequently affecting animal and plant species distribution in space and time (Fritz *et al.* 2002; Du Toit and Owen-Smith 1989). At high densities, large mammalian herbivores can prevent seedling establishment and inhibit regeneration of plants through browsing/grazing pressure (Cumming and Cumming 2003; Birkett 2002; Bond and Loffell 2001; Moolman and Cowling 1994) and compete with mesomix-feeders for food (Fritz *et al.* 2002). According to Bryant *et al.* (1991) heavy browsing usually favours an increase in unpalatable species that are heavily defended.

Plant responses to mammalian browsing could vary (Bergstrom 1992). This depends on plant characteristics, intensity and frequency of defoliation, plant growth stage at the time of defoliation, plant parts influenced, and varying effects of environmental factors before and after defoliation (Teague 1985). Plant defences against herbivory include plant resistance traits that reduce herbivore performance; tolerance traits, such as mass compensatory growth abilities; and phenological escape that reduces plant availability (Argrawal 2000; Augustine and McNaughton 1998). Tolerance and resistance traits have been observed in woody plant species in African savannas exposed to ungulate browsing (Fornara and du Toit 2007; Du Toit *et al.* 1990; Owen-Smith and Cooper 1987; Cooper and Owen-Smith 1986). Pellew (1983) demonstrated that browsing by giraffe stimulates *Acacia* shoot production in the Serengeti ecosystem of east Africa and, according to Fornara and du Toit (2007) and Du Toit *et al.* (1990), severe pruning of some *Acacia* species by browsing ungulates promotes rapid shoot growth. Leaves of heavily browsed trees seem to be highly palatable because of reduced intershoot competition, which results in condensed tannin levels being lower and nitrogen and phosphorus content being higher (Du Toit *et al.* 1990). This enhanced browse quality can attract increased browsing pressure (Du Toit *et al.* 1990). Studies by Goheen *et al.* (2007) and Dangerfield *et al.* (1996) indicated that heavy browsing caused negative effects on the reproductive ability of woody species. Similarly, Fornara and du Toit (2007) found phenological escape responses to be weak in heavily browsed *Acacia* stands and suggested that heavy browsing causes a negative effect on the reproductive success of woody species, suggesting that tolerance and resistance traits come at the expense of reproductive success (Fornara and Du Toit 2007).

A number of studies have drawn attention to the widespread degradation of the Thicket Biome (Lechmere-Oertel *et al.* 2005; Lechmere-Oertel 2003; Kerley *et al.* 1995). Transformation of thicket in response to herbivory results in a significant loss of plant and functional diversity (Lechmere-Oertel *et al.* 2005). Large areas of thicket have already suffered extensive degradation (La Cock *et al.* 1990; Lloyd *et al.* 2002), while the system is under constant pressure from agriculture and unsustainable game farming (Lechmere-Oertel *et al.* 2005; Lechmere-Oertel 2003).

Although this chapter explores the impact of general ungulate browsing on *Acacia karroo* and *Grewia occidentalis*, a lot of literature sited comes from work done on giraffe, as it is the main animal focused on in this study. Giraffe are browsing mega-herbivores which remove large quantities of vegetation and have powerful effects on plant dynamics and hence on the biodiversity of ecosystems (Owen-Smith 1988). Owen-Smith (1988) suggested that the impact of giraffe on tree populations is comparably less detrimental than the impact of other mega-herbivores such as elephant (*Loxodonta Africana*). However, according to Birkett (2002), giraffe at high densities can suppress the growth of regenerating trees, which retards the recruitment of mature trees. Similarly, Bond and Loffell (2001) showed that giraffe introduced into an area are capable of causing tree mortality due to their browsing. Giraffe did not historically occur in the Southern Cape (Skead 1987) and thus Mosaic Thicket has evolved in the absence of this mega-herbivore. It is therefore imperative to determine what kind of impact they may have on the Mosaic Thicket of the Southern Cape.

Monitoring the utilization of all plants in a vegetation type would be very difficult and is therefore not a practical management option (Stuart-Hill 1999). However, the condition of key browse species could be used to monitoring the impact of browsing on a vegetation type (Stuart-Hill 1999; Hurt and Hardy 1989). In this study, *A. karroo* and *G. occidentalis* were chosen as indicator species for a browsing impact survey. Parker and Bernard (2005) found *Acacia karroo* to be the most important species in the diet of giraffe in the Solid Thicket of the Eastern Cape. *A. karroo* also formed most of the giraffe diet in my study and was preferred in summer and autumn (Chapter 2). Unexpectedly, the contribution to the diet of the deciduous species, *Grewia occidentalis*, remained low although the species was preferred by giraffe throughout all seasons (Chapter 2). *G. occidentalis* is classified as a palatable species (Watson and Owen Smith 2002) that commonly occurs in Mosaic Thicket (Hoare *et al.* 2006). This shrub is unarmed and consequently heavily browsed by ungulates (Watson and Brown 2001; Watson 1999). According to Watson (1999), *G. occidentalis* commonly occurs in clumps with certain shrub species known as nurse shrubs. These bush clumps act as nurse sites sheltering seedlings from desiccation, wind and herbivory (Crawley 1997). Watson (1999) suggested that nurse shrubs are essential for the establishment and maintenance of *G. occidentalis* by providing adequate protection against browsing. Skirted shrubs appear to physically defend *G. occidentalis* against browsing by wild and domestic herbivores (Watson and Brown 2001; Watson 1999).

The aims of this study were to determine: (1) the utilization of *Acacia karroo and Grewia occidentalis* by browsers in a heavily and a lightly used site; (2) the reproductive success (occurrence of pods/fruit) of *A. karroo* and *G. occidentalis* at the two sites; and (3) the influence of bush clumps on the utilization and reproductive success of *G. occidentalis*. Evidence from the past indicates that heavy utilization and the occurrence of nurse shrubs are important factors playing a role in the successful establishment and maintenance of certain palatable species (Vandenberghe 2009; Gómez-Aparicio 2005; Watson and Brown 2001; Watson 1999, Augustine and McNaughton 1899).

4.2 METHODS

4.2.1 STUDY SITE

A detailed description of the study site is given in Chapter 2. Briefly, the study took place on a 429 ha estate, Nyaru, situated in the Mosaic Thicket of the Southern Cape.

The present study was conducted during the period April to May 2009. The mean annual rainfall recorded at the Mossel Bay weather station for the year 2009 was 303 mm, while the long term mean annual rainfall recorded for the period 1985-2009 was 539.8 mm.

The study was done on two thicket sites on the estate, the first in an area with high densities of browsing ungulates, including giraffe, and here after referred to as the heavily used site; and the other in a site of similar vegetation where the number of browsers was low and giraffe seldom occurred and hereafter referred to as the lightly used site (Figure 4.1). The lightly used site was less accessible to browsers since it was separated from the rest of the estate by a steep slope and a small, non-perennial stream.

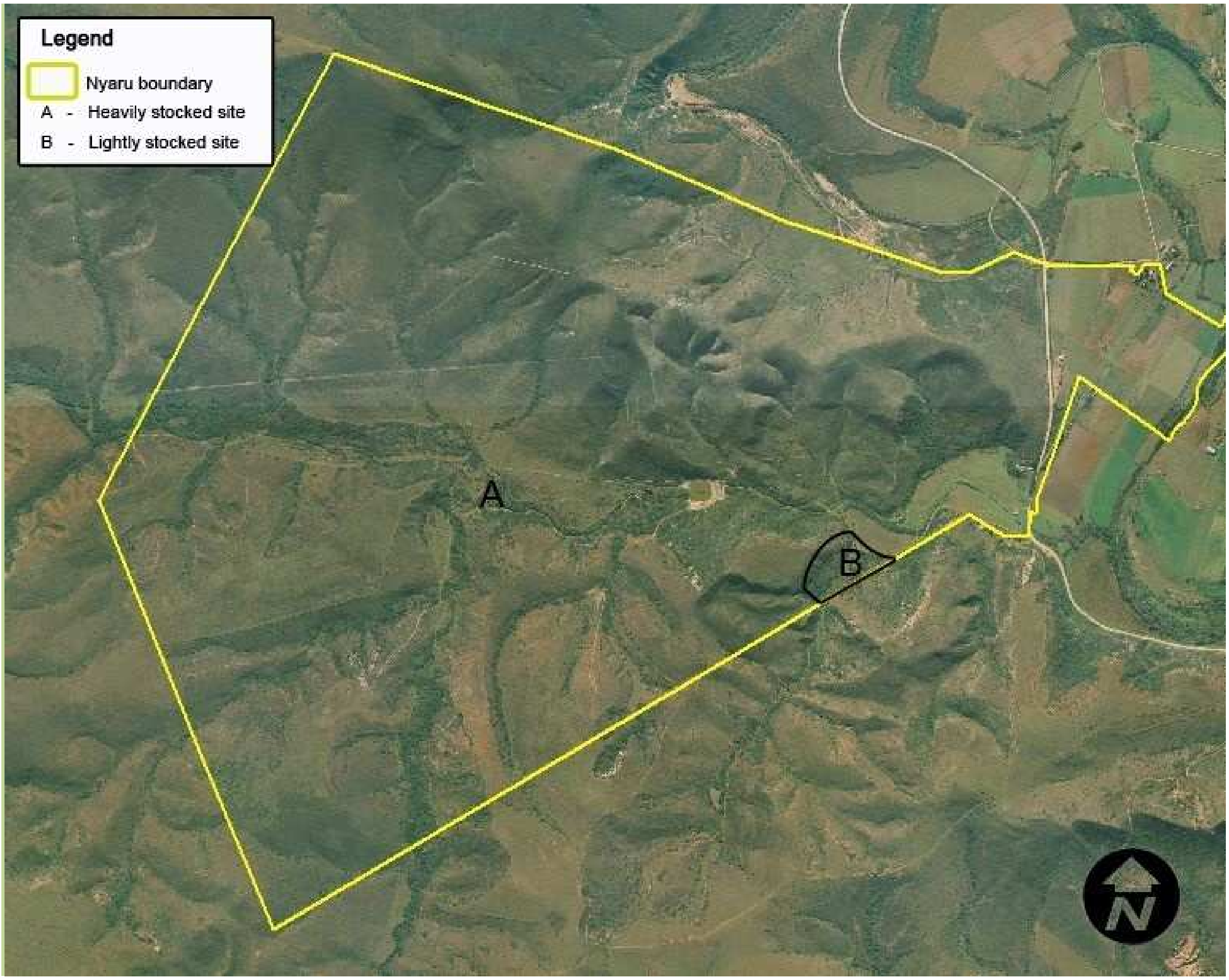

Figure 4.1: An aerial photograph of Nyaru indicating the heavily used site (A), and the lightly used site (B) (Google Earth 2007).

4.2.2 DATA COLLECTION

Data were recorded along a single line transect at each of the two sites. A total of 30 plants of each species were sampled at 10 m intervals on each transect as Trollope (2004) suggested that 25 points per sample site is adequate to show key differences in the condition of vegetation between sample sites. The closest plant to each point was used for data collection. For each plant encountered, the following was recorded: (1) The proportion of shoots eaten. This was estimated using the eight-point scale of Walker (1976). The mean proportion of shoots eaten per plant, per species was calculated using the midpoint of each rank (Walker 1976). (2) Counts of the number of pods/fruits. (3) In the case of *G. occidentalis*, whether the shrub grew alone or clumped with other species.

The above estimations were done at different height intervals. For *A. karroo,* height interval 1 = <2 m; height interval 2 = 2–4 m; and height interval 3 = >4 m. For *G. occidentalis,* height interval 1 = <2 m; and height interval 2 = >2 m. *G. occidentalis* was only surveyed at two height intervals since the species seldom occurred at heights >2 m.

Although the study design is pseudoreplicated (Hurlbert 1984), the design was used to limit differences in vegetation composition, management practices, browser species and browser abundance between properties in Mosaic Thicket.

The Chi-square goodness of fit test (Zar 1984) was used to test for differences in the observed and expected frequency of occurrence of *G. occidentalis* clumped and not clumped with other species at the two sites. A non-parametric Mann-Whitney U test (Zar 1984) was used to compare the percentage shoots eaten and the number of pods on *A. karroo* between sites at the various height intervals. To compare the percentage shoots eaten on *G. occidentalis* across sites and growing association (clumped versus alone) at the two height intervals, the Two factor ANOVA (Zar 1984) and Tukey multiple comparison tests were used (Zar

1984). The occurrence of fruit on *G. occidentalis* could only be compared between growing associations at the lightly stocked site (see below). This was done with the use of the Student t-test (Zar 1984). Percentages were arcsine transformed for analysis (Zar 1984).

4.3 RESULTS

Acacia karroo at the heavily used site was browsed at significantly higher intensities than those at the lightly used site at all height intervals sampled (Table 4.1). The mean number of pods on *A. karroo* was significantly lower at the lightly used site than at the heavily used site at heights <2 m (Table 4.2). In contrast, the mean number of pods on *A. karroo* was significantly lower at the heavily used site than at the lightly used site at heights >2 m (Table 4.2).

The proportion of *Grewia occidentalis* growing alone and clumped with other species differed significantly between the two sites ($X^2 = 4.44$, df = 1, P = 0.035; Table 4.3). The majority of *G. occidentalis* at the lightly used site were recorded as clumped with other species (73.3 %), while *G. occidentalis* at the heavily used site was recorded as clumped (46.7 %) and alone (53.3 %) at similar frequencies (Table 4.3).

At both height intervals sampled, *G. occidentalis* was browsed at significantly higher intensities at the heavily used site than those at the lightly used site (Table 4.4). There were no significant differences between the intensity of browsing of *G. occidentalis* growing alone and those clumped with other species at either of the two height intervals sampled (Table 4.4).

Table 4.1: The percentage shoots browsed (mean ± SD) of *Acacia karroo* at various height intervals at the two sites.

Height class (m)	**Heavily used site**	**Lightly used site**	**Mann-Whitney U - test**
<2	58.4 ± 23.0	32.5 ± 18.5	3.7, n1 = 27, n2 = 25, P < 0.001
2–4	74.5 ± 16.5	17.7 ± 15.1	5.9, n1 = 24, n2 = 27, P < 0.001
>4	71.3 ± 17.6	6.0 ± 6.7	4.0, n1 = 9, n2 = 15, P < 0.001

Table 4.2: The number of pods (mean ± SD) on *Acacia karroo* at various height intervals at the two sites.

Height class (m)	**Heavily used site**	**Lightly used site**	**Mann-Whitney U - test**
<2	1.5 ± 2.5	0.5 ± 1.6	3.7, n1 = 27, n2 = 25, P < 0.001
2–4	5.5 ± 5.4	74.1 ± 162.6	5.9, n1 = 24, n2 = 27, P < 0.001
>4	60.8 ± 119.9	293.0 ± 329.0	4.0, n1 = 9, n2 = 15, P < 0.001

Table 4.3: The number of *Grewia occidentalis* plants recorded growing alone and clumped with other species at each site. Percentages are given in brackets.

Association	**Heavily used site**	**Lightly used site**
Alone	16 (53.3)	8 (26.7)
Clumped	14 (46.7)	22 (73.3)
Total	**30**	**30**

Table 4.4: The percentage shoots browsed (mean ± SD) and the number of fruits (mean ± SD) on *Grewia occidentalis* growing in clumps and growing alone at two height intervals at the two site.

Association	**Height class**	**Heavily used site**		**Lightly used site**		**Two factor ANOVA**
	(m)	Clumped (n = 14)	Alone (n = 16)	Clumped (n = 22)	Alone (n = 8)	
% Browsed	1 (< 2)	55.8 ± 18.2[a]	69.7 ± 0.0[a]	25.5 ± 29.0[b]	22.6 ± 26.6[b]	Two factor ANOVA[1]
	2 (> 2)	69.7 ± 0 [a]	65.4 ± 8.6[a]	3.0 ± 8.0[b]	10.7 ± 22.1[b]	Two factor ANOVA[2]
Number of fruit	1 (< 2)	0.5 ± 2.7	0	4.7 ± 7.7	15.6 ± 38.9	t-test[3]
	2 (> 2)	3.4 ± 6.8	0	27.4 ± 17.23	15.1 ± 11.77	t-test[4]

[1]Site, $F = 56.2$, df = 1, 78, $P < 0.001$; growing association, $F = 1.15$, df = 1, 78, $P > 0.05$; site x growing association, $F = 2.62$, df = 1, 78, $P > 0.05$

[2]Site, $F = 53.0$, df = 1, 21, $P < 0.001$; growing association, $F = 0.04$, df = 1, 21, $P > 0.05$; site x growing association, $F = 0.52$, df = 1, 21, $P > 0.05$

[3] lightly used site $t = 1.24$, $P > 0.05$

[4] lightly used site $t = 1.80$, $P > 0.05$

a - means with same letters do not differ significantly

There was a general trend of fewer fruits on *G. occidentalis* at the heavily used site than at the lightly used site (Table 4.4). Fruits were absent on *Grewia occidentalis* growing alone at the heavily used site at both height intervals sampled (Table 4.4). There were no significant differences between the mean number of fruits on *G. occidentalis* growing alone and those clumped with other species at the lightly used site at both height intervals sampled (Table 4.4).

4.4 DISCUSSION

According to Pellew (1984b), browsing by giraffe in their natural distribution range appears to have no negative effect on plant productivity of *Acacia* species, at least not in the short term. However, Birkett (2002) found giraffe browsing at high densities reduced tree growth in Kenya, and Bond and Loffell (2001) found that giraffe altered the species distribution and composition of a savanna system. In the present study, there was a general trend of less browsing at the lightly used site compared to the heavily used site. The intensity of browsing decreased with increase in height at the lightly used site, while similar intensities of browsing occurred over all height intervals sampled at the heavily used site. This could be a result of the lightly used site being more easily accessed by smaller browsers than by giraffe and suggests that high densities of giraffe has a perceptible impact on the palatable *Acacia karroo* and *Grewia occidentalis* in thicket since giraffe are, except for kudu, the only species on the estate that are able to browse at heights of 2–5 m.

Working in savanna, Du Toit *et al.* (1990) proposed that severe pruning by browsing ungulates reduces intershoot competition for nutrients, promoting rapid shoot regrowth in *Acacia* species. Also in savanna, Fornara and du Toit (2007) found that large herbivores induce a physiological response that increases the regrowth of foliage in heavily browsed *Acacia nigrescens,* enabling them to survive under heavy browsing. According to Fornara and Du Toit (2007), heavily browsed woody plants can maintain dominance within a plant community due to tolerance traits of rapid regrowth and resistance in the form of spinescence. However, a study done by Pellew (1984a) demonstrated that plant spinescence is not influential in affecting giraffe browsing. In the present study, *A. karroo* was browsed at significantly higher intensities at the heavily used site compared to the lightly used site. The animal species that utilized *A. karroo* were not recorded in this study although it was established that *A. karroo* formed the bulk of the giraffe diet in thicket (Chapter 2). Whether *A. karroo* will maintain its dominance within the thicket community (Chapter 3) in the long term will depend on how individual plants survive and reproduce and if some can escape from herbivory.

A recent study by Goheen *et al.* (2007) showed negative effects of tree pruning on the reproductive ability of *Acacia drepanolobium* in an eastern African savanna. According to Dangerfield *et al.* (1996) plant response to browsing in the form of rapid growth compensation or increased physical or chemical protection might affect its competitive ability, and subsequent reproductive potential. Heavy browsing may prevent shrubs reaching maturity and seed set, ultimately affecting recruitment (Dangerfield *et al.* 1996). Fornara and du Toit (2007) found fewer trees carrying pods and fewer pods per tree in heavily browsed stands of *Acacia nigrescens*, suggesting a long term negative effect of chronic browsing on plant reproductive success. The results of the present study indicate that heavy browsing has a perceptible impact on the reproductive success of *A. karroo*. At the heavily used site *A. karroo* carried substantially fever pods per tree compared to the lightly used site at heights >2 m. This is likely to lead to lower regeneration and thus reduced densities of *A. karroo* in the long term.

Working in the Karoo, Watson (1999) found that *G. occidentalis* growing with nurse shrubs had lower levels of utilization than *G. occidentalis* growing alone. He suggested that nurse shrubs are essential for the establishment and maintenance of *G. occidentalis* by providing adequate protection against browsing. Similarly, on a domestic stock farm in the Eastern Cape, Watson and Brown (2001) found that *G. occidentalis* growing with skirted shrubs had lower intensities of browsing than those growing alone, suggesting that skirted shrubs physically defend *G. occidentalis* against browsing. Watson and Brown (2001) found that *G. occidentalis* grew alone at relatively light levels of browsing while, under relatively heavy browsing, *G. occidentalis* mainly grew in clumps with other species. In the present study, fewer *G. occidentalis* were clumped with other species at the heavily used site compared to the lightly used site. This could be attributed to the intense browsing pressure at the heavily used site causing protective clumps to be eaten away, thus exposing *G. occidentalis* to higher ungulate browsing. *G. occidentalis* was browsed at significantly higher intensities at the heavily used site compared to the lightly used. There was a general trend of fewer fruits on *G. occidentalis* at the heavily used site compared to the lightly used site and fruits were absent on *Grewia occidentalis* growing alone at the heavily used site. This suggests a negative effect of heavy browsing on plant reproductive success and emphasizes the importance of nurse plants for the successful recruitment and hence long term prevalence of *G. occidentalis* in thicket. If recruitment through seedlings does not take place, the potential for natural rehabilitation of transformed thicket is minimised (Sigwela (2004).

4.5 CONCLUSION

Overall, *Acacia karroo* and *Grewia occidentalis* were browsed at significantly higher intensities at the heavily used site compared to the lightly used site. Heavy browsing causes a significant reduction in the biomass and structural complexity of thicket vegetation and the canopy tree guild in transformed thicket is not stable owing to ongoing adult mortality and little successful recruitment (Lechmere-Oertel *et al.* 2005). *Acacia karroo* carried significantly fewer pods per tree at the heavily used site compared to the lightly used site. Fewer *G. occidentalis* were clumped with other species at the heavily used site compared to the lightly used site. Fewer fruits occurred on *G. occidentalis* at the heavily used site compared to the lightly used site and no fruit occured on *G. occidentalis* growing alone at the heavily utilized site. Fewer pods and fruits leads to lower regeneration and thus reduced numbers of these species. The long term effects of heavy browsing will depend on the ability of individual plants to escape from herbivores and reproduce.

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CHAPTER 5: MANAGEMENT IMPLICATIONS AND FUTURE RESEARCH

5.1 INTRODUCTION

In this thesis, management aspects of extralimital giraffe in the Mosaic Thicket of the southern Cape were explored, including giraffe diet composition and preference; the ecological browsing capacity of thicket for giraffe; and the impact of browsing on two palatable thicket species. The aims of this chapter are (1) to provide management recommendations; and (2) to make suggestions on possible future research that could build on the findings of this study.

5.2 MANAGEMENT IMPLICATIONS

It is recognised that this study represents a "snap-shot" into the management of giraffe in Mosaic Thicket, and that the ability to generalize or to make assumptions regarding resource use is therefore limited. Nevertheless, the findings of this study provide baseline data to build future research on and acts as a starting point for the introduction of adaptive management principles.

Ungulate species are important regulators of change in ecosystems (Hobbs 1996; Gordon *et al.* 2004). They create spatial heterogeneity, alter succession processes, and control the switching of ecosystems between alternative states (Hobbs 1996). Interactions between herbivores and vegetation that drive landscape change are localized; therefore management of herbivore impacts on vegetation may require a flexible, site-specific approach (Gordon *et al.* 2004). The most appropriate management system for an individual property will depend on its resources as well as the objectives of the landowner (Stuart-Hill 1999). An adaptive management program is advocated (Carruthers and Boshoff 2008; Biggs and Rogers 2003; Stuart-Hill 1989a). This involves setting specific economic and biological objectives and continuously monitoring progress towards these while recording relevant management actions and environmental change (Stuart-Hill 1999). Any change in the condition of the vegetation can then be related back to the management applied and/or the environmental conditions experienced. The prevention of resource deterioration should be non-negotiable in any management system (Stuart-Hill 1989b). Localized impacts on vegetation have cascading effects on biodiversity, since changes in vegetation structure and composition that are induced by large herbivores affects habitat suitability for many other species (Gordon *et al.* 2004).

Giraffe have the potential to modify vegetation and habitat to which they are introduced, especially in areas where the vegetation has adapted without their presence (Bond and Loffell 2001). This emphasises the need for appropriate monitoring of new and existing introductions to detect changes in the environment. Programs that would monitor the effect of introduced herbivores, especially extralimital species, should be established to detect change in vegetation structure as a result of introduced herbivores. Such monitoring programmes should be enforced onto private reserves and should be incorporated into government policy to regulate new introductions (Stuart-Hill 1993). A standardised approach should be developed to ensure compatibility of monitoring data collected from different sites (Stuart-Hill 1999). The costs of monitoring are a negligible proportion of the cost of managing the entire system (Stuart-Hill 1999). Weighing these costs against the importance of knowing if the management system is harming or benefiting the vegetation, suggests that monitoring is well worth the time and effort spent (Stuart-Hill 1999).

The importance of monitoring for the successful management of natural resources is becoming increasingly recognised (Stuart-Hill 1993). Few land managers are, however, using adequate monitoring techniques because of tediousness and skill limitations (Stuart-Hill 1999; Stuart-Hill 1993). Accurate monitoring techniques are vital in order for managers to be pro-active and adapt their management before irreversible damage occurs (Stuart-Hill 1993). Monitoring must also be repeatable (Coetzee 2005).

Examining the utilization and reproductive success of key browse species is an effective monitoring tool (Hurt and Hardy 1989; Stuart-Hill 1989b; Teague 1989; Willis and Trollope 1987; Heard *et al.* 1986). Browse monitoring programmes could consist of fixed point photography sites containing key browse species (Birnie *et al.* 2005; Hurt and Hardy 1989). These sites should be photographed and examined at the end of the dry season and during the peak flowering/seeding period (Birnie *et al.* 2005; Sessions and Kelly 2001). Should an obvious negative impact be discernable, such as the appearance of a browse line and a drop in the quantity of leaves, flowers/fruit and seedlings from one year to the next, browse stocking rates should be re-assessed (Birnie *et al.* 2005). Fixed point photography sites should preferably be supplemented with quantitative monitoring techniques (Coetzee 2005) as was done in this study, but will require a good knowledge of plant indicator species.

Based on abundance, palatability, productivity and sensitivity to overutilization, it appears that *Acacia karroo* and *Grewia occidentalis* are suitable indicator species in thicket. The current giraffe stocking rate at Nyaru is substantially higher than the stocking rate estimate made in this study. Since a negative impact is discernable on the reproductive success of both *A. karroo* and *G. occidentalis,* it is recommended that the owner of Nyaru re-assess his giraffe stocking rate and remove at least six of the giraffe from the property. Five of the 19 private estates surveyed in the southern Cape (Chapter 1) had higher giraffe stocking rates than the recommendation of this study. However, stocking rate calculations were based on the size of each property and not the actual amount of suitable giraffe habitat available.

With the introducing of extralimital or exotic species, the most important consideration is not whether the habitat is suitable to sustain the species, but what the ecological impacts of such introduced species on the indigenous habitats would be (Bothma 2004). Studies have shown that the introduction of extralimital or exotic wildlife to natural ecosystems can cause major ecological problems, including competition with indigenous species for habitat and food resources, competitive exclusion, loss of sensitive species, and a resultant loss of biodiversity (Burkett *et al.* 2002; Fialka 2002; Teer 2002; Delport *et al.* 2001; Bengtsson *et al.* 1997; Naem *et al.* 1994; Teer 1991). Although economic gains are a major driving force for the introduction of extralimital species (Castley *et al.* 2001; Bothma 2004), managing wildlife populations outside conservation and ecological principles holds inherent risks of undermining the natural resource base in an attempt to satisfy tourists and maximise financial gain (Bothma 2004; Kerley *et al.* 2003; Radder 2001). A resultant loss of biodiversity may reduce the stability of these habitats, making the remaining communities more vulnerable to invasions, disease or climate change that would ultimately lead to the loss of essential services provided by natural ecosystems (Naeem *et al.* 1994; Tilman and Downing 1994). This would in turn affect the long term economic viability of ecosystems (Bengtsson *et al.* 1997).

5.3 SUGGESTIONS FOR POSSIBLE FUTURE RESEARCH

This study was conducted on a single estate due to logistical difficulties which did not allow the study of giraffe on several properties. The focus was thus on a localized population within a confined area. It is recommended that future research consider the management of giraffe in thicket across landscapes. Dietary trends across landscapes will show the diet variability and the extent of preferences exhibited by giraffe in thicket. This will also mean that, in time, giraffe browsing capacity estimates will be obtained for different vegetation types in different condition states under varying amounts of rainfall. This will allow for more refined stocking rate recommendations.

Sex and age classes of large herbivores are affected by changes in the density of the herbivore populations and fluctuations in weather (Gordon *et al.* 2004) Management must consequently be adapted to the age and sex structure of a population, rather than to simple population counts (Gordon *et al.* 2004). This aspect of giraffe management was not dealt with in this thesis and requires further research.

The potential of giraffe to alter natural vegetation emphasises the need for proper monitoring of new and existing introductions to detect changes in the environment. The changes to thicket vegetation structure caused by giraffe browsing needs to be quantified. Although it is anticipated that change in the vegetation structure may be negative, this hypothesis will require further testing. Tree mortality, fitness and biomass removal could be included in such studies to show the full effect of giraffe browsing on principle and preferred species.

Another aspect not dealt with in this thesis is the effects of giraffe on indigenous herbivores occurring in the thicket. These herbivores have evolved and adapted to the environment in the absence of giraffe. The presence of giraffe may influence them directly or indirectly through competition for food and/or, space or just through behavioural changes.

There is a need to evaluate the true costs and benefits of extralimital species, including aspects such as long term ecological impacts, coalition with national conservation legislation, access to government conservation incentive schemes and visitor perceptions arising from the presence of such species.

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APPENDIX 1.1

QUESTIONNAIRE TO GAME RANCH OWNERS/ MANAGERS

Particulars of game ranch:

1. Name of ranch:…………………………………………………………………………..

2. Size of ranch:…………..

3. Management objectives (*Encircle those applicable*):

A) Tourism   B) Game farming   E) Other

C) Hunting   D) Biodiversity conservation

4. Species and numbers of browsers other than giraffe on property (estimates):…

Eland…………..	Impala……………	Other………………….
Nyala…………..	Springbok……….	………………………..
Bushbuck………	Kudu…………….	…………………………

5. Amount of water points on the property:...

6. Supplementary feeding: YES / NO

7. If yes, how often?……………………………………………………………………….

   For what species?………………………………………………………………………

   Supplement used:.………………...

Giraffe incidence:

8. Current amount of giraffes present on ranch: Male………../ Female………..

9. Date of first introduction and amount introduced:…...

10. Dates of other introductions (*if applicable*) and amount of giraffe introduced with each: ………..………

11. Number of calves born on property: Male……………..…/ Female.........……….

12. Number of giraffe mortalities and causes (if known) of death:..........................

…………………………………………………………………………………………………

13. Habitat/vegetation type on ranch where giraffe are observed most frequently:.

…………………………………………………………………………………………………

14. Problems experienced with the giraffes:…………………..................................

…………………………………………………………………………………………………

Thank you for your time and willingness to share information which will assist me with my research.

Regards, Andri Cornelius