THE FEEDING BIOLOGY AND POTENTIAL IMPACT OF INTRODUCED GIRAFFE (*GIRAFFA CAMELOPARDALIS*) IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

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The Giraffe

There comes a time when one desires The thoughts that move on dreaming spires. No callow quip or knowing laugh Was ever heard from young giraffe. The creature doesn't try to please By counterfeiting social ease, Is faced with no unnerving choice About the proper tone of voice, Is not compelled to make confession To any lack of self-possession. Silent, leaning through the leaves, He neither celebrates nor grieves; His physiognomy conceals Whatever joy or pain he feels, Yet no emotional inhibitions Lead him into false positions; And on his ever-listening face There lurks a steady, stupid grace.

> O would that I could learn the art To keep my busy head and heart So very, very far apart!

> > Ron Hall

ABSTRACT

Giraffe (Giraffa camelopardalis) are extralimital (non-native) to the Eastern Cape Province, South Africa yet they have and continue to be introduced to the region. Financial gain has arguably been the driving force behind these introductions as foreign tourists associate giraffe with Africa and the African wildlife experience. This raises a number of ethical, ecological and philosophical questions especially when it is considered that the impact of these browsers on the indigenous vegetation has remained largely unquantified. In this study I assessed the diet and potential impact of three populations of giraffe in the Eastern Cape Province between January 2002 and October 2003. The diet was assessed by both direct observations and faecal analysis. There was no significant difference (P > 0.05) between the results of the two methods of analysis, although direct observations appeared to be a superior method for assessing the diet of giraffe. The diet of giraffe in the Eastern Cape Province was similar to that within their native range with a deciduous species from the genus Acacia (Acacia karroo) being the most important component of the diet. However, giraffe in the Eastern Cape Province consumed more evergreen plant species than those within their native range. The relative lack of deciduous species in the Eastern Cape Province provides a likely explanation for such a result. Seasonal variation in the consumption of the most important species in the diet was evident and this was attributed to the deciduous nature of A. karroo and the seasonal growth of new shoots which were more palatable. The vegetation of the areas most commonly utilised by giraffe at each site was sampled using the point-centred-quarter method and the results related to the frequency of each species in the diet to calculate preference

iii

indices. Giraffe preference was strongest for *A. karroo* and this was attributed to the highly favourable chemical composition of the species. The browse utilisation of giraffe at each site was determined using the twig-length method and intake rates for the three most important species in the diet calculated using a pre-existing regression equation. Male giraffe fed at a higher rate than females. This was probably due to males adopting a "time-minimising" strategy to their feeding in order to allow more time for reproductive pursuits. Giraffe browse utilisation was highest where giraffe density was highest. However, several species were more heavily browsed than others even when giraffe density was low, suggesting that giraffe are capable of negatively affecting the indigenous flora of the province. I conclude that giraffe numbers should be reduced relative to property size in the Eastern Cape Province and that research into the impact of not only giraffe but the combined effects of giraffe and other extralimital herbivores on the indigenous flora and fauna be continued.

TABLE OF CONTENTS

FRONTISPIECE	ii
ABSTRACT	iii
LIST OF TABLES	vii
LIST OF FIGURES	Х
ACKKOWLEDGEMENTS	xiv
PREFACE	xvi
CHAPTER 1	
General introduction	1
1.1 Description	1
1.2 Taxonomy	2
1.3 Distribution and habitat	2
1.4 Behaviour	4
1.5 Reproduction	5
1.6 Diet	5
1.7 Giraffe and the Eastern Cape Province	5
1.8 Impact of giraffe	7
CHAPTER 2	
General description of the study sites	10
2.1 Location	10
2.2 Climate	10
2.2.1 Rainfall	11
2.2.2 Temperature	13
2.3 Kariega Game Reserve	15
2.3.1 Site description and history	15
2.3.2 Vegetation	16
2.3.3 Topography and geology	19
2.4 Kwandwe Private Game Reserve	19
2.4.1 Site description and history	19
2.4.2 Vegetation	20
2.4.3 Topography and geology	23
2.5 Shamwari Private Game Reserve	23
2.5.1 Site description and history	23
2.5.2 Vegetation	24
2.5.3 Topography and geology	28
2.6 Previous studies	28
CHAPTER 3	
The diet of introduced giraffe in the Eastern Cape Province, South Africa	29
3.1 Introduction	29
3.2 Materials and methods	36
3.2.1 Direct observations	36

3.2.2 Faecal collection and preparation	37
3.2.3 Microscopic analysis	38
3.2.4 Preparation of plant epidermal reference collection	39
3.2.5 Data analysis	39
3.3 Results	40
3.3.1 Direct observations	40
3.3.2 Faecal analysis	49
3.3.3 Method comparison	54
3.4 Discussion	62
CHAPTER 4	
Dietary preferences of introduced giraffe in the Eastern Cape Province,	
South Africa	68
4.1 Introduction	68
4.2 Materials and methods	72
4.2.1 Preference	72
4.2.2 Vegetation characterisation	73
4.3 Results	75
4.3.1 Vegetation characterisation	75
4.3.2 Preference	79
4.4 Discussion	83
CHAPTER 5	
The potential impact of introduced giraffe on the indigenous vegetation of	
the Eastern Cape Province, South Africa	87
5.1 Introduction	87
5.2 Materials and methods	91
5.2.1 Browse utilisation	91
5.2.2 Feeding rates	92
5.2.3 Data analysis	94
5.3 Results	94
5.3.1 Browse utilisation	94
5.3.2 Feeding rates	106
5.4 Discussion	109
CHAPTER 6	
General conclusions and management implications	114
REFERENCES	122

LIST OF TABLES

Table 3.1: The mean annual frequency of occurrence of plant species in the diet of giraffe across all sites and seasons as determined by direct observations (A) and faecal analysis (B) for the study period 2002-2003. Values are percentages ± 1 SD. Columns do not add up to 100 due to rounding off. ^{*e*} Evergreen; ^{*d*} Deciduous; ^{*s*-*d*} Semi-deciduous. **Table 4.1:** The botanical composition of the five areas most commonly frequented by the giraffe at Shamwari as determined by the point-centred-quarter method of vegetation

characterisation. Values are means for six transects.

Table 4.2: The botanical composition of the six areas most commonly frequented by the giraffe at Kwandwe as determined by the point-centred-quarter method of vegetation characterisation. Values are means for six transects

Table 4.3: The botanical composition of the seven areas most commonly frequented by the giraffe at Kariega as determined by the point-centred-quarter method of vegetation characterisation. Values are means for seven transects.

Table 4.4: The strength-of-preference indices for the ten most important species in the diet of giraffe at Shamwari for the study period 2002-2003. * Estimated preference index assuming a 0.1% frequency in the field.

Table 4.5: The strength-of-preference indices for the ten most important species in the

 diet of giraffe at Kwandwe for the study period 2002-2003. * Estimated preference index

 assuming a 0.1% frequency in the field.

Table 4.6: The strength-of-preference indices for the ten most important species in the diet of giraffe at Kariega for the study period 2002-2003.

Table 5.1: The average utilisation ($\% \pm 1$ SD) and average twigs browsed ($\% \pm 1$ SD) by giraffe at each site.

Table 5.2: The average utilisation ($\% \pm 1$ SD) of twelve tree species (n = 51) by giraffe at Shamwari as determined from twig length measurements.

Table 5.3: The utilisation ($\% \pm 1$ SD) of tree species and percentage of trees browsed by giraffe at Shamwari in two areas of different giraffe frequency. Trees browsed = trees that were browsed by giraffe in each transect divided by all trees in the transect multiplied by 100.

Table 5.4: The average utilisation ($\% \pm 1$ SD) of twelve tree species (n = 71) by giraffe at Kwandwe as determined from twig length measurements.

Table 5.5: The utilisation ($\% \pm 1$ SD) of tree species and percentage of trees browsed by giraffe at Kwandwe in three areas of different giraffe frequency. Trees browsed = trees that were browsed by giraffe in each transect divided by all trees in the transect multiplied by 100.

Table 5.6: The average utilisation ($\% \pm 1$ SD) of twelve tree species (n = 36) by giraffe at Kariega as determined from twig length measurements.

Table 5.7: The utilisation ($\% \pm 1$ SD) of tree species and percentage of trees browsed by giraffe at Kariega in two areas of different giraffe frequency. Trees browsed = trees that were browsed by giraffe in each transect divided by all trees in the transect multiplied by 100.

Table 5.8: The estimated feeding (intake) rates of male and female giraffe for the three most important species in the diet at each site in the Eastern Cape Province. TPB = Average time per bite (min); FR = Feeding rate (g.min⁻¹); n = number of observations. Numbers in brackets indicate standard deviations.

Table 6.1: A summary table of the importance of the two most important components (*Acacia karroo* and *Rhus longispina - R. crenata* and *R. pallens* in the case of Kariega), and the evergreen species in the diet of giraffe during the summer and winter months. AK = *Acacia karroo*; RL = Rhus longispina (R. crenata and R. pallens for Kariega); EG = Evergreen species. Data are average frequency of occurrence values for each season, rounded off to the nearest percentage.

LIST OF FIGURES

Figure 1.1: The distribution of giraffe in Africa, from Skinner & Smithers (1990).

Figure 2.1: The annual precipitation for Grahamstown over the eleven-year period

(1993-2003). The dashed line indicates the eleven-year mean for annual precipitation.

Figure 2.2: The mean monthly rainfall (± 1 SD) in Grahamstown over the eleven-year period (1993-2003).

Figure 2.3: The monthly rainfall during the study period (2003-2003) in relation to the mean monthly rainfall for the eleven-year period 1993-2003.

Figure 2.4: The mean monthly maximum and minimum temperatures in Grahamstown for the eleven-year period 1993-2003.

Figure 2.5: The mean monthly maximum and minimum temperatures for Grahamstown during the study period 2002-2003.

Figure 2.6: The Kariega Game Reserve depicting the five major vegetation types present on the reserve.

Figure 2.7: The Kwandwe Private Game Reserve depicting the seven major vegetation types present on the reserve.

Figure 2.8: The Shamwari Private Game Reserve depicting the thirteen major vegetation types represented on the reserve, after O'Brien (2000). Cleared and cultivated lands have been combined.

Figure 3.1: The most important species in the diet of giraffe at Shamwari. The mean values ± 1 SD for each season are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

Figure 3.2: The most important species in the diet of giraffe at Kwandwe. The mean values ± 1 SD for each season are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

Figure 3.3: The most important species in the diet of giraffe at Kariega. The mean values ± 1 SD for each season are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

Figure 3.4: The five most important species in the diet of giraffe at Shamwari as assessed by faecal analysis. Mean values ± 1 SD are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

Figure 3.5: The five most important species in the diet of giraffe at Kwandwe as assessed by faecal analysis. Mean values ± 1 SD are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

Figure 3.6: The five most important species in the diet of giraffe at Kariega as assessed by faecal analysis. Mean values ± 1 SD are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

Figure 3.7: The correlation between the results of the two methods of diet assessment for giraffe in the Eastern Cape Province. Values are percentages in each case. Dashed lines indicate 95% confidence limits; Observation = Direct observations; Faecal = Faecal analysis.

Figure 3.8: The relative importance of the five most important plant species in the diet of giraffe in the Eastern Cape Province as determined by each method of diet assessment. * P < 0.05 Students t-test.

Figure 3.9: A comparison between the seasonal importance of the five most important species in the diet of giraffe as determined by each method of diet assessment at Shamwari including the unidentified component. A = Direct observations; B = Faecal analysis. * P < 0.05 as determined previously.

Figure 3.10: A comparison between the seasonal importance of the five most important species in the diet of giraffe as determined by each method of diet assessment at Kwandwe including the unidentified component. A = Direct observations; B = Faecal analysis. * P < 0.05 as determined previously.

Figure 3.11: A comparison between the seasonal importance of the five most important species in the diet of giraffe as determined by each method of diet assessment at Kariega including the unidentified component. A = Direct observations; B = Faecal analysis. * P < 0.05 as determined previously.

Figure 5.1: The percentage browse utilisation of giraffe at Shamwari plotted against the percentage twigs browsed. Ak = *Acacia karroo*; At = *Azima tetracantha*; Eu = *Euclea undulata*; Go = *Grewia occidentalis*; Pa = *Portulacaria afra*; Rc = *Rhus crenata*; Rp = *Rhus pallens*; Rl = *Rhus longispina*; Sa = *Schotia afra*; Si = *Sideroxylon inerme*.

Figure 5.2: The percentage browse utilisation of giraffe at Kwandwe plotted against the percentage twigs browsed. Ak = *Acacia karroo*; At = *Azima tetracantha*; Bo = *Boscia oleoides*; Ch = *Carissa haematocarpa*; Eu = *Euclea undulata*; Gb = *Gymnosporia*

buxifolia; Gp = *Gymnosporia polycantha;* Ly = *Lycium* sp.; Oe = *Olea europea;* Pc = *Pappea capensis;* Rl = *Rhus longispina;* Sa = *Schotia afra.*

Figure 5.3: The percentage browse utilisation of giraffe at Kariega plotted against the percentage twigs browsed. Ac = *Acacia caffra*; Ak = *Acacia karroo*; Cs = *Capparis* sepiaria; Dd = *Diospyros dichrophylla*; Gb = *Gymnosporia buxifolia*; Rp = *Rhus pallens*; Sa = Schotia afra; Si = *Sideroxylon inerme*; Sm = *Scutia myrtina*.

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PREFACE

This thesis is structured as follows:

- Chapter one is a general introduction including notes on the biology, impact of giraffe and a brief introduction to the study area followed by the broad aims of the project.
 This is not an experimental chapter and is not structured as such. This chapter is intended set the scene and introduce the important components of the project.
- Chapter two is a detailed description of the three study sites utilised in the project.
 Again this is not an experimental chapter and consequently does not have aims or objectives.
- Chapters three to five are the three experimental chapters of the thesis. Each chapter takes the format of a scientific paper and is designed to stand alone with its own introduction, aims, materials and methods, results and discussion.
- Chapter six is a concluding chapter where the conclusions from the previous chapters are highlighted along with potential suggestions for reserve managers.

CHAPTER 1

GENERAL INTRODUCTION

1.1 DESCRIPTION

The giraffe (*Giraffa camelopardalis*, Linnaeus) is the tallest even-toed ungulate in the world (Skinner & Smithers, 1990). Giraffe are covered in large, irregularly shaped chestnut-brown to black patches separated from one another by a network of off-white, white or yellowish-white bands (Dagg, 1971; Skinner & Smithers, 1990). These dark patches apparently serve a thermoregulatory function but may have initially evolved as a form of camouflage in the giraffe's forest or woodland ancestors (Kingdon, 1979; Skinner & Smithers, 1990). The dark patches may darken with age especially in male giraffe (Foster, 1966; Kingdon, 1979; Skinner & Smithers, 1990). Giraffe are approximately 4.3m to 5.2m tall, although the tallest male recorded stood almost 6m. (Dagg, 1971; Skinner & Smithers, 1990). The average mass for adult male giraffe is 1191kg while the average mass for adult females is 828kg (Dagg, 1971; Skinner & Smithers, 1990). Both males and females possess horns covered with skin. Unlike the bovids, the horns of giraffe are soft and cartilaginous at birth, ossifying with age, and eventually fusing with the skull (Skinner & Smithers, 1990). Males are distinguished from females by having thicker horns that lack the characteristic "tuft" of hair found at the tip of the horns in females.

1.2 TAXONOMY

The Giraffidae has two genera, each with a single species. One of these species is the giraffe and the other the Okapi (*Okapia johnstoni*, Lankester) of the lowland forests in central Africa (Nowak & Paradiso, 1983). Several species of giraffe were once recognised, however, the genus is now considered monospecific (Dagg, 1971; Grzimek, 1990). Two subspecies occur in southern Africa, namely: *G. c. capensis* (Lesson) which occurs in the Mpumalanga Province of South Africa, southwestern Mozambique and southern and southeastern Zimbabwe, and *G. c. angolensis* (Lydekker) from northwestern Zimbabwe, northern Botswana and northern Namibia (Skinner and Smithers, 1990). The two southern subspecies differ primarily in their markings; *G. c. angolensis* has larger patches than *G. c. capensis* (Kingdon, 1979). The patches in both subspecies are numerous and have jagged outlines and the patches of *G. c. capensis* have firmer outlines than those of *G. c. angolensis* (See Kingdon, 1979).

1.3 DISTRIBUTION AND HABITAT

Giraffe are distributed in a patchy and discontinuous fashion south of the Sahara in areas dominated by miombo-woodland (Figure 1.1), after once being reasonably widespread throughout the continent (Churcher, 1978; Skinner & Smithers, 1990). They occur predominantly in savanna habitats, where they browse on trees and shrubs and are primarily diurnal in habit spending the majority of the day feeding and ruminating (Dagg, 1962; Happold, 1969; Hofmann & Stewart, 1972; Leuthold & Leuthold, 1978a; Pellew, 1984a; Skinner & Smithers, 1990). Giraffe favour open or broken savanna habitats where visibility is good and they are less prone to predation (Skinner & Smithers, 1990).

However, nomadic males frequently forage in denser habitats (Foster, 1966; Fourie, 1977). Thus, it is not surprising that more males than females are killed by lions (Hall-Martin, 1975). During the wet season giraffe tend to utilise areas dominated by deciduous vegetation (e.g. areas dominated by *Acacia* spp.) because of the increased protein and water content of the leaves (Cooper *et al.*, 1988; Pellew, 1984b). However, in the dry season they concentrate along watercourses and in habitat types where the tree species are often evergreen (Hall-Martin, 1974a; Owen-Smith, 1992). Hall-Martin (1974a) demonstrated that the movement of giraffe into alternative habitats during the dry season is reflected in an increased utilisation of the tree species found in those areas.



Figure 1.1: The distribution of giraffe in Africa, from Skinner & Smithers (1990).

1.4 BEHAVIOUR

Giraffe are gregarious but form looser herds than most other ungulates (Le Pendu et al., 2001; Pratt & Anderson, 1985). Herd structure and numbers are highly variable, and older males are more nomadic than females and consequently have larger home ranges (Foster, 1966; Foster & Dagg, 1972; Leuthold & Leuthold, 1978b; Leuthold, 1979). Giraffe are not territorial, but may spend extended periods in certain areas depending on the availability of browse. Strong social bonds in giraffe, apart from the cow-calf relationship where calves can suckle up until one and a half years of age, are not reported in the literature (Langman, 1977; Le Pendu et al., 2001). Vocalisation is limited (Stanton, 1955), although recent research suggests that giraffe can vocalise at frequencies below the threshold of human hearing using infrasound as a covert form of communication (Mason, 2002; von Muggenthaler et al., 1999). Apart from older males soliciting receptive females more often than younger males, no other social segregation or hierarchy by sex or age is evident in giraffe (Innis, 1958; Le Pendu et al., 2001). Adult male giraffe will frequently engage in "necking" behaviour or spar with one another presumably to determine this sexual dominance (Berry, 1973; Coe, 1967; Innis, 1958). When "necking", two males will stand stiff-legged several metres apart, both usually facing the same direction, and one will initiate the contact by striking a blow to the chest of the other animal with its head and, or neck. This is then reciprocated and repeated for extended periods (Berry, 1973; Coe, 1967). Interestingly, Simmons & Scheepers (1996) suggest that a longer neck and heavier skull increase a male's chance of mating (after winning a "necking" bout) and may have been an important selection criterion in the evolution of a long neck in giraffe.

1.5 REPRODUCTION

Amongst the ungulates only the giraffe has a gestation period that is longer than a year (*c*. 450 days)(Mentis, 1972; Robinson *et al.*, 1965; Savoy, 1966; Skinner & Smithers, 1990; Zellmer, 1960). Daylength acts as an indirect stimulus on female giraffe via changes in the nutritional status of the vegetation and conception seems to be correlated to an increase in rainfall which occurs a month prior to conception itself (Hall-Martin *et al.*, 1975). Parturition can occur throughout the year but distinctive seasonal peaks during the dry season are evident in most populations (Berry, 1973; Fairall, 1968; Foster & Dagg, 1972; Hall-Martin *et al.*, 1975). Calves weigh ~102kg at birth and stand ~1.5m tall (Hall-Martin *et al.*, 1975). A female becomes sexually mature at 4.5 years and remains reproductively active until the age of 20 (Furstenburg, 1991; Skinner & Smithers, 1990). Given the inter-calving interval of ~ 20 months (Leuthold & Leuthold, 1978b) a female is capable of producing nine calves in her lifetime (Furstenburg, 1991). The longevity of giraffe is 28 years (Foster & Dagg, 1972).

1.6 DIET

A full introduction to giraffe diet and feeding behaviour can be found in the introduction to chapter 3.

1.7 GIRAFFE AND THE EASTERN CAPE PROVINCE

The Eastern Cape Province, South Africa forms a complex transition zone between four major phtyochoria, the Cape, Tongoland-pondoland, Karoo-Namib and Afromontane (Lubke *et al.*, 1986). Consequently, the region is high in plant species diversity. This

diversity once supported a vast array of mammals, many of which, especially the large carnivores, were shot-out towards the latter half of the nineteenth century (Boshoff & Kerley, 2001; Skead, 1987). Now, the pattern of land use in the Eastern Cape is changing rapidly from agriculture and livestock farming to conservation and game farming. Farmers are converting their farms into game farms while existing reserves are expanding. While this change in land use can potentially increase the natural diversity of the region many private wildlife operations have introduced and continue to introduce non-native mammalian species due to their tourism or hunting potential (Castley *et al.*, 2001). The giraffe is one such species.

Historical records indicate that the most southerly occurrence of extant giraffe in Africa was the northern border between South Africa and Swaziland (Figure 1.1; Skinner & Smithers, 1990). However, fossil records of *Giraffa camelopardalis* and its extinct relatives have been found in the south-western (Darling district of the Western Cape Province) and central portions (Free State Province) of South Africa (Cooke 1974; Singer & Boné, 1960), suggesting that the distribution of giraffe in southern Africa may have been far wider than was originally thought. However, giraffe have never been recorded along the eastern seaboard of South Africa despite anecdotal reports of bushman paintings in certain parts of the Eastern Cape and remains found at archaeological sites in the KwaZulu-Natal Province (Goodman & Tomkinson, 1987; Plug & Badenhorst, 2001; Skead, 1987). It is generally accepted that a combination of excessive hunting, disease and climate change reduced the distribution of giraffe in Africa (Kingdon, 1979; Nowak & Paradiso, 1983). The same combination of factors may have been responsible for the

extirpation of giraffe from the Eastern Cape Province. However, without more convincing evidence, and for the purposes of this study, giraffe are regarded as extralimital (non-native) in the Eastern Cape Province (Castley *et al.*, 2001).

1.8 IMPACT OF GIRAFFE

Introductions of large mammalian herbivores, such as giraffe, beyond their natural range may be economically viable in the short term (five - ten years). However, the ecological repercussions of such introductions are unknown. Giraffes are classified as browsing megaherbivores; a herbivorous mammal with males exceeding 1000kg (Owen-Smith, 1992) and have high absolute energy requirements (Bell, 1971). In order to satisfy such requirements an adult female giraffe must consume approximately 2.1% (~16.60kg.) of its live-weight per day (Pellew, 1984a). Thus, giraffe are capable of negatively affecting the vegetation of the area they inhabit. Bond & Loffell (2001) demonstrated that introduced giraffe at the Ithala Game Reserve in the Kwa-Zulu Natal Province have altered the species distribution and composition of the savanna ecosystem, through differential mortality of Acacia davyi. In addition, woodland regeneration after fire in the Serengeti (which is within the natural range of giraffe) has been shown to be prevented by giraffe (Pellew, 1983a). By preventing the vertical growth of tree saplings, the giraffe maintain the trees within the fire-susceptible size class (Pellew, 1983a). More recently, Birkett (2002) demonstrated using modelling techniques that giraffe in Kenya would have the greatest impact on the three to five meter size class of trees. This would cause the tree density of the park to decline by two percent per annum if giraffe browsing was combined with that of elephant (Loxodonta africana, Blumenbach) and black rhino

(*Diceros bicornis*, Linnaeus). Augustine & McNaughton (1998) postulated that an increase in the density of herbivores in a specific area will reduce selectivity (consumption of preferred species) because of the reduced availability of preferred plant species per animal, but increase the absolute amounts of tissue removal from the remaining plants to such an extent that there will be a significant (negative) effect on the species composition of the community (Augustine & McNaughton, 1998).

The introduction of giraffe to the Eastern Cape Province has raised a number of ecological, ethical and philosophical questions. The boom in the game farming and tourism industry in the Eastern Cape Province has meant that many of the new game farms and game reserves have stocked extralimital species with little or no scientific evidence to support their actions. Historically, most of the land in the Eastern Cape was used for small stock farming, as the region is not particularly suitable for crop cultivation. Consequently, much potentially irreparable damage to the natural vegetation due to overstocking and bush clearing has occurred (LaCock, 1992). Thus, the introduction of extralimital herbivores to a region that is already suffering from past mis-management must be questioned, especially when one considers the potential for these herbivores to further alter the structure of the vegetation. However, the advent of game farms and game reserves in the province has released large areas from such farming pressure. In addition, game farms and game reserves inject 40 times as much income into the province compared to stock farming and have created 23 times as many jobs (Parker & Bernard, 2003). O'Connor et al. (2003) demonstrated the importance of incorporating social, political and economic factors into a conservation strategy. This is especially important in

the Eastern Cape Province where unemployment is high, average income per household is low, and where tourism could potentially increase the income to the province. In addition, data on the ecological impact of giraffe is non-existent for the Eastern Cape Province and this needs to be addressed before any decisions regarding the fate of extralimital herbivores in the province are made. In this thesis, I examine and describe the diet and general feeding biology of giraffe in the Eastern Cape Province, South Africa and ascertain which tree species are likely to be most affected by giraffe browsing. This information will assist managers and scientists in making calculated management decisions future of giraffe in the province and the conservation of indigenous vegetation.

CHAPTER 2

GENERAL DESCRIPTION OF THE STUDY SITES

2.1 LOCATION

The study was conducted at three sites near Grahamstown in the Eastern Cape Province of South Africa. The sites were selected based on their size, proximity to Grahamstown, differing habitat types, giraffe population size, presence or absence of predators and the length of time the giraffe had been present on each property. Kariega Game Reserve (hereon referred to as Kariega) lies approximately 45km South of Grahamstown in the Kariega River valley (33°35'S, 26°37'E). Kwandwe Private Game Reserve (Kwandwe) is situated approximately 27km Northeast of Grahamstown in the Great Fish River valley (33°09'S, 26°37'E). Shamwari Private Game Reserve (Shamwari) is 60km Southwest of Grahamstown, along the N2 national road to Port Elizabeth (33°20'S, 26°01'E).

2.2 CLIMATE

Due to a lack of climatic data for each site, the climatic data for Grahamstown were used as a convenient point of reference for the general climatic conditions experienced at each site. However, details of the localised climate at each site are given under the site descriptions. Grahamstown can be described as having a humid, temperate (warm) climate with rainfall in all seasons.

2.2.1 Rainfall

Frontal systems are responsible for the majority of precipitation in Grahamstown. However, there are usually 15 days of thunderstorms a year, most often occurring during the summer months (Stone et al., 1998). The annual precipitation, as measured at the Grahamstown weather station, for the eleven-year period 1993-2003 is illustrated in Figure 2.1. The mean annual precipitation for this period was 504 ± 37 mm, which was only slightly higher than the mean annual precipitation $(478 \pm 41 \text{ mm})$ for the study period (2002-2003). However, significantly less rain fell in 2003 (Figure 2.1). However, it must be noted that the October to December data were not available at the time of writing. Rainfall in the Eastern Cape Province is not as seasonal as it is for other parts of southern Africa, such as the Mpumalanga Province which experiences distinct wet and dry seasons (Ogutu & Owen-Smith, 2003). This is ascribed to the Eastern Cape Province being a transition zone of climatic types (Stone et al., 1998). Significantly, areas with highly seasonal rainfall are within the native range of giraffe. Rainfall can be expected all year round in Grahamstown with approximately 82 days of rain a year (Figure 2.2; Stone et al. 1998). However, distinct bimodal peaks during March-April and November-December are evident (Figure 2.2). During the study period (2002-2003), the pattern of monthly rainfall was similar to the average monthly rainfall. However, below average rain fell in five months of 2002, while August-October had exceptionally high rainfall (Figure 2.3). During 2003 below average rain fell in most months (Figure 2.3).



Figure 2.1: The annual precipitation for Grahamstown over the eleven-year period (1993-2003). The dashed line indicates the eleven-year mean for annual precipitation.



Figure 2.2: The mean monthly rainfall (± 1 SD) in Grahamstown over the eleven-year period (1993-2003).



Figure 2.3: The monthly rainfall during the study period (2002-2003) in relation to the mean monthly rainfall for the eleven-year period 1993-2003.

2.2.2 Temperature

The mean monthly maximum and minimum temperatures as recorded in Grahamstown for the period 1993-2003 reflect a temperate climate (Figure 2.4). The winter months (June-August) are the coldest, while December, January and February are the hottest (Figure 2.4). The mean monthly temperatures during the study period (2002-2003) were similar to the eleven-year monthly means (Figures 2.4 and 2.5). In Grahamstown, temperatures can range between 40°C on the hottest day and -5° C on the coldest night. On average, the temperature will exceed 35°C on 5-10 days a year. Widespread frost (temperatures below 0°C) is only experienced five days a year, usually between 1 July and 1 August (Stone *et al.*, 1998). The mean annual temperature varies between 16° and 20°C (Stone *et al.*, 1998).



Figure 2.4: The mean monthly maximum and minimum temperatures in Grahamstown for the eleven-year period 1993-2003.



Figure 2.5: The mean monthly maximum and minimum temperatures for Grahamstown during the study period 2002-2003.

2.3 KARIEGA GAME RESERVE

2.3.1 Site description and history

Kariega is 1900Ha in size and is bounded by the 343 regional road in the west, by the Kariega River in the East, by the Southwell secondary road in the South and by a secondary road in the North. The perennial Kariega River flows through the reserve for 11km and is the major water source apart from several small dams. Kariega falls within the spring-dominated rainfall strip of the province but has a pronounced bimodal rainfall pattern (Stone *et al.*, 1999). This bimodal pattern of rainfall results in Kariega having the highest rainfall of the three sites (~ 700mm) per annum (Low & Rebelo, 1996). The increased precipitation at Kariega can also be attributed to coastal fog, which occurs when moist air from the sea moves over a cold land surface (Stone et al., 1998). The reserve's proximity to the coast also means that the weather is influenced by the land/sea breezes, which occur in the late afternoon/evening due to the differential heating and cooling of the land and sea (Stone *et al.*, 1998). Effectively, these breezes have a moderating affect on the temperature by decreasing day-time temperatures and increasing night-time temperatures resulting in reduced frost which can cause dramatic leaf-loss on some tree species (Parker et al., 2003; Stone et al., 1998).

Before the reserve was formed in 1990, the land was used predominantly for small stock farming with some crops grown on the flood plain of the Kariega River. The areas that were ploughed up for crop planting near the river have been lying fallow since the reserve was formed and are now in various successional stages of reverting to the natural vegetation. Six giraffe, along with a number of other extralimital species, were

introduced to the reserve in 1991. From a nucleus of two males and four females, the population has grown to sixteen animals (five males and eleven females) in 2003. No large predators have been introduced to the reserve, however, leopard (*Panthera pardus*, Linnaeus) and Caracal (*Felis caracal*, Schreber) have been sighted. No giraffe mortalities have been recorded since their introduction.

2.3.2 Vegetation

The vegetation of Kariega comprises Coastal Forest, Valley Thicket, Eastern Thorn Bushveld, Secondary Acacia Thicket and Old farmlands (Figure 2.6). The Coastal Forest occurs in the deep valleys of the reserve along the East and West boundaries. It is characterised by species such as *Mimusops caffra, Apodytes dimidiata, Sideroxylon inerme, Cassine aethiopica* and some *Strychnos* spp. (Low & Rebelo, 1996). Valley thicket is a very dense thicket of evergreen woody shrubs and trees found on the slopes of most of the hills in the reserve (Figure 2.6). *Cassine aethiopica, Euphorbia triangularis, E. tetragona* and *Plumbago auriculata* are indicator species of this vegetation type (Low & Rebelo, 1996). *Acacia cyclops* (an alien invasive species) has also invaded portions of this vegetation type on the reserve.

The northern regions, as well as a few ridges in the South of the reserve are dominated by Eastern Thorn Bushveld (Figure 2.6). This vegetation type is characterised by small (< 3m) *Acacia karroo* trees and some invasive thicket species such as *Diospyros dichrophyla, Rhus* spp., *Scutia myrtina* and *Ehretia rigida* (Low & Rebelo, 1996). *Acacia mearnsii* (another alien invasive) is also found at relatively high densities. Fire and grazing are essential in structuring the dynamics of this vegetation type (Low & Rebelo, 1996).

Secondary Acacia thickets are dominated by *Acacia karroo* and occur along portions of the river where indigenous vegetation has been removed. The *A. karroo* trees are typically much taller in this region (4-5m).

The Old Farm Land is found on the flood plains of the Kariega River (Figure 2.6). These areas are dominated by grass species such as *Panicum stapfianum, Eragrostis curvula* and *Themeda triandra*. Exotic tree species (e.g. *Populus deltoides)* have also been planted in places.



Figure 2.6: The Kariega Game Reserve depicting the five major vegetation types present on the reserve.

2.3.3 Topography and geology

Kariega ranges in altitude from 23m at the base of the Kariega River valley to 262m at the entrance gate in the northwestern corner of the reserve. The northern half of the reserve is situated on a plateau above the Kariega River valley. The southern half of the reserve is dominated by undulating hills in the West and flat low-lying ground in the East.

The dominant geological formations of the reserve include Beaufort Group shale, mudstone, solonetic soils and sandstone; and Cape Supergroup sandy clays and lithosols (Low & Rebelo, 1996).

2.4 KWANDWE PRIVATE GAME RESERVE

2.4.1 Site description and history

Kwandwe is ~16 000 Ha in size and is bounded by the R67 regional road in the East, the Great Fish River in the North-east and fences bordering farmland in the North, West and South. A secondary road passes through the centre of the reserve, which is permanently manned by a gate-guard at each end. The perennial Great Fish River flows through the reserve for 25km. Two large man-made dams and several smaller dams provide important sources of water. Kwandwe straddles both the spring and autumn-dominant rainfall regions of the province. Consequently, distinct bimodal rainfall is experienced (Stone *et al.*, 1998). However, rainfall at Kwandwe is only approximately 400mm per annum (Low & Rebelo, 1996). Kwandwe is situated on the leeward side of an extension of the *Kaprivierberge* and thus receives less rainfall than Grahamstown. Kwandwe is not affected by land/sea breezes like Kariega, thus, the reserve experiences hot summers

(temperatures often exceeding 35° C) and cold (below 5° C) winters with widespread frost due to radiational cooling on clear winter nights (Stone *et al.*, 1998). Thunderstorm development is promoted by the high temperatures during the summer months (Stone *et al.*, 1998).

Several farms that were previously utilised for ostrich and small stock farming were purchased to form Kwandwe in 2000. Thirty-one giraffe (twelve males and eighteen females) were introduced to the reserve in 2001. This population has grown to 34 in 2003 with five calves born and two deaths. One death was due to stress during translocation while one was believed to have been due to extreme cold.

Large predators on the reserve include lion (*P. leo*, Linnaeus), leopard, cheetah (*Acinonyx jubatus*, Schreber) and brown hyaena (*Hyaena brunnea*, Thunberg).

2.4.2 Vegetation

The vegetation of Kwandwe can be divided into seven major vegetation types, namely: Medium Portulacaria Thicket, Short Euphorbia Thicket, Tall Euphorbia Thicket, Riverine Thicket, Bushclump Karoo Thicket, Bushclump Savanna and Karoo Shrubland (Figure 2.7).

The Medium Portulacaria Thicket is analogous to the Xeric Succulent Thicket described by Low & Rebelo (1996). Xeric Succulent Thicket is dominated by a high proportion of succulent shrubs, trees and lianas as well as some sclerophyllous trees and shrubs (Low & Rebelo, 1996). This vegetation is invasive in savanna and grassland vegetation in the absence of browsers such as black rhino (*Diceros bicornis*, Linnaeus) and kudu
(*Tragelaphus strepsiceros*, Pallas). Indicator species include *Grewia robusta*, *Brachylaena ilicifolia, Portulacaria afra, Maytenus capitata* and *Rhigozum obovatum* (Low & Rebelo, 1996).

Short Euphorbia Thicket derives its name from the short (< 1m), succulent, *Euphorbia bothae* plants that dominate the vegetation type. Other important species include *Euclea undulata, Rhus* spp., *Lycium* spp. and *Rhigozum obovatum*.

Tall Euphorbia thicket is generally found on the slopes of the hills in the northern part of the reserve and is characterised by the presence of *Euphorbia tetragona, E. triangularis, Cassine aethiopica, Schotia afra, Pappea capensis* and *Euclea undulata* (Low & Rebelo, 1996).

As the name suggests, the Riverine Thicket dominates the watercourses and most of the drainage lines within the reserve (Figure 2.7). Dense stands of *Acacia karroo* make up the bulk of the vegetation interspersed with some *Lycium* spp. and *Azima tetracantha*. *Pappea capensis, Rhus longispina, Euclea undulata, Aloe ferox* and *Schotia afra* are characteristic of the Bushclump Karoo Thicket.

Bushclump Savanna consists of bushclumps of several *Rhus* spp., *Pappea capensis*, *Schotia afra* and *Carissa haematocarpa* interspersed with Karroid shrubs such as *Pentzia incana* and several grass species.

The Karoo Shrubland is analogous to the Eastern Mixed Nama Karoo described by Low & Rebelo (1996). It is a mixture of grasses and shrubs and dependent on seasonal rainfall (Low & Rebelo, 1996). *Pentzia incana* and *Eriocephalus ericoides* are indicator shrub species while *Pappea capensis* and *Acacia karroo* comprise the small tree component.



Figure 2.7: The Kwandwe Private Game Reserve depicting the seven major vegetation types present on the reserve.

2.4.3 Topography and geology

Kwandwe ranges in altitude from 580m in the Northeast on the *Fish River Rand*, to 283m in the Great Fish River valley. The reserve is dominated by steep valleys and gorges in the South and Northeast and undulating hills in the central portion.

The dominant geological formations include Ecca Group shales producing deep limerich, sandy loam soil, Cape Supergroup sandy clays and lithosols, Dwyka and Ecca Formations and deep solonetic soles from Beaufort group dolerites (Low & Rebelo, 1996).

2.5 SHAMWARI PRIVATE GAME RESERVE

2.5.1 Site description and history

Shamwari is approximately 20 000 Ha in size and lies between Alicedale in the North and the N2 national road in the South. Three secondary roads cross the length of the reserve and each entrance is permanently manned by a gate-guard. The major water source is the semi-perennial Bushman's River, which flows through the reserve for 27.6km. Numerous small dams and pans, dotted throughout the reserve, are the other important water sources. Shamwari is situated in the spring dominant rainfall strip of the province and receives approximately 550mm of rainfall per annum (Low & Rebelo, 1996; Stone *et al.*, 1998). However, bimodal rainfall is experienced during the autumn and spring months (O'Brien, 2000). Shamwari's locality means that the climate of the reserve is intermediate compared to the other two sites. It receives slightly less rainfall than Kariega, and temperatures similar to Grahamstown. Frost can occur on cold winter nights especially in the low-lying areas.

Shamwari was formed in 1993 after several farms previously used for small stock and beef farming were purchased. Many areas that had natural vegetation removed when the area was used for farming were incorporated into the reserve. These areas have been lying fallow since the reserve's inception (some longer) and are in various successional stages of reverting to the original vegetation. Giraffe (numbers unknown) were introduced in 1993 and 1994. The current population (2003) stands at eighteen individuals with an equal sex ratio. Seven calves have been born and two mortalities recorded. One calf was killed by lions and one adult female injured and subsequently preyed upon by lions.

The large predators on the reserve include lion, leopard, cheetah, brown hyaena and wild dog (*Lycaon pictus*, Temminck).

2.5.2 Vegetation

Shamwari can be divided into thirteen vegetation types (O'Brien, 2000). These are Afromontane Forest, Subtropical Thicket, Bontveld, Bushclump Savanna, Grassy Fynbos, Karoo Scrub, Riverine bush, Montane Grassland, Open Grassland, Primary Acacia Thicket, Secondary Acacia Thicket and Cleared and cultivated land (Figure 2.8). The Afromontane Forest has a patchy distribution on the reserve, restricted to deep valleys where moisture is highest (Figure 2.8). It is characterised by numerous tall (30-40m) trees. Species such as *Podocarpus* spp., *Apodytes dimidiata, Halleria lucida* and

Calodendrum capense are prevalent, while *Gymnosporia buxifolia*, *Scutia myrtina* and *Rhoicissus tridentata* dominate the shrub layer (Low & Rebelo, 1996). The Subtropical Thicket is analogous to the Valley Thicket found at Kariega. The Subtropical Thicket accounts for 44.2% of the total area of the reserve (Figure 2.8). Bontveld is restricted to the flat and moderately sloped calcrete soils in the South of the reserve (Figure 2.8). The vegetation consists of bushclumps interspersed with grass and/or Karoo shrubs. The bushclumps in the Bontveld are typically composed of several *Rhus* spp., *Canthium inerme, Zanthoxylem capense, Scutia myrtina* and *Grewia occidentalis* (O'Brien, 2000).

The Bushclump Savanna is analogous to the Bushclump Savanna found at Kwandwe. However, fewer *Pappea capensis* trees are present. It only occurs on deep soils, without calcrete substrata in the southern part of the reserve (O'Brien, 2000).

The Grassy Fynbos is only found on the quartzite ridges in the northern part of the reserve (Figure 2.8). Characteristic species of this vegetation type are *Leucadendron salignum, Passerina vulgaris, Aspalathus chortophila* and *Metalasia muricata* (O'Brien, 2000).

The Karoo Scrub is analogous to the Karoo Shrubland found at Kwandwe and is only found in the southwestern part of the reserve (Figure 2.8).

The Riverine bush (Riverine thicket) is limited to the banks of the Bushmans River and some temporary watercourses (Figure 2.8). *Combretum caffrum, Acacia caffra* and *Plumbago auriculata* are characteristic of the vegetation type (O'Brien, 2000).

The Montane Grassland only occurs on quartzite ridges above Subtropical Thicket at an altitude greater than 400m (Figure 2.8). These areas are dominated by *Themeda triandra*,

Eragrostis curvula and *Sporobolus fimbriaus* but can be invaded by thicket species in the absence of bulk grazers (O'Brien, 2000).

Open Grasslands are only found in the South of the reserve (Figure 2.8). *Themeda triandra, Eragrostis curvula* and *Digitaria eriantha* dominate the vegetation of the area (O'Brien, 2000).

Primary Acacia thicket is generally found on the low-lying flat land of the reserve, near watercourses. It is often found in areas that were previously cleared for agriculture. It is dominated by *Rhus longispina* with some *Acacia karroo*. Other characteristic species include *Azima tetracantha* and *Gymnosporia polycantha* (O'Brien, 2000).

Secondary Acacia thicket occurs where Primary Acacia thicket has been disturbed either through overgrazing or mismanagement. *Acacia karroo* dominates these thickets with very few *R. longispina* and *A. tetracantha*. When combined the Primary and Secondary Acacia thickets account for 7.4% of the total area of the reserve (Figure 2.8). The cleared and cultivated lands are disturbed habitats that have either been cleared to create grazing for stock or lands that were used to cultivate crops (O'Brien, 2000). This vegetation type is typical of the area surrounding homesteads, on cut-lines (e.g. fire breaks or similar area where bush has been cleared) and near the Bushmans River (Figure 2.8). *Azima tetracantha* and various grass species are often prevalent in these areas (O'Brien, 2000).



Figure 2.8: The Shamwari Private Game Reserve depicting the thirteen major vegetation types represented on the reserve, after O'Brien (2000). Cleared and cultivated lands have been combined.

2.5.3 Topography and geology

Shamwari ranges in altitude from 196m in the South to 628m in the North. The topography ranges from gently undulating hills in the South to deep valleys and gorges in the North.

The dominant geological formations in the reserve are Bokkeveld Series shale, Witteberg quartzites, Karoo sandstone and Sundays River Formations. The quartzite ridges traverse the central and northern parts of the reserve, while the southern part of the reserve is dominated by the Sundays River Formation resulting in shallow soils underlain by calcrete. Four main substrata are available for the plants, namely: shale, sandstone, quartzite and calcrete. In addition, deeper alluvial soils are found on the lower lying lands (O'Brien, 2000).

2.6 PREVIOUS STUDIES

Predictably, almost all of the studies on giraffe feeding biology and impact have been conducted within their native range. These areas are characterised by highly seasonal rainfall that affects the availability of plant species, which are vastly different to those in the Eastern Cape Province (*inter alia* Field & Ross, 1976; Hall-Martin, 1975; Kok & Opperman; 1985, Leuthold & Leuthold, 1972; Omphile, 1997; Pellew, 1984b; Stevens, 1975). Only one study, assessing giraffe diet, has been completed in the Eastern Cape Province, which was the pilot survey for the present study (Parker *et al.*, 2003). The only other work on extralimital giraffe was completed in the Kwa-Zulu Natal Province (Bond & Loffell, 2001; Goodman & Tomkinson, 1987). Here again, many food species differed and climatic conditions were not the same as those of the Eastern Cape Province.

CHAPTER 3

THE DIET OF INTRODUCED GIRAFFE IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

3.1 INTRODUCTION

The diet selection of herbivores can be defined as the selection of various plant species from an apparent over-abundance of food items in the environment (Norbury & Sanson, 1992; Pellew, 1984b). From this "super-abundance" of food, herbivores select the best quality food to satisfy their daily metabolic and reproductive requirements (Pellew, 1984b). This selection is affected by factors such as plant availability, chemical composition, time available for feeding each day, digestive physiology, plant defences, body size and experience (Owen-Smith, 1982; Pellew, 1984b). Food selection in turn, affects social structure, dispersal patterns and predator avoidance (Jarman, 1974). A herbivore must also continually modify its feeding strategy to satisfy metabolic and reproductive requirements as the nutritional quality and availability of food items fluctuate seasonally, between and amongst species (Pellew, 1984b). To appreciate fully how a herbivore must modify its feeding behaviour and selection strategy, a comprehensive knowledge of its diet is required. The diet assessment of herbivores is crucial, not only in understanding trophic relationships, but also in providing insight into potential competition with other herbivores and the influences the herbivore may have on an ecosystem (Bookhout, 1996). In addition, studies of herbivore diets are useful in that

they provide the initial step towards understanding the resources and habitat required before any management efforts can be initiated (Bookhout, 1996).

Giraffe are almost exclusively browsers of leaves and shoots from trees and shrubs (Hofmann & Stewart, 1972; Klasen, 1963) and their diet has been well documented throughout their native range (Field & Ross, 1976; Fourie, 1977; Hall-Martin, 1974b; Leuthold & Leuthold, 1972; Nesbit Evans, 1970; Oates, 1970; Pellew, 1984a, b; Sauer et al., 1977; Stephens, 1975; van Aarde & Skinner, 1975). Giraffe diet is typically composed of numerous species with various Acacia species being the most important and preferred food source during the wet season (du Toit, 1990a; Field & Ross, 1976; Hall-Martin, 1974b, Leuthold & Leuthold, 1972; Oates, 1970; Parker et al., 2003; Sauer et al., 1977; van Aarde & Skinner, 1975). Giraffe prefer Acacia species as they are high in protein, low in fibre and high in water content (Cooper et al., 1988; Sauer et al., 1977). Only three studies have found *Acacia* species to be an insignificant component of the diet (Klasen, 1963; Omphile, 1997; Pratt & Anderson, 1982). Klasen (1963) concluded, after observing the feeding habits of giraffe in Zambia, that although the Acacia genus was known to represent a large proportion of the diet, no records of giraffe feeding on Acacia were made during their study. However, the study was limited to the dry season (July – October 1962) when giraffe are most likely to utilise alternative food sources. A similar study in the wet season may well have revealed different results. Omphile (1997), studying the seasonal diet and habitat use of large herbivores in the Chobe National Park, Botswana found that although three Acacia species (known to be consumed by giraffe) were present in the study area no traces were found in the droppings. Such a spurious

result was probably an artefact of the diet sampling method, which resulted in the complete absence of *Acacia* in the diet. It also questions the validity of faecal analysis as a suitable method for assessing the diet of giraffe. Pratt & Anderson (1982), studying giraffe in Tanzania found that only two *Acacia* species were consumed, but that *Croton macrostachyus* appeared to be more important. The reliability of these observations is again questionable. The study was aimed primarily at assessing the population, distribution and behaviour of giraffe in the Arusha National Park. Consequently, no systematic observations (or subsequent quantification) of the diet were made during the year long study and the data presented were based merely on an incomplete list provided by the park warden and some opportunistic observations.

The diet of giraffe fluctuates seasonally, primarily because *Acacia* species are deciduous and are consequently less available in the dry season, thus giraffe include a higher proportion of evergreen or semi-deciduous vegetation in their diet during these months (Parker *et al.*, 2003; Sauer *et al.*, 1977; Sauer *et al.*, 1982; Sauer, 1983). Flowers, pods and fruit of various food plants are sometimes consumed by giraffe (du Toit, 1990a; Field & Ross, 1976; Hall-Martin, 1974b; Hofmann & Stewart, 1978; Kok & Opperman, 1980) but graminoid species are seldom consumed (Skinner & Smithers, 1990). If unhardened shoots are available, giraffe will pluck them off using their tough lips, often stimulating increased shoot production in some *Acacia* species (du Toit *et al.*, 1990b). When hardened shoots or branches are available, giraffe feed higher in the tree canopy than other savanna browsers promoting resource partitioning between themselves and the other browsers (du Toit, 1990b). Male giraffe also tend to feed higher in the canopy than females (du Toit,

1990b; Ginnett & Demment, 1999) and it was originally thought that males gained access to more nutritious shoots in the upper canopy (du Toit, 1990b). However, Woolnough & du Toit (2001) later demonstrated that there were no differences in the chemical composition of leaves at different heights, but that leaf biomass was significantly higher at increased heights, implying that larger browsers (giraffes being sexually dimorphic) gained a bite-size advantage by browsing higher in the canopy.

Various methods of herbivore diet assessment are available, including direct observations, analysis of mouth contents, faecal samples, fistula samples and stomach contents (Bookhout, 1996; MacLeod *et al.*, 1996; Norbury & Sanson, 1992). These techniques can be broadly classified as either being Observational methods or Postingestion samples (Bookhout, 1996). There are several inherent problems associated with each of these methods. Thus, the choice of an appropriate method should take these into account and a method chosen depending on the study animal, study area (scale) and the specific outcomes of the research (Norbury & Sanson, 1992).

Mouth content assessments enable a researcher to easily identify undigested food. However, the sample size is small and either tame animals have to be used or many animals killed in order to increase sample size (Norbury & Sanson, 1992). Quite clearly, a 4-5m giraffe would not lend itself to a mouth content analysis.

Fistula and stomach content techniques can provide accurate estimates of the dietary composition of herbivores. Specifically, accurate measures of giraffe diet were achieved in the Mpumalanga Province through the stomach content analysis of culled animals (Hall-Martin, 1974b). However, stomach content analyses require the killing of large

numbers of animals and fistula techniques are only suitable for tame or easily handled animals (Norbury & Sanson, 1992). Neither of these techniques would be suitable for assessing giraffe diet in the Eastern Cape Province as no tame animals (except in zoos) are present, giraffe are not easily caught or handled, and low numbers and high costs preclude the use of stomach content analysis.

Direct observations are often restricted to a single animal for just a short portion of its feeding time in a limited part of its range (Norbury & Sanson, 1992). Identifying plant species consumed from a distance also becomes a problem if an observer is unfamiliar with the vegetation of the area (Bookhout, 1996). In addition, the technique is limited to herbivores living in relatively open habitats, and excludes nocturnal foraging (Bookhout, 1996). Furthermore, observations of herbivore diet are often translated from recorded feeding time into relative occurrence, which may not reflect the actual proportions of food items in the diet (Bookhout, 1996; Norbury & Sanson, 1992). However, giraffe are a highly conspicuous species, spending the majority of their time in open-savanna habitats and do not feed prodigiously at night (Pellew, 1984a; Skinner & Smithers, 1990). Giraffe are also predominantly browsers of leaves and shoots (Hofmann & Stewart, 1972; van Aarde & Skinner, 1975). They do not spend protracted periods feeding from a tree for very little reward and the time spent foraging is roughly equivalent to the proportion in the diet. In other words, because giraffe are large browsers that have relatively high absolute energy requirements, and because they do not typically forage for long periods on food items that will ultimately form a small proportion of the diet e.g. fruits, observations can be used as an effective method to assess diet selection. In addition, numerous studies have shown that observations of giraffe do not unduly disturb their

feeding habits or behaviour and have been successful in describing the diet (Berry, 1973; Field & Ross, 1976; Innis, 1958; Kok & Opperman, 1980; Leuthold & Leuthold, 1972; Oates, 1970; Parker *et al.*, 2003; Pellew, 1984b; Sauer *et al.*, 1977; van Aarde & Skinner, 1975). Furthermore, problems with "snap-shot" sampling effects using one animal in a limited part of its range, during a single portion of its browsing time can be overcome by adaptation of experimental design.

Faecal analysis is a widely used technique for herbivore diet selection studies (Gaylard, 1994; Kigozi, 2000; Landman & Kerley, 2001; MacLeod et al., 1996; Omphile, 1997; Post et al., 2001). Faecal samples are easy to collect, there is minimal disturbance to the animal and samples can cover a much broader spatial and temporal range than other methods (Bookhout, 1996; Norbury & Sanson, 1992). In addition, the frequency of occurrence of plant species fragments in the faeces can be converted to relative density, which reflects the actual proportion of each species in the diet (Sparks & Malechek, 1968). However, faecal samples may not accurately reflect the diet of herbivores due to differential digestion of some plant species e.g. fibrous plants such as grass are overrepresented in the diet (MacLeod et al., 1996; Norbury & Sanson, 1992; Westoby et al., 1976). Sample preparation, growth stage of the plant, observer bias and microscopic analysis can also significantly compromise results (Holechek, 1982; Holechek & Vavra, 1981; Holechek et al., 1982). Moreover, if several herbivore species such as giraffe, kudu and eland (*Taurotragus oryx*, Pallas) that produce similar faeces inhabit the same area, then additional care must be taken when collecting samples (Norbury & Sanson, 1992). However, correct adaptation of experimental design to ensure samples are collected immediately after defecation, prepared correctly and analysed by a trained observer

following a standardised procedure can remove most potential sources of error. Furthermore, the application of correction factors to account for differential digestion of certain species can improve the precision of the method (Dearden *et al.*, 1975; Norbury & Sanson, 1992).

It is apparent that both direct observations and faecal analysis would be appropriate techniques to assess the diet of giraffe in the Eastern Cape Province. However, due to the inherent biases within each method it was decided to employ both in the current study, which would also provide an opportunity to compare the effectiveness of each method in assessing giraffe diet.

Giraffe diet has been the focus of much research around Africa. However, only one study emanates from the Eastern Cape Province where giraffe have been introduced beyond their native range (Parker *et al.*, 2003). This pilot study illustrated that giraffe in the Eastern Cape Province, like giraffe in their native range, prefer deciduous species such as those from the genus *Acacia* during the summer months, and switch to more evergreen species during the winter when the preferred species decrease in abundance (Parker *et al.*, 2003). However, the study was restricted to one study site for just two seasons using one method. Thus, a more intense study of the diet of giraffe in the Eastern Cape Province is required. In this chapter, I assess the diet of giraffe using two techniques as the first step in understanding the ecological importance of the species in the Eastern Cape Province. The specific aims of this part of the study were:

To determine the diet of giraffe in the Eastern Cape Province ;

 \bullet to ascertain the seasonal variation in the diet;

- to assess the effectiveness of direct observations and faecal analysis as methods of diet analysis for giraffe;
- to compare the diet of giraffe in their native range to those introduced to the Eastern Cape Province.

3.2 MATERIALS AND METHODS

3.2.1 Direct observations

Direct observations of the diet of the giraffe at each site were made using the interval scan method, making feeding records every two minutes over a period of one hour (Parker et al., 2003; Rose, 2000; Tacha et al., 1985; van Aarde & Skinner, 1975). A feeding record was defined as each instance in which one plant species was consumed by one animal during a particular scan. Therefore, if ten giraffe were feeding on A. karroo during a scan, there would have been ten feeding records for A. karroo for that scan. Six days of observations were conducted at each site for each season; autumn (March-May), winter (June-August), spring (September-November) and summer (December-February). On each day, the first group of giraffe encountered was observed so as to reduce observer bias for a particular group of giraffe or region. Three one hour long observation sessions were undertaken each day such that one hour was completed during the morning (defined as 06:00-09:00), one hour at midday (11:30-13:30) and one hour in the afternoon (15:00-18:00). For each six-day session (i.e. each season's data) there were thus eighteen hours of observation, six in the morning, six at midday and six in the afternoon. Feeding records for the plant species consumed, the time of day, number of animals, habitat type, other behaviour and weather conditions were recorded. The feeding

records for each species consumed during an hour were totalled and expressed as a percentage of all feeding records for that hour (i.e. frequency of occurrence). The plant species that displayed a frequency of occurrence of > 20% on any one day that observations were conducted were recognised as the most important species at each site.

3.2.2 Faecal collection and preparation

Fresh faecal samples (n = 5 piles) were collected from each study site on a monthly basis from April 2002 to March 2003. At each site, a group of giraffe was located and droppings collected immediately after defecation. There were two reasons for using this procedure. Firstly, to ensure that only giraffe droppings were collected as they are of a similar size and shape to those of kudu and eland, and secondly, to record the age and sex of the giraffe providing the sample. Samples were stored in a -10^{0} C freezer until analysis to prevent the growth of potentially damaging bacteria and fungi. Prior to analysis 2-3 droppings from each sample were randomly selected and prepared for analysis following a protocol modified from Gaylard (1994). The droppings from each sample were ground in a pestle and mortar and boiled in 20ml of 10% nitric acid for two minutes over a low heat in a 300ml beaker. The sample was then made up to 100ml with dH₂O and boiled for a further five minutes. After digestion the entire sample was centrifuged at 5000 rpm for ten minutes and the supernatant discarded. The remaining pellet was then suspended in 5ml of FAA (Formalin-Acetic acid-Alcohol) preservative.

3.2.3 Microscopic analysis

The analysis of plant epidermal fragments in the droppings was modified from various sources (Dearden et al., 1975; Havstad & Donart, 1978; Holechek, 1982; Holechek & Gross, 1982; Holechek & Vavra, 1981; Holechek et al., 1982; Norbury & Sanson, 1992; Sparks & Malechek, 1968; Voth & Black, 1973; Williams, 1969). Monthly samples for each season (as described above) were combined to reduce the error associated with "snap-shot" sampling. For a large ruminant like the giraffe, individual faecal samples may only represent one large meal in a certain area. Thus, by combining samples a more representative picture of the diet was obtained. For each season, ten slides comprising one drop of the thoroughly mixed combined sample were assessed to ensure a 90% confidence that an estimate of the diet selection would fall within 10% of the mean (Holechek et al., 1982). Twenty frequency observations (i.e. the first 20 identifiable epidermal fragments per slide) at 400X magnification were made per slide (Holechek et al., 1982). Epidermal fragments were identified to species level by comparison with a reference collection of the ten most important species in the diet of giraffe, as determined by direct observation at each site (the faecal analysis was only completed after the direct observations). Holechek & Vavra (1981) demonstrated that all major species in the diet would be detected within 10% of the mean, at the 95% confidence level, with nine slides or more assessed per sample. All fragments that did not match the ten most important species in the reference collection were recorded as unidentified. Frequency of occurrence values (%) were calculated for each plant species in each season using the total number of fragments. Ideally, the microscopic analysis should have been completed by an observer unfamiliar with the direct observation results to prevent observer bias in

the results. However, the lack of a suitably qualified laboratory technician made this impossible.

3.2.4 Preparation of plant epidermal reference collection

A reference collection of the plant species consumed by giraffe at each site was compiled using method modified from Kigozi (2000) and MacLeod *et al.* (1996). Leaves were cut into thin (10 x 10mm) strips and boiled in 20ml of 10% nitric acid for 5-10 minutes depending on the texture of the leaf. The strips were then washed with dH₂O to remove any residual acid and the epidermis peeled off using fine forceps. The abaxial and adaxial surfaces were then mounted on standard glass histology slides with Haupt's adhesive and stained with 1% safranin. Excess stain was washed off the slides and they were dehydrated by soaking for 5 minutes in ascending concentrations of alcohol. Alcohol was removed from the epidermi by soaking for 5 minutes in xylene. The slides were then covered with a cover slip using DPX mountant. Digital images of both abaxial and adaxial surfaces were taken at 400X magnification and stored in an image database.

3.2.5 Data analysis

Differences in the frequency of occurrence of species in the diet between the three different times of the day that observations were made and between seasons was tested using a Kruskal-Wallis two-way ANOVA (Sigmastat version 2; Jandel Corporation) after arcsine transformation. Differences in the importance of species in the diet between seasons as determined by faecal analysis were tested using a Kruskal-Wallis ANOVA (Sigmastat version 2; Jandel Corporation) after arcsine transformation. The results from

the two methods of diet assessment were compared by correlating frequency of occurrence values for the two methods for each plant species. The difference between the importance of the five most important species in the diet as determined by each method of analysis was tested using a student's t-test (Sigmastat version 2; Jandel Corporation).

3.3 RESULTS

3.3.1 Direct observations

The direct observations revealed that 48 plant species from 30 families were consumed by giraffe in the Eastern Cape Province at the three sites over the study period (Table 3.1). These included Forty-six woody plant species, one shrub and one grass species (Table 3.1). The mango (Anacardiaceae), spike thorn (Celastraceae) and thorn-tree (Mimosaceae) families were the best represented in terms of numbers of species consumed. However, the Mimosaceae and Anacardiaceae made up the majority (>65%) of the diet in terms of frequency of occurrence (Table 3.1). *Acacia karroo* (43%) and *Rhus longispina* (17%) were the two most important species in the diet across all three sites and seasons (Table 3.1). The remaining species were all below 6% in importance. Most of the species consumed (38 or 79%) were evergreen. Two alien invasive species to South Africa (*Acacia mearnsii* and *A. cyclops*) as well as one species (*Dombeya rotundifolia*) listed as threatened in the South African Red Data book for plants were consumed by the giraffe. A very small proportion of the diet remained unidentified (Table 3.1). **Table 3.1:** The mean annual frequency of occurrence of plant species in the diet of giraffe across all sites and seasons as determined by direct observations (A) and faecal analysis (B) for the study period 2002-2003. Values are percentages ± 1 SD. Columns do not add up to 100 due to rounding off. ^{*e*} Evergreen; ^{*d*} Deciduous; ^{*s*-*d*} Semi-deciduous.

Family	Species	Α	В
Agavaceae	Agave sp.	0.20 ± 2.99	-
Anacardiaceae	Harpephyllum caffrum ^e	0.15 ± 1.27	-
	Rhus crenata ^e	2.25 ± 7.98	2.42 ± 5.54
	Rhus lancea ^e	0.02 ± 0.18	-
	Rhus longispina ^e	16.62 ± 22.48	13.13 ± 12.75
	Rhus pallens ^e	2.72 ± 9.67	1.33 ± 3.53
Apocynaceae	Carissa haematocarpa ^e	0.07 ± 0.75	-
Asteraceae	Brachylaena ilicifolia ^e	0.02 ± 0.32	-
	Tarchonanthus camphoratus ^e	0.90 ± 0.74	-
Bigoniaceae	Tecomaria capensis ^e	0.01 ± 0.18	-
Boraginaceae	Ehretia rigida ^d	0.11 ± 1.07	-
Caesalpiniaceae	Schotia afra ^e	3.20 ± 8.84	3.21 ± 4.29
	Schotia latifolia ^e	0.81 ± 5.22	2.29 ± 5.18
Capparaceae	Boscia oleoides ^e	1.15 ± 4.79	1.67 ± 3.51
	Capparis sepiaria ^e	0.31 ± 1.47	1.92 ± 3.90
Celastraceae	Cassine aethiopica ^e	0.27 ± 1.69	0.50 ± 1.88
	Gymnosporia buxifolia ^e	0.49 ± 2.45	-
	Gymnosporia polycantha ^e	0.85 ± 4.02	2.25 ± 4.24

	Maytenus capitata ^e	0.08 ± 0.41	-
Chenopodiaceae	Exomis microphylla	0.53 ± 5.64	-
Combretaceae	<i>Combretum</i> caffrum ^d	0.05 ± 0.45	-
Ebenaceae	Diospyros dichrophylla ^e	0.58 ± 3.54	-
	Diospyros lycioides ^e	0.06 ± 0.36	
	Euclea undulata ^e	5.36 ± 12.42	5.92 ± 7.39
Flacourtiaceae	Dovyalis caffra ^e	0.03 ± 0.36	-
Loganiaceae	Buddleja saligna ^e	0.28 ± 1.65	-
	Strychnos decussata ^e	0.11 ± 0.8	-
Mimosaceae	Acacia caffra ^d	0.34 ± 3.24	0.13 ± 1.02
	Acacia cyclops ^e	0.94 ± 6.64	0.13 ± 0.78
	Acacia karroo ^d	43.27 ± 36.37	31.96 ± 18.26
	Acacia mearnsii ^e	0.48 ± 2.77	-
Oleaceae	Olea europea ^e	0.62 ± 5.12	-
Plumbaginaceae	Plumbago auriculata ^e	0.11 ± 0.72	-
Poaceae	Grass sp.	0.07 ± 0.74	0.50 ± 1.76
Portulacaceae	Portulacaria afra ^e	1.91 ± 8.59	2.25 ± 4.62
Ptaeroxylaceae	Ptaeroxylon obliquum ^{s-d}	0.06 ± 0.63	-
Rhamnaceae	Scutia myrtina ^e	2.03 ± 7.25	4.54 ± 6.05
Rubiaceae	Canthium spinosum ^e	2.28 ± 8.61	1.88 ± 4.20
	Coddia rudis ^e	0.09 ± 1.36	-
Salicaceae	Populus deltoides ^d	0.04 ± 0.46	-
Salvadoraceae	Azima tetracantha ^e	1.81 ± 4.69	1.13 ± 2.79

Chapter 3

Santalaceae	Osyris compressa ^e	0.01 ± 0.09	-
Sapindaceae	Pappea capensis ^e	3.81 ± 11.74	4.38 ± 7.82
Sapotaceae	Sideroxylon inerme ^e	1.98 ± 6.86	2.38 ± 5.38
Solanaceae	Lycium sp. ^e	3.11 ± 10.77	1.08 ± 3.05
Sterculiaceae	Dombeya rotundifolia ^d	0.02 ± 0.23	-
Tiliaceae	Grewia occidentalis ^e	0.31 ± 2.67	-
	Grewia robusta ^e	0.18 ± 1.54	0.83 ± 2.70
	Unidentified	0.36 ± 1.50	14.21 ± 16.70
Total		100.72	100.04

The relative importance (frequency of occurrence) of the various species in the diet at each site was not significantly different between the three different times of the day that observations were conducted (Kruskal-Wallis ANOVA; P>0.05). Thus, the data for each day were combined and frequency of occurrence values calculated for each season. Only those species that exhibited a frequency of occurrence of greater than 20% on any one day on which observations were made were recognised as the most important species in the diet at each site.

At Shamwari 23 species were consumed, ten were recognised as the most important, nine of which were evergreen (Figure 3.1). *Acacia karroo* was the most important species in the diet during all seasons except winter, when significantly less was consumed (Figure 3.1; P<0.05; df = 3; F = 19.72). *Rhus longispina* was the second most important species in the diet at Shamwari, with significantly more being consumed in winter than autumn (Figure 3.1; P<0.05; df = 3; F = 3.15). *Euclea undulata* was the third most important

species in the diet and was most important during the spring and summer months (Figure 3.1). The importance of the other species remained low during all seasons. However, significant seasonal fluctuations were evident in *Schotia afra* (P < 0.05; df = 3; F = 3.89) with more eaten in winter than spring and summer and *Gymnosporia polycantha* (P < 0.05; df = 3; F = 3.82) with more eaten in winter and spring than summer and autumn (Figure 3.1).

A similar pattern to that found at Shamwari was present at Kwandwe. Twenty-two species were consumed, of which seven species constituted the most important species in the diet. Of these species, *Acacia karroo* and *A. caffra* were deciduous and the remaining five species evergreen. *Acacia karroo* was the most important species, with significantly less being consumed in the winter than summer and autumn (Figure 3.2; P < 0.05; df = 3; F = 8.59). Although not statistically significant, the importance of *R. longispina* (again the second most important species) increased in the winter months. *Pappea capensis* was the third most important species at Kwandwe with significantly more being consumed in the summer than spring (Figure 3.2; P < 0.05; df = 3; F = 3.53). The fourth most important species (*Euclea undulata*) was consumed equally throughout the year (Figure 3.2). The importance of the remaining species was low, but peaks in the importance of *Portulacaria afra* (P<0.05) and *Lycium* sp. (P>0.05) during the autumn and winter, respectively were evident (Figure 3.2).

The number of important species in the diet of the giraffe at Kariega was substantially higher (15) than the other two sites and the majority of these species (14) were evergreen (Figure 3.3). The total number of species consumed at Kariega (37) was also higher than

at the other reserves. *Acacia karroo* was again the most important species overall. Although the giraffe consumed less *A. karroo* in the winter, the reduction in utilisation was not statistically significant as it was at the other two sites (Figure 3.3). *Rhus crenata, R. pallens, Schotia afra, Canthium spinosum, Sideroxylon inerme* and *Scutia myrtina* were the other important species at Kariega (Figure 3.3). Only the frequency of occurrence of *S. afra* and *S. myrtina* changed between seasons. Significantly more *S. afra* (P < 0.05; df = 3; F = 3.09) was eaten in autumn and winter than spring while *S. myrtina* was significantly (P < 0.05; df = 3; F = 3.86) more important in spring than winter and autumn (Figure 3.3). The alien *A. cyclops* was significantly more important in the spring than winter and summer (Figure 3.3; P < 0.05; df = 3; F = 2.85).



Figure 3.1: The most important species in the diet of giraffe at Shamwari. The mean values ± 1 SD for each season are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).



Figure 3.2: The most important species in the diet of giraffe at Kwandwe. The mean values ± 1 SD for each season are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).



Figure 3.3: The most important species in the diet of giraffe at Kariega. The mean values ± 1 SD for each season are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

In general terms, the results from the direct observation indicate that during the summer months the diet of giraffe in the Eastern Cape Province was dominated by *A. karroo* and *R. longispina* (Figures 3.1-3.3). During the winter *R. longispina* became more important in the diet than *A. karroo* at two of the sites. However, the combined importance of these two species in the winter was lower than in the summer.

3.3.2 Faecal analysis

For each reserve, the most important plant species in the diet were used for the reference collection. With an overlap of species between reserves (e.g. *A. karroo*) this gave a total of 21 species in the reference collection. A total of 22 plant species from fifteen families were identified in the droppings of the giraffe from the three sites (Table 3.1). Of these, 21 were woody plant species and one was a grass, which was identified by its characteristic long rectangular epidermal cells in spite of not being part of the reference collection (Table 3.1). The mango and thorn-tree families comprised the majority (49%) of the diet as determined by faecal analysis (Table 3.1). *Acacia karroo* (32%) and *Rhus longispina* (13%) were the most prevalent species in the droppings of giraffe in the Eastern Cape Province with most of the species consumed (19 of 23) being evergreen (Table 3.1). The remaining species all comprised less than 6% of the diet. One invasive alien species (*A. cyclops*) was identified in the droppings. A high proportion (14%) of epidermal fragments present in the faeces of the giraffe remained unidentified (Table 3.1).

Although all ten of the most important species in the reference collection for each site were consumed (i.e. observed in the droppings), for practical purposes only the five most important species are represented for each site. The five most important species in the diet of the giraffe at Shamwari were *Acacia karroo*, *Rhus longispina*, *Euclea undulata*, *Gymnosporia polycantha* and *Capparis sepiaria* (Figure 3.4). *Acacia karroo* was the most important component of the diet during all seasons except winter when it was significantly less important (Figure 3.4; P < 0.05; df = 3; F = 9.87). In contrast, *R. longispina* was significantly more important during the winter than in autumn (P < 0.05; df = 3; F = 4.57). *Euclea undulata* was significantly more important in winter than spring (Figure 3.4; P < 0.05; df = 3; F = 5.55). The importance of *G. polycantha* and *C. sepiaria* remained relatively constant throughout the year.

Similar trends were evident in the diet of the giraffe at Kwandwe with *A. karroo* again being the most important component of the diet in all seasons except the winter when significantly less was consumed (Figure 3.5; P < 0.05; df = 3; F = 40.51). The second most important component of the diet, *R. longispina*, was significantly more important in the winter than the summer (P < 0.05; df = 3; F = 10.37). *Pappea capensis* was the third most important species at Kwandwe, with significantly more being consumed in the summer than any other season (Figure 3.5; P < 0.05; df = 3; F = 16.12). *Euclea undulata* and *P. afra* were most important during the winter months and least important during the summer (Figure 3.5).

Acacia karroo was the most important species in the diet at Kariega. However, unlike the other two sites, it was significantly more important in spring than any other season (Figure 3.6; P < 0.05; df = 3; F = 25.94). The importance of the four remaining species

was similar (all less than 20%). Significantly less *R. crenata* (P < 0.05; df = 3; H = 12.22), *S. inerme* (P < 0.05; df = 3; F = 5.17) and *S. latifolia* (P < 0.05; df = 3; H = 22.89) was consumed in spring than any other season when the importance of *A. karroo* was highest (Figure 3.6).



Figure 3.4: The five most important species in the diet of giraffe at Shamwari as assessed by faecal analysis. Mean values ± 1 SD are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).



Figure 3.5: The five most important species in the diet of giraffe at Kwandwe as assessed by faecal analysis. Mean values ± 1 SD are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).



Figure 3.6: The five most important species in the diet of giraffe at Kariega as assessed by faecal analysis. Mean values ± 1 SD are shown. * P < 0.05 between seasons for a species (Kruskal-Wallis ANOVA).

3.3.3 Method comparison

The direct observations identified 48 plant species in the diet of giraffe, while the faecal analysis identified only 23 species (Table 3.1). Both methods found that the majority of species consumed were evergreen and that *A. karroo* and *R. longispina* were the two dominant food items (Table 3.1). The two methods of diet assessment yielded results that were closely correlated for the 23 species identified in the droppings (Figure 3.7). A comparison between the relative importances of the five most important species in the diet (as determined by direct observations) revealed that the results obtained for direct observations and faecal analysis were similar (Figure 3.8). Faecal analysis found both of the dominant species to be slightly less important than the direct observation estimates, while the estimated importance of the other species in diet was similar. Significantly more epidermal fragments remained unidentified after the faecal analysis (Figure 3.8; P < 0.05; t = 32805.00). However, this was a direct consequence of the procedure used for the faecal analysis. The faecal analysis also found grass to be more important in the diet than the direct observations (Table 3.1).



Figure 3.7: The correlation between the results of the two methods of diet assessment for giraffe in the Eastern Cape Province. Values are percentages in each case. Dashed lines indicate 95% confidence limits; Observation = Direct observations; Faecal = Faecal analysis.



Figure 3.8: The relative importance of the five most important plant species in the diet of giraffe in the Eastern Cape Province as determined by each method of diet assessment. * P < 0.05 Students t-test.
The differences in the importance of the five most important species in the diet at Shamwari as determined by each method between seasons are illustrated in Figure 3.9. The three most important species were common to both analyses while the fourth and fifth were different to each analysis (Figure 3.9). The faecal analysis usually estimated the importance of each species to be lower than the direct observations with less within season variation (Figure 3.9). The seasonal variation of the two most important species was similar between the two methods. In both analyses *A. karroo* was significantly less important in winter, when *R. longispina* became the most important species (Figure 3.9). As would be expected the unidentified component was high for the faecal analysis and low for the direct observations (Figure 3.9).

The five most important species in the diet at Kwandwe, as determined by each method, were identical (Figure 3.10). As was found at Shamwari, faecal analysis estimated the importance of the five species to be lower than direct observations with less variation within each season (Figure 3.10). The seasonal fluctuations in each species as determined by the two methods were very similar.

Three of the five most important species were identified by both methods of analysis at Kariega (Figure 3.11). However, each method identified a different *Schotia* species to be amongst the top five species in the diet. *Acacia karroo* was the most important species determined by both methods and the third and fourth most important species in the diet were also the same (Figure 3.11). The faecal analysis again estimated the importance of these species below that of the direct observations with less within season variation (Figure 3.11). The seasonal trends in the three species common to each analysis were similar except for *A. karroo. Acacia karroo* exhibited a distinct peak in utilisation in the

spring according to the faecal analysis and was otherwise utilised at a constant level (~22%). In contrast, the observations indicated that *A. karroo* was least important in the winter and increased in utilisation during the spring and summer (Figure 3.11). The direct observations found that *C. spinosum* was relatively unimportant in the autumn but became the second most important item in the diet in winter and spring, but this species was not one of the top five detected by faecal analysis. Faecal analysis indicated that *S. myrtina* (the second most important item in the diet) did not show any dramatic fluctuation between seasons except for a slight decrease in the spring (Figure 3.11), but it was not one of the top five detected by faecal analysis.



Species



Figure 3.9: A comparison between the seasonal importance of the five most important species in the diet of giraffe as determined by each method of diet assessment at Shamwari including the unidentified component. A = Direct observations; B = Faecal analysis. * P < 0.05 as determined previously.



Figure 3.10: A comparison between the seasonal importance of the five most important species in the diet of giraffe as determined by each method of diet assessment at Kwandwe including the unidentified component. A = Direct observations; B = Faecal analysis. * P < 0.05 as determined previously.







Figure 3.11: A comparison between the seasonal importance of the five most important species in the diet of giraffe as determined by each method of diet assessment at Kariega including the unidentified component. A = Direct observations; B = Faecal analysis. * P < 0.05 as determined previously.

3.4 DISCUSSION

Giraffe typically select more than 20 plant species in their diet (Leuthold & Leuthold, 1972; Hall-Martin, 1974b; van Aarde & Skinner, 1975; Sauer et al., 1977; Sauer et al., 1982). This is ascribed to the fact that giraffe are capable of traversing large distances within their home ranges where they encounter and use a wider variety of vegetation types than other browsers (Skinner & Smithers, 1990). In addition, due to their inherent need to consume large quantities of forage to sustain their metabolic and reproductive requirements (Bell, 1971; Pellew, 1984a) giraffe have less time to be selective and consequently include a wide diversity of plant species in their diet (Innis, 1958). The results for the present study conform to such a finding with more than twenty species being consumed at each site. However, the number of species consumed was greater at Kariega (37) than the other two sites (22 and 23 respectively). The small size of Kariega provides a likely explanation for such a difference, as being confined into such a small area at a relatively high density (there are similar numbers of giraffe as at Shamwari, but in a smaller area) forces the animals to feed on a greater number of species. Although, the giraffe at all sites consumed a large variety of species, the majority (60-90%) of the diet comprised two or three species, the most important of which was Acacia karroo. Field & Ross (1976), Hall-Martin (1974b), Innis (1958), Kok & Opperman (1980), Leuthold & Leuthold (1972), Oates (1970), Stephens (1975) and van Aarde & Skinner (1975) all found leguminous plant species such as members of the genus Acacia to be the most prevalent in the diet of giraffe. The results from this study indicate a similar trend with most of the important species belonging to the thorn-tree (Mimosaceae) family that is leguminous. The reason for this apparent preference is the high protein and water

content of the leaves (Cooper *et al.*, 1988; Hall-Martin & Basson, 1975; Sauer, 1983). However, other important factors such as condensed tannin and fibre content may influence this selection and these are discussed in chapter four. The proportion of grass in the diet of giraffe is typically low (Field & Ross, 1976; Fourie, 1977; Hall-Martin, 1974b; Leuthold & Leuthold, 1972; Nesbit Evans, 1970; Oates, 1970; Pellew, 1984a, b; Sauer *et al.*, 1977; Stephens, 1975; van Aarde & Skinner, 1975). The results from this study conform to this, with relatively little grass being consumed.

At Shamwari and Kwandwe, in all seasons and for both methods of diet assessment, Acacia karroo and Rhus longispina were the two most important species in the diet of the giraffe. At Kariega A. karroo and two other Rhus species (R. crenata and R. pallens) were the most important species in the diet. At all three sites Acacia karroo was significantly less important in the diet during the winter when significantly more R. longispina (R. crenata and R. pallens in the case of Kariega) was consumed. This dietary switch is attributed to the deciduous nature of A. karroo, which looses its leaves in the winter at which time members of the genus *Rhus* become more important (Parker *et al.*, 2003). Giraffe prefer new and growing shoots when they are available due to their increased succulence or water content, and higher protein content (Cooper et al., 1988; Hall-Martin & Basson, 1975; Sauer, 1983). Such a preference could explain the seasonal variation of the other tree species at the three sites. For example Scutia myrtina at Kariega becomes significantly more important in the spring when the trees produced new leaves. An alternative explanation for the seasonal variation could be due to the trees flowering or fruiting as giraffe are known to consume both (du Toit, 1990a; Hall-Martin, 1974b; van

Aarde & Skinner, 1975). This was certainly the case with *Pappea capensis* at Kwandwe where the giraffe were observed consuming the leaves and fruit in the summer months. Previous studies on giraffe diet indicate that dominant deciduous species such as Acacia make up the bulk of the diet during the wet season (October-March). However, during the dry season (April-September) these deciduous species loose their leaves and the giraffe tend to concentrate along watercourses where they subsist on the only remaining, less preferred semi-deciduous or evergreen species (Hall-Martin, 1974b; Hall-Martin & Basson, 1975; Owen-Smith, 1992; Sauer, 1983; Sauer et al., 1977; Sauer et al., 1982; van Aarde & Skinner, 1975). The dry season is thus a nutritionally limiting period for giraffe and other browsers due to reduced food availability and increased distances between feeding sites (Hall-Martin & Basson, 1975; van der Waal et al., 2003). During this period giraffe are often in poor condition and increased mortality due to malnutrition and predation is common (Hall-Martin & Basson, 1975). The results from this study also indicate preference for deciduous species (Acacia karroo) during the summer and an increase in the importance of evergreen species (e.g. Rhus longispina) during the winter. Significantly, unlike giraffe within their native range the majority of species consumed in the Eastern Cape Province were evergreen. This is probably due to the reduced number of deciduous species in the province forcing the giraffe to adapt to a new (evergreen) food source that is available all year round. Evidence of giraffe death due to malnutrition does not exist in the Eastern Cape Province, supporting the fact that suitable browse is available for consumption throughout the year.

In a review of the problems associated with methods for assessing the diet of terrestrial herbivores, Norbury & Sanson (1992) highlight the need for researchers to clearly outline the objectives and degree of accuracy required in their study and in doing so, most sources of error can be eliminated. It is apparent from the introduction to this chapter that both direct observations and faecal analysis were techniques that could be adequately modified to achieve the objectives of this part of the study. The results obtained for the diet selection of giraffe in the Eastern Cape Province were similar for each method, although some differences were evident. Such a finding emphasises the need to assess the effectiveness of the two methods of analysis. In general, the faecal analysis estimated the importance of species in the diet to be lower than that of the direct observations, with less within species variation. This can be attributed to the fact that direct observations were only made over a period of one hour at a time. This increased the importance of the various species in the diet as well as the within species variation despite the fact that three hours of observation a day for six days a season were performed. By pooling the faecal samples for each season, the faecal analysis covered a much broader spatial and temporal scale, which resulted in more conservative diet estimates (Norbury & Sanson, 1992). Microscopic analyses of faeces tend to overestimate plant species that have a characteristic cell shape or pattern as they are easier to identify (Dearden *et al.*, 1975; Havstad & Donart, 1978; Westoby et al., 1976). This would account for the observed discrepancy in the importance of grass (which has characteristic oblong shaped epidermal cells) in the diet as determined by each method. In addition, faecal analysis underestimates the importance of less important food items as they are less likely to be identified when sub-sampling (Dearden et al., 1975; Havstad & Donart, 1978). This

explains why a species such as *Schotia afra* was not identified in the droppings at Shamwari. The fact that at least the three most important species in the diet were recognised in the droppings at Shamwari and Kwandwe and not Kariega is curious, especially when one considers that *C. spinosum* (the second most important species according to the direct observations) has a characteristic crenated cell shape. At present there does not seem to be any logical explanation for such a result. The high proportion of unidentified fragments in the faeces was probably an artefact of the experimental design in which the reference collection only included the ten most important species in the diet at each site.

It is clear that neither method can estimate the diet of giraffe without some form of bias. However, faecal analysis requires large amounts of equipment for faecal sample and reference slide preparation. It also incurs relatively high costs for reagents, chemicals and observer training and requires long hours of labour to prepare reference slides as well as to prepare and analyse faecal samples (Norbury & Sanson, 1992). By comparison, direct observation requires relatively little equipment, similar hours of labour, and incurs similar costs in terms of fuel and observer training should the observer not have knowledge of the local vegetation.

It is the opinion of the author that direct observation is the method of choice for assessing the diet of giraffe. Although the two methods of diet assessment are similar in almost every respect, direct observations allow the researcher to obtain "hands-on" experience of the diet of giraffe in the field. Field experience affords the researcher a first-hand knowledge of feeding behaviour that cannot be replaced by laboratory work and literature

review. Direct observations provide information on the diet that would not otherwise be known i.e. consumption of fruits that are completely digested. Should the study animal have been a shy and reclusive blue duiker (*Philantomba monticola*, Thunberg) where observations were not feasible then faecal analysis would clearly have been the method of choice.

CHAPTER 4

DIETARY PREFERENCES OF INTRODUCED GIRAFFE IN THE EASTERN CAPE PROVINCE, SOUTH AFRICA

4.1 INTRODUCTION

Large mammalian browsers are surrounded by a "super-abundance" of food whilst feeding. However, some plant species, or even entire stands of vegetation, can be more extensively utilised than others (Owen-Smith, 1982). The likelihood of one species being browsed over another is governed by a number of factors, which can be defined as the acceptability of a plant species to the browser (Owen-Smith & Cooper, 1987; Watson & Owen-Smith, 2002). The factors that influence this acceptability include chemical factors such as nutrients and secondary metabolites (Owen-Smith, 1982; Owen-Smith & Cooper, 1987), physical features of the plant associated with the leaves e.g. spines (Belovsky & Schmitz, 1994; Cooper & Owen-Smith, 1986; Owen-Smith, 1982), and the phases of leaf and shoot growth (Watson & Owen-Smith, 2002). However, the third factor is inextricably linked to chemical composition. If a species, which is usually avoided, has a flush of new growth it can become acceptable to a browser, because the new shoots have higher protein and lower total fibre (Owen-Smith & Cooper, 1987; Watson & Owen-Smith, 2002). This observed switch in acceptability is attributed to the difference in protein and condensed tannin content in the leaves. Whereas leaves that would not normally be consumed in the mature growth phase have comparatively

low protein-high tannin content, leaves in the new growth phase have high protein-high tannin (Cooper *et al.*, 1988).

The acceptability of plant species to giraffe is largely dependant on the chemical contents of the leaves as Pellew (1984b) demonstrated that spinescence (thorns) had no significant effect on the feeding rates achieved by giraffe in the Serengeti. Giraffe employ a unique feeding technique, where they strip the leaves off the terminal segments of shoots with mouth or tongue movements which minimise the effect that spinescence has on feeding rate and subsequent acceptability (Kingdon, 1979; Cooper & Owen-Smith, 1986). Other authors have also found that food selection in giraffe is correlated to the chemical constituents (Hall-Martin & Basson, 1975; Sauer, 1983; Sauer *et al.*, 1982). Chemical factors that influence acceptability can be nutrients such as protein and minerals, fibre that influences digestibility, or secondary metabolites such as condensed tannin that reduce the digestive availability of nutrients (Cooper & Owen-Smith, 1985). The water content or succulence of leaves can also affect giraffe browse acceptability (Sauer *et al.*, 1982).

Most animals require organic nitrogen (crude protein) in their diet in order to synthesise amino acids for the production of protein (Campbell, 1996). However, only half of the required 20 amino acids for protein production can be synthesised by the animal itself, the remaining essential amino acids, must be obtained from its food in a pre-assembled form (Campbell, 1996). Should the animal's diet lack one or more of the essential amino acids it will become malnourished. However, ruminants obtain the amino acids required for protein synthesis from the digestion of microbial proteins, which have been flushed

through to the abomasum and not from ingested plant proteins, which are rapidly fermented to ammonia in the rumen. This ammonia is taken up by the gut microbes for their own protein synthesis (Owen-Smith, 1982). Despite this, ruminants still require threshold levels of plant protein to supplement microbial synthesised protein in order to prevent certain amino acids becoming limiting (Owen-Smith, 1982). In addition, protein can be required by herbivores for biosynthesis when carbohydrates and fats are in short supplies e.g. during a drought (Campbell, 1996; Owen-Smith, 1982). Furthermore, in ruminants, a diet that incorporates a high nitrogen (protein) content positively influences the microflora of the rumen in such a way that fermentation rates are increased (Owen-Smith, 1982). Thus, plant species with a higher protein content will be more acceptable to a browsing herbivore such as the giraffe.

Dietary fibre affects the acceptability of plant species to a browsing ruminant by reducing digestibility (Dorgeloh, 1999; Owen-Smith, 1982). The rates of digestion in the rumen are dependent on the total content of the cell wall constituents. Plant species that increase the retention time in the rumen restrict digestion rates (Owen-Smith, 1982). In addition, species with a high cell wall content can dilute the concentrations of protein and other important nutrients. Thus, high dietary fibre can decrease ingestion rates of all nutrients by enforcing a slower turnover of stomach contents (Dorgeloh, 1999; Owen-Smith, 1982). However, ruminants are capable of cycling urea from muscle catabolism to the rumen, thereby effectively maintaining acceptable rates of fermentation when a sub-optimal diet, such as during the dry season, is unavoidable (Owen-Smith, 1982). Although ruminants have the ability to cope with a high fibre diet, plant species vary in

the proportion of fibre present and a browser such as the giraffe would preferentially select those species with a lower fibre content.

Secondary metabolites, tannins in particular, are a complex group of high molecular weight polyphenols, capable of precipitating proteins (Martin & Martin, 1982). Tannins are involved in defending plants against herbivory by either inactivating digestive enzymes or protecting cell walls from microbial attack (Cooper & Owen-Smith, 1985). Condensed tannins (proanthocyanidins) specifically function as protection for the plant cell wall against microbial attack (Cooper & Owen-Smith, 1985). Since ruminants rely on microbial fermentation as their mode of digestion, plant species that have high condensed tannin levels tend to inhibit fermentation, and in so doing effectively lower the nutritional value of the plant (Cooper & Owen-Smith, 1985). Thus, plant species that have a lower condensed tannin content would be more acceptable to giraffe (Caister *et al.*, 2003).

Several authors have demonstrated that giraffe exhibit distinct preferences for certain species, both within and outside of their native range (Chapter 3; Dagg, 1960; Kok & Opperman, 1985; Oates, 1970; Parker *et al.*, 2003; Pellew, 1984b; Sauer *et al.*, 1977) and it is apparent that the factors discussed above may be responsible for these food preferences. The specific aims of this part of the study were:

To determine the food preferences of giraffe in the Eastern Cape Province; and
to discuss how chemical factors may influence giraffe food preference in the Eastern Cape Province.

4.2 MATERIALS AND METHODS

4.2.1 Preference

Preference is usually quantified by calculating preference indices for the species in the diet. The most widely used method of calculating preference is by dividing the percentage utilisation in the diet by the percentage availability in the environment (Uresk, 1984). In this study, the strength-of-preference variable (preference index) used by Caister et al. (2003), specifically designed for timed feeding data for giraffe, was employed. The percentage availability in the field was subtracted from the percentage utilisation in the diet and divided by 100. Thus, a value of zero indicated that a tree species was eaten at the same frequency with which it occurred in the field. A positive value indicated a selective preference and a negative value a selective avoidance of the species (Caister *et al.*, 2003). However, it must be noted that a selective avoidance does not necessarily mean a species is avoided completely. A species could be an important component of the diet and still have a negative preference value should the species occur at high densities in the habitat. Unlike other preference index calculations, the strengthof-preference variable accounts not only for variation in the availability of species in the habitat, but also for the proportion of a species in the diet. As an example, in past studies if a species comprised 50% of the diet and 25% of the habitat it would have had a preference index of 2. Similarly, if a species comprised 5% of the diet and only 2.5% of the habitat it would also have had a preference index of 2. However, the strength-ofpreference variable accounts for such differences in importance in the diet where although the second species would still be preferred, its strength-of-preference variable would be lower than the first species because it constitutes a smaller proportion of the

diet. The data from the direct observations (mean annual frequency of occurrence) of the diet were used as a measure of the utilisation for the ten most important species in the diet of giraffe at each site. Data from vegetation characterisation estimates (described below) at each site were used as a measure of the availability of each species in the habitat. In the event that frequency data were unavailable in the field for the preference calculation of a species, an assumed frequency of 0.1% was used (Uresk, 1984).

4.2.2 Vegetation characterisation

The vegetation of the areas most commonly utilised by giraffe at each site was characterised using the point-centred-quarter method (Cottam & Curtis, 1956). This method was chosen over and above other methods as it provides the least variable results for distance measures and provides more data on each tree species per sampling point than do other methods (Cottam & Curtis, 1956). In addition, the method has been used extensively to characterise vegetation in previous studies of giraffe feeding ecology (Bond & Loffell, 2001; Field, 1975; Parker *et al.*, 2003; Pellew, 1983b). Furthermore, with a sample size of > 28, the method has a standard error of < 10% which is considered satisfactory for biological studies (Cottam & Curtis, 1956). Point-centred-quarter methods are also the most practical in terms of the costs associated with labour, time and equipment (Rutherford, 1979; RA Lubke Pers. Comm. Botany Department, Rhodes University.).

Transects (n = 6-7 straight line transects depending on the number of vegetation types used by the giraffe) of 30 points were conducted in the areas most commonly utilised by giraffe at each reserve during the summer and autumn months (November-April) of

2002/3. A predetermined, random number of paces were measured between each point. At each point a cross was laid down with one axis along the line of the transect, to represent four quarters and the closest individual tree in each quarter sampled. Trees were the only vegetation units sampled as giraffe seldom fed on grass or shrubs. Trees of all heights were sampled, as giraffe do not have a preference for trees of any particular height class in the Eastern Cape Province (Pers. Obs.). For each tree that was sampled the species was recorded and the distance (m) from point to tree, height (m) and canopy cover projected onto the ground estimated by the observer for all transects (m^2) . Trees >10m from the sampling point were excluded from the analysis to ensure that no one tree was sampled twice. From these data the frequency (number of trees of a species \div total number of trees x 100), density (trees per hectare), and relative dominance (canopy cover of each species \div total canopy cover x 100) of each species sampled at each transect were calculated. The relative dominance values were equivalent to the relative frequency of vegetation available to giraffe at each site and used to calculate the strength-of-preference variable for the preference indices (Caister et al., 2003).

Density was calculated using the equation from Pollard (1971):

$$\tilde{\mathbf{N}}_{\mathrm{p}} = -\frac{4(4n-1)}{\pi \sum \left(r^{2}_{ij}\right)}$$

Where \tilde{N}_p = Point-centred-quarter estimate of population density (m⁻²) n = Number of random points π = 3.14159 r_{ij} = Distance (m) from random point *i* to the nearest tree in quadrant *j* (*j* = 1,2,3,4; *i* = 1, ...*n*)

Density values were converted to number of trees per hectare by multiplying the resulting population density (m⁻²) by 10 000.

4.3 RESULTS

4.3.1 Vegetation characterisation

The botanical composition of the areas most frequently utilised by giraffe in the Eastern Cape Province varied between sites (Tables 4.1 - 4.3). However, *A. karroo* trees made up a large proportion of the trees per hectare (Tables 4.1 - 4.3) and were usually one of the most dominant species (in terms of canopy cover available to giraffe) in the areas frequented by giraffe. Not surprisingly, other important food items were also prevalent in terms of number of trees per hectare and relative dominance (Tables 4.1 - 4.3). At Shamwari *R. longispina, A. karroo* and *R. pallens* dominated the vegetation of the areas utilised by giraffe. However, *A. karroo* was the most common tree species in these areas, having the greatest number of trees per hectare than any other species (Table 4.1). Although, *P. afra* was relatively common its relative dominance was much lower than *R. longispina,* which was found at similar densities (Table 4.1).

Kwandwe was more diverse than Shamwari in terms of the total number of species represented in the areas giraffe used for foraging (Table 4.2). However, the density of *Rhigozum obovatum* was twice as high as any other species. Despite this, its small size meant that very little was available for giraffe to browse (Table 4.2). *Pappea capensis*, *P. afra* and *A. karroo* dominated the available browse at Kwandwe and were amongst the most common species. Other species that had high densities but low dominance were *Grewia robusta*, *Gymnosporia polycantha* and *Lycium* sp. (Table 4.2).

Kariega was the most diverse (total species richness) of all the sites (Table 4.3). *Acacia karroo* and *R. pallens* were the most common species. However, *R. pallens* had much larger canopies, which resulted it being almost three times as dominant as *A. karroo*

(Table 4.3). Plumbago auriculata, Azima tetracantha, Diospyros dichrophylla and

Lycium sp. were all well represented in the areas utilised by giraffe but did not produce proportionate levels of available browse because of their small size (Table 4.3).

Table 4.1: The botanical composition of the five areas most commonly frequented by the giraffe at Shamwari as determined by the point-centred-quarter method of vegetation characterisation. Values are means for six transects.

Species	No.	Freq.	Density	Canopy	Relative
		(%)	(trees/Ha)	cover	dominance
				(\mathbf{m}^2)	(%)
Acacia karroo	171	35.33	210.50	283.00	20.80
Azima tetracantha	40	8.26	53.40	66.70	4.90
Buddleja saligna	3	0.62	9.50	66.70	0.29
Capparis sepiaria	1	0.21	18.20	4.00	0.29
Carissa haematocarpa	1	0.21	6.10	6.00	0.44
Diospyros lycioides	2	0.41	12.20	2.70	0.20
Euclea undulata	19	3.90	55.70	84.80	6.23
Gymnosporia polycantha	60	12.40	97.10	122.93	9.04
Lycium sp.	2	0.41	12.20	4.50	0.33
Olea europea	8	1.65	66.00	47.50	3.49
Pappea capensis	6	1.24	14.70	4.80	0.35
Portulacaria afra	6	1.24	109.30	36.00	2.65
Rhus crenata	1	0.21	6.10	6.00	0.44
Rhus longispina	92	19.01	110.70	351.70	25.85
Rhus pallens	45	9.30	152.30	237.50	17.46
Schotia afra	7	145	57.60	35.00	2.57
Scutia myrtina	10	2.07	30.00	31.80	2.34
Tarchonanthus camphoratus	10	2.07	42.00	31.50	2.32
TOTAL	484	100.00	617.90	960.40	100.00

Table 4.2: The botanical composition of the six areas most commonly frequented by the

giraffe at Kwandwe as determined by the point-centred-quarter method of vegetation

Species	No.	Freq.	Density	Canopy	Relative
		(%)	(trees/Ha)	cover (m ²)	dominance
					(%)
Acacia karroo	91	14.38	179.00	59.30	10.86
Azima tetracantha	20	3.16	46.40	13.90	2.54
Brachylaena ilicifolia	5	0.79	45.20	3.60	0.65
Carissa haematocarpa	14	2.21	60.60	19.80	3.62
Combretum caffrum	1	0.16	9.60	36.00	6.59
Crassulaceae portulaceae	1	0.16	17.00	2.00	0.37
Diospyros lycioides	3	0.47	24.40	5.50	1.01
Ehretia rigida	9	1.42	37.70	1.70	0.30
Euclea undulata	26	4.11	64.10	25.10	4.60
Grewia occidentalis	1	0.16	19.60	7.00	1.28
Grewia robusta	56	8.85	166.40	12.70	2.32
Gymnosporia buxifolia	1	0.16	6.90	2.00	0.37
Gymnosporia polycantha	28	4.42	142.90	16.70	3.05
Jasminum angularae	2	0.32	34.00	1.60	0.29
Jutropha capensis	1	0.16	17.00	0.80	0.15
<i>Lycium</i> sp.	102	16.11	171.60	32.50	5.94
Maytenus capitata	17	2.69	83.30	12.80	2.34
Olea europea	4	0.63	38.50	39.00	7.14
Ozoroa mucronata	1	0.16	17.00	4.50	0.82
Pappea capensis	30	4.74	101.90	77.60	14.20
Plumbago auriculata	2	0.32	14.60	4.80	0.87
Portulacaria afra	37	5.85	200.00	74.30	13.60
Ptaeroxylon obliquum	1	0.16	17.00	0.50	0.09
Rhigozum obovatum	145	22.91	443.90	26.60	4.88
Rhoicissus tridentata	1	0.16	17.00	1.30	0.24
Rhus crenata	1	0.16	17.00	0.50	0.09
Rhus longispina	19	3.00	48.50	22.70	4.16
Rhus pterota	3	0.47	24.40	4.00	0.73
Rhus rhemannia	1	0.16	9.60	25.00	4.58
Schotia afra	10	1.58	35.50	12.70	2.33
TOTAL	633	100.00	1402.60	317.40	100.00

characterisation. Values are means for six transects

Table 4.3: The botanical composition of the seven areas most commonly frequented by

 the giraffe at Kariega as determined by the point-centred-quarter method of vegetation

 characterisation. Values are means for seven transects.

Species	No.	Freq.	Density	Canopy	Relative
		(%)	(trees/Ha)	$cover(m^2)$	dominance
Acacia caffra	4	0.63	60.60	3.00	0.29
Acacia cyclops	2	0.32	7.60	15.40	1.52
Acacia karroo	98	15.51	213.50	68.50	6.76
Acacia mearnsii	9	1.42	22.00	22.40	2.21
Acalypha glabrata	1	0.16	11.30	1.00	0.10
Azima tetracantha	51	8.07	153.40	56.70	5.60
Canthium inerme	2	0.32	10.80	18.50	1.83
Canthium spinosum	7	1.11	53.60	12.40	1.22
Capparis sepiaria	12	1.90	78.60	11.20	1.11
Carissa bispinosa	9	1.42	54.80	4.70	0.46
Coddia rudis	3	0.47	23.00	4.30	0.42
Crotolaria sp.	1	0.16	7.70	0.50	0.05
Diospyros dichrophylla	67	10.60	125.40	77.30	7.63
Dovyalis caffra	1	0.16	15.20	6.00	0.59
Ehretia rigida	12	1.90	44.50	14.90	1.47
Euclea undulata	5	0.79	31.90	26.50	2.62
Exomis microphylla	6	0.95	67.60	4.40	0.43
Grewia occidentalis	6	0.95	40.70	13.40	1.32
Gymnosporia buxifolia	5	0.79	36.20	41.00	4.05
Harpephyllum caffrum	1	0.16	5.20	20.00	1.97
Lycium sp.	38	6.01	110.30	16.40	1.62
Olea europea	11	1.74	48.30	10.00	0.99
Osyris compressa	2	0.32	15.30	8.50	0.84
Pappea capensis	1	0.16	11.30	0.30	0.03
Plumbago auriculata	36	5.70	144.20	57.00	5.63
Pterocelastrus tricuspidatus	4	0.63	17.10	36.50	3.60
Putterlickia pyracantha	2	0.32	22.50	3.10	0.31
Rhus crenata	20	3.16	89.60	99.50	9.82
Rhus incisa	9	1.42	25.10	20.60	2.03
Rhus pallens	147	23.26	209.10	189.90	18.74
Rhus pterota	2	0.32	28.00	14.00	1.38
Schotia afra	4	0.63	56.10	9.50	0.94
Schotia latifolia	4	0.63	56.10	8.00	0.79
Scolopia zeyheri	5	0.79	56.40	6.10	0.60
Scutia myrtina	31	4.91	50.10	44.10	4.35
Sideroxylon inerme	5	0.79	28.60	56.00	5.53
Suregada africana	3	0.47	33.80	2.00	0.20

Tarchonanthus camphoratus Tecomaria capensis	2 1	0.32 0.16	15.20 15.20	7.00 0.20	0.69 0.02
Zanthoxylem capense	3	0.47	33.80	2.50	0.25
TOTAL	632	100.00	2129.50	1013.00	100.00

4.3.2 Preference

The giraffe at Shamwari showed a selective preference for five of the ten most important species in the diet as determined in chapter three (Table 4.4). The strongest preference was for Acacia karroo while the remaining four species had relatively lower strengths of preference. The giraffe exhibited a selective avoidance for the other five most important species in the diet including *Rhus longispina*, which was one of the more important components (23%) of the diet (Table 4.4). Selective avoidance was highest for Gymnosporia polycantha, Schotia afra, Capparis sepiaria and Portulacaria afra were consumed at similar frequency to their occurrence in the field (Table 4.4). Cassine aethiopica was low in availability but selectively preferred (Table 4.4). The preferences of giraffe at Kwandwe extended to four species (Table 4.5). Acacia *karroo* was again the most preferred species followed by the relatively lower strengths of preference for *R. longispina* and *E. undulata*. The Giraffes showed the strongest avoidance for *P. afra* (Table 4.5). Although not very abundant, *Boscia oleoides* was selectively preferred (Table 4.5). Pappea capensis, which featured prominently in the diet (11%) was selectively avoided.

The giraffe at Kariega also showed a strong preference for *A. karroo* with decreasing strengths of preference for a further six important species (Table 4.6). Unlike the other two sites, only three species were avoided, these being *Rhus pallens* (8% of the diet).

Sideroxylon inerme (5%) and *R. crenata* (7%). *Sideroxylon inerme* and *Scutia myrtina* were eaten at similar frequencies to their availability (Table 4.6).

In general terms, *A. karroo*, which made up the majority of the diet of giraffe in the Eastern Cape Province, was consumed at a greater frequency than its availability at all sites. The strength of preference for the remaining major food items of giraffe was dependent on the availability at each site.

Table 4.4: The strength-of-preference indices for the ten most important species in the diet of giraffe at Shamwari for the study period 2002-2003. * Estimated preference index assuming a 0.1% frequency in the field.

Preference index
0.3061
0.0184
0.0047
0.0014
-0.0066
-0.0118
-0.0273
-0.0274
-0.0728
0.0065*

Table 4.5: The strength-of-preference indices for the ten most important species in the diet of giraffe at Kwandwe for the study period 2002-2003. * Estimated preference index assuming a 0.1% frequency in the field.

Species	Preference index
Acacia karroo	0.2916
Rhus longispina	0.2249
Euclea undulata	0.0205
Schotia afra	-0.0069
Azima tetracantha	-0.0159
Grewia robusta	-0.0179
Pappea capensis	-0.0296
Lycium sp.	-0.0322
Portulacaria afra	-0.0986
Boscia oleoides	0.0335*

Table 4.6:	The strength-of	f-preference	indices	for the	ten most	important	species in	the
diet of gira	affe at Kariega f	or the study	period 2	2002-20	03.			

Species	Preference index
Acacia karroo	0.3162
Canthium spinosum	0.0563
Schotia afra	0.0398
Lycium sp.	0.0313
Schotia latifolia	0.0164
Acacia cyclops	0.0129
Scutia myrtina	0.0059
Sideroxylon inerme	-0.0013
Rhus pallens	-0.0105
Rhus crenata	-0.0322

4.4 DISCUSSION

Distinct dietary preferences have been reported for giraffe throughout Africa and these preferences change seasonally (Berry, 1973; Caister et al., 2003; Dagg, 1960; Foster, 1966; Oates, 1970; Sauer et al., 1977). Seasonal changes in preference have been attributed to both changes in the availability of important food items and chemical changes in the leaves (Oates, 1970; Parker et al., 2003; Sauer et al., 1982). Acacia species are most preferred by giraffe due to their high protein and water content (Caister *et al.*, 2003; Dagg, 1960; Foster, 1966; Hall-Martin & Basson, 1975; Oates, 1970; Sauer et al., 1977; van Aarde & Skinner, 1975). Various other species are also preferred, mainly in the dry season, when the Acacia species loose their leaves. However, as was discussed earlier; distinct preference switches are also evident when new leaves become available due to more favourable leaf chemistry (Pellew, 1984a; Watson & Owen-Smith, 2002). A similar trend was also observed in kudu browsing in deciduous savanna, where trees that were usually avoided became preferred when new leaves were available (Owen-Smith & Cooper, 1987). Thus, phenological changes may influence giraffe preference. The results from this study conform to this general trend with A. karroo being most preferred across all three sites followed by a number of other species. However, several important components of the diet in terms of frequency of occurrence (e.g. R. longispina at Shamwari and *P. capensis* at Kwandwe) were avoided by the giraffe. This can be attributed to the fact that although these species were important in the diet, they were abundant in the field and were not eaten at a greater frequency to what was available. It is also possible that by pooling the use data, seasonal preferences were masked. Conversely, *Boscia oleoides*, a less important species in the diet at Kwandwe, was preferred, probably

as a result of an exceptionally low availability (not officially recorded in the vegetation surveys). This may reflect a highly favourable leaf chemistry (e.g. extremely high protein) for this species but no values are available. The fact that seven species were preferred at Kariega could be due to a number of factors. One possibility is that the number of giraffe at Kariega is similar to Shamwari, but at Kariega they have a much smaller area available in which to forage (9.5 %; see chapter 2). Consequently, they are forced to feed for protracted periods on species that they would not normally utilise so extensively thus producing positive preference values. Alternatively, the absence of potential predators may allow the giraffe to utilise habitats that they would not normally exploit (e.g. dense thickets) thereby making a different suite of food items available. However, a combination of both may provide a more plausible explanation.

Acacia sp. are the primary food source for giraffe in Africa and generally have a high crude protein, low fibre and high condensed tannin content (Caister *et al.*, 2003; Cooper & Owen-Smith, 1985; Cooper *et al.*, 1988; Dagg, 1960; du Toit *et al.*, 1990; Pellew, 1984a; Sauer *et al.*, 1982). Scogings (1998) assessed the resistance of six savanna trees in the Eastern Cape Province to browsing, and found similar results for *A. karroo*. Clearly the nutritional quality of *A. karroo*, combined with its abundance explain why it is the most preferred species. Similarly, Watson & Owen-Smith (2002) demonstrated that the plants with the lowest fibre content were more acceptable to eland in the semi-arid part of the Eastern Cape Province. However, it seems counterintuitive that giraffe would prefer a species with extremely high condensed tannin levels which protect plant cells against microbial and fungal attack. At high concentrations, condensed tannins tend inhibit the

fermentation of plant cell components by the symbiotic microflora of ruminants, thus lowering the nutritional quality of some plant species (Cooper & Owen-Smith, 1985). Thus, species with condensed tannin levels > 5% of dry mass are rejected by browsers (Cooper & Owen-Smith, 1985). Browsing ruminants such as kudu, impala (Aepyceros *melampus*, Lichtenstein) and goats (*Capra* sp.) conform to such a trend (Copper & Owen-Smith, 1985). However, the results from this and other studies indicate that giraffe generally select species with considerably higher tannin. It has been suggested that giraffe are capable of utilising species with high condensed tannin present in the leaves due to the production of large amounts of proline-rich saliva, which deactivates the inhibitory effects of the tannin (Robbins et al., 1987). However, it has since been demonstrated that no one chemical factor governs the acceptability of browse plants to ruminants (Cooper et al., 1988). Cooper et al. (1988) proposed that the difference between the nutrient contents (represented by protein) and secondary metabolites (condensed tannin) provided a more convincing explanation for the dietary preferences of ungulates. Initially, Pellew (1984a) suggested that giraffe in the Serengeti concentrated their feeding on the tree species with the highest density of new shoots because of their high protein and low fibre ratio. Cooper *et al.*, (1988) argued that although the levels of condensed tannin remained as high in these new shoots as they did in mature leaves, the difference between the increased protein and condensed tannin was sufficiently large to result in the trees becoming highly acceptable. However, du Toit et al. (1990) later demonstrated that Acacia species, which were heavily browsed, had significantly lower condensed tannins and higher protein than any other trees (du Toit et al., 1990). It was further demonstrated that the browsing action of giraffe was analogous to pruning which

induced an increase in shoot growth and consequently more new shoots with a high protein, low condensed tannin content (du Toit *et al.*, 1990). Thus, by creating a positive feedback between shoot growth and leaf chemistry giraffe are capable of increasing the difference between protein and condensed tannin, making members of the genus *Acacia* highly acceptable forage. It remains to be seen whether the same feedback mechanism is in operation in *A. karroo* in the Eastern Cape Province. However, the large amount of time spent by giraffe in the Eastern Cape Province feeding on *A. karroo* would allude to a similar process occurring.

It is tentatively suggested that the difference between protein and condensed tannin may be the most influential factor in determining the preferences of the giraffe in the Eastern Cape Province. However, further research on the leaf chemistry of the preferred and avoided species of giraffe in the province is required to test this suggestion.

CHAPTER 5

THE POTENTIAL IMPACT OF INTRODUCED GIRAFFE ON THE INDIGENOUS VEGETATION OF THE EASTERN CAPE PROVINCE, SOUTH AFRICA

5.1 INTRODUCTION

Large mammalian herbivores can have major impacts on ecosystem structure (Augustine & McNaughton, 1998; Bergstrom, 1992; Cumming, 1982; Hobbs, 1996; McInnes et al., 1992; Tilghman, 1989; Vesey-FitzGerald, 1973). The extent of large herbivore impact can range from extensive damage to vegetation structure, affecting animal and plant species distribution in space and time (Cumming et al., 1997; Keesing, 1998; McInnes et al., 1992; Moolman & Cowling, 1994) to preventing regeneration or seedling growth of plants through browsing/grazing and trampling pressure (Cumming & Cumming, 2003; Pellew, 1983a; Ruess & Halter, 1990; Tilghman, 1989). In African savanna ecosystems, the dynamic balance between the proportion of herbaceous and woody plants is governed, to a large extent, by fire and large herbivores (Barnes, 2001; Bergstrom, 1992; Bowland & Yeaton, 1997; Buechner & Dawkins, 1961; Ruess & Halter, 1990). Fire is responsible for preventing seedling growth as well as preventing bush encroachment in grassland areas when grass height and density are high after rain (Barnes, 2001; Buechner & Dawkins, 1961). Large herbivores (browsers) are capable of inhibiting the growth of seedlings and small trees, and causing tree death (Bond & Loffell, 2001; Birkett, 2002; Ruess & Halter, 1990). The combined effects of fire and large herbivores upon

ecosystems can result in open woodlands being converted to grassland and forest converted to open woodland (Barnes, 2001; Buechner & Dawkins, 1961; Pellew, 1983a). Such effects within confined areas (such as fenced game reserves) where the traditional migration patterns of large herbivores have been restricted can be detrimental to the balance between woody and herbaceous plants. Browsing by large herbivores on tree saplings can prevent the vertical growth of the saplings, and maintain the trees within the fire-susceptible height class (Barnes, 2001; Pellew, 1983a; Ruess & Halter, 1990). Thus, woodland regeneration and consequently available browse for consumption by large herbivores becomes limited. In addition, changes in species distribution or even species extinctions may occur (Barnes, 2001; Bond & Loffell, 2001).

Giraffe are classified as browsing megaherbivores; a herbivorous mammal with males exceeding 1000kg (Owen-Smith, 1992) and have high absolute energy requirements (Bell, 1971). In order to satisfy such requirements an adult female giraffe must consume approximately 2.1% (~16.60kg.) of its live-weight per day (Pellew, 1984a). Thus, giraffe are capable of negatively affecting the vegetation of the area they inhabit. Bond & Loffell (2001) demonstrated that introduced giraffe at the Ithala Game Reserve in the Kwa-Zulu Natal Province of South Africa altered the species distribution and composition of the savanna ecosystem, through differential mortality of *Acacia davyi*. In addition, woodland regeneration after fire in the Serengeti has been shown to be prevented by giraffe (Pellew, 1983a; Ruess & Halter, 1990). Browsing by giraffe and indeed other browsers increased the vulnerability of the trees to fire and further browsing (Pellew, 1983a; Ruess & Halter, 1990). More recently, Birkett (2002) demonstrated, using modelling techniques, that

giraffe in Kenya would have the greatest impact on the 3-5m size class of trees. This would cause the tree density of the park to decline by two percent per annum if giraffe browsing was combined with that of elephant and black rhino (*Diceros bicornis*, Linnaeus).

All seven of southern Africa's major vegetation biomes are represented in the Eastern Cape Province of South Africa (Low & Rebelo, 1996). Of these seven, the thicket biome is one of the best represented (17%) in the province (Low & Rebelo, 1996; Lubke et al., 1986). The thicket biome comprises five main vegetation types: Dune Thicket; Mesic Succulent Thicket; Spekboom Succulent Thicket; Valley Thicket and Xeric Succulent Thicket with Valley Thicket being the most common (9%) of the five vegetation types (Low & Rebelo, 1996). In general, the vegetation found in the thicket biome is low (2-3m), dense, often spinescent, succulent, evergreen and not fire-prone (Hoffman, 1989; Lubke et al., 1986; Moolman & Cowling, 1994). Many of the plant species found in the thicket biome are endemic to the region (Lubke *et al.*, 1986), which is further reflected in the fact that the thicket biome is a major centre of endemism for several succulent and geophytic plant species (Hoffman & Cowling, 1991). In addition, the thicket biome contains the highest number of threatened plant species in the Eastern Cape Province (Lubke *et al.*, 1986). However, much of the area covered by thicket is not conserved (Low & Rebelo, 1996; LaCock, 1992; Lubke et al., 1986). Furthermore, the high quality of the forage has meant that much of the vegetation is threatened by intensive goat or ostrich farming outside of protected areas (Low & Rebelo, 1996). It has been shown that extensive goat production on thicket vegetation is deleterious to the high productivity of

the vegetation type due to the inherently slow growth rates of the plants which are unable to cope with the intensive "bottom-up" browsing by goats (Moolman & Cowling, 1994). Thicket vegetation also appears to be adversely affected by the "top-down" browsing effects of indigenous herbivores like elephants, at least at high densities, as such browsing reduces cover and species richness (Moolman & Cowling, 1994). Thus, fundamentally different processes shape the thicket biome in the Eastern Cape Province compared to its savanna ecosystem counterparts. Fire seems to play little or no part at all, while large herbivores tend to assert a greater influence on the modification of the vegetation in the ecosystem.

It is clear that the thicket biome is an important component of, and conservation priority for, the Eastern Cape Province. It is also apparent that it is susceptible to the browsing of large herbivores and can be altered, in many cases, irreversibly by such browsing. In light of the fact that giraffe have never occurred in the Eastern Cape Province, and are capable of negatively affecting the vegetation of the region they inhabit, especially in a region where the vegetation has evolved in the absence of such a large browser (Skead, 1987) it is imperative to ascertain what kind of impact they may have on the indigenous vegetation. The specific aims of this part of the study were:

- ✤ To determine the browse utilisation of giraffe in the Eastern Cape Province; and
- to determine the intake rates of the most important species in the diet in order to reflect the potential biomass removal by giraffe in the Eastern Cape Province.

5.2 MATERIALS AND METHODS

5.2.1 Browse utilisation

The twig-length technique was chosen to establish the extent of giraffe browse utilisation in the Eastern Cape Province (Jensen & Scotter, 1977). The method relies on the actual measurements of twig lengths before and after the dormant (winter) period (Jensen & Scotter, 1977). This method is superior to other similar methods used to measure browse utilisation in that it reduces the potential bias between observers and establishes more precise measures of utilisation (Jensen & Scotter, 1977). At each site, transects (n = 5-6) of fifteen points were conducted in the areas most commonly utilised by giraffe. The areas were categorised as having a high, moderate/high or moderate giraffe frequency as determined by the direct observations. For each transect, a predetermined, random number of paces between each point were measured. At each point the nearest tree was marked with a numbered stake and five branches tagged with cable-ties. This random method of tree selection, however, resulted in different sample sizes for different plant species. The cable-ties were positioned all around the canopy, higher than 2m to exclude the possibility of any other browsers utilising the marked branches. Elephants (Loxodonta *africana*, Blumenbach) were the only herbivores not excluded by this procedure. However, the absence of these animals from Kariega rendered it a natural control. The tagged branches were measured (in cm) from tag to tip. This procedure was carried out immediately prior to and immediately following the winter (dormant period) at each site to control for any shoot growth i.e. the difference in the length of twigs on marked trees could only be due to giraffe browsing. The differences in the twig lengths for each tree were converted to percentage utilisation and the average utilisation of each species

calculated. For each tree, the number of browsed branches was expressed as a percentage of all tagged branches (% twigs browsed)

5.2.2 Feeding rates

Although giraffe are known to bite off the terminal ends of branches while browsing (du Toit *et al.*, 1990; Pellew, 1984b) their long tongue and comb-like incisors enable them to strip the leaves off a length of twig without decreasing the length (Kingdon, 1979; Skinner & Smithers, 1990). Thus, the twig-length method may underestimate the amount of browse utilised by giraffe in the Eastern Cape Province. Consequently, the feeding rates for the three most important species in the diet were determined at each site to assess the biomass removal from the three most important food items at each site. Initially, direct feeding rate estimates were conducted at each site. An animal was selected at random and the time taken to browse a branch recorded. Once the animal had moved off, the branch was collected along with a corresponding un-browsed branch. The branches were returned to the laboratory, dried to constant mass at 60°C, weighed to the nearest 0.01g and the difference in biomass calculated. The feeding rate (g/min^{-1}) was then determined by dividing the resulting biomass by the time taken to browse the branch. However, as Ginnett & Demment (1997) found, this method was extremely difficult to use effectively as exiting the vehicle to remove browsed branches disturbed the giraffe and often the browsed branches were inaccessible even using a stepladder. Thus, indirect estimates of bite rates were made using the statistical relationship developed by Ginnett & Demment (1997,1999) from which feeding rates could be determined. At each site, a giraffe was selected at random and the sex and age recorded.
As the animal approached a tree and lowered its head to feed a foraging record was started. The time spent on the tree, the species consumed and the number of bites were recorded. A foraging record was terminated when the animal raised its head and moved away from the tree (Ginnett & Demment, 1997). Occasionally a giraffe would stop feeding and stand vigilant for a while before recommencing its feeding on the same tree. In such instances the foraging record was momentarily halted, but continued when the animal began feeding again. The bite sizes of the three most important items in the diet of giraffe were calculated using the equation derived by Ginnett & Demment (1997, 1999):

Females: S = (35.71 TPB) - 0.79

Males: S = (50 TPB) - 1.45

Where S = bite size (total dry matter of each bite)

TPB = time per bite (min) representing the inverse of biting rates from the field. The basic premise behind these equations is that a linear relationship exists between the bite mass and biting rates of giraffe (Ginnett & Demment, 1997). This results in a regression equation from which an inverse prediction can estimate bite mass (S; bite size) from an independent set of observed bite rate data (Ginnett & Demment, 1997). Thus, once the bite mass (S; bite size) is determined the feeding (intake) rates (g/min⁻¹) can be calculated by multiplying the bite size by the number of bites taken on a tree and dividing this by the total time spent by the giraffe on the tree. The average feeding rates for the three most important species at each site were calculated in this fashion.

5.2.3 Data analysis

Correlation coefficients for the percentage twigs browsed and the percentage utilisation at each site were calculated using Sigmastat version 2; Jandel Corporation. The differences in utilisation and percentage twigs browsed between sites were tested using a Kruskal-Wallis ANOVA in each case (Sigmastat version 2; Jandel Corporation). The differences between male and female feeding rates at each site were determined by using a student's t-test for each species (Sigmastat version 2; Jandel Corporation).

5.3 RESULTS

5.3.1 Browse utilisation

At all three sites there was a weak positive correlation between utilisation and the percentage of the marked twigs that were browsed (compare Figures 5.1 - 5.3). At Kwandwe and Shamwari, there was a tendency for percentage browsed twigs to be close to 100% at utilisation levels above 40% (Figures 5.1 & 5.2) while at Kariega, there was only one tree on which all tagged twigs had been browsed. Because of the positive correlation between the proportion of twigs browsed and the level of utilisation, an increase in one will lead to an increase in the other and thus a rapid increase in total biomass removal from the tree. Giraffe utilised significantly more browse at Shamwari than at any other site (Table 5.1; Figure 5.1 - 5.3; P < 0.05; H = 12.810; df = 2). However, no one species was utilised more than any other at any of the sites (Figures 5.1 - 5.3; P > 0.05; H = 26.921; df = 20). The proportion of twigs browsed was high at all sites (Table 5.1), but highest at Shamwari (Figure 5.1 - 5.3; P < 0.05; H = 15.659; df =

2). However, no one species had significantly more twigs browsed than any other at any of the sites (Figures 5.2 - 5.3; P > 0.05; H = 24.303; df = 20).

Table 5.1: The average utilisation (% \pm 1 SD) and average twigs browsed (% \pm 1 SD) by giraffe at each site.

	Utilisation	Twigs browsed
Shamwari	43.49 ± 34.92	70.45 ± 20.27
Kwandwe	21.19 ± 21.57	65.78 ± 22.41
Kariega	25.23 ± 22.35	64.55 ± 15.03



Figure 5.1: The percentage browse utilisation of giraffe at Shamwari plotted against the percentage twigs browsed. Ak = *Acacia karroo*; At = *Azima tetracantha*; Eu = *Euclea undulata*; Go = *Grewia occidentalis*; Pa = *Portulacaria afra*; Rc = *Rhus crenata*; Rp = *Rhus pallens*; Rl = *Rhus longispina*; Sa = *Schotia afra*; Si = *Sideroxylon inerme*.



Figure 5.2: The percentage browse utilisation of giraffe at Kwandwe plotted against the percentage twigs browsed. Ak = *Acacia karroo*; At = *Azima tetracantha*; Bo = *Boscia oleoides*; Ch = *Carissa haematocarpa*; Eu = *Euclea undulata*; Gb = *Gymnosporia buxifolia*; Gp = *Gymnosporia polycantha*; Ly = *Lycium* sp.; Oe = *Olea europea*; Pc = *Pappea capensis*; Rl = *Rhus longispina*; Sa = *Schotia afra.*



Figure 5.3: The percentage browse utilisation of giraffe at Kariega plotted against the percentage twigs browsed. Ac = *Acacia caffra*; Ak = *Acacia karroo*; Cs = *Capparis* sepiaria; Dd = *Diospyros dichrophylla*; Gb = *Gymnosporia buxifolia*; Rp = *Rhus pallens*; Sa = Schotia afra; Si = *Sideroxylon inerme*; Sm = *Scutia myrtina*.

Acacia karroo was the most utilised plant species at Shamwari followed by Azima tetracantha, Rhus crenata and Schotia afra (Table 5.2). However, the utilisation estimates for *R*. *crenata* and *S*. *afra* were based on one sample only. Interestingly, the utilisation of A. karroo was high despite the measurements of utilisation being made during the winter when A. karroo loses its leaves (Table 5.2). Although an important component of the diet, *R. longispina* did not have very high utilisation. Two species exhibited negative utilisation or shoot growth (Table 5.2). However, both of these measurements were based on low sample sizes. The extremely high standard deviations indicate high levels of variation in the utilisation of the species at Shamwari with some branches not being browsed while others were completely defoliated (Table 5.2). The proportion of trees browsed in two areas of differing giraffe frequency was, as expected, higher where giraffe frequency was highest (Table 5.3). However, a direct comparison between the utilisation of various species was precluded by the lack of an adequate number of samples for each species. This was because of the sampling method, where sample sizes were variable and very small for some species. Thus, when data were subdivided into areas of different giraffe frequency the analysis became more difficult and less reliable. Nonetheless, where giraffe frequency was moderate R. crenata and R. longispina were utilised the most while A. karroo, A. tetracantha and Euclea undulata were more heavily browsed where giraffe frequency was high (Table 5.3). However, some *E. undulata* and *R. longispina* trees were more heavily browsed than others (Table 5.3).

Table 5.2: The average utilisation (% ± 1 SD) of twelve tree species (n = 51) by giraffe

Species	Utilisation
Acacia karroo $(n = 12)$	76.02 ± 28.17
Azima tetracantha $(n = 5)$	42.73 ± 43.01
<i>Euclea undulata</i> $(n = 5)$	19.75 ± 38.47
<i>Grewia occidentalis</i> (n = 1)	13.97
Gymnosporia polycantha $(n = 2)$	-7.83 ± 5.40
$Olea \ europea \ (n = 1)$	-0.68
Portulacaria afra (n = 4)	8.84 ± 35.65
<i>Rhus crenata</i> $(n = 1)$	36.78
<i>Rhus longispina</i> $(n = 17)$	9.00 ± 18.90
<i>Rhus pallens</i> $(n = 1)$	13.11
Schotia afra $(n = 1)$	28.77
Sideroxylon inerme $(n = 1)$	0.88

at Shamwari as determined from twig length measurements.

Table 5.3: The utilisation ($\% \pm 1$ SD) of tree species and percentage of trees browsed by giraffe at Shamwari in two areas of different giraffe frequency. Trees browsed = trees that were browsed by giraffe in each transect divided by all trees in the transect multiplied by 100.

Giraffe frequency	Trees browsed	Species	Utilisation
Moderate	76.92		
		Euclea undulata	5.78 ± 28.68
		Gymnosporia polycantha	-4.01
		Olea europea	-0.68
		Portulacaria afra	14.90 ± 41.06
		Rhus crenata	36.78
		Rhus longispina	22.15 ± 25.16
		Rhus pallens	13.11
		Sideroxylon inerme	0.88
High	95.83		
		Acacia karroo	76.02 ± 28.17
		Azima tetracantha	42.73 ± 43.01
		Euclea undulata	40.72 ± 52.99
		Grewia occidentalis	13.97
		Gymnosporia polycantha	-11.65
		Portulacaria afra	-9.34
		Rhus longispina	10.83 ± 12.38
		Schotia afra	28.77

At Kwandwe, *Boscia oleoides* and *Olea europea* were the only two species to be heavily utilised (Table 5.4). However, samples sizes for both of these species were low (Table 5.4). Compared to Shamwari, the utilisation of *A. karroo* was relatively low. The utilisation of other important species in the diet (i.e. *E. undulata, P. capensis* and *R. longispina*) was low even with reliable sample sizes (Table 5.4). The utilisation of *R. longispina* at Kwandwe (10.23%) was very similar to that at Shamwari (9.00%). The variation in the levels of utilisation was, as was found at Shamwari, high for most species (Table 5.4). Fewer trees (but still very high at 93%) were browsed where giraffe frequency was moderate, but this was not substantially different to areas where giraffe frequency was moderate/high or high. The proportion of trees browsed was >90% in all three areas (Table 5.5). *Boscia oleoides* and *Acacia karroo* were the most heavily utilised species where giraffe frequency was moderate (Table 5.5). The defoliation of a single *B*. *oleoides* was extremely high. However, in the moderate/high giraffe frequency areas, both *A. karroo* and one *B. oleoides* showed negative utilisation. A single *Olea europea* was heavily browsed where giraffe frequency was moderate/high (Table 5.5). *Euclea undulata* trees were browsed the most heavily in areas of high giraffe frequency, although some remained un-browsed generating the high standard deviations (Table 5.5).

Table 5.4: The average utilisation ($\% \pm 1$ SD) of twelve tree species (n = 71) by giraffe at Kwandwe as determined from twig length measurements.

Species	Utilisation
Acacia karroo $(n = 15)$	12.27 ± 23.76
Azima tetracantha $(n = 4)$	3.67 ± 12.38
Boscia oleoides $(n = 2)$	36.98 ± 74.03
Carissa haematocarpa $(n = 1)$	8.47
<i>Euclea undulata</i> $(n = 11)$	8.60 ± 29.04
<i>Gymnosporia buxifolia</i> (n = 1)	16.19
<i>Lycium</i> sp. $(n = 5)$	7.07 ± 12.77
Maytenus capitata $(n = 3)$	12.44 ± 20.35
<i>Olea europea</i> $(n = 1)$	56.31
Pappea capensis $(n = 13)$	7.77 ± 14.37
<i>Rhus longispina</i> $(n = 13)$	10.23 ± 19.03
Schotia afra (n = 2)	7.05 ± 1.38

Table 5.5: The utilisation ($\% \pm 1$ SD) of tree species and percentage of trees browsed by giraffe at Kwandwe in three areas of different giraffe frequency. Trees browsed = trees that were browsed by giraffe in each transect divided by all trees in the transect multiplied by 100.

Giraffe frequency	Trees browsed	Species	Utilisation
Moderate	92.59	Acacia karroo	40.28 ± 45.56
		Azima tetracantha	17.58
		Boscia oleoides	89.32
		Carissa haematocarpa	8.47
		Euclea undulata	-7.91 ± 5.07
		Lycium sp.	-5.50
		Maytenus capitata	-11.06
		Pappea capensis	4.64 ± 10.72
		Rhus longispina	2.26 ± 11.56
		Schotia afra	8.02
Moderate/high	100.00	Acacia karroo	-2.86 ± 21.98
		Boscia oleoides	-15.37
		Euclea undulata	14.50
		Gymnosporia buxifolia	16.19
		Maytenus capitata	24.40
		Olea europea	56.31
		Pappea capensis	-1.67
		Rhus longispina	11.35 ± 16.30
High	100.00	Acacia karroo	12.51 ± 17.47
		Azima tetracantha	-0.97 ± 10.04
		Euclea undulata	31.93 ± 38.52
		Lycium sp.	10.21 ± 12.31
		Maytenus capitata	23.97
		Pappea capensis	14.13 ± 23.95
		Rhus longispina	16.81 ± 28.59
		Schotia afra	6.07

Giraffe browse utilisation at Kariega was highest on *Acacia caffra* (Table 5.6) and *Gymnosporia buxifolia, Sideroxylon inerme* and *Capparis sepiaria* were the other species that giraffe heavily browsed. However, the utilisation of all four of these species was based on low sample sizes. As at Kwandwe, the utilisation of *A. karroo* was low despite a favourable sample size. *Rhus pallens* exhibited a similar trend in its utilisation to *R. longispina* at Kwandwe (Table 5.6). Interestingly, the variation in the utilisation of the different species at Kariega was less pronounced (as reflected in the standard deviation) than at the other two sites, implying a more uniform browsing pressure. The proportion of trees browsed in the moderate/high and high giraffe frequency areas was similar and high (> 95%; Table 5.7). Whereas *A. karroo, S. inerme* and *C. sepiaria* were heavily utilised in the moderate/high areas, *A. caffra* and *G. buxifolia* were the trees more heavily browsed in the high giraffe frequency areas (Table 5.7).

Table 5.6: The average utilisation ($\% \pm 1$ SD) of twelve tree species (n = 36) by giraffe at Kariega as determined from twig length measurements.

Species	Utilisation
Acacia caffra (n = 2)	64.23 ± 5.90
Acacia karroo $(n = 11)$	7.29 ± 17.22
Capparis sepiaria $(n = 1)$	36.26
<i>Diospyros dichrophylla</i> (n = 2)	-0.47 ± 0.37
Gymnosporia buxifolia (n = 1)	51.10
<i>Lycium</i> sp. $(n = 1)$	-1.43
$Olea\ europea\ (n = 1)$	-17.91
<i>Rhus crenata</i> $(n = 1)$	-17.82
<i>Rhus pallens</i> $(n = 10)$	8.74 ± 17.62
Schotia afra $(n = 1)$	0.72
<i>Scutia myrtina</i> $(n = 3)$	14.12 ± 12.09
Sideroxylon inerme $(n = 2)$	$46.51{\pm}6.88$

Table 5.7: The utilisation ($\% \pm 1$ SD) of tree species and percentage of trees browsed by giraffe at Kariega in two areas of different giraffe frequency. Trees browsed = trees that were browsed by giraffe in each transect divided by all trees in the transect multiplied by 100.

Giraffe frequency	Trees browsed	Species	Utilisation
Moderate/high	95.84		
		Acacia karroo	47.36
		Capparis sepiaria	36.26
		Diospyros dichrophylla	$\textbf{-0.47} \pm 9.37$
		Olea europea	-17.91
		Rhus crenata	-17.82
		Rhus pallens	12.14 ± 24.80
		Schotia afra	0.72
		Scutia myrtina	2.95
		Sideroxylon inerme	46.51 ± 6.88
High	96.12	-	
		Acacia caffra	64.23 ± 5.90
		Acacia karroo	3.28 ± 11.55
		Gymnosporia buxifolia	51.10
		Lycium sp.	-1.43
		Rhus pallens	7.12 ± 7.20
		Scutia myrtina	19.71 ± 10.24

Interpretation of these utilisation data are confounded by the variable and small sample sizes, but some trends are evident. The key species in the diet of giraffe in winter (the time the browse utilisation experiment was conducted) at all reserves was a member of the genus *Rhus* (Tables 5.2; 5.4; 5.6). At Shamwari and Kwandwe utilisation of *Rhus longispina* was similar and surprisingly low (Tables 5.2; 5.4). At Kariega, utilisation of *R. pallens* was similarly low (Table 5.6). *Euclea undulata*, another important species in the diet during winter at Shamwari and Kwandwe, was utilised at similarly low levels but utilised more at Shamwari (Tables 5.2; 5.4). At Kwandwe, the evergreen species, *Pappea*

capensis, was also utilised at low levels (Table 5.4). *Acacia karroo*, the key species in summer, which was far less important in the winter than *R. longispina* nevertheless had variable but higher utilisation levels at Shamwari and Kwandwe than *R. longispina* (Tables 5.2; 5.4). At Kariega, the utilisation of *A. karroo* was low compared to the other two sites (Table 5.6).

5.3.2 Feeding rates

At Shamwari, the time per bite, as determined by field observations, for *A. karroo* and *E. undulata* was similar for male and female giraffe (Table 5.8). However, female giraffe had a much higher time per bite for *R. longispina*. The estimated intake rates for the three most important species in the diet of giraffe at Shamwari were highest for the non-spinescent *E. undulata* (Table 5.8). Males took larger bites than females resulting in higher intake rates for all species except for *R. longispina* (Table 5.8). Male giraffe consumed significantly more *E. undulata* (P < 0.05; t = 9.186; df = 22) and *Acacia* karroo (P < 0.05; t = 4.082; df = 46) per minute than females.

The time taken by male and female giraffe for each bite on the three most important species in the diet of giraffe at Kwandwe were similar (Table 5.8). The pattern of variation in the estimated intake rates of male and female giraffe at Kwandwe was similar to Shamwari with male giraffe feeding at a higher rate than females on *A. karroo* and *P. capensis* (Table 5.8). However, significantly more *R. longispina* was consumed by females per minute (P < 0.05; t = -3.830; df = 35).

The time per bite values for the three most important species at Kariega were similar for male and female giraffe (Table 5.8). For female giraffe, the average feeding rate of *R*.

pallens, the second most important species in the diet, was higher than the two other components of the diet (Table 5.8). Significantly more *A. karroo* was consumed by male giraffe per minute at Kariega than by females (P < 0.05; t = 2.444; df = 88). The overall trend of the *Rhus* species being consumed at a higher rate by females was not evident at Kariega. However, the male intake rate was based on a single observation only (Table 5.8).

Table 5.8: The estimated feeding (intake) rates of male and female giraffe for the three most important species in the diet at each site in the Eastern Cape Province. TPB = Average time per bite (min); FR = Feeding rate (g.min⁻¹); n = number of observations. Numbers in brackets indicate standard deviations.

		MALES		FEMALES			
	Species	ТРВ	n	FR	ТРВ	n	FR
Shamwari	Acacia karroo	0.05 (0.00)	11	21.42 (5.78)	0.04 (0.01)	37	14.23 (4.93)
	Rhus longispina	0.04 (0.01)	19	14.29 (6.42)	0.10 (0.19)	29	16.30 (9.36)
	Euclea undulata	0.08 (0.01)	13	31.52 (2.26)	0.06 (0.01)	11	22.42 (2.62)
Kwandwe	Acacia karroo	0.05 (0.01)	17	19.92 (5.19)	0.05 (0.04)	31	17.54 (5.81)
	Rhus longispina	0.04 (0.00)	14	6.66 (6.39)	0.04 (0.01)	23	13.87 (5.01)
	Pappea capensis	0.05 (0.01)	5	19.83 (4.85)	0.04 (0.02)	5	13.48 (7.07)
Kariega	Acacia karroo	0.05 (0.01)	21	18.74 (6.01)	0.04 (0.00)	69	16.12 (3.67)
	Rhus pallens	0.05	1	21.00	0.06 (0.02)	12	20.75 (4.46)
	Canthium spinosum	0.05 (0.00)	4	22.29 (2.76)	0.06 (0.02)	7	15.19 (9.26)

5.4 DISCUSSION

In this study, giraffe browse utilisation was not significantly higher on any one species than another. However, certain species were utilised more at some sites than others. Notably, Acacia karroo, Azima tetracantha and Euclea undulata at Shamwari, one Boscia oleoides and one Olea europea at Kwandwe and Acacia caffra, Sideroxylon *inerme* and one *Gymnosporia buxifolia* at Kariega. In addition, some of these species were utilised differently even at the same site. The likely explanation for the greater giraffe impact on these species is that they may have a more favourable chemical content than other species. Structural defences such as thorns are unlikely to influence the extent of giraffe browsing to any great degree even though A. karroo; A. caffra and G. buxifolia all have thorns (see discussion in Chapter 4). Pellew (1984a) and Cooper & Owen-Smith (1986) have both demonstrated that plant spinescence is not influential in affecting giraffe browsing. As far as differential utilisation of the same species within and between reserves is concerned, it would be expected that some trees would be utilised more than others simply because where giraffe frequency is higher there would be a greater chance of more trees being browsed. However, the very small sample sizes for many of these species means that the results should be interpreted with some caution. Interestingly, the trees that were adequately sampled (usually the more important species in the diet) generally exhibited low utilisation by giraffe except for A. karroo at Shamwari. Such a result is likely to be due to the fact that too few of these important tree species were included in the analysis, which resulted in low utilisation values. In addition, giraffe at Shamwari spent more time in A. karroo dominated habitats than giraffe at Kwandwe and Kariega resulting in more concentrated browsing on A. karroo (Pers. Obs.). This finding

highlights the necessity of ensuring an adequate sample size of marked trees for all the important items in the diet of giraffe in future research.

Some species exhibited negative utilisation and this probably indicates that at the time of the second measurement some of the trees had already responded to the change of seasons. The fact that there was more variation in the levels of giraffe browse utilisation at Shamwari and Kwandwe is indicative of a lower overall giraffe density resulting in some trees being utilised and others not. Giraffe density at these two sites is < 0.005/Ha while giraffe density at Kariega is 0.01/Ha with substantial portions of the reserve unsuitable for giraffe browsing (see chapter two). Such a result suggests that giraffe at Kariega are currently over-stocked.

Previous studies on the impact of giraffe in savanna ecosystems have all focussed on the effects that giraffe have on several *Acacia* species, one of their staple food items (Birkett, 2002; Bond & Loffell, 2001; Pellew, 1983a; Ruess & Halter, 1990). These studies have all shown that giraffe browsing can be detrimental to recruitment and growth in these species (Birkett, 2002; Bond & Loffell, 2001; Pellew, 1983a; Ruess & Halter, 1990). By contrast, the results from this study indicate that giraffe utilisation and consequently potential impact on *A. karroo* was low, except at Shamwari. However, it must be noted that the utilisation experiments were conducted in the winter when the direct observations showed that *A. karroo* was not the most important component of the diet. The high levels of utilisation in summer (based on the direct observation estimates) and continued utilisation in the winter suggest that, like previous studies, giraffe browsing could be detrimental to *A. karroo* recruitment and growth in the Eastern Cape Province. The study

also indicates that the utilisation of other important species in the diet (e.g. *R. longispina, E. undulata* and *P. capensis*) is low, suggesting that on the whole giraffe utilisation of the indigenous vegetation is currently low. However, high levels of utilisation of some targeted tree species (e.g. *B. oleoides* and *S. inerme*), albeit based on small sample sizes but supported by incidental observations, is cause for concern. Important indigenous plant species may be threatened by giraffe browsing. The results from this study not only provide vital insight into the species most affected by introduced giraffe in the Eastern Cape Province but also provide some important clues as to what factors may be important in browse acceptability to giraffe.

Sex differences in the feeding rates of giraffe have been reported by a number of authors (Ginnett & Demment, 1997, 1999; Pellew, 1984a; Young & Isbell, 1991). In general, males exhibit higher daily forage intake rates than females. Ginnett & Demment (1997) suggest that such a phenomenon is attributed to an increased bite size for males and a reduced chewing effort per bite. By achieving a higher intake rate male giraffe are able to adopt a "time-minimising" strategy when it comes to feeding in order to leave more time for reproductive pursuits (Ginnett & Demment, 1997, 1999). Male giraffe devote less time to foraging per day than do females (Ginnett & Demment, 1997; Pellew, 1984a). The results from this study conform to this with male giraffe having elevated intake rates. However, female giraffe consumed significantly more *R. longispina* per minute than males at two of the sites. The bite size (S) of the female giraffe at Kwandwe and Shamwari was higher than the bite size of the males (results not shown). Bite size is positively related to intake or feeding rate (Ginnett & Demment, 1997). Thus, by taking

larger bites of *R. longispina* the female giraffe were capable of increasing their feeding rate on this species. The explanation for this increased bite-size may be because the leaf biomass of *R. longispina* is higher at the preferred feeding heights of female giraffe, allowing them to gain a bite-size advantage over the males (Woolnough & du Toit, 2001; chapter 3 introduction). Alternatively, female giraffe may increase their feeding rate on *R. longispina* as the chemical composition leaves may be beneficial in terms of the energy requirements when they are pregnant or lactating. The feeding rates of giraffe on Acacia karroo in this study are similar to those determined for several Acacia species in East Africa by Pellew (1984b). He demonstrated that with feeding rates in the order of 20-30g.min⁻¹ giraffe in the Serengeti were capable of removing ca 85% of the new shoot production. However, Pellew (1984a) and later du Toit et al. (1990) showed that Acacia species are generally resilient to giraffe browsing with du Toit et al. (1990) going as far as to suggest that shoot growth in some *Acacia* species is promoted by the browsing action of ungulates. Whether this applies to A. karroo in the Eastern Cape Province, however, remains to be seen. At present, the potential impact of giraffe on the indigenous vegetation of the Eastern Cape Province appears to be low. However, the high utilisation of certain species, even at low giraffe densities (i.e. Shamwari and Kwandwe), suggests that should giraffe numbers increase, unchecked, the potential impact of giraffe on the indigenous vegetation would be high. Whether the indigenous vegetation of the province can sustain giraffe browsing at high levels or not is another issue entirely. I advocate targeted research on the browse utilisation and impact of giraffe on the important species in the diet as well as those species (Boscia oleoides, Sideroxylon inerme, Olea europea

and Acacia caffra) that exhibited unusually high utilisation despite having low sample sizes.

CHAPTER 6

GENERAL CONCLUSIONS AND MANAGEMENT IMPLICATIONS

The aim of this chapter is to integrate the information from the previous three chapters and to discuss the important general conclusions of the study. Management recommendations based on these conclusions are also included.

At Shamwari, 23 plant species were consumed over the study period with Acacia karroo and *Rhus longispina* being the two most important species in the diet. The proportion of evergreen species in the diet was high. However, A. karroo and R. longispina dominated the diet (in terms of frequency of occurrence) for most of the study period except in the winter months when A. karroo lost its leaves (Table 6.1). This was when most of the evergreen species were consumed, including important thicket species such as Portulacaria afra, Scutia myrtina and Schotia afra (Table 6.1). The dietary preference of giraffe at Shamwari was highest for A. karroo, probably due to its favourable leaf chemistry. Interestingly, however, R. longispina, the second most important species in the diet appeared to be avoided by the giraffe and this probably reflects its high availability in the habitat. In terms of browse utilisation, A. karroo was the most heavily utilised species at Shamwari, even during the winter period when its importance in the diet decreased dramatically. Acacia karroo is the dominant tree species in two of the thirteen vegetation types at Shamwari, and a key species in a further three vegetation types which cover approximately 20% of the total reserve area (O'Brien, 2000). The utilisation of other species, with adequate sample sizes, was low suggesting that the potential impact

on these species is low. In addition, the high levels of variation in the utilisation of the different species indicate that although some trees were utilised, others were not utilised at all.

Table 6.1: A summary table of the importance of the two most important components (*Acacia karroo* and *Rhus longispina - R. crenata* and *R. pallens* in the case of Kariega), and the evergreen species in the diet of giraffe during the summer and winter months. AK = *Acacia karroo*; RL = Rhus longispina (*R. crenata* and *R. pallens* for Kariega); EG = Evergreen species. Data are average frequency of occurrence values for each season, rounded off to the nearest percentage.

	AK	RL	EG
Shamwari			
Summer	59%	20%	21%
Winter	15%	34%	50%
Kwandwe			
Summer	38%	25%	37%
Winter	10%	40%	49%
Kariega			
Summer	45%	11%	40%
Winter	23%	22%	52%

These findings suggest that at present, Shamwari is capable of supporting its current giraffe population without any adverse affects on the indigenous vegetation. However, the consumption of important thicket species during the winter and the targeted utilisation of *A. karroo* is some cause for concern. Giraffe at Shamwari tend to utilise *A. karroo* throughout the year even during the winter months. Thus, should the availability of *A. karroo* dramatically decrease due to excessive browsing it would be expected that the utilisation of thicket species would increase. Excessive browsing is deleterious to thicket vegetation due to the inherently slow growth rates of the plants (Moolman & Cowling, 1994). Therefore, I suggest that giraffe numbers at Shamwari should either be reduced or alternatively strictly maintained at the current population density to prevent such a scenario from developing.

The giraffe at Kwandwe consumed 22 plant species with *A. karroo* and *R. longispina* being most important in the diet. Like the giraffe at Shamwari, the diet of giraffe at Kwandwe included a high proportion of evergreen species, but *A. karroo* and *R. longispina* made up the bulk of the diet throughout the year (Table 6.1). However, unlike Shamwari evergreen species (including *P. afra*) were more important throughout the year and not only in the winter months and *A. karroo* was less important in summer (Table 6.1). The giraffe exhibited the strongest preference for *A. karroo* and *R. longispina* presumably due to a combination of favourable leaf chemistry of *A. karroo* and the lower availability of *R. longispina* at Kwandwe than at Shamwari. The browse utilisation of giraffe was low for all of the species that were adequately sampled indicating that the

impact on these species was low. As was the case at Shamwari, the variation in the utilisation of these species was high. However, impact of giraffe on *Boscia oleoides* was high. Although the number of trees sampled for the browse utilisation estimates of *B. oleoides* was low, incidental observations suggest that giraffe browsing on the trees was prolific and when a *B. oleoides* was encountered it was almost completely defoliated. It would appear that the vegetation of Kwandwe is capable of supporting its current giraffe population. However, the visible impact of giraffe on species such as *B. oleoides* and the consistent consumption of important thicket (evergreen) species throughout the study period would suggest that a reduction in giraffe numbers is necessary to ensure the future conservation of the indigenous vegetation.

A total of 37 plant species comprised the diet of giraffe at Kariega with *Acacia karroo* being the most important species in the diet. However, unlike the other two sites, two different *Rhus* species (*R. crenata* and *R. pallens*) were more important in the diet than *R. longispina*, presumably due to the low availability of the latter at Kariega (Table 6.1). Evergreen species formed a greater proportion of the total diet of giraffe at Kariega than Shamwari and Kwandwe and were not only important during the winter months (Table 6.1). Giraffe preference was strongest for *A. karroo*. However, more species had positive preference indices at Kariega compared to the other sites, the utilisation of the well-sampled tree species was low. However, the utilisation of *A. caffra, Capparis sepiaria* and *Sideroxylon inerme*, which had very low sample sizes, was high. When these results are combined with incidental observations of giraffe browsing, *S. inerme* appeared to be the

most adversely affected. Distinct browse lines on this usually well-rounded canopy tree species were clearly evident. Unlike the other two sites the variation in the utilisation of the tree species by giraffe was lower at Kariega, suggesting that fewer trees remained unbrowsed by giraffe and that giraffe impact on the indigenous vegetation was higher and more uniform than at the other two sites.

These results indicate that giraffe at Kariega are currently over-stocked. The incorporation of a greater number of plant species in the diet is indicative of the fact that preferred food items such as *A. karroo* are less available than at the other two sites. In addition, visible damage to *S. inerme,* as well as less variation in the utilisation of plant species on the reserve, suggest high giraffe impact. I recommend that the giraffe density at Kariega be reduced to that of the other two sites.

The shift in land-use in the Eastern Cape Province from traditional pastoralism to game farming and game reserves has radically altered the communities of large herbivores present (Castley *et al.*, 2001). Large, relatively homogeneous herds of domestic animals such as goats and ostrich have been replaced by more diverse herbivore communities. The deleterious effects of domestic herbivores in the thicket vegetation of the Eastern Cape Province is well known (Hoffman & Cowling, 1990; Stuart-Hill, 1992) and much of the impact on the thicket vegetation by domestic species is attributed to over-stocking (Stuart-Hill, 1990). However, the introduction of large indigenous herbivores has also led to degradation of the thicket vegetation (Moolman & Cowling, 1994), which some contend is not as detrimental as browsing by domestic species such as goats (Moolman & Cowling, 1994; Stuart-Hill, 1992). A similar dispute as to whether cattle grazing in the

southwestern rangelands of the USA is more detrimental to the overall biodiversity than that of extinct and extant indigenous mammals also exists (Brown & McDonald, 1995; Dudley, 1997). Arguably, the introduction of indigenous herbivore species should always be favoured as they presumably shape the ecosystem through unique browsing and grazing effects which do not operate within single species herds of domestic herbivores (Bond & Loffell, 2001). Recent research supports such a contention with Bakker et al. (2004) demonstrating that cattle grazing in the Netherlands returned less nitrogen to the soil than did common voles. Thus, the re-introduction of indigenous herbivores to the Eastern Cape Province may be more desirable than domestic livestock. However, the question as to whether non-native (extralimital) species such as giraffe are more detrimental to the indigenous vegetation than domestic livestock (which are also essentially non-native) still remains. Vazquez & Simberloff (2003) demonstrated that introduced cattle affected the interactions between the plant-pollinator network in the USA, while Kimball & Schiffman (2003) demonstrated that cattle grazing not only harmed native plant species but also promoted the growth of exotic species. However, Owen-Smith (1992) suggests that giraffe impact on tree populations in Africa is comparably less detrimental than the impact of other megaherbivores such as elephant because they do not cause widespread damage to mature trees (e.g. uprooting of trees, debarking and gap creation in forests). Instead, only when giraffe densities are high can they slow or suppress the growth of regenerating trees, retarding the recruitment of mature trees by keeping them within the fire susceptible size-class (see chapter 5 introduction; Birkett, 2002; Ruess & Halter, 1990). The results from this study (chapter 5) indicate that defoliation of mature trees has taken place. In general, this could be

attributed to high giraffe density and possibly over-stocking. However, species such as Boscia oleoides at Kwandwe were heavily browsed, although giraffe density was relatively low. Although based on a small sample size, opportunistic observations of giraffe browsing indicate that the utilisation of *B. oleoides* is greater than the results of this study suggest. This indicates that certain plant species in the Eastern Cape Province, which have probably evolved in the absence of giraffe, and may have slow growth rates (Aucamp & Tainton, 1984), are threatened by giraffe browsing, even at relatively low giraffe densities. It is debatable whether the overall impact of giraffe in the Eastern Cape Province is lower than that of domestic livestock, but the targeted selection of certain tree species, even at low giraffe densities, is a cause for concern. However, game farming and tourism operations in the Eastern Cape Province have provided 23 times as many employment opportunities than when the land was used solely for livestock farming (Parker & Bernard, 2003). Anecdotal evidence also suggests that game farming and tourism operations have increased the gross annual income of the province and provided much needed "spin-off" business to other local conservation and business enterprises. Whether these socio-economic benefits outweigh the ecological and conservation costs remains to be seen. However, what is clear is that further targeted research into the impact of giraffe and other introduced species on the indigenous flora is desperately required.

This study provides important information on the diet and dietary preferences of giraffe. It also provides valuable insight into the potential impact of giraffe in the Eastern Cape Province. I believe that the results of this work provide vital baseline data for introduced

giraffe, on which further studies should be based. The Eastern Cape Province provides a unique environment for many indigenous herbivores. Notably, the endangered black rhino that thrives in thicket vegetation (the second highest density of these animals in southern Africa is in the Eastern Cape Province). When one considers that introduced herbivores such as giraffe are capable of adversely affecting the very environment that these endangered animals need for survival, not to mention the plethora of other indirect effects, surely their introduction must be questioned?

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