THE FEEDING ECOLOGY OF THE BLACK RHINOCEROS (*DICEROS BICORNIS MINOR*) IN THE GREAT FISH RIVER RESERVE, EASTERN CAPE PROVINCE, SOUTH AFRICA

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A thesis submitted to the Department of Livestock and Pasture Science, Faculty of Science and Agriculture, in partial fulfillment of the requirements for the degree of Master of Science in Agriculture.

University of Fort Hare

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DECLARATION

I declare that this thesis is my own original work being submitted in partial fulfillment of the requirements for the degree of Master of Science in the Faculty of Science and Agriculture at the University of Fort Hare, Alice. It has not been submitted before for any other degree or examination at any other university.

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__________day of_________________________2008

TABLE OF CONTENTS

ABSTRACT **VI**

ACKNOWLEDGEMENTS **VIII**

LIST OF FIGURES **x**

CHAPTER ONE GENERAL INTRODUCTION **1**

1.1 Introduction **1**

1.2 Objectives **3**

1.3 References **4**

CHAPTER TWO LITERATURE REVIEW **6**

2.1 The feeding of black rhino in thicket **6**

2.2 Assessing the diet of the black rhino **7**

2.3 Determining preference **9**

2.4 Determining the condition of vegetation **10**

2.5 References **12**

CHAPTER THREE PRINCIPAL BROWSE SPECIES IN THE DIET OF THE BLACK RHINO (*DICEROS BICORNIS MINOR*) IN SIX VEGETATION TYPES IN THE GREAT FISH RIVER RESERVE, SOUTH AFRICA **17**

Abstract **17**

3.1 Introduction **18**

3.2 Study site **19**
3.2.1 Locality 19
3.2.2 Climate and geography 20
3.2.3 Vegetation 21
3.2.4 Incidence of black rhino 23

3.3 Methods of veld condition assessment **24**
3.3.1 Backtracking 24
3.3.2 Relationship between stem diameter and dry mass 25
3.3.2.1 Woody species 25
3.3.2.2 Euphorbia bothae 27
3.3.3 Contribution of browse species to the diet of the black rhino 28
3.3.3.1 Comparison between two methods 29
3.3.3.2 Variation in diet composition 30
3.3.3.3 Contribution of woody species 30
3.3.3.4 Principal species 31

3.4 Results and discussion **31**
3.4.1 Relationship between stem diameter and dry mass 31
3.4.1.1 Woody species 31
3.4.1.2 Euphorbia bothae 34
3.4.2 Contribution of browse species to the diet of the black rhino 36
3.4.2.1 Comparison between two methods 37
3.4.2.2 Variation in diet composition 38
3.4.2.3 Contribution of woody species 40
3.4.2.4 Principal species 42

3.5 Conclusions **48**

3.6 References **49**

CHAPTER FOUR SEASONAL VARIATION IN THE DIET OF THE BLACK RHINO (*DICEROS BICORNIS MINOR*) IN THREE IMPORTANT VEGETATION TYPES IN THE GREAT FISH RIVER RESERVE, SOUTH AFRICA **56**

Abstract **56**

4.1 Introduction **57**

4.2 Study site **58**

4.3 Methods **58**
4.3.1 Determining the seasons of high and low rainfall 58
4.3.2 Browse data collection 59
4.3.3 Statistical analyses 60

4.4 Results and discussion **60**
4.4.1 Dry Forest 61
4.4.2 Medium Portulacaria Thicket 62
4.4.3 Short Euphorbia Thicket 64

4.5 Conclusions **67**

4.6 References **68**

CHAPTER FIVE PREFERENCE ESTIMATES OF WOODY BROWSE SPECIES IN THE DIET OF THE BLACK RHINO (*DICEROS BICORNIS MINOR*) IN THE GREAT FISH RIVER RESERVE, SOUTH AFRICA **71**

Abstract **71**

5.1 Introduction **72**

5.2 Study site **74**

5.3 Methods **74**
5.3.1 Diet composition 74
5.3.2 Available browse 74
5.3.3 Preference 75
5.3.4 Feeding site selection 77

5.4 Results and discussion **78**
5.4.1 Preference 78
5.4.2 Feeding site selection 88

5.5 Conclusions **91**

5.6 References **93**

CHAPTER SIX AN ASSESSMENT OF THE CONDITION OF THREE VEGETATION TYPES FOR BLACK RHINO (*DICEROS BICORNIS MINOR*) IN THE GREAT FISH RIVER RESERVE, SOUTH AFRICA **98**

Abstract **98**

6.1 Introduction **99**

6.2 Study site **102**

6.3 Methods **102**
6.3.1 Establishment of VCA sites 102
6.3.2 Grouping of sites 103
6.3.3 Sampling procedure 104
6.3.4 Analysis of veld condition data 106
6.3.4.1 Botanical Composition 106
6.3.4.2 Density 106
6.3.4.3 Available Browse 106
6.3.4.4 Potential browsing units 108
6.3.4.5 Acceptable browsing units 109
6.3.4.6 Browsing Intensity 110

6.4 Results and discussion **111**
6.4.1 Association between sites 111
6.4.3 Stratification of browsing 115
6.4.4 Forage factors 116
6.4.5 Assessment of the condition of three vegetation types 118
6.4.5.1 Potential browsing units 120
6.4.5.2 Acceptable browsing units 121
6.4.5.3 Browsing intensity 123

6.5 Conclusions **126**

6.6 References **127**

CHAPTER SEVEN GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS **132**

7.1 General discussion **132**

7.2 Conclusions **134**

7.3 Recommendations **135**

APPENDICES **138**

THE FEEDING ECOLOGY OF THE BLACK RHINOCEROS (*DICEROS BICORNIS MINOR*) IN THE GREAT FISH RIVER RESERVE, EASTERN CAPE PROVINCE, SOUTH AFRICA

Derek H Brown

Abstract

The great Fish River Reserve in the Eastern Cape supports a large expanding population of black rhino (*Diceros bicornis minor*), an endangered species, and management aimed at ensuring maximum population growth relies on information that was largely lacking in the thicket biome. This includes dietary related information that contributes to estimates of carrying capacity. The overall objective of this study was to gain insight into the feeding ecology of the black rhino in thicket by determining the principal and preferred forage species in different vegetation types across seasons, and applying this information to a recently developed technique for assessing the condition of vegetation. Backtracking was used to collect data on feeding in terms of both number of bites and dry mass estimates based on stem diameter – dry mass regressions developed for key species. The diet was assessed in each vegetation type and species contributing 5% or more to the diet were considered principal species. Preference for forage species was also determined for each vegetation type where availability was determined both simultaneously with feeding and also in the greater environment thereby allowing for two estimates. The condition of three vegetation types was determined for the black rhino using an adaptation of the point centered quarter method where a greater number of acceptable browsing units per hectare reflected better condition. With few exceptions the contribution of different browse species to the diet of the black rhino was determined favourably both in terms of dry mass and in terms of the simpler approach of the number of bites. Although black rhino browsed a total of over 90 species, the bulk of the diet in each vegetation type was composed of a few principal species that contributed 5% or more to the diet. Of these, *Grewia robusta* was the most important of the principal species in the Great Fish River Reserve in terms of its total contribution

to the diet. Some of the principal species displayed significant seasonal variation in the diet in Medium *Portulacaria* Thicket but not in Dry Forest. In Short *Euphorbia* Thicket it was only the succulent annual members of the Aizoaceae that displayed significant seasonal variation. Principal species were invariably also significantly preferred in at least one vegetation type. Some, however, exhibited markedly greater offtake of the total available browse by feeding rhino with the two tree *Euphorbia* species being extreme cases where the entire plants were often felled before browsing. The Point Centered Quarter method adapted for thicket was used in three of the six vegetation types and determined Medium *Portularia* Thicket to have the greatest number of acceptable browsing units per hectare although Short *Euphorbia* Thicket had the best ration of acceptable browsing units per hectare to potential browsing units per hectare. This suggested that Short *Euphorbia* Thicket provided for the most efficient feeding.

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LIST OF FIGURES

Figure 3.1.	The location of the Great Fish River Reserve, South Africa	20
Figure 3.2.	Relationship between twig diameter and dry mass for six well-utilised woody browse species in the thicket of the Great Fish River Reserve, South Africa.	32
Figure 3.3.	Simultaneous correlation between twig diameter and dry mass for the six well-utilised woody browse species combined (see Figure 2.1 for species names) growing in the thicket of the Great Fish River Reserve, South Africa.	33
Figure 3.4.	Correlation between stem diameter and dry mass for 100 mm lengths of green and grey stems of *Euphorbia bothae*.	35
Figure 3.5.	The distribution over time of backtracks of black rhino in the Great Fish River Reserve, South Africa.	36
Figure 3.6.	Dendrogram of a cluster analysis (Group Average method on Bray-Curtis dissimilarities) indicating association between the diet composition of black rhinos represented in terms of dry mass (dm) and number of bites (bite) in six vegetation types in the Great Fish River Reserve, South Africa.	37
Figure 3.7.	Non-Metric Scaling ordination (rotated onto first two principal component axes) of variation in diet composition (% contribution in terms of bites) measured in backtracks in all seasons in six vegetation types in the Great Fish River Reserve, South Africa. The first axis (horizontal) and second axis (vertical) represent 65% and 35% of the total variation in the two-dimension NMS solution (stress = 0.2355).	39
Figure 4.1.	Rainfall for the study period (striped bars) showing mean monthly rainfall for the period 1981-1993 (solid bars) in the Great Fish River Reserve, South Africa. Bars with horizontal stripes represent wet season months and bars with vertical stripes represent dry season months.	59
Figure 6.1.	The approximate location of the 12 veld condition assessment sites established in three vegetation types in the Great Fish River Reserve.	103
Figure 6.2.	Schematic representation of the point centered quarter method used to sample woody vegetation in three vegetation types in the Great Fish River Reserve.	105
Figure 6.3.	Association between veld condition assessment sites in three vegetation types indicated by a dendrogram of a cluster analysis (Group Average method on Bray-Curtis dissimilarities) performed on the number of BU / ha of woody species in the four veld condition assessment sites in each of three vegetation types in the Great Fish River Reserve.	112

Figure 6.4. Availability estimates of woody species based on height of plants regressed against availability estimates based on maximum canopy diameter of plants in Medium *Portulacaria* Thicket in the Great Fish River Reserve. 113

Figure 6.5. Availability estimates of woody species based on height of plants regressed against availability estimates based on maximum canopy diameter of plants in Short *Euphorbia* Thicket in the Great Fish River Reserve. 114

Figure 6.6. Availability estimates of woody species based on the height of plants regressed against availability estimates based on maximum canopy diameter of plants in Tall *Euphorbia* Thicket in the Great Fish River Reserve. 114

Figure 6.7. The number of potential BU's/ha contributed by plants in the 0.5 m height categories in three vegetation types in the Great Fish River Reserve. 120

LIST OF TABLES

Table 3.1.	The vegetation types recognized in the Great Fish River Reserve with the equivalent vegetation units recognized by Vlok and Euston-Brown (2002) where appropriate.	22
Table 3.2.	Introductions of black rhino *Diceros bicornis minor* to the Great Fish River Reserve (Fike 1998).	23
Table 3.3.	Summary of average length of *Euphorbia bothae* removed through browsing by black rhino from 11 clumps as determined from the difference between the length of the browsed stem and that of an adjacent stem with similar growth history. n = number of stems; Std. Dev. = Standard Deviation.	34
Table 3.4.	Percentage of the diet in three forage categories in terms of number of bites (Bites) and dry mass (DM) in six vegetation types in the Great Fish River Reserve, South Africa.	40
Table 3.5.	Percent contribution in terms of dry mass (DM) and number of bites (Bites) for principal browse species (those contributing ≥5% to diet of black rhino in any one of six vegetation types) of the Great Fish River Reserve, South Africa. n = number of bites	43
Table 4.1.	Percent contribution of principal (% number of bites ≥ 5 %) browse species in the diet of the black rhino in Dry Forest in the wet and early dry seasons in the Great Fish River Reserve, South Africa. n = Number of bites.	61
Table 4.2.	Percent contribution of principal (% bites ≥ 5 %) browse species in the diet of the black rhino in Medium *Portulacaria* Thicket in the wet and early dry seasons in the Great Fish River Reserve. Taxa shaded in grey displayed significant change in contribution between the two seasons as determined by the Indicator Species Analysis. n = Number of bites.	62
Table 4.3.	Percent contribution of six most important browse species in the diet of the black rhino in Short *Euphorbia* Thicket in the wet and early dry seasons in the Great Fish River Reserve, South Africa. Taxa shaded in grey displayed significant change in contribution between the two seasons as determined by the Indicator Species Analysis. n = Number of bites.	65
Table 5.1.	Estimates of preference in Medium *Portulacaria* Thicket where the forage ratio (FR) is based on availability on backtracks and the preference ratio (PR) is based on availability on veld condition assessment sites.	80
Table 5.2.	Estimates of preference in Short *Euphorbia* Thicket vegetation where the Forage Ratio (FR) is based on availability as determined on backtracks and the Preference Ratio (PR) is based on availability as determined from veld condition assessment sites.	81

Table 5.3.	Estimates of preference in Tall *Euphorbia* Thicket vegetation where the Forage Ratio (FR) is based on availability on backtracks and the Preference Ratio (PR) is based on availability on veld condition assessment sites.	82
Table 5.4.	Forage ratios of woody species (P < .05) in the diet of the black rhino in Bushclump Karroid Thicket, Dry Forest and Riverine *Acacia* Thicket vegetation types where availability was determined on backtracks.	83
Table 5.5.	Significantly preferred (P) and rejected (R) woody species (P < .05) in the diet of the black rhino in Bushclump Karroid Thicket (BKT), Dry Forest (DF) and Riverine Acacia Thicket (RAT) vegetation types where availability was determined on backtracks. Only those species where availability (n) was ≥ 5 are presented.	85
Table 5.6.	Percent availability of woody species on backtracks versus in veld condition assessment sites in the three vegetation types yielding most data. Species arranged according to availability on backtracks with the 15 most available presented.	89
Table 6.1.	Number of bites by black rhino in four different height categories in six vegetation types in the Great Fish River Reserve.	115
Table 6.2.	Forage Factors based on Preference Ratios (PR) for black rhino of all woody browse species in the veld condition assessment sites in Medium *Portulacaria* Thicket, Short *Euphorbia* Thicket and Tall *Euphorbia* Thicket vegetation types in the Great Fish River Reserve.	116
Table 6.3.	Acceptable BU's/ha of three vegetation types based on forage factors and potential BU's/ha of selected woody species in the Great Fish River Reserve.	119
Table 6.4.	The percent of total available browse removed by feeding rhino (%OT) from woody species in three vegetation types. Species where n≥10 are presented.	123

LIST OF APPENDICES

Appendix 1	Recording sheet for backtracking of black rhino	137
Appendix 2	Percent contribution of browse species to the diet of the black rhino in terms of number of bites (bites) and dry mass (DM) in Bushclump Karroid Thicket, Dry Forest and Medium *Portulacaria* Thicket.	138
Appendix 3	Percentage contribution of browse species to the diet of the black rhino in terms of number of bites (B) and dry mass (DM) in Riparian *Acacia* Thicket, Short *Euphorbia* Thicket and Tall *Euphorbia* Thicket.	141
Appendix 4	Dominant woody species in number of plants/ha for three vegetation types. Only species contributing ≥ 50 plants/ha are presented.	144
Appendix 5	The Bonferroni confidence intervals[1] and forage ratio (FR) values for the utilization of woody browse species in the diet of the black rhino in Medium *Portulacaria* Thicket where availability is determined from plants adjacent to browsed individuals on backtracks.	145
Appendix 6	An assessment of the condition of Medium *Portulacaria* Thicket for black rhino in the Great Fish River Reserve	146
Appendix 7	An assessment of the condition of Short *Euphorbia* Thicket for black rhino in the Great Fish River Reserve.	147
Appendix 8	An assessment of the condition of Tall *Euphorbia* Thicket for black rhino in the Great Fish River Reserve.	148

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Introduction

The black rhinoceros (*Diceros bicornis*) is a charismatic yet critically endangered (Emslie and Brooks 1999) megaherbivore of sub-Saharan Africa. The four sub-species recognized by Du Toit (1987) suffered dramatic population declines principally caused by poaching driven by the trade in rhino horn (Emslie and Brooks, 1999; Skinner and Smithers, 1990). While sub-species *longipes* is on the verge of extinction, and *michaeli* are dramatically reduced, sub-species *bicornis* and *minor* have fared somewhat better. The vast majority of the latter two sub-species are in South Africa and Namibia. Most of the South African animals are of the sub-species *minor*, while all of the Namibian animals are of the sub-species *bicornis* (Adcock 2003).

The primary conservation goals of the South African Development Community Rhino Management Group (RMG) are to develop as rapidly as possible and conserve genetically viable populations totaling at least 2000 *D. b. minor*, 200 *D. b. bicornis*, and 75 *D. b. michaeli* in natural habitat in the region in the long term. Between 1999 and 2001 *D. b. bicornis* in Namibia had an estimated average annual growth rate of 7.3%. In comparison, *D. b. minor* in South African had an estimated average annual growth rate of only 2%. This was well below the acceptable minimum of 5% (Adcock 2003).

To achieve these goals, and to address the poor growth rate in South Africa, the RMG identified several important areas for future expansion of rhino populations and also aspects requiring attention. The RMG recommends that formal assessments or reassessments of specific habitat conditions and/or likely habitat carrying capacities are needed for several areas (Adcock 2003). Because the thicket vegetation of the Eastern Cape is identified as an important area for the expansion of black rhino populations, it should be seen as an important area for refining carrying capacity estimates for black rhino.

Adcock (2000) developed a carrying capacity model for black rhino for the RMG based on a set of multiple-regression coefficients. Information was obtained from numerous localities supporting black rhino in South Africa including the Great Fish River Reserve (GFRR). This model has been used to predict the ecological carrying capacity (ECC) of these areas for black rhino, and additional data constantly helps to refine the model.

Although this model has predicted the ECC of the GFRR, a point of concern is the effect that black rhino will have on the condition of thicket in terms of its ability to provide suitable browse for black rhino. This concern is justified by the large size of this near-optimally performing population, and also by the pending re-introduction of elephants (*Loxodonta africana*). Black rhino and elephant are mega-herbivores and are considered to be a driving force in thicket (Cowling *et al*. 2005). Also, thicket is poorly understood highly palatable vegetation that is sensitive to degradation by browsers (Hoffman and Cowling 1990; Furstenburg *et al*. 1996; Kerley 1996; and Evans *et al*. 1997). Therefore, an understanding of the effect of black rhino on this vegetation in the GFRR is a priority, particularly as pursuing this objective will also provide information that would contribute to the ECC model of the RMG.

- An understanding of the diet of the black rhino is fundamental to understand the effect of black rhino on thicket. Although Ausland *et al*. (2002), Ganqa *et al*. (2005) and van Lieverloo and Schuiling (2004) studied the diet of the black rhino in the GFRR, these studies were of limited duration resulting in inadequate seasonal coverage, pooled data from different vegetation types, difficulty in quantifying *Euphorbia bothae* and no information on browse availability. A combination of suitably selected sites representative of the different vegetation types used by black rhino for feeding and a suitable repeatable technique would be required for assessing the condition of vegetation in terms of the suitability of the forage it provides for black rhino.

1.2 Objectives

The objectives of this study were:

1 To determine the principal species in the diet of the black rhino in six well utilised vegetation types;

2 To determine the preferred species in the diet of the black rhino in six well utilised vegetation types;

3 To determine seasonal changes in the principal browse species in three vegetation types;

4 To determine the condition of three different thicket vegetation types for black rhino using an adaptation of the point centered quarter method.

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CHAPTER TWO

LITERATURE REVIEW

2.1 The feeding of black rhino in thicket

The feeding ecology of the black rhino has been studied fairly widely in Africa (Loutit *et al*. 1987; Goddard 1968 and 1970; Joubert and Eloff 1971, Mukinya 1977; Kotze and Zacharias 1993, Oloo *et al*. 1994; Schenkel and Schenkel-Hulliger 1969; Dudley 1997, Emslie 1999 Von Holdt 1999, and Buk 2004). Until recently, Hall Martin *et al*. (1982) conducted the only comprehensive study on the feeding of the black rhino in thicket.

Ausland *et al*. (2002) studied the diet of the black rhino in the GFRR and compared forage quality of preferred plants to that of rejected plants in autumn. They found that preferred plants did not differ from rejected plants in terms of dry mass per twig, leaf dry mass, neutral detergent fibre or crude protein concentrations.

van Lieverloo and Schuiling (2004) analysed the diet profile of the black rhino in the GFRR using faecal analysis but also used backtracking for comparison. They found that, while the two methods yielded similar results, backtracking yielded no grass in the diet while faecal analysis yielded 4.5%. They found that five species accounted for 69% of the diet. Browse quality analyses were carried out for the 5 most preferred species, the 4 most rejected species, and 8 principle species. These analyses showed that preferred and rejected species were similar in quality because digestibility (in vitro), macro-minerals (N, P, Na, Ca, K and Mg) and fibre-constituents (neutral detergent fibre) were not significantly different. They concluded that black rhinos do not maximize nutrient intake.

Winkel (2004) conducted the first study on the feeding of black rhino on the Double Drift section of the GFRR where he used the backtracking method to determine feeding in three vegetation types. He also determined forage availability in two of these vegetation types using the point centered quarter method and was therefore able to determine preference for browse species. He also analysed 12 plant species for Nitrogen, Phosphorus, neutral detergent fibre, digestability, tannins and total phynolics. His conclusion was that black rhino foraging patterns were not the result of high nutritional quality of selected plant species, nor by the avoidance of plant secondary metabolites.

Ganqa *et al*. (2005) studied diet selection of the black rhino and also forage quality factors affecting diet selection in the GFRR. They found that crude protein was the major factor affecting diet selection of woody plants. They also found seasonal differences in the preference of browse species with *Euphorbia bothae* the most preferred in summer and *Jatropha capensis* the most preferred in winter.

2.2 Assessing the diet of the black rhino

A number of methods have been used to assess the diet of the black rhino: backtracking; direct observation; faecal analysis; and indirect quantitative methods. The choice of technique is influenced by a variety of factors including the type of vegetation, the temperament of the animal(s), the terrain especially soil substrate, and the facilities at the disposal of the researcher.

Backtracking involves following the recent feeding path of a rhino by tracking and noticing the characteristic feeding signs particularly twigs cut at an angle. This method has been used in thicket by Ausland *et al*. (2002), van Lieverloo and Schuiling (2004), Winkel (2004), and Ganqa *et al*. (2005) in the GFRR, and by Hall-Martin *et al*. (1982) in the Addo Elephant National Park. Mukinya (1977), Oloo *et al*. (1984) and Loutit *et al*. (1987) used this method elsewhere in Africa. Bactracking has some distinct advantages:

- It is suited to very dense vegetation where visibility is often compromised.
- It is suited to arid and semi-arid areas since the characteristically bare soil facilitates tracking.
- The diet may be analyzed according to the locality and hence the vegetation type. This is not always possible with methods like faecal analysis.
- It is inexpensive and gives the observer intimate knowledge of the browsing behaviour of black rhino.

Goddard (1968 and 1970) used direct observation in the Ngorongoro Crater. This method is suitable to open vegetation where feeding is not obscured. Data is typically collected in terms of number of bites or feeding stations.

Faecal analysis involves identifying and quantifying epidermis and/or cuticle fragments of ingested plants. This is possible as the plant cuticle, an indigestible layer covering the epidermis, bears a specific pattern of underlying epidermal cells and hairs along with structures of its own. This pattern is best developed in mature leaves and can be identified down to species level, even after passage through the herbivore gut. For this method to be successful, a slide 'library' of the possible food items must be established first. This was used in thicket by van Lieverloo and Schuiling (2004) and in Kenya by Waweru (1985).

Indirect plant-based methods include the 'browse-bottle' or 'standardized browse volume' method (e.g. Emslie and Adcock 1994 and Kotze and Zacharias 1993). This method recognizes a standard volume of browse based on a twig and its leaves, adjusting length or width to account for species and growth form differences to maintain the overall "volume" of the browse unit across different plants. It is faster than taking individual measurements of stem diameter and relies on observer reliability. Data can be collected in this way on backtracks or on transects established in different vegetation types.

2.3 Determining preference

Estimates of preference for different browse species depends on data on the contribution of those browse species to the diet and the availability of that browse in the environment. Data on availability can either be determined simultaneously with dietary intake, or can be determined separately.

Owen-Smith and Cooper (1987) derived acceptability indices for kudu where availability was determined by recording woody plant species within neck reach (0.5m) of a string laid along a feeding path in the Nylsvlei Nature Reserve. For comparative purposes in a separate study, they recorded plants available for consumption during foraging periods by noting the species present within a 10m radius of the animal during successive 30 min periods. The 10m radius was chosen to represent the range over which woody plants were readily visible to a foraging kudu. They limited estimates of availability to woody species but excluded those <0.5m in height. Hendricks *et al*. (2002) recorded those plants available for consumption within 2m of a plant that was browsed by goats in succulent karroo vegetation. This distance was also chosen based on visibility while feeding. Also with goats, Breebaart *et al*. (2002) based their estimates of woody browse availability on the neck and height reach of the animal along the feeding path – this based on the method of Owen-Smith and Cooper (1987). The criteria used to determine what food is available are therefore based on both the study animal and the type of vegetation.

Buk (2004) followed a similar procedure for black rhino in the Augrabies Falls National Park where he determined preference using an estimate of availability obtained by recording plants within one meter of the feeding path of a rhino. For comparitive purposes he also determined availability in the wider environment using randomly located belt transects. This allowed for a second estimate of preference.

Estimates of availability are frequently obtained with either of the above two methods, and estimates of preference based on these estimate of availability are subsequently determined. Given the concept of the influence of feeding site selection.

2.4 Determining the condition of vegetation

The condition of vegetation has usually been determined for grasslands, and was defined as 'the condition of vegetation in relation to some functional characteristic' (Trollope *et al*. 1990) or 'the state of a vegetation type relative to its optimum state for a particular purpose/species' (Hardy *et al*. 1999).

Determining the condition of vegetation requires some knowledge of the feeding ecology of the browser(s) in question and the amount of available browse. An understanding of the feeding ecology of a species can be determined by finding out how frequently it feeds on various browse species relative to their environmental availability (preference). Possible methods for black rhino have been discussed (2.2).

Available browse refers to leaves, twigs, flowers, fruit and even bark that may be eaten by a browser below a certain upper limit of browsing (Bothma *et al*. 2004). Estimating available browse by direct destructive sampling and weighing is exceptionally time-consuming and expensive (Adcock 2006). As such, much of the focus on determining the availability of browse has been on more rapid indirect methods that still retain acceptable accuracy.

Netshiluvi and Scholes (2000) investigated all efficient ways of estimating available browse and other attributes like plant biomass where a mathematical relationship is determined between more easily measured aspects of plant size and the target attribute (such as available browse). The basis for this is the necessary physical relationship between a plants size and its above ground biomass. They found strong relationships between browse availability and various plant dimensions for 23 species of trees.

The suitability of the sampling design also depends on the type of vegetation. The methods developed by Teague *et al.* (1981), Trollope (1986) and Smit (1989a and 1989b) involved belt transects suitable for data collection in more open vegetation. Smit (1989a and 1989b) demonstrated highly significant correlations between the volumes of the canopy sections being measured and the leaf mass contained within the volumes. Stuart-Hill (1989) described a method for thicket vegetation involving the point centered quarter (PCQ) method developed by Cottam and Curtis (1956) for conducting bush surveys. This plotless (distance) method is more time efficient than methods involving belt transects and is much more flexible because the sample size does not need to be adjusted for the particular density of the vegetation type being studied (Cottam and Curtis 1956). It was also more suited to the dense spiny thicket vegetation.

To solve the problem associated with the PCQ method of oversampling the short woody plants and undersampling the taller woody plants in the vegetation, Trollope *et al*. (2006) adapted the PCQ method for the thicket of the Great Fish River Reserve. This adapted method was also simpler and more time efficient allowing for repeatability. These attributes were seen as essential in a method for assessing and monitoring vegetation on a field scale for management purposes. Data collected from this adapted method were used to describe botanical composition, density, structure, phytomass and browsing potential of trees and shrubs. Phytomass was represented by the number of tree equivalents, a concept introduced by Teague *et al*. (1981), while the browsing potential reflected palatability. This method provided the means of being able to assess the condition of the woody vegetation in terms of its potential to provide forage for different ungulates species.

In developing a manual for assessing the availability of browse specifically for black rhino, Adcock (2006) motivated for a visual method focusing on plant canopy attributes. This was because methods based on measuring plant dimensions were still too time consuming and compromised the number of sites that could be sampled in a vegetation type. Adcock's method involved establishing circular plots in which canopy cover and vertical fill were assessed, followed by an assessment of the plant species contributing to that available browse. This would then be used in combination with knowledge on the species' value to potential black rhino diet.

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CHAPTER THREE

Principal Browse Species in the Diet of The Black Rhino (*Diceros bicornis minor*) in Six Vegetation Types in the Great Fish River Reserve, South Africa

Abstract

The backtracking method was used to study the diet of the black rhino *Diceros bicornis minor* in the Great Fish River Reserve of the Eastern Cape Province from July 2002 until July 2003. The contribution of browse species to the diet of black rhino were determined for six different vegetation types. Contribution to the diet was expressed both in terms of percentage dry mass and percentage number of bites. In each case, principal species were those contributing ≥5% to the diet. Both measures of the contribution of browse species tended to determine the same species as being principal and the use of the simpler method based on number of bites is recommended for future studies. A distinct exception to this was *Portulacaria afra* in Medium *Portulacaria* Thicket. While *P. afra* was abundant and characteristic of Medium *Portulacaria* Thicket, it was only a principal species in terms of dry mass contribution, but markedly unimportant in terms of number of bites. *Grewia robusta*, a semi-deciduous woody shrub, was a principal browse species in five of the six vegetation types, and probably the most important principal species in the entire study. *Euphorbia bothae*, a latex filled stem succulent, contributed the most of any browse species in a vegetation type but was a less important principal species as a whole than indicated by previous studies because of the restricted area of Short *Euphorbia* Thicket. Eighteen browse species were identified as principal species across all of the six vegetation types surveyed.

Key words: backtracking, *Diceros bicornis*, Euphorbiaceae

3.1 Introduction

The population of black rhino in the Great Fish River Reserve (GFRR) of the Eastern Cape Province displays all the signs of near optimal performance viz. low mortality, low inter-calving intervals, young age at first calving and has recently met the criteria of a key 1 population (Emslie and Brooks 1999). The performance of this population represents a positive contribution to efforts at attaining a total population of 2000 *Diceros bicornis minor* in South Africa (Brooks and Adcock 1997).

Associated with such good population performance are a number of management concerns. The population may overshoot the ecological carrying capacity (ECC) of the area due to birth-lag effects (Adcock 2000). This invariably results in decreased population performance, increased intraspecific competition, increased mortality, and impact on the browse resource. Of these concerns, impact on the browse resource is of greatest concern. Thicket, dominating large parts of the GFRR, is characterized by particularly palatable browse (Aucamp *et al*. 1978). It is particularly sensitive to disturbance and easily becomes degraded (Stuart-Hill 1992). Maintaining the condition of the vegetation will enable the GFRR to maintain a population of black rhino that performs well.

The above concerns reveal the importance of determining the ECC. According to the South African Development Community Rhino Management Group (RMG), black rhino populations should be maintained at 75% of the ECC such that population performance is optimum. Integral to developing a carrying capacity model for black rhino is the description of the diet of the species. Emslie and Brooks (1999) and Adcock (2000) undertook the challenge of determining ECC of an area for black rhino for the RMG, and regarded browse availability and browse quality as the two environmental variables of this model that were most frequently unavailable from the localities, and also the most difficult variables to determine.

When this study commenced, only an introductory study by Ausland *et al*. (2002) on the diet of the black rhino had been undertaken in the GFRR and data were not analyzed per vegetation type, hence a certain level of bias toward those areas with greater visibility, rhino density and accessibility for sampling. Subsequently, during this study period, Winkel (2004), van Lieverloo and Schuiling (2004), and Ganqa *et al*. (2005) also conducted studies that contributed to existing knowledge on the feeding ecology of black rhino in thicket. A limiting factor to all these studies was that the duration of the studies did not allow for sufficient sampling across vegetation types.

This study aimed to provide a more comprehensive understanding of the diet of the black rhino by sampling across the vegetation types and across seasons. It also aimed to provide an understanding of the principal browse species in the diet of the black rhino in the different vegetation types. Contribution of species to the diet was determined by two methods thereby allowing for comparison.

3.2 Study site

3.2.1 Locality

The GFRR is located in the Fish River valley between Grahamstown and Alice in the Eastern Cape Province. Originally it comprised three separate reserves in the form of the Andries Vosloo Kudu Reserve (AVKR) established in 1973, the Double Drift Game Reserve established in 1986 and the Sam Knott Nature Reserve (SKNR) established in 1987. This study was conducted in the AVKR and to a lesser extent in the SKNR sections south of the Fish River between 32^{o} 53' and 33^{o} 09' S; and 26^{o} 37' and 26^{o}53' E (Figure 3.1).

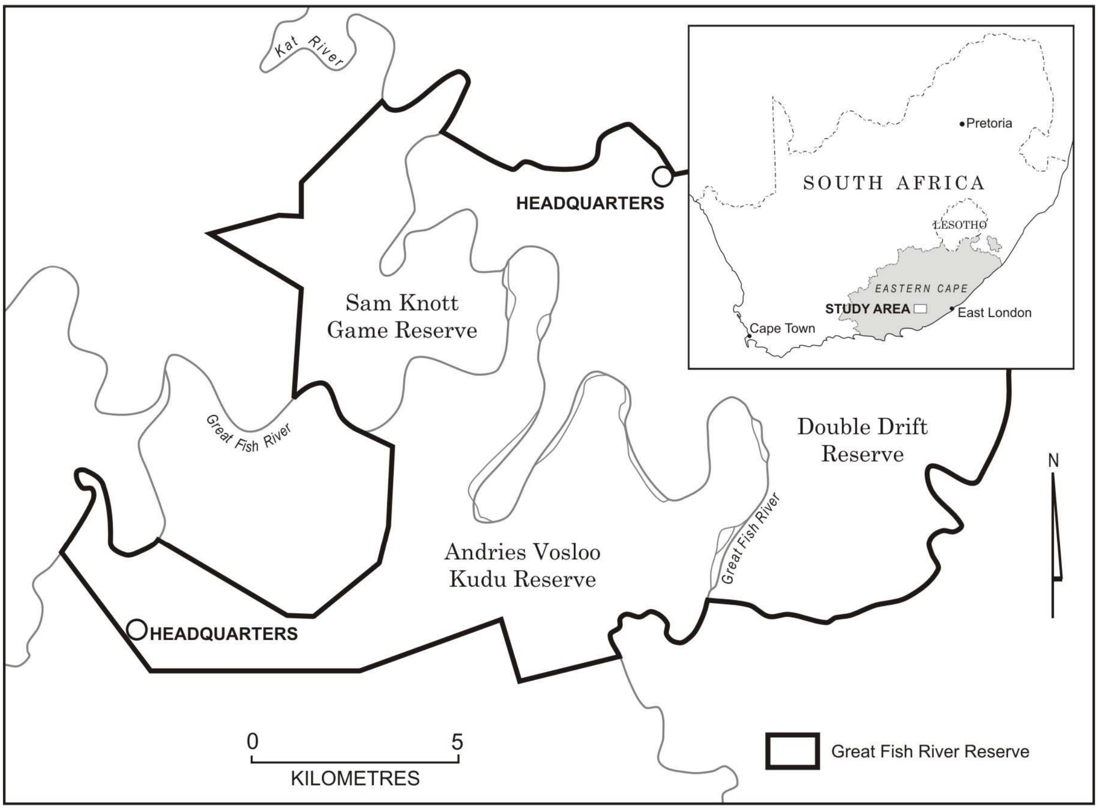


Figure 3.1. The location of the Great Fish River Reserve, South Africa.

3.2.2 Climate and geography

The GFRR has a semi-arid climate. According to the Köppen classification the climate of the study area may be described as *Cfa* where C represents a warm temperate climate with the coldest month having a maximum temperature of 18^{o}C and a minimum temperature -3 ^{o}C; f refers to sufficient precipitation during all months; and a represents a maximum temperature greater than 22 ^{o}C. Maximum temperatures can exceed 40°C in summer (Palmer 1981). The mean annual rainfall is 434mm, with peaks often occurring in October (spring) and March (autumn), and dry winters (Evans *et al*. 1997).

The perennial Fish and the Kat Rivers are the dominant topographical features in the reserve. Other tributaries are ephemeral, though some are dammed and provide water for lengthy periods.

The geology of the area is that of the Karoo Sequence (SACS 1980). The Fort Brown Formation of the Ecca Group characterizes the low-lying area to the south of the Sam Knott section. This formation is rhythmically bedded shale with isolated sandstone intercalations (SACS 1980). The Koonap Formation, also of the Beaufort Group occurs in the vicinity of the Great Fish River, and has sandstone and limestone as well as the mudstones. Dolerite dykes cut through these formations and can be seen on the river.

3.2.3 Vegetation

The majority of the vegetation of the GFRR comprises thicket (Low and Rebelo 1996). The thicket of the GFRR was classified by Vlok and Euston-Brown (2002) under the primary tier of Fish River Thicket and included the following units: Fish Valley Thicket; Fish Spekboom Thicket; Doubledrift Karroid Thicket; Fish Thicket; and Fish Noorsveld.

During the development and application of a technique for determining the condition of the vegetation in the GFRR, Trollope *et al*. (2006) recognized ten vegetation types on the basis of structure and dominant species and because these vegetation types seemed to recognize changes in the vegetation at an optimum scale it follows that these vegetation types were recognized in this study (Table 1.1).

Of the ten vegetation types recognized in the GFRR, data on feeding by black rhino was obtained in six. The other vegetation types were either more prevalent on the Double drift section of the GFRR where fieldwork was not conducted, or were generally of limited area and are therefore not relevant to this styudy.

Table 3.1. The vegetation types recognized in the Great Fish River Reserve with the equivalent vegetation units recognized by Vlok and Euston-Brown (2002) where appropriate.

Vegetation Type	Vlok and Euston-Brown	Description
Acacia Savanna (AS)		Open thornveld characterized by *Acacia karroo*.
Bushclump Karroid Thicket (BKT)	Doubledrift Karroid Thicket	Well defined fairly tall (±3m) bushclumps interspersed with grass on the higher-lying areas receiving higher rainfall. In the degraded state karroid shrubs replace the grass. Tends towards Dry Forest on steeper south facing slopes and valleys. Characterized by *Rhus* spp., *Scutia myrtina* and *Sideroxylon inerme*.
Dry Forest (DF)	Fish Thicket	Well-treed vegetation (>5m) typically of south facing slopes and drainage lines, particularly in valleys characterized by *Schotia latifolia*, *Harpephyllum caffrum*, *Hippobromus pauciflorus* and *Olea europaea* woody trees.
Grassland (G)		Open grassland characterized by either *Themeda triandra*, *Sporobolus fimbriatis*, or *Digitaria eriantha*.
Karroid *Cynodon* Shrubland		Open shrubby vegetation characterised by karroo shrublets and *Cynodon dactylon* . This vegetation is probably the result of past disturbance.
Medium *Portulacaria* Thicket (MPT)	Fish Spekboom Thicket	Extremely dense vegetation of moderate height (± 3m) frequently occurring on northern aspects and characterized by *Portulacaria afra* succulent shrubs.
Riverine *Acacia* Thicket (RAT)		Well-treed vegetation (>5m) lining the riparian zone of the Fish River and characterized by *Acacia karroo*. woody trees. This vegetation type is not of the thicket biome, and is driven by disturbance through periodic flooding.
Riverine *Combretum* Thicket (RCT)		Well-treed vegetation (>5m) lining river courses including parts of the Fish River and characterized by dominant stands of *Combretum caffrum* woody trees.
Short *Euphorbia* Thicket (SET)	Fish Noorsveld	Fairly open vegetation characterized by short (< 2m) *Euphorbia bothae* succulent shrubs.
Tall *Euphorbia* Thicket (TET)	Fish Valley Thicket	Well-treed vegetation (>5m) usually occurring on steep slopes and characterized by dense stands of *Euphorbia tetragona* and *E. triangularis* succulent trees.

Thicket has a great variety of growth forms that, by virtue of the intertwined and frequently thorny nature, make it dense and often difficult to penetrate. The vegetation is typically 2–3m high and succulents can contribute in excess of 20-30% relative cover (Cowling 1984). Thicket is highly nutritious and vulnerable to degradation and desertification through overutilization (Hoffman and Cowling 1990; Furstenburg *et al*. 1996; Kerley 1996; and Evans *et al*. 1997). There is also little evidence of recovery of severely degraded vegetation (Stuart-Hill and Dankwerts 1988).

3.2.4 Incidence of black rhino

According to the accounts of early pioneers, thicket in the vicinity of the GFRR supported large numbers of game including black rhino, with the last black rhino apparently killed in 1842 (Skead 1989). Currently, the GFRR supports a high density of browsers with grazers becoming more prevalent in the northern and eastern parts of the Double Drift section of the complex. Kudu (*Tragelaphus strepsiceros*) is the most common browser in the GFRR.

Table 3.2. Introductions of black rhino *Diceros bicornis minor* to the Great Fish River Reserve (Fike 1998).

Year	No. Rhino Introduced	Locality
1986	4	Grasslands
1989	6	Retreat – Drift
1990	3	Ballinafad
1991	2	Kat River Mouth
1997 (Aug)	5	Botha's Post
1997 (Sept)	6	Botha's Post
1997 (Nov)	2	Botha's Post

Black rhino were first re-introduced to the GFRR in May 1986 (Table 1.3). Subsequently, additional animals were introduced on six separate occasions (Fike 1998). An additional group of 20 animals were introduced to the Double Drift section of the complex in 2000. This was partly because the Great Fish River is an effective barrier inhibiting the crossing of animals and hence the establishment of a population on the Double Drift section (Fike 2003).

The population of black rhino has been performing near-optimally with good intercalving intervals and a high average annual recruitment rate and has recently become a key-1 population according the criteria presented by Emslie and Brooks (1999).

3.3 Methods of veld condition assessment

The study was conducted from mid-July 2002 until mid-July 2003. This period comprised an unusually wet spring and early summer period (August to December) thereafter remaining wet but becoming hotter during the summer and cooler and drier during the early winter period (January to June).

3.3.1 Backtracking

Backtracking is a method where the observer follows fresh tracks and signs of feeding rhino allowing the observer to collect data on browsing and browse availability. It is a widely used method, and was chosen for this study for a number of reasons detailed in Chapter 2 (2.2).

Backtracking involved locating a feeding rhino or fresh tracks (<5hrs) and associated feeding. This was done in the early morning because data collection was time-consuming and dependent on many hours of daylight. Backtracking was possible because the black rhino browses in a very characteristic way, the browsed twigs typically being cleanly cut at an angle. Once an animal or fresh tracks was located the following data were collected:

- Species browsed
- Number of bites, each allocated to one of four height classes (0-0.5 m; 0.51-1 m; 1.01-1.5 m; >1.5 m)

- Twig diameters, each allocated to one of four diameter classes (0-3.5 mm; 3.51-6.5 mm; 6.51-10 mm; >10 mm)
- Diameters for the *Euphorbia* (stem succulent) species allocated to one of three diameter classes (10-15 mm; 15.1-20 mm; 20.1-25 mm; >25 mm)
- The vegetation type and location

A bite was defined as any number of twigs <5 mm in diameter browsed within a radius of 50 mm of one another more or less on the same plane (Hall-Martin *et al*. 1982). Twigs with a diameter ≥5 mm were regarded as single bites. Species names follow Germishuizen and Meyer (2004). The field template is attached as Appendix 1.

The data collected allowed for measuring the contribution of the browse species to the diet of the rhino in two ways that could subsequently be compared. Browse species contribution could be measured in terms of number of bites and also in terms of dry mass. Data on number of bites are rapid to collect while that on dry mass are far more laborious since they require the individual categorization of measurements of all browsed twigs and use of that data to estimate the dry mass contribution of browse species.

3.3.2 Relationship between stem diameter and dry mass

3.3.2.1 Woody species

To determine the contribution of a browse species in terms of dry mass, a regression equation must be developed where twig diameter predicts dry mass (e.g. Mapuma *et al*. 1996 and Telfer 1969).

Preliminary analysis of the backtracking data allowed six woody species to be selected based on their important contribution to the diet of the rhino in terms of number of bites. These species (*Coddia rudis, Euclea undulata, Grewia robusta*, *Jatropha capensis*, *Plumbago auriculata*, and

Schotia afra) also represent a range of growth forms. Regressions developed for these species were based on the same three twig diameter classes used in the collection of data on browsing.

A combined regression was applied to those species for which individual regressions were not possible due to lack of adequate data. This combined regression was determined from all the stem diameter and dry mass data from the six woody species. Exceptions to this were *Euphorbia tetragona* and *E*. *triangularis* where the regression developed for *E. bothae* was used. This was justified because of the similarity of the succulent terminal stems of all three species. Due to the unusual growth form of the stems of *Cussonia spicata* (a softly woody tree) and *Opuntia ficus-indica* (a large stemmed succulent), and the leaves of *Dietes vegeta* and *Sansevieria hyacinthoides* (perennials with long blade-like leaves), dry mass estimates were not determined for these species. They were very seldom browsed and their exclusion from the analyses was of little practical significance.

To develop regression equations, 60 twigs were selected so that the three twig diameter categories (0-3.5 mm, 3.51-6.5 mm and 6.51-10.5 mm) were equally represented with 20 twigs each. This was done for each of the six species and ensured that the full range of twig diameters was represented. There were very few browsed twigs > 10.5 mm. That the black rhino may select more twigs in one category than another was not a concern for this procedure. Not more than five twigs were selected from a plant to ensure that a number of different plants were harvested. Harvested twigs were placed in airtight plastic bags to limit evapo-transpiration and stored at below freezing point until they could be weighed.

The dry mass of twigs relative to the stem diameter was determined gravimetrically by placing twigs of similar diameter in the oven simultaneously to avoid differences in drying time. Twigs were dried at 60^{o}C with the drying period varying from 24 to 144 hrs. The data were analyzed with a simple regression analysis where the dependent variable was the dry mass of twigs and the independent variable was the twig diameters.

3.3.2.2 Euphorbia bothae

Euphorbia bothae is a low growing thorny stem-succulent shrub commonly known as 'noors' (Acocks 1988). Although this member of the Euphorbiaceae is frequently consumed by the black rhino (Ausland *et al*. 2002; van Lieverloo and Schuiling 2004) its unusual growth form makes it difficult to quantify the amount of material browsed by a black rhino (Ausland *et al*. 2002). The approach to develop stem diameter-dry mass regressions was therefore different.

Preliminary analysis of the relationship between stem diameter and dry mass revealed that the dry mass of *E*. *bothae* could not be reliably predicted unless stems of the same length were sampled. Therefore, to predict the dry mass of stems of *E*. *bothae* browsed by black rhino where measurements were taken of the stem diameter in the field, an estimate of the mean length of portions of *E*. *bothae* removed by the rhino was required.

To estimate the mean length of the portion of stem removed by rhino, 15 sites were selected for fixed-point photography and at each site five clumps were identified and photographed together with a meter-stick for scale. The intention was to compare photographs of a clump before and after browsing to determine the change in the length of stems that were browsed. The technique failed for two reasons. Firstly, black rhino rarely browsed on any of the clumps that had been photographed and secondly the two clumps that were browsed were browsed very heavily and most of the stems were removed more than once making it impossible to determine how many bites of what length occurred on a stem.

Because of this, an alternative approach was used where 11 clumps that had been browsed by black rhino on backtracks were investigated. Browsed stems were compared with adjacent unbrowsed stems of similar branching history. The difference between the length of the browsed stem and the adjacent unbrowsed stem was determined in each case. An adjacent unbrowsed stem was considered for measurement if it originated from the same point as the browsed stem, was longer than the browsed stem, and had the same side branch structure. The mean of the differences of these measurements was assumed to represent the mean length of browsed portions of *E. bothae*. It was these lengths that were then sampled to determine a relationship between stem diameter and dry mass for use in determining the contribution of *E. bothae* in the diet of the black rhino.

E. bothae plants displayed terminal nodes that were grey and others that were green. Field observations indicated that grey nodes typically represented nodes that had been browsed previously and could be considered inactive, while green nodes were typically unbrowsed and actively growing. Although regressions were developed for both grey and green terminal nodes, the regression of green stems was chosen for determining the dry mass contribution of *E. bothae* to the diet of the black rhino because these were the stems most frequently browsed. Regressions were developed for both green and grey stems to determine whether there was a significant difference between dry mass estimates of the two categories.

Of the 15 sites established for fixed photography and growth measurements of *E. bothae* clumps, the first ten were sampled to test for a relationship between stem diameter and dry mass. At each of ten sites five green and five grey stems were selected from a clump that had not already been marked for fixed photography and growth measurements. These stems were cut at 100 mm - this length representing the approximate length of the average bite. The 100 stems were selected such that the range of stem diameters equally represented the following categories: 10-15 mm; 15.1-20 mm and 20.1-25 mm. The diameter measurements were taken from the surface between flanges on the stems, to the opposite surface.

3.3.3 Contribution of browse species to the diet of the black rhino

To determine the contribution of browse species in the diet of the black rhino, each backtrack was placed in the appropriate vegetation type, and contribution was determined both in terms of the number of bites and the dry mass for each vegetation type. The contribution in terms of the number of bites was determined by summing the number of bites taken in each height category for that species in that vegetation type and was also expressed as a percent of the total contribution of all species.

Total dry mass contribution of a species was determined by applying the appropriate regression equation to the mean diameter of each twig diameter class and then multiplying this value by the total number of twigs recorded in that diameter class for that species. For example, in the diameter class 0 – 3.5 mm, the median diameter would be 1.75 mm. This value was applied to the regression equation, and then multiplied by the total number of twigs in that diameter class for that species. The total dry mass contribution of a species was the sum of the dry mass estimates for each diameter class.

3.3.3.1 Comparison between two methods

The Mantel test for association between two distance matrices (Luo and Fox 1996) was used to compare the diet composition (expressed as the percentage contribution of each species to the diet) measured in terms of number of bites with that measured in terms of dry mass for all six vegetation types. These two methods were used simultaneously and therefore determined the diet on the same data derived from combining the backtracks in the six vegetation types (i.e. n = 12).

This test used the Sorensen (Bray-Curtis) distance measure (Sorensen 1948; Bray and Curtis 1957) and random permutations of the distance matrix (n = 10 000) to test the significance of the Mantel statistic. In the multivariate context, the standardized Mantel statistic is akin to the Pearson coefficient and ranges from –1 (negative association) to +1 (positive association). The Mantel test is a non-parametric test that is particularly well suited to dietary studies and has been used in numerous studies (e.g. Luo *et al*. 1994 and Kinkaid and Cameron 1982). This analysis was performed by PC-ORD, Version 4.25 (McCune and Mefford 1999) and cluster analysis was used to provide an accompanying visual representation of the similarity between the diet composition measured by the two methods at each site and the difference between diets in the different vegetation types

3.3.3.2 Variation in diet composition

PC-ORD, Version 4.25 (McCune and Mefford 1999) was used to test whether dissimilarity among diets (n = 90 transects) was greater between than within vegetation types. Data on diet composition measured from July 2002 – July 2003 on 90 transects in six vegetation types (n = 6, 14, 22, 5, 30, and 13 for BKT, DF, MPT, RAT, SET, and TET respectively) was examined with a Multi-Response Permutation Procedure (MRPP), using a Bray-Curtis dissimilarity measure. Diet composition determined by number of bites was expressed as percentages.

Non-metric Multi-dimensional Scaling (NMS) (Winkyst 1.0) of a Bray-Curtis distance matrix, followed by rotation by Principal Components Analysis (PCA) using Canoco 4.5 (ter Braak and Smilauer 2002) to display the main directions of variation in diet composition within and between vegetation types, was used to provide an accompanying visual presentation of the variation in diet composition.

3.3.3.3 Contribution of woody species

The contribution of forage species in the diet of the black rhino was determined for three categories: woody species, non-woody species, and grass. Non-woody species included annual herbs, perennial herbs, karroid shrubs, geophytes and some climbers. Woody species include the stem succulent *Euphorbia bothae*, *E*. *tetragona* and *E*. *triangularis*. The contribution of woody species was determined for each vegetation type and measured in terms of both dry mass and number of bites.

3.3.3.4 Principal species

Principal species were considered to be those species that contributed ≥5% to the diet in that vegetation type either in terms of number of bites or in terms of dry mass. The contributions of principal species were tabulated for each vegetation type including those contributions in other vegetation types that were <5%. Any reference to the importance of species refers to their importance in terms of their percent contribution to the diet.

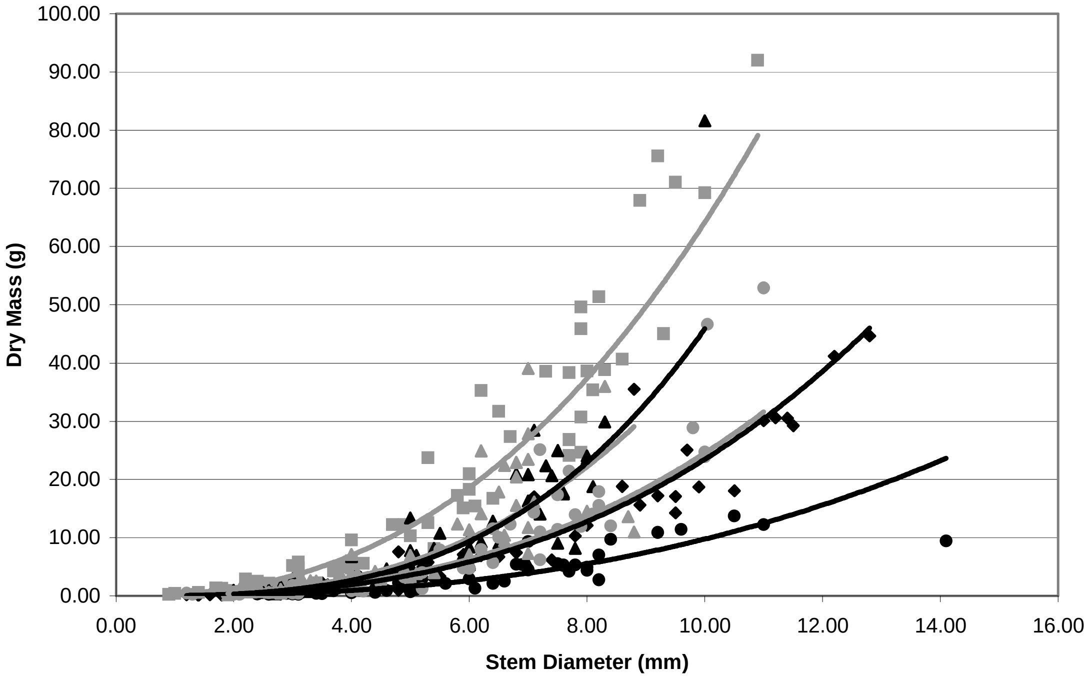
The contributions of all species to the diet of the black rhino in each vegetation type are presented in Appendices 2 and 3. In isolated cases very similar browse species of the same family were grouped together where their identification was difficult and the growth form very similar.

3.4 Results and discussion

3.4.1 Relationship between stem diameter and dry mass

3.4.1.1 Woody species

The relationships between stem diameter and dry mass for six woody browse species is presented in Figure 3.2. The coefficients of determination (r^2) for the regression equations developed for the six woody species were all high, being > 0.8 in every case meaning that stem diameter accounted for > 80% of the variation in the dry mass of twigs available for browsing in the six woody species.



	Species	Equation	r^2	df	p
◆	*Coddia rudis*	$y = 0.0439x^{2.7275}$	0.9308	59	< 0.05
■	*Euclea undulata*	$y = 0.2409x^{2.4256}$	0.9539	59	< 0.05
▲	*Grewia robusta*	$y = 0.0354x^{3.1127}$	0.879	59	< 0.05
●	*Jatropha capensis*	$y = 0.0258x^{2.577}$	0.8539	59	< 0.05
△	*Plumbago auriculata*	$y = 0.0619x^{2.8286}$	0.8764	59	< 0.05
○	*Schotia afra*	$y = 0.0542x^{2.6551}$	0.8671	59	< 0.05

Figure 3.2. Relationship between twig diameter and dry mass for six well-utilised woody browse species in the thicket of the Great Fish River Reserve, South Africa.

Based on field observations the divergence in the relationships described by the six equations depicted in Figure 3.2 can be explained by the morphology of the species concerned. The amount of dry mass estimated from the regression of *Euclea undulata* was higher than for any other species probably due to its well-developed branch structure, while that estimated from the regression of *Jatropha capensis* was lower than for any other species probably because of its high water content. The amount of dry mass estimated from the regressions of *Coddia rudis* and

Schotia afra was similar and this may be attributed to the intense browsing history that characterized both species.

To determine the dry mass contribution to the diet of the black rhino of those species for which the relationship between stem diameter and dry mass was not determined, a regression based on data of stem diameter and dry mass of all six species was applied (Figure 3.3). The results indicate that the coefficient of determination (r^2) for the regression equation developed for the six woody species simultaneously was 0.75, meaning that stem diameter accounted for 75% of the variation in the dry mass of twigs available for browsing where data from all six woody species are considered simultaneously.

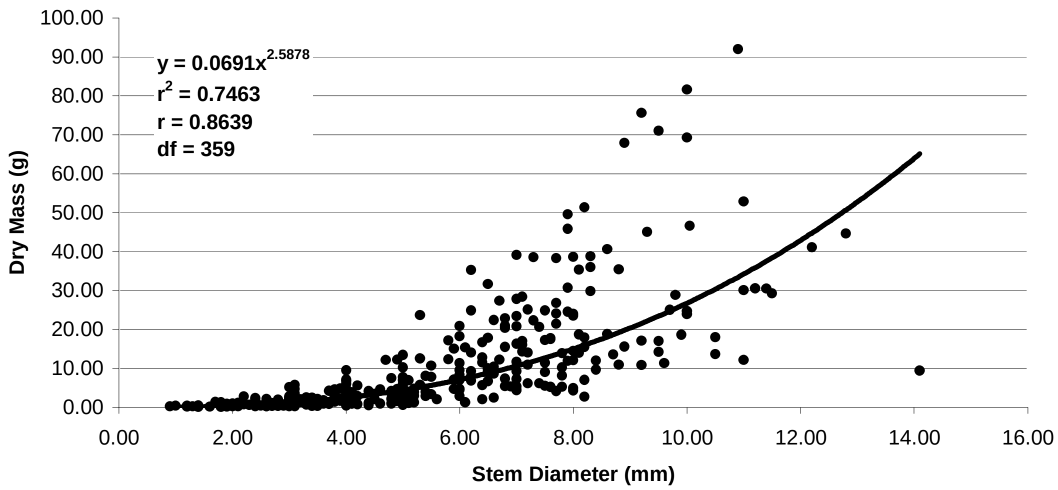


Figure 3.3. Simultaneous correlation between twig diameter and dry mass for the six well-utilised woody browse species combined (see Figure 2.1 for species names) growing in the thicket of the Great Fish River Reserve, South Africa.

Because regression equations were specifically developed for those species that were regarded as the most important and hence most frequently represented in the tables, it can be appreciated that the contribution in terms of dry mass is probably more accurate than the contribution in terms of number of bites for these species. Conversely, it is likely that, due to varying physiognomy, the contribution in terms of dry mass of certain species where the combined regression was applied was over-estimated in some cases, and under-estimated in other cases.

3.4.1.2 Euphorbia bothae

Due to the unusual growth form of *Euphorbia bothae*, preliminary investigation revealed the necessity of determining the length of the average bite before the relationship between stem diameter and dry mass could be determined. The differences between browsed and unbrowsed stems of *E. bothae* as a means of determining the average browsed length of *E. bothae* by black rhino are tabulated in Table 3.3.

Table 3.3. Summary of average length of *Euphorbia bothae* removed through browsing by black rhino from 11 clumps as determined from the difference between the length of the browsed stem and that of an adjacent stem with similar growth history. n = number of stems; Std. Dev. = Standard Deviation.

		AVERAGE LENGTH (mm)				
Clump	n	Browsed Stem	Std. Dev.	Unbrowsed Stem	Std. Dev.	Difference
1	20	210.5	±82.9	280.8	±103.2	70.3
2	22	271.4	±231.3	369.3	±257.3	98
3	7	103.9	±48	172.6	±65.3	68.7
4	9	146.7	±56.4	252.8	±55.8	106.1
5	7	154.3	±61.3	247.1	±83.4	92.9
6	5	144	±71.6	248	±56.2	104
7	12	197.1	±93.7	329.2	±88.4	132.1
8	4	148.8	±39.7	252.5	±49.2	103.8
9	10	149.5	±94	260.5	±95.1	111
10	8	462.5	±154.2	508.1	±121.2	45.6
11	7	170	±67.9	316.4	±102.7	146.4
Grand Average		210.6		306.7		96.1

The greater mean length of portions browsed at clump seven and eleven probably represent instances where the same stem was browsed twice. Since clumps in Table 3.3 were not characterized by extremely heavy browsing that was occasionally seen in the field, the length of

96.1mm was more likely to be an underestimate than an overestimate. To simplify the procedure of sampling stems for developing a regression between stem diameter and length, lengths of 100 mm were cut.

The relationships between stem diameter and dry mass of 100 mm lengths of green and grey stems of *Euphorbia bothae* were determined (Figure 3.4). The results indicate that the coefficients of determination (r^2) for the regression equations developed for the green and grey stems of *E. bothae* were lower than those for the woody species at 0.63 and 0.48 respectively meaning that stem diameter accounted for 63% and 48% of the variation in the dry mass of the green and grey stems available for browsing.

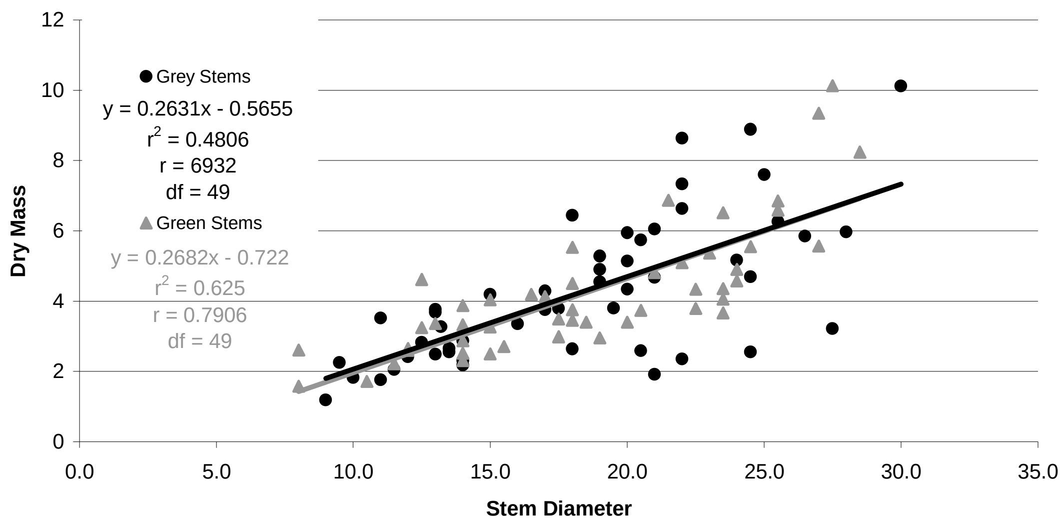


Figure 3.4. Correlation between stem diameter and dry mass for 100 mm lengths of green and grey stems of *Euphorbia bothae*.

The regressions for both green and grey stems are very similar (Figure 3.4). In light of this, the regression developed for the green stems was used for determining the dry mass of the browsed portion of stems because black rhino tended to browse these actively growing stems more frequently.

3.4.2 Contribution of browse species to the diet of the black rhino

A total of 90 backtracks over 13 months (Figure 3.5) yielded 3549 browsed plants and 14 994 bites over the six vegetation types. The majority of data came from the SET and MPT vegetation types where number of browsed plants (n) was 985 and 975 respectively followed by DF (n = 529), TET (n = 504), RAT (n = 272) and BKT (n = 267). About 90 plant species (including a few species groups) were recorded as browsed by black rhino (Appendices 2 and 3).

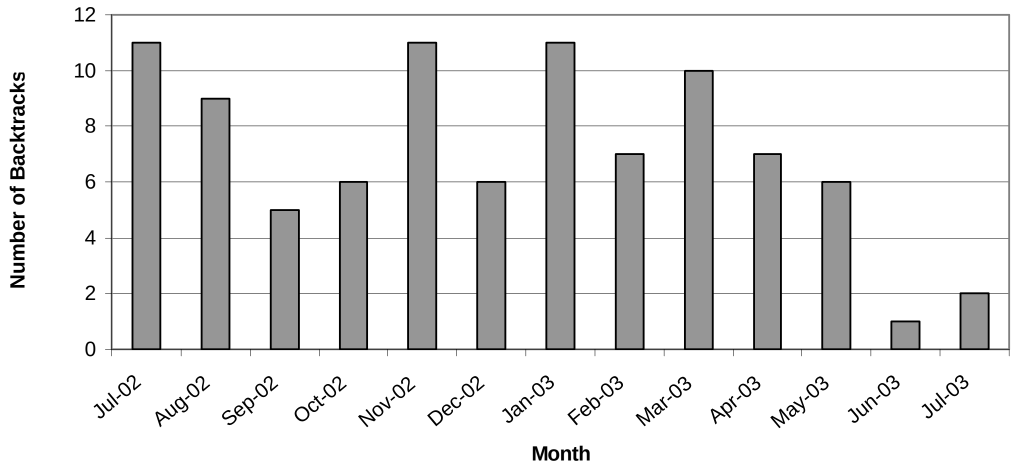
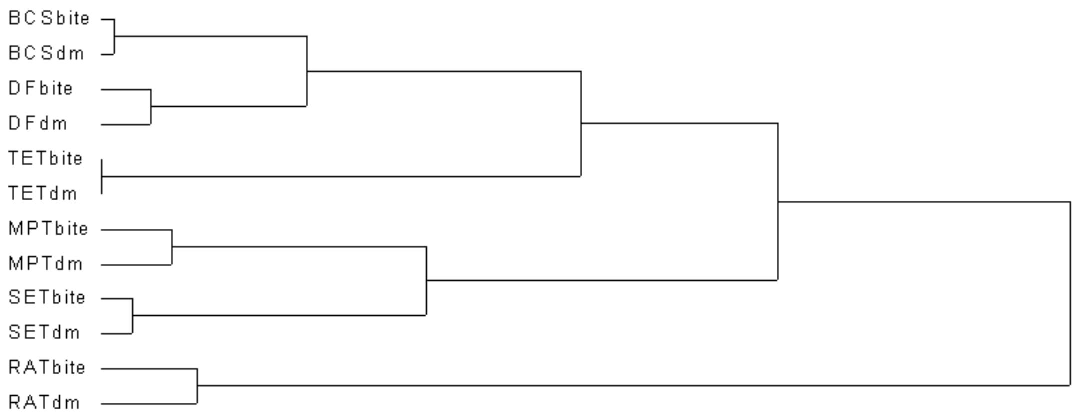


Figure 3.5. The distribution over time of backtracks of black rhino in the Great Fish River Reserve, South Africa.

The number of species browsed by black rhino in this study was similar to the number recorded at localities where intensive field work was conducted such as that by Hall-Martin *et al*. (1982) at the Addo Elephant National Park (111 spp.); and by Goddard (1968) and (1970) at Ngorongoro Crater and Olduvai Gorge (191 spp. for both sites), and Tsavo National Park (102 spp.) respectively; and by Oloo *et al*. (1994) at Laikipia, Kenya (103 spp.). The number of species browsed by black rhino in this study was greater, however, than that recorded for the more arid localities such as the Augrabies Falls National Park (51 spp.) and Damaraland (74 spp.) by Buk (2004) and Loutit *et al*. (1987) respectively.

3.4.2.1 Comparison between two methods

Because two different methods were used to determine the contribution of browse species to the diet of black rhino, comparisons could be drawn. The standardized Mantel statistic (r = 0.989; p = 0.001) confirmed the strong association between diet estimates based on number of bites and those based on dry mass. The association between the estimates of the diet composition in the six vegetation types by the two methods was presented visually by using cluster analysis (Figure 3.6).



BCS = Bushclump Karroid Thicket
DF = Dry Forest
MPT = Medium *Portulacaria* Thicket
SET = Short *Euphorbia* Thicket
RAT = Riverine *Acacia* Thicket
TET = Tall *Euphorbia* Thicket

Figure 3.6. Dendrogram of a cluster analysis (Group Average method on Bray-Curtis dissimilarities) indicating association between the diet composition of black rhinos represented in terms of dry mass (dm) and number of bites (bite) in six vegetation types in the Great Fish River Reserve, South Africa.

Diets of all the vegetation types as determined by the number of bites and dry mass methods displayed a similar pattern where the main differences were between sites rather than between methods. The diets of RAT showed greatest variation when compared to diets from all other vegetation types as indicated by the branching on the extreme right of Figure 3.6. This variation was probably influenced by the greater incidence of herbs in the RAT diet samples than in the diet samples of the other vegetation types. Figure 2.5 suggests that either method may be used to describe the diet of the black rhino.

3.4.2.2 Variation in diet composition

The test statistic from the Multi-Response Permutation Procedure (MRPP) ($T = -24.093$; $p<0.0001$) was negative, indicating a significantly large separation in the diet samples (backtracks) from the different vegetation types. The least variable diet was in SET with a mean distance value of 0.518 ($n = 30$) while DF had the most variable diet with a mean distance value of 0.783 ($n = 6$). All the other vegetation types had mean distance values > 0.7.

The relationship between the diets in the vegetation types was further explored and presented visually (Figure 3.7) where non-metric scaling ordination was used to show the spread (relative variation) of the backtracks in each vegetation type where the diet in each was determined by number of bites.

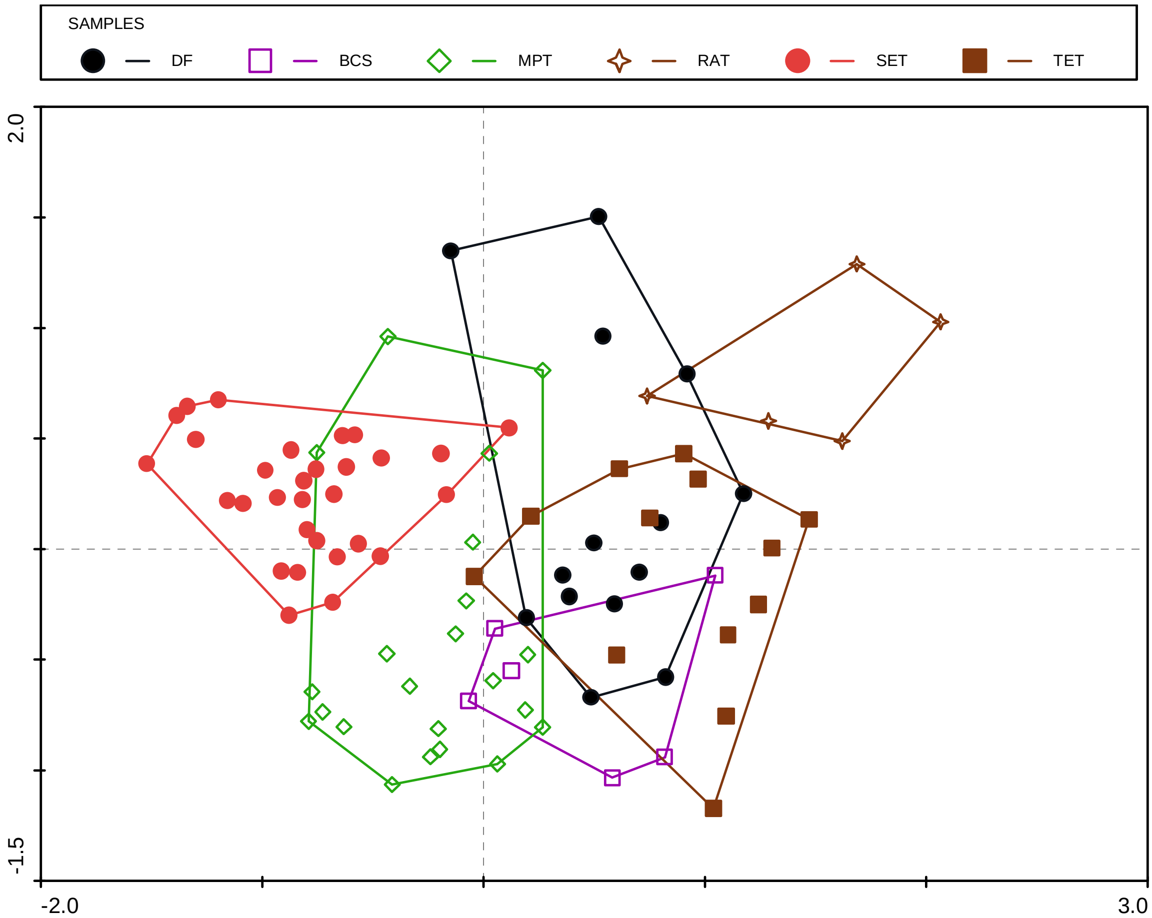


Figure 3.7. Non-Metric Scaling ordination (rotated onto first two principal component axes) of variation in diet composition (% contribution in terms of bites) measured in backtracks in all seasons in six vegetation types in the Great Fish River Reserve, South Africa. The first axis (horizontal) and second axis (vertical) represent 65% and 35% of the total variation in the two-dimension NMS solution (stress = 0.2355).

Diet samples (backtracks) of each vegetation type typically displayed cohesion that indicated affinity to that vegetation type to which they were designated. The pronounced overlap between the diets as described by backtracks of DF and TET was not surprising considering the similarity between these vegetation types in terms of the species composition. Consequently, there was reasonable overlap in the diets and the contribution of the principal species is presented and discussed later. The isolated spread of diet samples of RAT is expected since it is not of the thicket biome and *Verbecena encelioides*, an annual herb largely restricted to this vegetation type, dominated the diet. SET displayed the greatest cohesion between diet samples thereby complementing the results of the MRPP, and was markedly separated along the second axis. It also displayed little overlap with the other diets and was most different to the RAT vegetation.

3.4.2.3 Contribution of woody species

Non-woody species include grass, annual herbs, perrenial herbs, karroid shrubs, geophytes and some climbers. The importance of woody browse species to the diet of the black rhino is shown in Table 3.4 where woody browse species contributed to > 88% of the diet in five of the six vegetation types. RAT is the only vegetation type where non-woody species contributed to a great portion of the diet. The contribution of all species recorded in the diet of the black rhino in the six vegetation types are attached as Appendices 2 and 3.

Table 3.4. Percentage of the diet in three forage categories in terms of number of bites (Bites) and dry mass (DM) in six vegetation types in the Great Fish River Reserve, South Africa.

	Bushclump Karroid Thicket				Dry Forest				Medium *Portulacaria* Thicket			
Category	Bites	%	DM (g)	%	Bites	%	DM (g)	%	Bites	%	DM (g)	%
Grass	0	0.0	0.0	0.0	1	0.0	4.5	0.0	1	0.0	0.0	0.0
Non-woody	109	10.2	364.8	3.7	251	11.8	1183.8	0.0	232	6.3	1728.0	4.5
Woody	958	89.8	9444.6	96.3	1882	88.2	18796.7	94.1	3447	93.7	36794.0	95.5
Grand Total	1067	100.0	9809.4	100.0	2134	100.0	19985.0	100.0	3680	100.0	38522.0	100.0

	Riverine Acacia Thicket				Short *Euphorbia* Thicket				Tall *Euphorbia* Thicket			
Category	Bites	%	DM (g)	%	Bites	%	DM (g)	%	Bites	%	DM (g)	%
Grass	0	0.0	0.0	0.0	3	0.1	1.2	0.0	0	0.0	0.0	0.0
Non-woody	473	57.4	3058.8	48.1	357	6.6	1301.9	0.0	173	6.9	886.9	4.6
Woody	351	42.6	3302.8	51.9	5021	93.3	37468.0	96.6	2332	93.1	18384.6	95.4
Grand Total	824	100.0	6361.6	100.0	5381	100.0	38771.1	100.0	2505	100.0	19271.5	100.0

Of the 18 principal species (Table 3.5), only *Verbecena encelioides* and the Acanthaceae (here represented by *Justicia protracta*) are non-woody. Both of these species were recorded in RAT. *V. encelioides* (n = 231), the most important principal species, is an exotic annual weed (Henderson and Anderson 1966) that only provides browse during the summer. As such, its importance is seasonal. *Justicia protracta* (n = 175) is a perennial, however, and quantification of this species was difficult because of the fine nature of the stems – it was sometimes difficult to notice browsing and it is possible that this species contributes more to the diet than determined for this vegetation type in this study.

The contribution of grass to the diet of the rhino in all vegetation types is negligible (Table 3.4). Where grass was recorded, it was apparently accidentally eaten while the rhino was browsing a woody plant. Although direct observation was not a suitable technique for providing quantifiable data due to reasons explained under methods, individuals were frequently observed feeding (n > 30) and there was never evidence of grass being eaten. When black rhino were seen feeding at ground level in areas devoid of woody shrubs, close inspection revealed that the animals were either eating annuals or forbs (such as members of the Mesembryanthemaceae) and not grass.

Goddard (1968 and 1970) used direct observation to determine the diet of black rhino in East Africa and found that, although grass was consumed, it represented a very small proportion of the diet. Hall Martin *et al*. (1982) found that backtracking revealed that little grass was eaten while dung analysis revealed that, although grass was more evident, the contribution of grass followed the rainfall pattern. Oloo *et al*. (1994) used the backtracking technique to determine the diet of black rhino on a well-vegetated ranch in Kenya. Grass was not recorded from the diet.

The contribution of grass to the diet of the black rhino may vary as grass and bush availability vary from locality to locality. Mabinya *et al*. (2002) used thin layer chromatography to estimated grazing of seven herbivores from the analysis of dung in the GFRR in March. The dung from black rhino and giraffe *Giraffa camelopardalis* had the least detectable amounts of phenolic acids indicating a negligible amount of grass. Also in the GFRR, van Liverloo and Schuiling (2004) found a 4.5% contribution of grass in the diet with faecal analysis.

3.4.2.4 Principal species

In five of the six vegetation types the three most important principal species contributed more than 50% of the diet in terms of dry mass, although the contribution of the three most important principal species in terms of number of bites was consistently marginally lower (Table 3.5). The three most important principal species contributed 51.6% and 48.1% (TET), 75.4% and 69.9% (SET), 74.2% and 69.2% (RAT), 51.9% and 47.9% (MPT), 48.5% and 37.7% (DF), and 56.6% and 43.5% (BKT) to the diet of the black rhino in terms of dry mass and number of bites respectively for each vegetation type. In SET, the three most important principal species made up 75.42% of the total dry mass contribution. This is largely attributed to the contribution of *Euphorbia bothae* to the diet. Very high contribution by one species to the diet of the black rhino was also found by Buk (2004) in Augrabies Falls National Park where *Zygophyllum cf. dregeana* contributed to more than a third of the diet.

Studies on the feeding ecology of the black rhino have consistently shown that although a great number of species are browsed, a small number of principal species contribute to the bulk of the diet (e.g. Goddard 1968; Joubert and Eloff 1971; Hall-Martin *et al*. 1982, Emslie and Adcock 1994 and Buk 2004). In the GFRR Ausland *et al*. (2002) also found that in all three seasons, the three most important species made up more than 50% of the diet in terms of number of plants selected. In Itala Game Reserve, northern Natal, Kotze and Zacharias (1993) found that the ten most frequent species contributed 80% of the measured diet.

Table 3.5. Percent contribution in terms of dry mass (DM) and number of bites (Bites) for principal browse species (those contributing ≥5% to diet of black rhino in any one of six vegetation types) of the Great Fish River Reserve, South Africa. n = number of bites

		BKT			DF			MPT			RAT			SET			TET		
Species	Family	n	Bites %	DM %	n	Bites %	DM %	n	Bites %	DM %	n	Bites %	DM %	n	Bites %	DM %	n	Bites %	DM %
Acalypha glabrata	Euphorbiaceae	76	7.1	7.7	—	—	—	17	0.5	0.2	35	4.2	6	—	—	—	104	4.2	3.6
Acanthaceae sp	Acanthaceae	3	0.3	0	—	—	—	20	0.5	0.2	175	21.2	5.3	—	—	—	44	2.9	1.4
Azima tetracantha	Salvadoraceae	45	4.2	3	182	8.5	7.9	111	3	2.4	25	4.7	3.4	182	3.4	3.4	121	4.8	3.8
Brachylaena ilicifolia	Compositae	76	7.1	9.2	33	1.5	1.6	172	4.7	4.1	—	—	—	101	1.9	1.7	—	—	—
Coddia rudis	Rubiaceae	199	18.6	27.4	289	13.5	18.2	253	6.9	12.4	—	—	—	—	—	—	150	6	9.4
Croton rivularis	Euphorbiaceae	55	5.2	2.4	16	0.7	0.1	—	—	—	—	—	—	—	—	—	—	—	—
Euclea undulata	Ebenaceae	19	1.8	2.2	166	7.8	19.3	274	7.4	13.1	—	—	—	210	3.9	10.4	30	1.2	1.9
Euphorbia bothae	Euphorbiaceae	—	—	—	—	—	—	34	0.9	0.6	—	—	—	2719	50.5	38.9	—	—	—
Euphorbia tetragona	Euphorbiaceae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	191	7.6	8.2
Euphorbia triangularis	Euphorbiaceae	—	—	—	—	—	—	—	—	—	22	2.7	1.9	—	—	—	208	8.3	6.9
Grewia occidentalis	Tiliaceae	22	2.1	2.4	169	7.9	6.4	5	0.1	0.1	17	2.1	3.3	—	—	—	32	1.3	1.5
Grewia robusta	Tiliaceae	190	17.8	20	190	8.9	11	944	25.6	26.5	—	—	—	835	15.5	26	124	5	5.3
Gymnosporia capitata	Celastraceae	65	6.1	5.7	41	1.9	1.8	129	3.5	3	—	—	—	114	2.1	2	14	0.6	0.6
Jatropha capensis	Euphorbiaceae	90	4.4	2.2	90	4.2	2.2	409	11.1	4.7	—	—	—	40	0.7	0.4	341	13.6	11.1
Plumbago auriculata	Plumbaginaceae	69	6.5	4.9	327	15.3	10.9	13	0.4	0.3	165	20	30.9	47	0.9	0.5	656	26.2	31.1
Portulacaria afra	Portulacaceae	—	—	—	2	0.1	0.4	40	1.1	9.4	—	—	—	16	0.3	1.7	—	—	—
Rhigozum obovatum	Bignoniaceae	—	—	—	—	—	—	411	11.2	8.5	—	—	—	68	1.3	0.9	1	0	0
Verbecena encelioides	Compositae	—	—	—	—	—	—	12	0.3	0.2	231	28	37.3	—	—	—	—	—	—

BKT = Bushclump Karroid Thicket
DF = Dry Forest
MPT = Medium *Portulacaria* Thicket
SET = Short *Euphorbia* Thicket
RAT = Riverine *Acacia* Thicket
TET = Tall *Euphorbia* Thicket

Grewia robusta, *Plumbago auriculata*, *Euclea undulata*, and *Coddia rudis* were principal species in five, four, three and three vegetation types respectively (Table 3.5). Although 11 of the 18 principal species were principal in one vegetation type only, these frequently contributed only marginally less than 5% to the diet in vegetation types where they were not principal.

A number of members of the Euphorbiaceae were principal species (Table 3.5). In SET the stem succulent *Euphorbia bothae* was eaten in great quantity. At 50.5%, the contribution in terms of number of bites was markedly greater than the contribution of any other species in any vegetation type. In TET, *E*. *tetragona* and *E*. *triangularis*, two species of tree euphorbia with similar terminal branches to those of *E*. *bothae*, were of similar importance to one another. *Acalypha glabrata*, an unarmed woody shrub, was principal in the more mesic BKT and RAT vegetation types while *Jatropha capensis*, a latex-bearing member of the Euphorbiaceae, was principal in MPT and TET. Both these species also contributed marginally less than 5% to the diet of the rhino in at least one other vegetation type.

The importance of the Euphorbiaceae has been well documented in the diet of the black rhino (e.g. Loutit *et al*. 1987; Goddard 1968; Mukinya 1977; Oloo *et al*. 1994; Schenkel and Schenkel-Hulliger 1969; and Buk 2004). In the GFRR, Ausland *et al*. (2002) found *E*. *bothae* to be the most commonly browsed species. Browsing of the tree *euphorbia* species was invariably associated with the felling of these individuals by the feeding rhino with this phenomenon also documented by Dudley (1997) in Malawi where *E. ingens* was heavily utilised in a wasteful manner by black rhino under controlled fenced off conditions. Plants invariably died after being pushed over. The importance of *A*. *glabrata*, a preferred species (Chapter 5) localized to mesic areas, was based on one backtrack in each vegetation type with heavy browsing on isolated stands. Emslie (1999) regards *A*. *glabrata* as a principal species in the diet of the black rhino in Hluhluwe Game Reserve. The contribution of *J. capensis* in terms of dry mass was typically much lower than that in terms of number of bites probably because of the high water content. In the absence of dry mass data, the importance of this species may have been exaggerated. *J*. *capensis* is typically highly stunted, presumably indicating a heavy browsing history. Ausland *et al*. (2002), van Lieverloo and Schuiling (2004), and Ganqa *et al.* (2005) also found *J. capensis* to be a commonly browsed species in the GFRR.

The finding that *Acacia karroo*, an armed deciduous woody tree and the characteristic woody species in RAT (pers. obs.), was largely ignored by feeding black rhino was supported by Ausland *et al*. (2002), van Lieverloo and Schuiling (2004), and Ganqa *et al.* (2005) in the GFRR. This is a suprising finding considering that the Mimosaceae was found to be the most important family in studies in Kaokoland (Joubert and Eloff 1971), Itala (Kotze and Zacharias 1993), Laikipia (Oloo *et al*. 1994), Lewa (von Holdt 1999), and Augrabies Falls (Buk 2004) with the genus *Acacia* being most prevalent in the diet. Tatman *et al*. (2000), found that black rhino home ranges in Kenya consisted of more *Euclea divinorum* bush communities and less *Acacia* vegetation and open grassland, thus illustrating the importance of *E. divinorum* rather than the *Acacias*. As for areas where *Acacias* are important (Oloo *et al*. 1994; von Holdt 1999; and Emslie 1999) browsing of *A*. *karroo* in the GFRR was inevitably of young plants.

Although *Portulacaria afra* was principal in terms of the dry mass contribution in MPT, the contribution in terms of number of bites was markedly different and indicated it to be unimportant. No regression between stem diameter and dry mass was determined specifically for *P*. *afra*, and the estimate based on the combined regression does not account for the succulent nature of thick twigs of *P. afra* and the contribution in terms of dry mass was a likely overestimate. The ease with which a feeding rhino could break (but not eat) a stem meant that signs of feeding were carefully checked to avoid error. The estimate based on number of bites is considered far more accurate.

Considering that *P*. *afra* characterizes and dominates MPT in terms of availability (Chapter 5), it is rather surprising that it was not more important - especially considering that the succulent nature of the species could be a source of moisture for feeding rhino. Hall-Martin *et al*. (1982) recorded

P. *afra* as an important browse species during dry periods in the enclosure at the Addo Elephant National Park. Winkel (2004), working on the Double Drift Section of the GFRR during the late dry season, also found no browsing of *P*. afra, suggesting that the black rhino may not browse *P*. *afra* as a source of water in the GFRR although it has a rather xeric climate. Maddock *et al* (1995) also found *P*. *afra* to be rejected by black rhino in a captive feeding study in the GFRR, but the rhino originated from an area without *P*. *afra* and they hypothesized that this rejection was due to the lack of familiarity of the rhino with *P*. *afra*.

Grewia robusta followed *E*. *bothae* as the next most important principal species in SET although the contributions in terms of dry mass and in terms of number of bites were suprisingly different (26% and 15.5% respectively). The contribution of this species was similar in MPT where it was the most important principal species. It was the second most important principal species in BKT and was also a principal species in DF and TET. Ausland *et al*. (2002) found it to be one of the four most commonly browsed plants in the GFRR.

Plumbago auriculata was the most important principal species in TET and was also a principal species in BKT, DF and RAT. It typically showed an intense browsing history in areas frequented by black rhino and was presumably a highly palatable species. Although *P. auriculata* contributed to over 30% of the diet in RAT, this contribution was influenced by the frequent occurrence of this species where drainage lines enter the Great Fish River. There were thus large areas of RAT thicket where *P*. *auriculata* did not occur. In common with *Acalypha glabrata*, it occured in the more mesic areas and was consequently patchily distributed.

Coddia rudis, a deciduous woody shrub, was the most important principal species in BKT, potentially the most important principal species in DF, and a principal species in MPT and TET. Perhaps more so than other woody species, it was typically very heavily browsed. It would appear that the intensity of browsing of this and other species was related to the past browsing history, with stunted stubby individuals being ignored or less intensely browsed. Winkel (2005) also found that it was the most important browse species in BKT in the Double Drift Section of the GFRR.

Azima tetracantha, principal in terms of dry mass contribution only in DF, was determined to contribute a greater amount to the diet in terms of number of bites. Considering that a regression specific to this species was not developed, and that it was typically scrambling with elongated branches, the estimate according to number of bites was probably more realistic. Although *A*. *tetracantha* did not contribute to more than5% of the diet in terms of dry mass in most cases, it featured in the top ten species in five of the six vegetation types. *A*. *tetracantha* was also found to be an important browse species in the Addo National Park by Hall-Martin *et al*. (1982).

Euclea undulata, an evergreen shrub or small tree, was principal in MPT and SET and was the most important principal species in DF contributing 19.27% of the diet in terms of dry mass although the contribution in terms of number of bites was markedly less (7.78%). Ausland *et al*. (2002) also found *E*. *undulata* to be one of the four most commonly browsed plants in the GFRR and Winkel (2005) found that it contributed >10% to the diet in the vegetation types he surveyed in the Double Drift Section of the GFRR.

Species principal to fewer vegetation types were *Rhigozum obovatum* (MPT), *Grewia occidentalis* (DF), *Brachylaena ilicifolia* (BKT) and *Gymnosporia capitata* (BKT). Hall-Martin *et al*. (1982) found that *R. obovatum* was particularly heavily used after rains induced leaf flushing and Buk (2004) found that *R*. *trichotonum*, a similar species, was a principal species in all three seasons in Augrabies Falls National Park although it was more important in the late dry and rainy seasons. Seasonal change in feeding of this species was also found in the GFRR (Chapter 3).

3.5 Conclusions

While number of bites could be used as a good indicator of the relative contributions of the different browse species, there are certain species where the contribution in terms of number of bites was not a reliable indicator. Most notable were *Jatropha capensis* and *Euclea undulata*. There were other species, however, where the contribution determined from the combined regression equation was unlikely to be a reliable indicator. For such species, the contribution to the diet would best be determined from a regression developed specifically for the species in question, or from the number of bites recorded. This applies to *Portulacaria afra* in particular.

Eighteen browse species contributed ≥5% to the diet in terms of dry mass in at least one of the vegetation types. Yet, in five of the six vegetation units, the three most important principal browse species contributed more than 50% of the diet in terms of dry mass. Of these, *Grewia robusta* was principal in five of the six vegetation types and considering that this species appeared to be widespread and was principal throughout the duration of this study (Chapter 3), it was probably the most important principal forage resource for black rhino in the GFRR.

While recognizing that this study did not sufficiently cover a period of great browse resource scarcity, it is these principal species that should be considered the key browse species for black rhino in the GFRR and should act as the indicators of the condition of the vegetation for black rhino. It is evident that, although the diet of the black rhino was diverse, a few principal species contributed to the bulk of the total forage intake.

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CHAPTER FOUR

SEASONAL VARIATION IN THE DIET OF THE BLACK RHINO (*DICEROS BICORNIS MINOR*) IN THREE IMPORTANT VEGETATION TYPES IN THE GREAT FISH RIVER RESERVE, SOUTH AFRICA

Abstract

Seasonal variation in the contribution of principal browse species to the diet of the black rhino was determined for three vegetation types in the Great Fish River Reserve in the Eastern Cape Province of South Africa for two seasons representing periods of high and low rainfall. The seasons represented an unusual distribution and amount of rainfall in keeping with the unpredictable climate of this semi-arid system. The Multi-Response Permutation Procedure found a significant difference in the overall diet in Medium *Portulacaria* Thicket between the two seasons with *Coddia rudis*, *Jatropha capensis*, *Lycium ferocissimum*, *Rhigozum obovatum* and members of the Aizoaceae, particularly *Mesembryanthemum aitonis* all exhibiting significant change. There was no significant difference in the overall diet in the Dry Forest and Short *Euphorbia* Thicket vegetation types in the two seasons. Significant seasonal variation in the diet in one vegetation type but not the others suggests that the intensity of utilization of vegetation types may differ between seasons, and research in this regard is encouraged. The phenological response to rainfall of deciduous species, such as *L*. *ferocissimum*, *R*. *obovatum* and *C*. *rudis*, seemed to be a factor in influencing the seasonal selection of these browse species. These became principal species when flowering and flushing in the wet season, or, in the case of *C*. *rudis*, during the onset of the dry season. This work did not account for the late dry season, and research in this regard is important such that

species heavily utilized during this period of resource scarcity may be recognized.

Key words: backtracking, *Diceros bicornis*, diet, rainfall

4.1 Introduction

Chapter 2 motivated for the importance of a dietary study in the context of managing a population of black rhino that has been performing nearly optimally in the palatable (Aucamp *et al* 1978) but browsing-sensitive thicket of the Great Fish River Reserve (GFRR) in the Eastern Cape Province. The principal species and the preferred species have been determined in the diet of the black rhino for six vegetation types in the GFRR. This information will contribute to knowledge of browse quality thereby facilitating an understanding of the interaction between black rhino and the browse species and identifying the species likely to be sensitive to browsing pressure. Also, this provides information for estimating the ECC of the GFRR.

Browse quantity and quality varies with season however (Caughley and Sinclair 1994), and although the principal and preferred species had been determined from data obtained over a period characterized by varying rainfall, it was pertinent to determine the influence of rainfall on the importance of the browse species. This has particular relevance to thicket because a distinguishing feature of the climate of thicket is the bimodal rainfall, with peaks in spring and autumn, although copious rain may fall at any time of the year (Vlok and Euston-Brown 2002). Thicket is also characterized by rainfall of a high coefficient of variation, and by periodic droughts (Vlok and Euston-Brown 2002) particularly in the more xeric types such as in the GFRR. Adcock (2000) states: 'Not only is the absolute amount of annual rainfall relevant to browse production and therefore black rhino carrying capacity, but also the spread of rainfall through the year' and Dankwerts and Tainton (1996) stressed the influence of intra- and inter-seasonal variation on the quantity and quality of browse in influencing carrying capacity.

The objective of this chapter was therefore to determine the influence of season on the importance of browse species in the diet of the black rhino in three vegetation types.

4.2 Study site

A description of the locality, climate, geology and vegetation of the GFRR may be found in Chapter 3. Only Dry Forest, Medium *Portulacaria* Thicket and Short *Euphorbia* Thicket are considered in this chapter.

4.3 Methods

4.3.1 Determining the seasons of high and low rainfall

The study was conducted from early July 2002 to early July 2003. An approach of defining season according to long-term averages was not accepted because July, August and September 2002, frequently regarded as the end of the dry season, experienced unusually heavy rainfall that was well above the mean monthly rainfall of 41.05mm for the study period (Figure 4.1) while the mean monthly rainfall for this study was also above the mean monthly rainfall for 1981 – 1993 of 37.5mm. July, August and September had 54.6, 172.1, and 81.7mm respectively. Although October and November had well below the long-term mean monthly rainfall for this period, receiving 5.5mm and 22.1mm respectively, the exceptional rainfall in the preceding months and good rainfall in December (65.6mm) negated this lack of rainfall. The vegetation remained in a lush condition, and persisted through December with 65.6mm for this month.

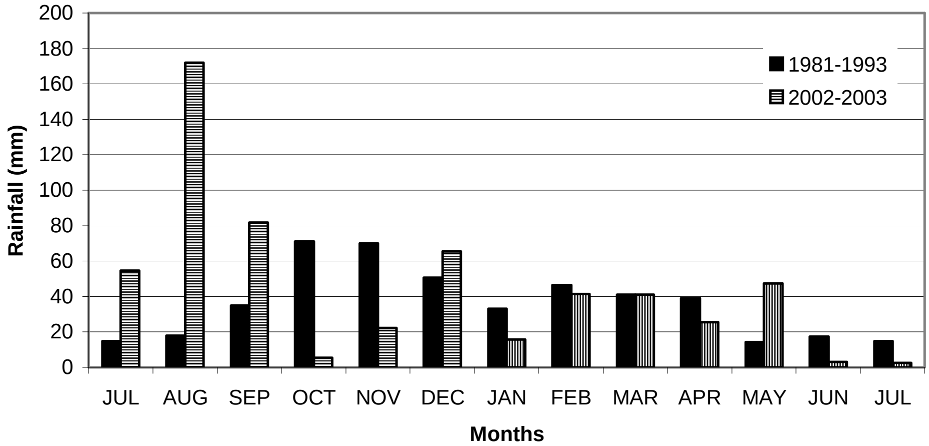

Figure 4.1. Rainfall for the study period (striped bars) showing mean monthly rainfall for the period 1981-1993 (solid bars) in the Great Fish River Reserve, South Africa. Bars with horizontal stripes represent wet season months and bars with vertical stripes represent dry season months.

The wet season was thus taken as the period after the first heavy rain in July (16^{th}) until the end of December (Figure 4.1) 2002. The early dry season was taken as the period from January through to early July 2003 when the last data were collected. The heat of January and February had the effect of dramatically drying out the vegetation, as was apparent by the lack of annuals and forbs and the wilting of some woody species. The effects of the later dry season (late July, August, and September 2003) on the contribution of browse species to the diet of the black rhino was not included since no data existed for this period.

4.3.2 Browse data collection

Data on browsing by black rhino was collected using the backtracking technique as described in Chapter 2. The contribution of browse species to the diet were determined both in terms of number of bites and in terms of dry mass. Since the two methods were found to be highly comparable, the contribution of the species to the diet in terms of number of bites was used for the seasonal comparisons. This approach was used in other studies (e.g. Hall-Martin *et al*. 1982; Loutit *et al*. 1987 and Matipano 2003), is more rapid, and also facilitated the statistical analyses.

A bite was taken to be any number of twigs that were less than 5 mm in diameter browsed within a radius of 50mm of one another more or less on the same plane. Twig with a diameter greater than 5mm were regarded as single bites (Hall-Martin *et al*. 1982).

The physiognomic state of various species was often noted to give an idea of why certain plants may have been browsed at that time. This was not done for all species and simply provided information that could be used to help explain selection.

4.3.3 Statistical analyses

PC-ORD, Version 4.25 (McCune and Mefford 1999) was used to test whether dissimilarity among diets (n=66 transects) was greater between than within the wet and dry seasons in the three vegetation types. Data on diet composition measured from July–Dec 2002 (wet season) and from January–July 2003 (dry season) on 66 transects in three vegetation types (n=10 and 4; 12 and 10; 15 and 15 for the wet and dry seasons of DF, MPT, and SET respectively) was examined with a Multi-Response Permutation Procedure (MRPP), using a Bray-Curtis dissimilarity measure. Diet composition determined by the number of bites was expressed as percentages.

Indicator Species Analysis (ISA) was used to determine species that displayed significant ($p<0.05$) change in terms of their contribution to the diet of the black rhino in the two seasons. Indicator values were calculated with the method of Dufrene and Legendre (1997) and the significance of the observed maximum indicator value for the species was determined with the Monte Carlo test with 1000 permutations.

4.4 Results and discussion

The test statistic from the Multi-Response Permutation Procedure (MRPP) was positive for DF and SET vegetation types (T=0.433; p=0.637 and T=0.153; p=0.451 respectively), indicating little separation in the diet samples (backtracks) from the two seasons. The test statistic (T=-5.123; p<0.0008) was negative for MPT, indicating a significant large separation in the diet samples (backtracks) from the two seasons. The MRPP, therefore, determines significant seasonal variation in the diet of the rhino only in MPT.

4.4.1 Dry Forest

Indicator Species Analysis (p<0.05) did not determine any browse species in DF as displaying a significant change in the contribution to the diet of the black rhino between wet and early dry seasons (Table 4.1).

Table 4.1. Percent contribution of principal (% number of bites ≥ 5 %) browse species in the diet of the black rhino in Dry Forest in the wet and early dry seasons in the Great Fish River Reserve, South Africa. n = Number of bites.

	Wet Season		Early Dry Season		
Species	n	% Number of Bites	n	% Number of Bites	p
Plumbago auriculata	151	11	176	25	0.664
Coddia rudis	190	13	99	14	0.789
Grewia robusta	85	6	105	15	0.213
Azima tetracantha	154	11	28	4	0.502
Grewia occidentalis	154	11	15	2	0.727
Euclea undulata	166	12	0	0	0.127
Jatropha capensis	29	2	61	9	0.589
Gymnosporia polyacantha	86	6	0	0	0.798
Gnidia thesioides	10	1	63	9	0.297
Other species	387	26	163	20	27.081
Total	1412	100	710	100	

Of the species principal to either the wet or early dry period in Dry Forest, *Jatropha capensis* and *Coddia rudis* were also principal in MPT and displayed significant change in seasonal contribution

(Table 4.1). While it is interesting that the contribution of these species did not differ significantly between seasons in DF, it is worth noting that *J. capensis* did contribute more in the early dry period than in the wet period.

4.4.2 Medium Portulacaria Thicket

Indicator Species Analysis ($p<0.05$) determined five species in MPT as displaying significant change in their contribution to the diet of the black rhino between wet and early dry seasons: members of the Aizoaceae (mostly *Mesembryanthemum aitonis*), *Jatropha capensis*, *Rhigozum obovatum*, *Coddia rudis*, and *Lycium ferocissimum* (Table 4.2).

Table 4.2. Percent contribution of principal (% bites ≥ 5 %) browse species in the diet of the black rhino in Medium *Portulacaria* Thicket in the wet and early dry seasons in the Great Fish River Reserve. Taxa shaded in grey displayed significant change in contribution between the two seasons as determined by the Indicator Species Analysis. n = Number of bites.

	Wet Season		Early Dry Season		
Species	n	% Number of Bites	n	% Number of Bites	p
Grewia robusta	290	14.41	654	39.21	0.097
Rhigozum obovatum	396	19.68	15	0.9	0.034
Jatropha capensis	108	5.37	301	18.05	0.032
Euclea undulata	230	11.43	44	2.64	0.384
Coddia rudis	53	2.63	200	11.99	0.013
Brachylaena ilicifolia	100	4.97	72	4.32	0.508
Ozoroa mucronata	160	7.95	0	0	0.088
Lycium ferocissimum	144	7.16	0	0	0.016
Gymnosporia capitata	40	1.99	89	5.34	0.306
Aizoaceae spp.	110	5.47	3	0.18	0.007
Other species	381	18.97	290	17.4	28.403
Total	2012	100	1668	100	

Jatropha capensis, a softly woody evergreen species with high water content, was browsed much more frequently in the early dry season than the wet season. Ganqa *et al*. (2005) also found greater use of this species in the typically dry winter months. It may have contributed to satisfying the increased water requirements of the rhino during those periods when many other browse species had lost moisture due to heat and lack of rain.

Rhigozum obovatum, an unarmed woody species, was browsed much more frequently in the wet season than in the early dry season. *R*. *obovatum* responded to the period of exceptional rainfall in late July, August and September by mass flowering and flushing of new leaves. Palmer (1981) revealed a response to rainfall by this species in the GFRR where bud production, flowering, and developing fruit followed the new leaf and shoot production within a month and it is likely that this flowering and flushing is accompanied by an increased uptake of nutrients making these plants more attractive to rhino. The flowering and flushing of *R*. *obovatum* resulted in a number of rhino focusing their feeding on an area particularly well represented with *R*. *obovatum*. Hall-Martin *et al*. (1982) found heavy utilization of *R*. *obovatum* after the late summer rains had induced flushing in the Addo National Park, and Buk (2004) found that *R*. *trichotonum*, a very similar species, was an important species where seasonal contribution was greatest in the late dry and wet seasons in the Augrabies Falls National Park.

Lycium ferocissimum, a thorny deciduous shrub, also flushed rapidly after rain and was also browsed much more frequently in the wet season than in the early dry season. It appeared to be a browse resource of similar value to black rhino as *R*. *obovatum* except that it had lower availability.

Coddia rudis, an unarmed deciduous woody shrub, was browsed more frequently in the early dry season than in the wet season. *C*. *rudis* was characteristically a hedged woody shrub that was browsed very heavily by black rhino when in new leaf in the early dry season. The percent contribution of *C*. *rudis* to the diet in DF was approximately equal in both seasons, suggesting that there may be other factors that influenced feeding on *C. rudis*. One factor may be the longer season that *C. rudis* appeared to remain in an actively growing and flushing state – into the early dry season – than most other plants. Matipano (2003) found that some species that dropped leaves later in the dry season were favored in the early dry season. This observation may apply to *Coddia rudis* in this study.

The frequent browsing of the Aizoaceae in the wet season was largely attributed to the presence of *Mesembryanthemum aitonis*, a succulent annual herb that typically occurred in more open and disturbed areas. The contribution of the Aizoaceae to the diet of the black rhino was probably underestimated due to the difficulty in identifying browsing on individual plants and also due to the rhino frequently uprooting and consuming entire plants thereby reducing evidence of browsing.

4.4.3 Short Euphorbia Thicket

In the SET (Table 4.3), only members of the Aizoaceae showed a significant change in the contribution to the diet between wet and early dry seasons ($p<0.05$). This significant change for the Aizoaceae also applied to the MPT (Table 4.2).

That no other species displayed a significant change in the contribution to the diet of the black rhino between wet and early dry seasons may be partly explained by dominance of *Euphorbia bothae*, a latex-bearing stem succulent, in the diet in both seasons, accounting for about half of all bites. With the exception of *Grewia robusta*, other species were utilized to a minor extent in both seasons. The comparable contributions of *E. bothae* in the wet and early dry seasons is in contrast to Ganqa *et al*. (2005) who maintained that it was more important in the hottest and driest period. The results of that study, however, were influenced by a lack of recognition of distinct vegetation types. Although the comparable percentage contributions may not translate to a similar intensity of use of vegetation type, the comparable total number of bites (n) recorded for both seasons do suggest that the use of the vegetation type may have been similar in both seasons.

Table 4.3. Percent contribution of six most important browse species in the diet of the black rhino in Short *Euphorbia* Thicket in the wet and early dry seasons in the Great Fish River Reserve, South Africa. Taxa shaded in grey displayed significant change in contribution between the two seasons as determined by the Indicator Species Analysis. n = Number of bites.

	Wet Season		Early Dry Season		
Species	n	% Number of Bites	n	% Number of Bites	p
Euphorbia bothae	1117	49.06	1177	55.52	0.407
Grewia robusta	385	16.91	309	14.58	0.676
Euclea undulata	98	4.3	85	4.01	0.838
Ozoroa mucronata	50	2.2	115	5.42	0.333
Azima tetracantha	57	2.5	99	4.67	0.483
Aizoaceae spp.	80	3.51	18	0.85	0.035
Other species	490	21.5	317	14.94	28.948
Total	2277	100	2120	100	

Hoffman (1989) found that plant species with water storage abilities seem to grow independently of rainfall. The results for *E. bothae* in this study suggest that this may be the case, and Palmer (1981) who studied the phenology (timing of metabolism and development) of 51 plant species in the GFRR over 16 months revealed that the phenology of *E. bothae* was correlated significantly with extreme minimum air temperature and not rainfall. It is therefore likely that the value of the succulent *E. bothae* as an important browse resource for black rhino is enhanced by its apparent acceptability at those times when the acceptability of other species is lower. Similarly, *Jatropha capensis* did not exhibit mass flowering or flushing, and it seems that its phenological responses were independent of the rainfall and its increased contribution to the diet of black rhino may have been more a function of its water storage characteristic rather than increased palatability due to rainfall.

Some studies that provide an indication of seasonal variation in the diet of black rhino have found that diet preferences tend to shift from deciduous to evergreen plants from wet to dry season

(Hall-Martin *et al*. 1982, Oloo *et al*. 1994, Atkinson 1995, Matipano 2003; and Buk 2004) suggesting that the palatability of browse species is correlated with the phenology of the species. Deciduous species loose their leaves in the dry season with a corresponding decrease in browse quality. In this study, only *Rhigozum obovatum* and *Lycium ferocissimum* were deciduous species that were browsed significantly more in the wet season. Thicket is characterized by an abundance of semi-deciduous shrubs (Vlok and Euston-Brown 2002) and it is rather surprising that only two deciduous shrub species showed a significant seasonal shift. Rainfall was the only environmental factor used to recognize the two seasons in this study, however, and phenological change may be triggered by numerous environmental factors and in some circumstances also by endogenous factors that are independent of the environmental variables (Palmer 1981).

The remarkable rainfall in July, August and September was an indication of the unpredictable climate recognized by Palmer (1981) for this area and by Vlok and Euston-Brown (2002) for thicket in general. The vegetation in an area with an unpredictable climate is likely to display ‘pulse-activity’ phenological responses where phenological activity is concentrated within a short period (Hoffman 1989). Further research should focus on identifying important browse species that exhibit phenological responses that appear not to be related to rainfall. As such, species will be identified that may be important in providing acceptable forage for black rhino at times when the acceptability of many species has decreased.

An important finding of this study is the overall seasonal variation of the contribution of woody browse species to the diet of the black rhino in one vegetation type but not in another – it may be that certain vegetation types are more suitable than others in the dry season. The implications of this finding would be clarified by further research accounting for the late dry season, and information on possible changes in utilization of the vegetation types. What is apparent, however, is that rainfall influenced the contribution of certain browse species to the diet of the black rhino and, as such, dietary studies are relative to the conditions prevalent at that time.

4.5 Conclusions

The overall diet of the black rhino changed significantly from one season to the next in Medium *Portulacaria* Thicket, but not in Short *Euphorbia* Thicket or Dry Forest. This significant change in the diet in Medium *Portulacaria* Thicket between seasons does not necessarily imply any change in the overall intensity of utilization of the vegetation type. Considering that the dry season is a period of greater resource scarcity, a vegetation type that is utilized more intensely during the dry season could be more susceptible to over-utilization by black rhino. The sampling intensity between seasons, based on total number of bites recorded, was similar for MPT and SET but not for TET.

Euphorbia bothae, the most important principal browse species in the diet in SET, contributed a similar amount to the diet in both seasons. The trend for deciduous species to be selected more in the wet season and evergreen species in the dry season was supported by *R*. *obovatum* and *L*. *ferocissimum* for the deciduous species, and *J*. *capensis* for the evergreen species. *C*. *rudis*, also a deciduous species, was selected significantly more in the early dry season and was probably due to a slower response to rainfall. The abundance of deciduous/semi-deciduous browse species in thicket suggested that more species should have displayed a significant difference between seasons. The phenological responses of plant species can be influenced by a number of factors other than rainfall, however, and further research covering all seasons - but in particular the late dry season - in each vegetation type will provide further insight into species displaying significantly different contribution to the diet. This would improve our understanding of species that are both important and susceptible to over-utilization by the black rhino during times of resource scarcity.

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CHAPTER FIVE

PREFERENCE ESTIMATES OF WOODY BROWSE SPECIES IN THE DIET OF THE BLACK RHINO (*DICEROS BICORNIS MINOR*) IN THE GREAT FISH RIVER RESERVE, SOUTH AFRICA

Abstract

Preference was determined for woody species in the diet of black rhino in six vegetation types in the Great Fish River Reserve, South Africa. For three vegetation types, two estimates of availability allowed for two estimates of preference. The first estimate of availability was derived from backtracks and was potentially influenced by site selection by feeding rhino. The second estimate of availability was derived from four veld condition assessment sites established in each of three vegetation types. Use of Bonferroni Confidence Intervals on the estimates of preference based on the two different estimates of availability invariably determined the same species as significantly preferred although the rank order varied. This suggests that either method could be used to gain an understanding of the preference for various browse species by black rhino. Significantly preferred species were typically also principal species (comprising ≥ 5% of diet) and rejected species were typically not principal species. The average percentage of available browse removed by feeding rhino on each browse species provided additional information to suggest those preferred browse species that may be particularly susceptible to the pressure induced by browsing. In the absence of information on the post-browsing productivity of the browse species, *Coddia rudis*, *Plumbago auriculata*, *Jatropha capensis*, *Euphorbia tetragona* and *E*. *triangularis* were likely to be most susceptible to pressure induced by browsing while *Grewia robusta* and

Rhigozum obovatum, although significantly preferred and important, were likely to be poor indicators of pressure induced by browsing. A comparison of the percentage availability of browse species on backtracks versus in the veld condition assessment sites revealed that site selection by feeding rhino was evident for certain species. Typically, sites were selected by feeding rhino where preferred species were more available and rejected species less available.

Key words*: Diceros bicornis,* Bonferroni, diet, preference

5.1 Introduction

Although knowledge of principal species is valuable, knowledge of preferred species contributes greatly to an understanding of the influence of a browser on its resource because it is the species that exhibit high and low preference values that are good indicators of veld condition (Petrides 1975). In particular, species exhibiting very high preference values may be browsed unsustainably and driven towards possible local extinction (eg. Buk 2004)

Preference, however, is even more difficult to estimate because it relies on estimates of both the diet composition and the availability of the forage (Norbury and Sanson 1992). While determining the diet of a herbivore is problematic, numerous authors have addressed these problems (e.g. Smith and Sheldrick 1979, Holecheck *et al*. 1982, and McInnes *et al*. 1983). The concept of availability, however, is possibly more problematic and attempts at determining availability and then preference have been numerous and varied (Rutherford 1979; Johnson 1980; Norbury and Sanson 1992). One of the problems is that, while preference for forage species ideally needs to be assessed when the availability of these species is of equal proportions in the environment (Norbury and Sanson 1992), this is probably never the case. A second problem is that food is selected on different scales (Johnson 1980). This has direct implications for the black rhino because, in common with most herbivores, it displays site selective feeding (Kotze and Zacharias 1993 and Buk 2004). It is assumed that measured availability is equivalent to an animal's perception of availability (Norbury and Sanson 1992). Normally, knowledge of the feeding habits of the browser being studied must be well known for such measured availability to correspond to the animal's perception of availability.

Availability has frequently been determined simultaneously with dietary intake. Owen-Smith and Cooper (1987) derived acceptability indices for kudu where availability was determined by recording woody plant species within neck reach (0.5m) of a string laid along a feeding path in the Nylsvlei Nature Reserve. Hendricks *et al*. (2002) recorded those plants available for consumption within 2m of a plant that was browsed by goats in succulent karroo vegetation. Also with goats, Breebaart *et al*. (2002) based their estimates of woody browse availability on the neck and height reach of the animal along the feeding path. The criteria used to determine what food is available should be based on both the study animal and the type of vegetation.

The availability of forage in this study was determined simultaneously with intake along the feeding path (here termed backtrack) followed by black rhino. Availability was also determined from veld condition assessment (VCA) sites established in three important vegetation types utilized by rhino. These two different estimates of availability were used to arrive at two estimates of preference for woody species.

Estimates of availability are frequently obtained with either of the above two methods, and estimates of preference based on these estimate of availability are subsequently determined. Given the concept of the influence of feeding site selection, it was pertinent to compare the two estimates of preference by identifying the significantly preferred and rejected species and then also determining the influence of feeding site selection on availability estimates. Additionally, the significantly preferred species are likely to be sensitive to browsing pressure and would be valuable indicator species of the impact of rhino on the vegetation.

5.2 Study site

A detailed description of the vegetation types identified for this study (Bushclump Savanna, Dry Forest, Medium *Portulacaria* Thicket, Riverine *Acacia* Thicket, Short *Euphorbia* Thicket, and Tall *Euphorbia* thicket), locality, climate, and geology is presented in Chapter 3.

5.3 Methods

5.3.1 Diet composition

The backtracking technique was chosen for reasons explained in Chapter 2. Each backtrack and associated data was allocated to one of the six vegetation types.

Preference was determined from the contribution in terms of number of bites rather than the total dry mass estimated from regressions developed for the twig diameters of a number of browse species (Chapter 2) because both measures were very similar, and measuring contribution in terms of number of bites is more rapid. Although data on the contribution of species to the diet is based on a minimum of 22 different individual black rhino, certain individuals yielded more data than others. This is inevitable because it is impractical to attempt to obtain data equally from individuals.

5.3.2 Available browse

Available browse referred to woody species, the stem succulent *Euphorbia bothae*, *E*. *tetragona*, *E*. *triangularis*, and the succulent *Portulacaria afra*. Perennial karroid (xeric-adapted) shrubs, annual and perennial herbs, geophytes and succulent climbers were not included. Black rhino seldom browsed these plant groups, while annual forbs were browsed mainly in the wet season.

Two estimates of availability were determined. The first estimate of availability was determined during backtracking where availability was expressed in terms of the presence of woody species within a 50 cm radius of a browsed plant. Fifty centimeters was chosen because the dense, tangled vegetation precluded most vegetation at a greater distance from being immediately available or visible to the feeding animal and the rhino could usually feed on those within 50cm without moving its position. The dense, tangled vegetation meant that many species rooted further away extended into this 50 cm limit. The availability of a species was therefore the number of times it was recorded as browsed plus the number of times it occurred as an associated specimen on a given backtrack. This estimate of availability was determined for all six vegetation types.

The second estimate of availability was determined from veld condition assessment (VCA) sites established in the three vegetation types (MPT, SET, TET) that yielded the most data on the diet of the black rhino. In each vegetation type, four VCA sites were established in areas considered to be suitable homogenous examples of that vegetation type that were also regularly frequented by rhino. Both the location of these sites and the Point Centered Quarter (PCQ) method adapted by Trollope *et al*. (2006) for thicket that was used for data collection are explained in Chapter 5. The availability of a species was expressed in terms of the number of browsing units per hectare of that species.

The estimates of availability taken on backtracks did not account for variation in the size of the plants and was therefore a more robust estimate of availability than that in the VCA sites that did account for size.

5.3.3 Preference

Estimates of preference were determined for woody species in each of the six vegetation types using Ivlev’s forage ratio (Ivlev 1961). The forage ratio was calculated as the proportion of a species eaten divided by the proportion of that species available in the environment. Values greater or less than one indicate species that are preferred or avoided, respectively (Petrides 1975). The forage ratio does have the weakness in that it varies asymmetrically between zero and infinity, confidence limits are not simply estimated, and conclusions about whether particular foods are preferred or rejected depends upon the set of food types that the investigator deems available to the animal (Owen-Smith and Cooper 1987). Regardless, the forage ratio was used because it allows for direct comparison between the ratios derived from the two estimates of woody species availability in three of the six vegetation types. Although the ratios do vary asymmetrically between zero and infinity, it is the rank order of the various species that is considered important in this study.

Because a second estimate of availability of woody species was determined by a different method for three of the six vegetation types, it follows that a second estimate of preference was determined for these species in these three vegetation types. Although the measure of preference/rejection was also determined using Ivlev's forage ratio, the second estimate of preference was termed a preference ratio to avoid confusion.

Because the assumption that preference indices are calculated as if animal diets and food availability were measured without error can lead to erroneous conclusions (Hobbs 1982), Bonferroni Confidence Intervals (BCIs) were applied to determine those species significantly rejected or preferred (Neu *et al*. 1974 and Byers and Steinhort 1984). If the expected frequency of utilization falls within these frequencies, then preference or rejection is not regarded as significant. BCI's have been used by a number of studies to indicate habitat preference (Yu and Peters 2002; Crane *et al*. 2001; and Yerkes 2000) and diet preference (e.g. Gallant *et al*. 2004 and, in South Africa, Breebaart *et al*. 2002). These intervals are determined with the following equation:

$$p_1 \pm Z_{\alpha/2k}\sqrt{p_1(1-p_1)/n}$$

p_i = Utilized Frequency; ∞ = 0.05; k = number of species; n = total number of individuals of all species.

An adjustment of $_{\infty/2k}$ is required for these intervals because several parameters are estimated simultaneously (Neu *et al*. 1974). The Bonferroni method assumes that sample size is sufficiently large so a normal distribution approximation to the binomial distribution is valid. Therefore, confidence intervals were regarded as valid only when np^1 and $n(1-p^1)$ were both ≥5 (Alldredge and Ratti 1986). Use of this method assumes that availabilities are measured without error and are not estimates. Browse availability is always an estimate though. Z values were determined from the statistical package R (2003). Where the available proportion lies outside of the confidence intervals there is evidence for preference/rejection. Where usage is zero, the confidence interval does not apply, and where a confidence interval is less than zero it is considered zero.

To allow for discussion on the possible effects of black rhino on the significantly preferred species, information from Chapter 5 on the average percentage of available browse removed by feeding rhino (% offtake) on each of these species is presented. Details of the method followed to determine % offtake values may be found in Chapter 5 where % offtake is considered to represent browsing intensity.

5.3.4 Feeding site selection

To determine possible site selection by black rhino, the percentage availability of woody species on backtracks was compared to that in the wider environment as sampled in the VCA sites. The number of times a species was recorded as associated with browsed specimens was considered to represent the availability on a backtrack. The availability in the environment was determined from the VCA sites (Chapter 5) and was therefore an expression of the density of a species per unit area corrected by height. Because the methods used to determine availability differed the differences in the availability cannot be ascribed totally to the sampling of the environment. The comparison was limited to MPT, SET, and TET. In each vegetation type, only the 15 most available species are presented, listed according to their percent occurrence on backtracks. The differences in availability were not subjected to statistical analysis – comparisons were drawn between differences in percentage values.

5.4 Results and discussion

5.4.1 Preference

Forage ratios and preference ratios for all woody species where availability was determined from backtracks and VCA sites respectively are presented for MPT, SET and TET in Tables 5.1, 5.2 and 5.3 respectively. Forage ratios for woody species where availability was determined only from VCA sites are presented for BKT, DF and RAT in Table 5.4. An example of the application of the BCI's is provided for MPT vegetation (Appendix 5).

Twelve woody species were significantly preferred across all vegetation types based on either estimate of availability and four woody species were significantly rejected. A significantly preferred woody species based on one estimate of availability was typically also significantly preferred based on the other estimate of availability. Also, where a species was significantly preferred in one vegetation type but not the other, it usually had a preference value that suggesting preference in the other vegetation type.

Although the Bonferroni method seemed suitable for determining significant preference, the np[1] ≥5 limitation meant that the significant rejection (p[2] > upper BCI) of species with a very low proportion in the diet and a very high proportion in the available environment were invariably not valid. Also, where contribution in the diet was zero, the confidence interval did not apply. Therefore, where rejection is discussed, this was not based on the Bonferroni limitations, but rather on the large differences between the proportion in the diet and that in the environment.

Table 5.1. Estimates of preference in Medium *Portulacaria* Thicket where the forage ratio (FR) is based on availability on backtracks and the preference ratio (PR) is based on availability on veld condition assessment sites.

Species	p1	p2	FR	p1	p2	PR	Species	p1	p2	FR	p1	p2	PR
Acalypha glabrata	0.005	0.001	4.8	0.005	0.000	22.0	*Gymnosporia polycantha*	0.001	0.006	0.2	0.001	0.001	1.0
Acacia karroo	0.004	0.008	0.6	0.004	0.000	19.4	*Asparagus species*	0.022	0.078	0.3	0.022	0.025	0.9
Lycium ferocissimum	0.041	0.022	1.9	0.041	0.002	18.7	*Carissa haematocarpa*	0.005	0.011	0.5	0.005	0.006	0.8
Coddia rudis	0.073	0.020	3.6	0.073	0.006	11.3	*Leucas capensis*	0.001	0.015	0.1	0.001	0.002	0.6
Rhus longispina	0.002	0.001	2.0	0.002	0.000	9.1	*Rhoicissus species*	0.006	0.045	0.1	0.006	0.013	0.5
Grewia occidentalis	0.001	0.002	0.9	0.001	0.000	6.5	*Ehretia rigida*	0.003	0.008	0.4	0.003	0.010	0.3
Pacchypodium succulentum	0.001	0.002	0.6	0.001	0.000	5.2	*Euphorbia bothae*	0.010	0.016	0.6	0.010	0.034	0.3
Azima tetracantha	0.032	0.013	2.4	0.032	0.006	5.0	*Pappea capensis*	0.001	0.002	0.4	0.001	0.008	0.1
Euphorbia mauritanica	0.002	0.016	0.1	0.002	0.001	3.5	*Phyllanthus verrucosus*	0.006	0.018	0.3	0.006	0.056	0.1
Rhus refracta	0.005	0.006	0.9	0.006	0.002	3.1	*Cassine crocea*	—	—	—	0.000	0.002	0.0
Grewia robusta	0.272	0.146	1.9	0.272	0.099	2.7	*Cussonia spicata*	—	—	—	0.000	0.001	0.0
Capparis sepiara	0.009	0.010	0.8	0.009	0.004	2.4	*Diospyros scabrida*	—	—	—	0.000	0.002	0.0
Ozoroa mucronata	0.046	0.009	5.0	0.046	0.020	2.3	*Euphorbia pentagona*	0.000	0.001	0.0	0.000	0.000	0.0
Plumbago auriculata	0.004	0.002	1.8	0.004	0.002	2.1	*Gymnosporia buxifolia*	—	—	—	0.000	0.003	0.0
Rhigozum obovatum	0.118	0.120	1.0	0.118	0.066	1.8	*Maytenus peduncularis*	—	—	—	0.000	0.000	0.0
Euclea undulata	0.079	0.039	2.0	0.079	0.046	1.7	*Opuntia ficus-indica*	—	—	—	0.000	0.000	0.0
Jatropha capensis	0.118	0.083	1.4	0.118	0.069	1.7	*Portulacaria afra*	0.012	0.141	0.1	0.012	0.390	0.0
Jasminum angularae	0.011	0.026	0.4	0.011	0.008	1.4	*Ptaeroxylon obliquum*	0.000	0.004	0.0	0.000	0.008	0.0
Sarcostemma viminale	—	—	—	0.000	0.000	1.3	*Putterlickia pyracantha*	0.000	0.002	0.0	0.000	0.000	0.0
Schotia afra	0.023	0.033	0.7	0.023	0.022	1.1	*Scolopia zeyheri*	—	—	—	0.000	0.000	0.0
Brachylaena ilicifolia	0.049	0.055	0.9	0.050	0.050	1.0	*Boscia oleoides*	0.000	0.001	0.0	—	—	—
Gymnosporia capitata	0.037	0.038	1.0	0.037	0.037	1.0	*Ellusine crocea*	0.000	0.001	0.0	—	—	—
							Total	1.000	1.000	1.0	1.000	1.000	1.0

Values shaded in dark grey - significantly preferred by the Bonferroni Confidence Intervals ($P < .05$)
Values shaded in light grey - significantly rejected by the Bonferroni Confidence Intervals ($P < .05$)
p^1 = proportion in diet p^2 = proportion in environment

Table 5.2. Estimates of preference in Short *Euphorbia* Thicket where the forage ratio (FR) is based on availability as determined on backtracks and the preference ratio (PR) is based on availability as determined from veld condition assessment sites.

Species	p1	p2	FR	p1	p2	PR	Species	p1	p2	FR	p1	p2	PR
Ozoroa mucronata	0.034	0.012	2.9	0.034	0.002	18.0	*Opuntia ficus-indica*	0.001	0.001	1.1	0.001	0.001	0.5
Azima tetracantha	0.036	0.019	1.9	0.036	0.003	13.4	*Leucas capensis*	0.002	0.006	0.4	0.002	0.005	0.4
Euclea undulata	0.041	0.020	2.1	0.041	0.006	7.2	*Jasminum angularae*	0.002	0.007	0.2	0.002	0.005	0.3
Rhoicissus species	0.010	0.052	0.2	0.010	0.002	5.4	*Portulacaria afra*	0.003	0.055	0.1	0.003	0.009	0.3
Plumbago auriculata	0.009	0.006	1.5	0.009	0.002	4.9	*Ehretia rigida*	0.001	0.006	0.2	0.001	0.006	0.2
Rhus longispina	0.008	0.008	1.0	0.008	0.002	4.2	*Gymnosporia polyacantha*	0.004	0.025	0.2	0.004	0.031	0.1
Asparagus species	0.027	0.069	0.4	0.027	0.007	4.1	*Pappea capensis*	0.000	0.004	0.1	0.000	0.003	0.1
Sarcostemma viminale	—	—	—	0.001	0.000	3.6	*Rhigozum obovatum*	0.013	0.091	0.1	0.013	0.165	0.1
Euphorbia bothae	0.536	0.270	2.0	0.535	0.244	2.2	*Acacia karroo*	0.000	0.005	0.0	0.000	0.002	0.0
Jatropha capensis	0.008	0.024	0.3	0.008	0.004	2.1	*Aloe ferox*	—	—	—	0.000	0.001	0.0
Grewia robusta	0.164	0.133	1.2	0.164	0.086	1.9	*Boscia oleoides*	—	—	—	0.000	0.001	0.0
Euphorbia mauritanica	0.005	0.019	0.3	0.005	0.003	1.7	*Pacchypodium succulentum*	0.000	0.001	0.0	0.000	0.001	0.0
Lycium ferocissimum	0.019	0.018	1.1	0.019	0.011	1.7	*Phyllanthus verrucosus*	0.000	0.017	0.0	0.000	0.005	0.0
Rhus refracta	0.007	0.009	0.8	0.007	0.004	1.6	*Putterlickia pyracantha*	—	—	—	0.000	0.002	0.0
Buddleja saligna	0.001	0.001	1.1	0.001	0.000	1.5	*Cadaba aphylla*	0.000	0.001	0.0	—	—	—
Gymnosporia buxifolia	0.001	0.001	1.1	0.001	0.000	1.5	*Capparis sepiara*	0.001	0.004	0.3	—	—	—
Carissa haematocarpa	0.004	0.008	0.5	0.004	0.003	1.3	*Cussonia spicata*	0.000	0.001	0.0	—	—	—
Schotia afra	0.015	0.025	0.6	0.015	0.012	1.2	*Euphorbia pentagona*	0.005	0.006	0.8	—	—	—
Brachylaena ilicifolia	0.020	0.040	0.5	0.020	0.029	0.7	*Grewia occidentalis*	0.000	0.001	0.0	—	—	—
Gymnosporia capitata	0.022	0.039	0.6	0.022	0.048	0.5	*Ptaeroxylon obliquum*	0.000	0.001	0.0	—	—	—
							Total	1.000	1.000	1.0	1.000	1.000	1.0

Values shaded in dark grey - significantly preferred by the Bonferroni Confidence Intervals (P < .05)
Values shaded in light grey - significantly rejected by the Bonferroni Confidence Intervals (P < .05)
p^1 = proportion in diet p^2 = proportion in environment

Table 5.3. Estimates of preference in Tall *Euphorbia* Thicket where the forage ratio (FR) is based on availability on backtracks and the preference ratio (PR) is based on availability on veld condition assessment sites.

Species	p1	p2	FR	p1	p2	PR	Species	p1	p2	FR	p1	p2	PR
Acalypha glabrata	0.044	0.038	1.2	0.044	0.001	75.8	*Rhus longispina*	0.003	0.009	0.4	0.003	0.015	0.2
Jasminum angularae	0.009	0.014	0.6	0.009	0.000	30.6	*Gymnosporia buxifolia*	0.001	0.005	0.2	0.001	0.010	0.1
Coddia rudis	0.064	0.022	2.9	0.064	0.003	21.9	*Phyllanthus verrucosus*	0.003	0.026	0.1	0.003	0.052	0.1
Pacchypodium succulentum	0.005	0.007	0.7	0.005	0.000	16.0	*Rhigozum obovatum*	0.000	0.006	0.1	0.000	0.004	0.1
Carissa haematocarpa	0.028	0.026	1.1	0.028	0.003	10.7	*Schotia afra*	0.001	0.018	0.0	0.001	0.017	0.1
Plumbago auriculata	0.278	0.081	3.4	0.278	0.041	6.7	*Acacia karroo*	0.000	0.002	0.0	0.000	0.003	0
Maytenus peduncularis	0.021	0.006	3.7	0.021	0.004	5.6	*Brachylaena ilicifolia*	0.000	0.001	0.0	0.000	0.010	0
Jatropha capensis	0.144	0.078	1.8	0.144	0.033	4.3	*Cassine crocea*	—	—	—	0.000	0.003	0
Grewia robusta	0.052	0.047	1.1	0.053	0.018	2.9	*Diospyros scabrida*	0.000	0.001	0.0	0.000	0.010	0
Secamone filiformis	—	—	—	0.001	0.000	2.9	*Dovyalis cafra*	—	—	—	0.000	0.003	0
Ozoroa mucronata	0.013	0.014	0.9	0.013	0.005	2.6	*Ehretia rigida*	0.003	0.068	0.0	0.003	0.137	0
Euclea undulata	0.013	0.010	1.2	0.013	0.008	1.7	*Gymnosporia polycantha*	0.000	0.004	0.0	0.000	0.017	0
Lycium ferocissimum	0.015	0.020	0.7	0.015	0.012	1.3	*Heteromorpha trifoliata*	0.000	0.001	0.0	0.000	0.000	0
Cussonia spicata	0.004	0.006	0.7	0.004	0.003	1.2	*Hibiscus sp.*	—	—	—	0.000	0.013	0.0
Azima tetracantha	0.051	0.062	0.8	0.051	0.066	0.8	*Pappea capensis*	0.001	0.013	0.1	0.001	0.020	0.0
Capparis sepiara	0.006	0.016	0.4	0.006	0.008	0.8	*Purple leaved spp.*	—	—	—	0.000	0.000	0.0
Olea europaea	0.008	0.009	0.9	0.008	0.010	0.8	*Rhus refracta*	0.000	0.020	0.0	0.000	0.034	0.0
Euphorbia tetragona	0.081	0.021	3.9	0.081	0.122	0.7	*Scolopia zeyheri*	0.000	0.004	0.0	0.000	0.001	0.0
Euphorbia triangularis	0.088	0.021	4.2	0.088	0.126	0.7	*Scutia myrtina*	—	—	—	0.000	0.001	0.0
Hippobromus paucifloris	0.000	0.002	0.2	0.000	0.001	0.7	*Tecoma capensis*	—	—	—	0.000	0.002	0.0
Asparagus species	0.019	0.116	0.2	0.020	0.032	0.6	*Allophylus decipiens*	0.000	0.003	0.0	—	—	—
Leucas capensis	0.006	0.039	0.2	0.006	0.015	0.4	*Buddleja saligna*	0.005	0.003	1.6	—	—	—
Opuntia ficus-indica	0.000	0.001	0.4	0.000	0.001	0.4	*Diospyros lycioides*	0.000	0.005	0.0	—	—	—
Grewia occidentalis	0.014	0.045	0.3	0.014	0.053	0.3	*Ellusine crocea*	0.000	0.003	0.0	—	—	—
Ptaeroxylon obliquum	0.004	0.017	0.2	0.004	0.012	0.3	*Euphorbia mauritanica*	0.000	0.002	0.0	—	—	—
Putterlickia pyracantha	0.006	0.018	0.3	0.006	0.020	0.3	*Euphorbia pentagona*	0.002	0.002	1.1	—	—	—
Gymnosporia capitata	0.006	0.043	0.1	0.006	0.026	0.2	*Portulacaria afra*	0.000	0.018	0.0	—	—	—
Rhoicissus species	0.003	0.009	0.3	0.003	0.011	0.2	*Zanthoxylem capensis*	0.000	0.001	0.0	—	—	—
							Total	1	1.000	1.0	1.000	1.000	1.0

Values shaded in dark grey - significantly preferred by the Bonferroni Confidence Intervals (P < .05)
Values shaded in light grey - significantly rejected by the Bonferroni Confidence Intervals (P < .05)

p^1 = proportion in diet
p^2 = proportion in environment

Table 5.4. Forage ratios of woody species (P < .05) in the diet of the black rhino in Bushclump Karroid Thicket, Dry Forest and Riverine *Acacia* Thicket vegetation types where availability was determined on backtracks.

	Bushclump Savanna			Dry Forest			Riverine Acacia Thicket		
Species	p1	p2	FR	p1	p2	FR	p1	p2	FR
Acacia karroo	0.003	0.013	0.2	0.000	0.002	0.0	0.106	0.417	0.3
Acalypha glabrata	0.079	0.036	2.2	—	—	—	0.095	0.030	3.2
Allophylus decipiens	0.003	0.002	1.7	0.000	0.002	0.0	—	—	—
Asparagus species	0.011	0.096	0.1	0.023	0.094	0.2	0.011	0.051	0.2
Azima tetracantha	0.047	0.009	5.0	0.096	0.029	3.3	0.106	0.047	2.3
Boscia oleoides	—	—	—	0.000	0.001	0.0	—	—	—
Brachylaena ilicifolia	0.079	0.043	1.8	0.017	0.035	0.5	—	—	—
Buddleja saligna	0.008	0.008	1.1	0.005	0.007	0.7	—	—	—
Cadaba aphylla	—	—	—	—	—	—	0.003	0.004	0.6
Capparis sepiara	0.006	0.017	0.4	0.013	0.024	0.5	—	—	—
Carissa haematocarpa	—	—	—	0.002	0.012	0.2	—	—	—
Clausina anisata	—	—	—	0.000	0.001	0.0	—	—	—
Coddia rudis	0.208	0.079	2.6	0.152	0.073	2.1	—	—	—
Diospyros lycioides	0.030	0.017	1.8	—	—	—	0.000	0.009	0.0
Diospyros scabrida	0.000	0.002	0.0	0.001	0.006	0.1	—	—	—
Dovyalis cafra	—	—	—	—	—	—	0.000	0.004	0.0
Ehretia rigida	0.020	0.055	0.4	0.002	0.064	0.0	0.000	0.013	0.0
Ellusine crocea	0.000	0.006	0.0	—	—	—	—	—	—
Euclea undulata	0.020	0.023	0.9	0.088	0.036	2.5	—	—	—
Euphorbia mauritanica	0.001	0.006	0.2	0.001	0.001	1.1	—	—	—
Euphorbia triangularis	—	—	—	—	—	—	0.060	0.009	7.0
Grewia occidentalis	0.023	0.040	0.6	0.089	0.055	1.6	0.046	0.034	1.4
Grewia robusta	0.198	0.104	1.9	0.100	0.050	2.0	—	—	—
Gymnosporia buxifolia	0.015	0.004	3.9	0.012	0.013	0.9	0.011	0.009	1.3
Gymnosporia capitata	0.068	0.070	1.0	0.022	0.038	0.6	0.000	0.004	0.0
Gymnosporia polycantha	0.000	0.008	0.0	0.045	0.029	1.6	0.035	0.034	1.0
Jasminum angularae	0.014	0.030	0.4	0.020	0.022	0.9	0.000	0.004	0.0
Jatropha capensis	0.049	0.017	2.9	0.047	0.045	1.1	—	—	—
Leucas capensis	0.000	0.002	0.0	0.006	0.011	0.5	0.054	0.098	0.6
Lycium ferocissimum	0.026	0.026	1.0	0.004	0.008	0.5	0.016	0.102	0.2
Maytenus peduncularis	0.000	0.002	0.0	—	—	—	—	—	—
Olea europaea	0.000	0.008	0.0	0.002	0.006	0.3	—	—	—
Opuntia ficus-indica	—	—	—	0.001	0.002	0.3	0.003	0.004	0.6
Ozoroa mucronata	0.000	0.009	0.0	0.013	0.011	1.2	—	—	—
Pappea capensis	0.001	0.013	0.1	0.003	0.008	0.3	—	—	—
Pavetta sp.	—	—	—	0.000	0.001	0.0	—	—	—
Phyllanthus verrucosus	0.003	0.032	0.1	0.002	0.054	0.0	0.000	0.004	0.0
Plumbago auriculata	0.072	0.043	1.7	0.172	0.071	2.4	0.447	0.072	6.2
Portulacaria afra	0.000	0.028	0.0	0.001	0.028	0.0	0.000	0.004	0.0
Ptaeroxylon obliquum	0.000	0.013	0.0	0.003	0.049	0.1	0.000	0.004	0.0
Putterlickia pyracantha	0.001	0.013	0.1	0.012	0.012	1.0	—	—	—
Rhigozum obovatum	—	—	—	0.000	0.003	0.0	—	—	—
Rhoicissus species	0.002	0.021	0.1	0.003	0.028	0.1	—	—	—
Rhus incisa	0.003	0.004	0.8	0.006	0.006	1.1	—	—	—
Rhus longispina	0.000	0.011	0.0	0.005	0.007	0.7	0.003	0.004	0.6
Rhus refracta	0.001	0.047	0.0	0.003	0.021	0.1	0.005	0.038	0.1
Schotia afra	0.002	0.006	0.4	0.000	0.013	0.0	—	—	—
Schotia latifolia	0.000	0.002	0.0	0.000	0.001	0.0	—	—	—
Scolopia zeyheri	0.001	0.006	0.2	0.001	0.008	0.1	—	—	—
Scutia myrtina	0.000	0.002	0.0	0.030	0.012	2.6	—	—	—
Tecoma capensis	0.005	0.028	0.2	0.000	0.002	0.0	—	—	—
Zanthoxylem capensis	0.000	0.008	0.0	0.000	0.003	0.0	—	—	—
Total	1.000	1.000		1.000	1.000		1.000	1.000	

Values shaded in dark grey - significantly preferred by the Bonferroni Confidence Intervals (P < .05)
Values shaded in light grey - significantly rejected by the Bonferroni Confidence Intervals (P < .05)
p^1 = proportion in diet p^2 = proportion in environment

In most cases, species determined as significantly preferred were also principal species (Section 3.4.2.4). Principal species significantly preferred in at least one vegetation type were *Azima tetracantha*, *Coddia rudis*, *Euclea undulata*, *Euphorbia bothae*, *E*. *tetragona*, *E*. *triangularis*, *Grewia robusta*, *Jatropha capensis*, *Plumbago auriculata*, and *Rhigozum obovatum*. In vegetation types where one of these species was not significantly preferred, it nevertheless typically had a preference or forage ratio that suggested preference. An abundance of species that are both principal and preferred should indicate good vegetation for black rhino.

Although the Euphorbiaceae family had a number of significantly preferred species, *Euphorbia tetragona* and *E*. *triangularis* were also significantly rejected where availability was based on the VCA sites – the only situation in this study where species were significantly preferred and rejected based on the two different estimates of availability. These contrasting results may be attributed to the exceptional estimate of availability for these species in the VCA sites where the entire tree was considered available because the tree was felled by rhino before feeding commenced. Because these trees invariably exceeded 2m, this exception resulted in a high estimate of availability.

Ausland *et al*. (2002), Winkel (2004), and Ganqa *et al*. (2005) also found preference for members of the Euphorbiaceae by black rhino in parts of the GFRR and many authors have found heavy utilization of the Euphorbiaceae elsewhere in Africa (Schenkel and Schenkel-Hulliger 1969; Mukinya 1977; Loutit *et al*. 1987; Oloo *et al*. 1994). While many of the Euphorbiaceae that are important or preferred by black rhino in various localities are characterised by milky latex, certain non-milky species may also be highly preferred. In Hluhluwe-Umfolosi Game Reserve in KwaZulu-Natal, Emslie and Adcock (1994) and Emslie (1999) found that the woody and non-milky *Acalypha glabrata* and *Spyrostachys africana* were particularly favoured browse species. *A*. *glabrata* occurred in parts of the GFRR as a low-density species of low overall availability (Chapter 5) and was only marginally not significantly preferred in TET vegetation. Regardless, the average percent of available browse removed by browsing rhino (% offtake) of 34% (Chapter

5) for *A*. *glabrata* was greater than the average % offtake for all species in MPT, SET and TET vegetation types and was testimony to the intensity of utilisation of this non-milky member of the Euphorbiaceae. Ausland *et al*. (2002) recorded *A*. *glabrata* as contributing 9.8% of the total winter diet in the AVKR section of the GFRR.

Preferred species are considered useful indicators of the impact of a browser on vegetation because browsers are likely to exert sustained feeding pressure on highly preferred species that may ultimately lead to a reduction in the density and/or browse availability, or even local extinction of the preferred browse species (Cowling and Kerley 2002 and Hendricks *et al*. 2002). Data on the % offtake by feeding rhino is presented for the significantly preferred species (Table 5.5) in three vegetation types and is considered to represent the potential impact that black rhino may have on these species. These indicate great variation in the average % offtake between species and in some instances within the same species in different vegetation types.

Table 5.5. The percent of total available browse removed by feeding rhino (% OT) from significantly preferred woody species in three vegetation types. N = number of plants.

	MPT		SET		TET			MPT		SET		TET	
Species	N	%OT	N	%OT	N	%OT	Species	N	%OT	N	%OT	N	%OT
Azima tetracantha	18	19	22	12	24	7	*Grewia robusta*	159	11	132	10	29	7
Coddia rudis	37	41	–	–	17	22	*Jatropha capensis*	124	45	13	33	69	37
Euclea undulata	26	15	21	21	–	–	*Ozoroa mucronata*	4	32	7	25	–	–
Euphorbia bothae	36	13	398	13	–	–	*Plumbago auriculata*	–	–	11	17	67	22
Euphorbia tetragona	–	–	–	–	19	100	*Rhigozum obovatum*	24	5	15	3	–	–
Euphorbia triangularis	–	–	–	–	18	72	Average*		22		15		30

*= Average across all individuals of all species

The highest average % offtake was for *Euphorbia tetragona* and *E*. *triangularis* trees because they were invariably felled before feeding commenced. Because such felling resulted in mortality, this is a good example of impact by black rhino on a species that may result in local extinction. Other species that had very high average % offtake values were the unarmed *Coddia rudis*, *Jatropha capensis*, and *Plumbago auriculata* shrubs. Exposed plants invariably had low-growing growth forms that were particularly hedged, while plants protected within bushclumps were un-hedged and taller. *Ozoroa mucronata*, a taller woody tree (3-4m) with a wide canopy spread, also had a high average % offtake although much browse was invariably above 2m in height and therefore unavailable to black rhino. The effect of feeding pressure on *O*. *mucronata* would therefore unlikely be greater than for *C*. *rudis*, *J*. *capensis*, and *P*. *auriculata* shrubs where entire plants were invariably available. With the exception of *O*. *mucronata*, it is these preferred species that may be particularly susceptible to browsing pressure from black rhino. The felling of the *E*. *tetragona* and *E*. *triangularis* trees was discussed by Heilmann *et al*. (In press) and provides the most visible indication of the impact of black rhino.

Contrary to the above species, *Euphorbia bothae*, *Grewia robusta* and *Rhigozum obovatum* had much lower % offtake values (Table 5.5). *E*. *bothae*, however, was an exception in that almost all of the plant was considered theoretically available (Chapter 5) because of the succulent stems. Therefore, while *G*. *robusta* and *R*. *obovatum* were significantly preferred species that would not provide good visible indication of the impact of black rhino on the vegetation, *E*. *bothae* probably would. If the assumption that high average % offtake values of browse species is an indication of heavy impact of browsing by black rhino is true, then data in Table 5.5 suggests that black rhino will impact heavily on some significantly preferred browsed species but not on others. The response of these browse species to browsing pressure is the unknown factor in this assumption, however.

Portulacaria afra and *Ehretia rigida*, un-armed species that were dominant in terms of both density (plants / ha) and availability (browsing units / ha) in MPT and TET (Chapter 5) respectively, both contributed an exceptionally low proportion in the diet (Table 4.2 and 4.4). In contrast, *Ehretia rigida* was highly preferred by black rhino in Itala Game Reserve (Kotze and Zacharias, 1993). Because Göthesen (1997) attributed rather low utilization of *E*. *rigida* by goats in the False Thornveld of the Eastern Cape Province to the structure of the plants, it is possible that *E*. *rigida* was rejected due to its growth form. Stems were thick and woody with leaves produced very close to the stems probably providing very little browse for black rhino.

Phyllanthus verrucosus, highly available in both MPT and TET (Chapter 5), was an exception to the Euphorbiaceae because it contributed an exceptionally low proportion in the diet. Although this species was typically highly stunted, individuals with more unrestricted growth seemed not to be browsed either. In RAT, the characteristic *Acacia karroo* also contributed an exceptionally low proportion in the diet. This is a surprising result because black rhino browse *Acacias* (including *A*. *karroo*) in other areas (e.g. Emslie and Adcock 1994 and Kotze and Zacharias 1993). Large trees were almost never browsed, with recently established saplings accounting for the contribution of this species to the diet. Saplings were usually browsed off near ground level (pers. obs.) and black rhino also favoured smaller specimens in Hluhluwe-Umfolosi Game Reserve (Emslie and Adcock 1994).

While the rank order usually varied, there tended to be agreement between the forage ratios and the preference ratios. The forage ratios determined for BKT, DF and RAT vegetation types, where availability of the browse species was determined only from backtracks, therefore probably depict preference and rejection favorably. These results tend to agree with Van Vreede *et al*. (1989) who determined whether food preference rankings developed from forage availability estimates from areas known to be utilized by wild free ranging deer were significantly different than food preference rankings developed using an extensive estimate of forage availability. Although the vegetation sampling for the entire area did consider the different vegetation communities, the data was subsequently pooled. In essence however, this study addressed a similar concept to that discussed. Van Vreede *et al*. (1989) concluded that there was little effect on the relative preference ranking of dietary items whether availability was determined within the animal's use area or over a much greater area.

5.4.2 Feeding site selection

The difference between the percent availability of woody species on backtracks (sites selected by feeding rhino) versus in the VCA sites in three vegetation types (the greater environment) indicate possible site selection (Table 4.6). These three vegetation types also yielded most of the feeding data. Reference to the importance of a species is based on the findings in Chapter 2 where principal species are those that contributed ≥ 5% of the diet in any vegetation type.

Table 5.6. Percent availability of woody species on backtracks versus in veld condition assessment sites in the three vegetation types yielding most data. Species arranged according to availability on backtracks with the 15 most available presented.

Medium *Portulacaria* Thicket					Short *Euphorbia* Thicket					Tall *Euphorbia* Thicket				
Species	n^1	%	n^2	%	Species	n^1	%	n^2	%	Species	n^1	%	n^2	%
Grewia robusta	286	14.7	76	10.4	Euphorbia bothae	522	26.8	241	37.0	*Asparagus* spp.	123	12	32	4.5
Portulacaria afra	276	14.2	533	39	*Grewia robusta*	258	13.2	127	11.9	*Plumbago auriculata*	86	8.4	35	5.6
Rhigozum obovatum	235	12.1	90	6.4	*Rhigozum obovatum*	176	9	180	24.2	*Jatropha capensis*	83	8.1	27	4.6
Jatropha capensis	162	8.4	72	7.4	*Asparagus* spp.	133	6.8	10	1.0	*Ehretia rigida*	72	7	156	18.2
Asparagus spp.	153	7.9	13	2.5	*Portulacaria afra*	106	5.4	28	1.2	*Azima tetracantha*	66	6.4	83	7.9
Brachylaena ilicifolia	108	5.6	56	5.2	*Rhoicissus species*	100	5.1	9	0.2	*Grewia robusta*	50	4.9	8	2.5
Rhoicissus species	90	4.6	17	1.4	*Brachylaena ilicifolia*	78	4	58	3.9	*Grewia occidentalis*	48	4.7	73	7.3
Euclea undulata	77	4.0	94	4.4	*Gymnosporia capitata*	76	3.9	167	5.9	*Gymnosporia capitata*	45	4.4	78	2.6
Gymnosporia capitata	75	3.9	103	3.3	*Schotia afra*	49	2.5	---	---	*Leucas capensis*	41	4	24	2.1
Schotia afra	65	3.4	38	1.9	*Gymnosporia polyacantha*	48	2.5	51	4.4	*Acalypha glabrata*	40	3.9	2	0.1
Jasminum angularae	51	2.6	7	0.9	*Jatropha capensis*	47	2.4	8	0.6	*Phyllanthus verrucosus*	28	2.7	37	7.3
Lycium ferocissimum	43	2.2	2	0.2	*Euclea undulata*	39	2	24	0.7	*Carissa haematocarpa*	27	2.6	2	0.3
Coddia rudis	40	2.1	8	0.7	*Azima tetracantha*	36	1.8	10	0.4	*Coddia rudis*	23	2.2	6	0.4
Phyllanthus verrucosus	36	1.9	38	6.1	*Euphorbia mauritanica*	36	1.8	5	0.5	*Euphorbia tetragona*	22	2.1	132	2.6
Euphorbia bothae	32	1.7	30	3.7	*Lycium ferocissimum*	35	1.8	13	1.7	*Euphorbia triangularis*	22	2.1	206	2.7
Total	1729	89.2	1177	93.5		1739	89.2	931	93.5		776	75.5	901	68.7

n^1 = frequency on backtracks and n^2 = frequency in VCA sites
Values in grey are those for the VCA sites

Coddia rudis, *Grewia robusta* and *Jatropha capensis* are three browse species that were principal (Chapter 2) and also significantly preferred in most of the vegetation types in which they occurred. The availability of these species was always greater at sites selected by feeding rhino than in the greater environment (Table 5.6) suggesting that feeding black rhino selected for areas with more preferred and principal species. The typically higher preference ratio relative to the forage ratio seems to be explained by the influence of site selection on that measure of availability. Because sites selected by feeding rhino are characterized by an increased estimate of the availability of the preferred species, it follows that the estimate of the contribution of that preferred species in that environment would be higher than the corresponding estimate in the greater environment.

Coddia rudis illustrates the above scenario. It was browsed both in MPT and TET vegetation types. In both cases, the preference ratio was far greater than the forage ratio (Tables 5.1 and 5.3). This was due to the patchy distribution of this species resulting in a lower probability of it being recorded in VCA sites. It was therefore likely to be determined as highly preferred when availability in the general environment is used, and less so where availability at sites selected by feeding rhino were used. Such high preference ratios are even more characteristic of species such as *Acalypha glabrata* that have a lower and patchier availability in the environment.

The concept of site (hierarchical) selection by feeding herbivores has received attention from numerous authors for numerous species. Kotze and Zacharias (1993) found that browse utilization by black rhino was extremely patchy within communities suggesting that there are other important factors affecting browse utilization besides plant species composition. They suggested that factors such as gentle slopes and paths enhance habitat suitability. Emslie (1999) also found broad scale patch selection in the Hluhluwe-Umfolosi Game Reserve in Natal. He recognized the importance of the influence of the size of individuals of a species on its attractiveness as browse for black rhino, coining the term ‘spize’ to represent both species and size. Preferred spizes were more available in those plots with evidence of browsing by black rhino while rejected spizes were more available in those plots with little or no evidence of browsing by black rhino. Dense grass was also found to detract from browsing in Hluhluwe-Umfolosi Game Reserve, although this factor was of no consequence in the GFRR.

Ehretia rigida and *Phyllanthus verrucosus* were two browse species that were unimportant (Chapter 3) and rejected in all vegetation types in which they occurred. Table 5.6 indicates that the availability of these species was always greater in the greater environment than at sites selected by feeding rhino. This suggests that in some cases site selection by feeding black rhino was for areas with fewer rejected and unimportant species. In MPT vegetation this was confirmed by the fact that the dominant and characteristic species, *Portulacaria afra*, both unimportant and rejected, was far more frequent in the general environment than in areas selected by feeding rhino.

Results for *Euphorbia bothae*, the characteristic species in SET vegetation, are more difficult to explain. It was both principal and significantly preferred yet was more frequent in the greater environment than in sites selected by feeding rhino (Table 5.6). Because *E*. *bothae* was of the highest availability (Chapter 6) in SET, it was possibly unnecessary for feeding rhino to actively seek out *E*. *bothae* plants – they could be found throughout that vegetation type. In the wet season rhino sought more open areas because such areas provided browse in the form of annual forbs. It is probable that data collected in these areas influenced the estimates of the availability of *E*. *bothae*.

5.5 Conclusions

The estimates of preference based on the two different estimates of availability invariably determined the same species as significantly preferred although the rank order varied. This suggests that either method could be used to gain an understanding of the preference of various browse species for black rhino. The only species determined as significantly preferred based on one estimate of availability and significantly rejected based on the other were the succulent tree *Euphorbia tetragona* and *E*. *triangularis* where atypical feeding introduced complications. The Bonferroni method seemed suitable for determining significantly preferred species but seemed to be unsuitable for species of low contribution to the diet. Where estimates of availability are obtained simultaneously with data on dietary intake, the advantage is that of time-efficiency. Where time is not a limiting factor, estimates of availability could be obtained from veld condition assessment sites established in representative examples of the vegetation types in question. This estimate of availability has value for circumstances where data on dietary intake has been obtained without availability data (e.g. faecal analysis). Significantly preferred species were usually also principal species and the average percent of available browse removed by a feeding rhino suggested that *Coddia rudis*, *Plumbago auriculata*, *Jatropha capensis*, *Euphorbia tetragona* and *E*. *triangularis* were more susceptible than others to pressure induced by browsing. *Grewia robusta* and *Rhigozum obovatum*, although significantly preferred and principal, were likely to be poor indicators of pressure induced by browsing. Site selection by feeding rhino was evident for certain species. Typically, sites were selected where preferred species were more available and rejected species less available.

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CHAPTER SIX

AN ASSESSMENT OF THE CONDITION OF THREE VEGETATION TYPES FOR BLACK RHINO (*DICEROS BICORNIS MINOR*) IN THE GREAT FISH RIVER RESERVE, SOUTH AFRICA

Abstract

The point centered quarter method adapted for use in thicket was used to sample the woody vegetation in three vegetation types in the Great Fish River Reserve thereby providing initial data from which change and trends in the vegetation could be determined. Browse availability was expressed in browsing units and a potential browsing unit for black rhino was equivalent to a shrub providing browse from 0-2m in height irrespective of whether it was acceptable or unacceptable to black rhino. Preference ratios of woody species were expressed as forage factors ranging from 0-1. The condition of the woody vegetation for black rhino was based on the number of acceptable browsing units per hectare determined by multiplying the forage factors by the potential browse units of each browse species. Although Medium *Portulacaria* Thicket had the most acceptable browsing units per hectare representing condition, Short *Euphorbia* Thicket had highest ratio of acceptable browsing units per hectare to potential browsing units per hectare suggesting the greatest efficiency of feeding. Although the trend in the condition of these vegetation types could not be determined, observation suggested that the condition of Short *Euphorbia* Thicket and Tall *Euphorbia* Thicket were decreasing because of impact of browsing on sensitive species. Estimates of the percent of available browse removed on individuals of browse species revealed that *Acalypha glabrata*, *Coddia rudis*, *Plumbago auriculata* and particularly *Jatropha capensis* were potentially sensitive to browsing by black rhino. Although loss of these species would impact biodiversity, the long-term response of the more available and preferred species like *Euphorbia bothae* and *Grewia robusta* would be more important in influencing overall condition for black rhino and research in this regard is recommended.

Key words: browsing unit, condition, *Diceros bicornis*, diet, forage factor, preference, PCQ method, thicket

6.1 Introduction

The different vegetation types of thicket usually support large numbers of browsers and the Great Fish River Reserve (GFRR) has a healthy expanding population of black rhino (*Diceros bicornis minor*). The confinement of large herbivores in a fenced conservation area that limits dispersion and migration forces the animals to feed continuously on a limited number of vegetation types, and may result in the deterioration of the condition of the vegetation. Numerous authors have illustrated that browsing by ungulates has consequences for the physiological function, growth and demographic processes of woody plants (e.g. Bergström 1992 and Myers and Bazely 1990) and may result in landscape-level changes in vegetation structure (Hobbs 1996).

The increasing density of black rhino and the proposed re-introduction of elephant (*Loxodonta africana*) to the GFRR necessitated implementing a program to assess and monitor the impact of large herbivores on the vegetation. Evaluating the condition of vegetation for wildlife is a prerequisite for management decision-making (Hobbs and Hanley 1990) and it was deemed necessary to determine the current condition of the vegetation such that the procedure could be repeated at appropriate intervals in the future to describe change and trends in the condition of the vegetation.

The condition of vegetation has usually been determined for grasslands, and was defined as ‘the condition of vegetation in relation to some functional characteristic’ (Trollope *et al*. 1990) or ‘the state of a vegetation type relative to its optimum state for a particular purpose/species’ (Hardy *et al*. 1999). Although the functional characteristic in this study is the ability to provide forage for black rhino, the optimum state of the thicket vegetation types in the GFRR for black rhino are unknown, and no comparisons can be made in this regard. Therefore, the importance of this work was to establish baseline data from which the trend in the condition of the vegetation could be determined because a site would be compared with itself over time (Hardy *et al*. 1999).

The condition of a vegetation type was based on the total number of acceptable BU’s/ha (Trollope *et al*. 2006) derived from the acceptable BU’s/ha of each species. The number of acceptable BU’s/ha was derived from data on the availability of a species, and its forage value determined from the estimates of preference for that species by black rhino. Changes in the number of acceptable BU’s/ha over time would reflect a corresponding change in the condition of that vegetation type for black rhino.

In 2000, an investigation was initiated into assessing various techniques for determining the condition of the thicket in the GFRR (Trollope *et al*. 2006). The techniques investigated were:

- Bush Assessment Method developed by Teague *et al*. (1981) and Trollope (1986);
- Bush Assessment Method for Valley Bushveld developed by Stuart-Hill (1989);
- Biomass Estimates From Canopy Volume (BECVOL) developed by Smit (1989a and 1989b).

The methods developed by Teague *et al*. (1981), Trollope (1986) and Smit (1989a and 1989b) were concluded to be unsuitable because data collection involved belt transects which were logistically impractical in the dense, intertwined and spiny thicket in the GFRR. The method described by Stuart-Hill (1989) was more promising in that it involved using the point centered quarter (PCQ) method developed by Cottam and Curtis (1956) for conducting bush surveys. This plotless (distance) method is more time efficient than methods involving belt transects and is much more flexible because the sample size does not need to be adjusted for the particular density of the vegetation type being studied (Cottam and Curtis 1956). While the technique proposed by Stuart-Hill (1989) overcame the problems associated with physically sampling the dense thicket, it did not attend to the problem associated with the PCQ method of oversampling the short woody plants and undersampling the taller woody plants in the vegetation. The technique was also too complex and laborious and did not completely fulfill the requirement of being simple, rapid and repeatable which is essential in a technique for assessing and monitoring vegetation on a field scale for management purposes (Trollope *et al*. 2006).

The assessment of these different survey methods culminated in the development of an adapted PCQ method for the thicket of the GFRR (Trollope *et al*. 2006). This method provided the means of being able to assess the condition of the woody vegetation in terms of its potential to provide forage for different ungulates species. The importance of different browse species in the diet of the black rhino were determined for six vegetation types in the GFRR (Chapter 3) and preferences were determined for woody species (Chapter 5). An indication of the value of different woody species to the diet of the black rhino was therefore available. Also, data on the percent of available browse removed by black rhinos on individual plants provided insight on species that may be susceptible to browsing and therefore could act as early indicators of the influence of black rhino on the condition of vegetation.

The objectives of this study were:

- To assess the adapted PCQ method by determining the condition of three well-utilized vegetation types for black rhino in the GFRR;

- To provide data on the current condition of the vegetation for black rhino such that the trend in the condition could be determined from comparisons with subsequent sampling;

- To identify species that may be good indicators of the impact of black rhino on the vegetation due to current heavy browsing on these species.

6.2 Study site

A description of the locality, climate, geology and vegetation of the GFRR is presented in Chapter 3. Only Medium *Portulacaria* Thicket, Short *Euphorbia* Thicket and Tall *Euphorbia* thicket are pertinent to this chapter.

6.3 Methods

The assessment of the condition of the woody vegetation for black rhino in the three vegetation types comprised determining the botanical composition, density and browse availability of the woody vegetation using the method developed by Trollope *et al*. (2006). Determining the condition of vegetation for black rhino however, necessitated interpreting these data with information on the upper limit of available browse for black rhino and the value of the different woody species to black rhino.

6.3.1 Establishment of VCA sites

Four Veld Condition Assessment sites were established in each of the following three vegetation types: Medium *Portulacaria* Thicket (MPT), Short *Euphorbia* Thicket (SET) and Tall *Euphorbia* Thicket (TET).

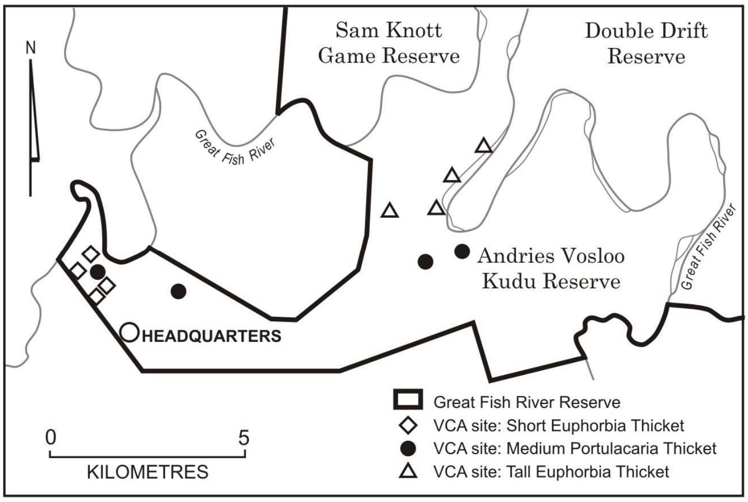


Figure 6.1. The approximate location of the 12 veld condition assessment sites established in three vegetation types in the Great Fish River Reserve.

The MPT represents an extensive and well-utilised vegetation type, yielding a major portion of the data collected on the diet of the black rhino. SET represents a very well-utilised vegetation type and, although of limited extent, it also yielded a large portion of the data on the diet of the black rhino. TET represents a vegetation type that was being dramatically transformed by the feeding activity of black rhino in some localities and also provided a significant portion of the research data. Care was taken that all sites were established in areas frequented by rhino and considered to be suitable homogenous examples of the vegetation type in question.

6.3.2 Grouping of sites

Because data from these four sites were grouped to estimate density and availability for each vegetation type as a whole, it was necessary to assess the similarity between the sites to justify the grouping. This was achieved by determining the availability of woody species in each site separately and then estimating the heterogeneity within each vegetation type using the Multi-Response Permutation Procedure (MRPP) available in the computer package PC-ORD (McCune and Mefford, 1999). A negative test statistic (T) would indicate significantly greater variability between the vegetation types than within the sites of each vegetation type at the chosen level of confidence (0.05).

The Bray-Curtis distance measure was used as a robust measure of ecological heterogeneity (Sorensen 1948; Bray and Curtis 1957) where greater distance measures mean greater heterogeneity. Cluster analysis was also used to provide a visual presentation of the associations of the vegetation types and the sites within each vegetation type.

6.3.3 Sampling procedure

Woody species (perennial trees and shrubs) contributed to >93% of all forage in the diet of the black rhino in terms of dry mass and number of bites in the MPT, SET, and TET (Section 3.4.2.3). It was therefore acceptable to focus only on woody species in assessing the condition of the vegetation for black rhino. The sampling procedure for the woody vegetation in the sites described earlier largely follows that presented by Trollope *et al*. (2006).

The sites typically involved laying out two parallel transects 220 and 240m long and 25m apart. Twelve and 13 recording points respectively were located at 20m intervals on each transect i.e. a total of 25 recording points per sample site (Figure 6.2). In each vegetation type, however, one site had been established that had twice the number of recording points (50). These 'calibration' sites were established as part of the development of the technique for assessing the condition of the vegetation in the GFRR and served as an additional source of information for investigating the diet of the black rhino.

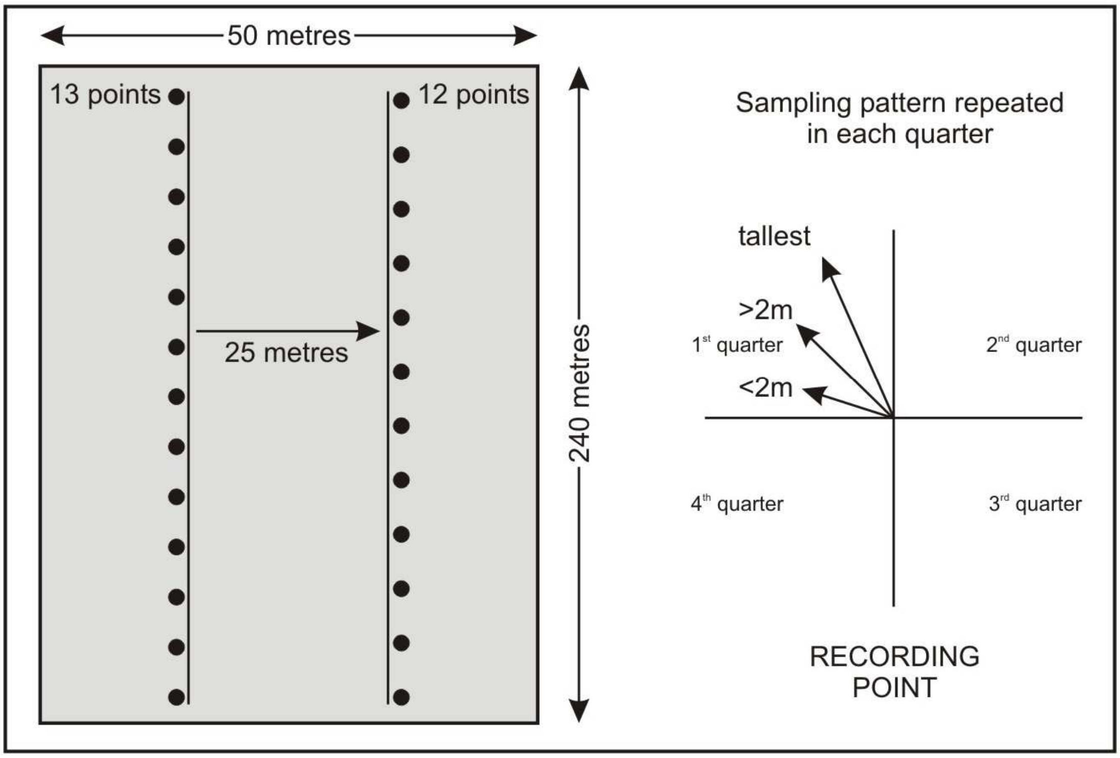


Figure 6.2. Schematic representation of the point centered quarter method used to sample woody vegetation in three vegetation types in the Great Fish River Reserve.

Data were recorded from the nearest rooted woody plants that were <2m, >2m, and tallest in height that were all within 10m from the recording point in each quarter. Where there were no woody plants that were <2m, >2m and the tallest in height within 10m in a quarter, zero plants were recorded.

The following data were recorded from the nearest rooted woody plants in the three height classes mentioned above in each of the four quarters surrounding the recording point: distance from recording point, species, overall height, height of lowest browseable material (LBM), and maximum canopy diameter (MCD). The number and size of the sample sites resulted in a sampling intensity of a maximum possible 1500 woody plants in each vegetation type (300 + 300 + 300 + 600).

The survey data were used to describe the botanical composition, density, browse availability, and ultimately the number of acceptable BU's/ha of the woody plants. These characteristics of the vegetation were derived from the data on the species, overall height, height of LBM, maximum canopy diameter and the preference indices of the woody plants.

6.3.4 Analysis of veld condition data

6.3.4.1 Botanical Composition

The total number of woody species recorded in the four different quarters used in the PCQ procedure were determined by expressing the frequency data for each species on a per quarter basis for the three height classes i.e. <2m, >2m and the tallest woody species within 10m of the recording point. The frequency for each recorded woody species was expressed as a percent of the total number of plants recorded on a per quarter basis.

6.3.4.2 Density

The total density of each woody species was estimated and expressed in plants/ha. The density of woody plants was calculated using the distance of the different woody plants from the recording point. The density of the woody plants was calculated by dividing the distance from the recording point, expressed in meters and then squared, into the area of a hectare i.e. 10 000 m^2 / D^2 (Cottam and Curtis, 1956). In this calculation the density of plants was estimated separately for each height class and the total density for the survey was calculated by determining the sum of the mean densities of woody plants estimated for the three different height classes i.e. <2m, >2m and the tallest woody plant >2m within 10m of the recording point.

6.3.4.3 Available Browse

Data on the browsing of black rhino in this study and in other studies reveal that >80% of the browsing by black rhino in the GFRR occurs below 1m (Ganqa *et al*. 2005 and van Lieverloo and Schuiling 2004). Two meters was taken as the upper limit of browse availability for black rhino however, because other authors accept that limit (e.g. Emslie and Adcock 1994 and Buk 2004); it is currently used across all localities for determining available browse for the rhino management group black rhino carrying capacity model (Adcock 2000), and using 2m therefore facilitates comparisons; and that most browsing in the GFRR was below 1m was probably strongly influenced by the typically low-growing physiognomy of the thicket. *Euphorbia tetragona* and *E*. *triangularis* trees were exceptions to this in that the entire trees were considered available because black rhino fell the trees before browsing.

Data collection on the browsing of black rhino (Chapter 2) involved assigning bites to 0 - 0.5, 0.51 – 1, 1.1 - 1.5, and >1.5m height categories. Analysis of this data revealed the total percent of all bites occurring in each of these categories. This information on browsing stratification will be valuable for future comparisons because it could reflect changes in browse available to black rhino in the GFRR.

Data on both height and canopy diameter of plants were collected and could be used to estimate browse availability. The browse availability of a species based on height measurements was determined by subtracting the measure of the LBM from the measure of the height of the plant, and then multiplying this by the density of that species per ha. The browse availability of a species based on the maximum canopy diameter measurements was determined by multiplying these measurements by the density of that species per ha. Where the LBM of a plant was above 2m, the maximum canopy diameter measurement was excluded from the analysis.

Estimates of availability based on height and canopy diameter measures were regressed to determine the correlation between these two parameters. The correlation co-efficient (see Results) for all three vegetation types was >0.88, and this relationship between these two parameters was considered to be scientifically adequate for either measurement to be used to determine the availability of browse. Height was selected as the measure to determine availability because it is more rapidly measured than canopy diameter, and it allowed availability to be expressed in browsing units as described below.

6.3.4.4 Potential browsing units

To express availability in a meaningful manner, the concept of the browsing unit (BU) was applied to the height measurement data. A BU is defined by Trollope *et al*. (1990) as a tree or shrub that is acceptable to goats and is either 1.5m in height or has browse within 1.5m of ground level. Because this definition does not account for measurements of the LBM, and because the upper limit of browsing for black rhino is generally taken as 2m and not 1.5m, a BU for black rhino is defined as equivalent to a shrub providing browse from 0-2m in height.

Potential BU's concerned all the available vegetation regardless of acceptability by rhino. An understanding of the vertical distribution of browse was provided by presenting the number of potential BU's/ha contributed by woody plants whose total height was in the different 0.5m height categories although the browse of plants that were >2m was presented as a single open-ended category. This was determined by sub-dividing the total density estimated for the <2m and >2m height classes on a proportional basis equal to the number of plants that were recorded in the 0.5m height categories for the <2m and > 2m classes in the sites in a vegetation type. In the case of the class of the tallest plants >2m within 10m of the recording points these numbers of plants were added to the appropriate height categories in the >2m height class. The density of plants in each 0.5m height category was multiplied by the average height for all the plants in that height category less the LBM and then divided by 2m to express the availability as BU's for black rhino.

6.3.4.5 Acceptable browsing units

The acceptable BU's/ha of a browse species is a function of the potential BU's/ha of that species as well as its value as a browse resource as indicated by its preference ratio (Chapter 5). Estimating preference requires data on the contribution of a browse species in the diet and data on the environmental availability of that browse species. The contribution of different browse species to the diet of the black rhino was determined from both the number of bites consumed from each species, and the dry mass consumed from each species. These two estimates were highly correlated (Section 3.4.2.1) and the contribution in terms of number of bites was used to determine the preference of black rhino for different browse species because it was a more rapid and easy parameter to record.

Estimates of preference for woody species were calculated using Ivlev's Forage Ratio (Ivlev 1961) with neutrally selected species having a preference value centering on one, while rejected species tended towards zero and preferred species tended towards infinity (Section 5.3.3). Ivlev's Forage Ratio is a practical method of determining preference with wide application because it can be applied to any estimate of availability and availability does not have to be determined simultaneously with dietary intake.

Because two estimates of preference based on two estimates of availability were determined in Chapter 5, two different names were used to distinguish between these estimates of preference. Those determined from estimates of availability obtained on backtracks were termed forage ratios, while those determined from estimates of availability obtained from the sites described earlier were termed preference ratios. Both estimates of preference were comparable in terms of preferred and rejected species, and either could be used. To determine the condition of the vegetation, the preference ratios were used because the same sites provided the data on browse availability expressed as potential BU's/ha.

To apply the preference ratios to data on woody species availability to determine the condition of the vegetation for black rhino, forage factors were used to 'weight' the preference ratios according to the full range of the preference ratios. A forage factor is a preference ratio expressed in a range from 0-1. Although Trollope *et al*. (2006) used forage factors to describe the forage potential of grasses, in this case it was used to describe the forage potential for woody species. The forage factors were determined as follows:

- Data on dietary intake of the black rhino and the availability of woody species were pooled for the three vegetation types. This was in keeping with fulfilling the overall requirement of developing a technique for assessing the condition of the vegetation that was simple, practical, and effective;

- Every value in the range of preference ratios was divided by the greatest value of the range thereby assigning a forage factor that ranged from 0-1 to each species.

The potential BU's/ha of each woody species were multiplied by the forage factor to give the acceptable BU's/ha of each woody species. The sum of the acceptable BU's/ha indicated the condition of that vegetation type for black rhino in terms of its ability to provide suitable accessible browse.

6.3.4.6 Browsing Intensity

During the collection of dietary data of the black rhino (Chapter 3) an estimate was also made of the proportion of available browse removed by the feeding rhino on each browsed plant (% offtake). These estimates, expressed as percents, were conducted on all woody species including the succulent *E. bothae*, *Euphorbia tetragona*, and *E. triangularis* and were considered to be an indication of browsing intensity.

For estimating the % offtake, available browse for black rhino was defined as that portion of an individual woody plant that comprises leaves and stems <10mm in diameter. The 10mm diameter limit was based on the finding of Ganqa *et al*. (2005) in the GFRR where only 1.4% and 0.3% of browsed twigs of all species excluding *Euphorbia bothae* were >10mm in diameter in summer and winter respectively.

The estimate of availability for *E*. *bothae* was greater because the succulent nature of the thicker stems meant that most of the plant was theoretically available for consumption by rhino. Similarly, the entire *E*. *tetragona* and *E*. *triangularis* trees were considered available because these trees were felled by black rhino before feeding, thereby equating to 'offtake'.

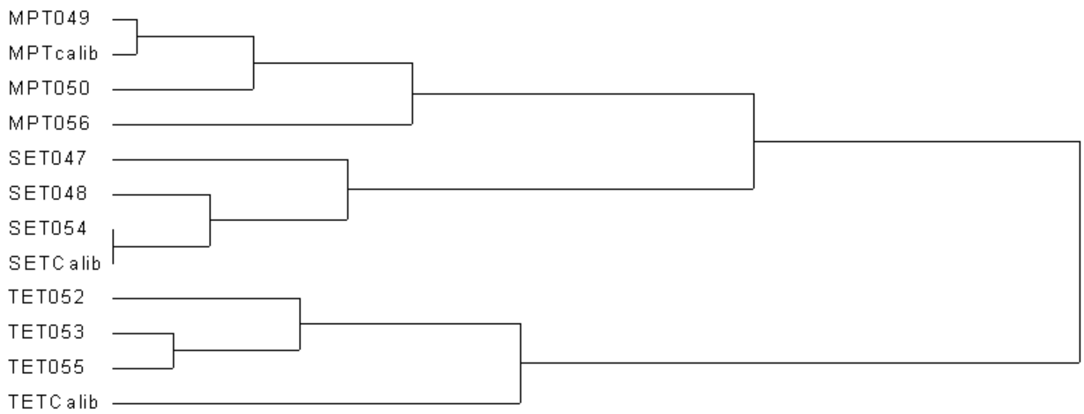
The % offtake of each woody species was determined for each vegetation type, and comparisons were then made between vegetation types for the same species. Although a subjective estimate, all estimates were by the same observer. In the absence of long-term data on the response of browse species to browsing pressure, these estimates of % offtake suggested the impact that browsing may have on a browse species. Species with a high % offtake value would probably be susceptible to browsing pressure, and could be considered early indicators of the impact of a black rhino on the vegetation.

6.4 Results and discussion

6.4.1 Association between sites

Because the sites were visually selected subjectively, it was necessary to determine whether they were adequately representative of the different vegetation types. The test statistic from the Multi-Response Permutation Procedure (MRPP) ($T = -7.036$; $p<0.0001$) was highly negative, indicating significantly greater variability among the vegetation types than between the sites of each vegetation type. The four sites in each of the three vegetation types were more similar to one another than they were to sites in the other vegetation types in terms of species composition and browse availability. The average Bray-Curtis distance measures were 0.315, 0.28, and 0.386 for MPT, SET, and TET respectively. Because larger average distance measures mean greater variability in species composition and browse availability, TET had the greatest variation between sites and SET had the least variation between sites. This may be seen in Figure 5.3.

To complement the results of the MRPP, a cluster analysis (Figure 6.3) was conducted on the survey data from the four sites in each of the three vegetation types to provide a visual representation of the association among the sites. Distance was the objective function.



MPT = Medium *Portulacaria* Thicket   SET = Short *Euphorbia* Thicket   TET = Tall *Euphorbia* Thicket

Figure 6.3. Association between veld condition assessment sites in three vegetation types indicated by a dendrogram of a cluster analysis (Group Average method on Bray-Curtis dissimilarities) performed on the number of BU's/ha of woody species in the four veld condition assessment sites in each of three vegetation types in the Great Fish River Reserve.

The dendrogram in Figure 5.3 shows that the sites displayed greater similarity to one another in each vegetation type than they did to the sites in the other vegetation types. In each vegetation type there were certain sites that displayed greater variation than others, the greatest variation being displayed by the 'calibration' site in TET. The sites in MPT and SET were more similar to one another than they were to TET. The initial visual identification of what constituted a given vegetation type was thus successful and data from each of the four sites for each vegetation type were pooled and analyzed together.

6.4.2 Relationship between two measures of availability of browse

The relationship between two measures of browse availability - height and the MCD of the different woody species - was determined for the three vegetation types (Figures 6.4, 6.5 and 6.6). The coefficient of determination (r^2) for the regression equations indicating the relationship between estimates of availability based on measurements of height and MCD were all high, ranging from 0.65 to > 0.99.

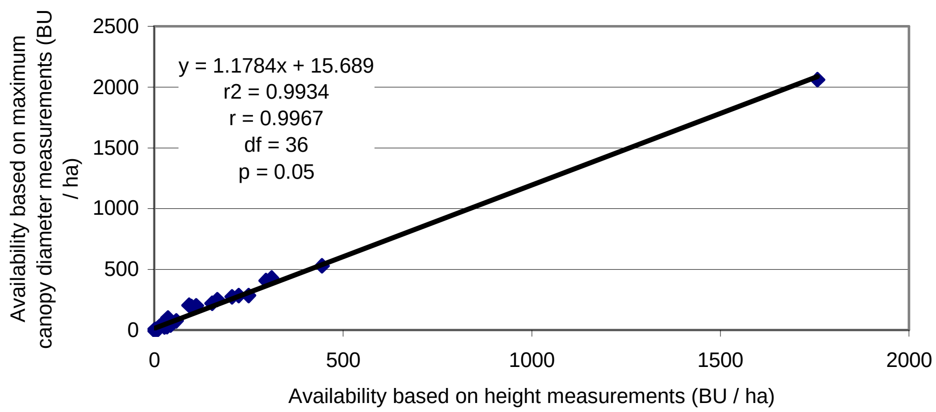


Figure 6.4. Availability estimates of woody species based on height of plants regressed against availability estimates based on maximum canopy diameter of plants in Medium *Portulacaria* Thicket in the Great Fish River Reserve.

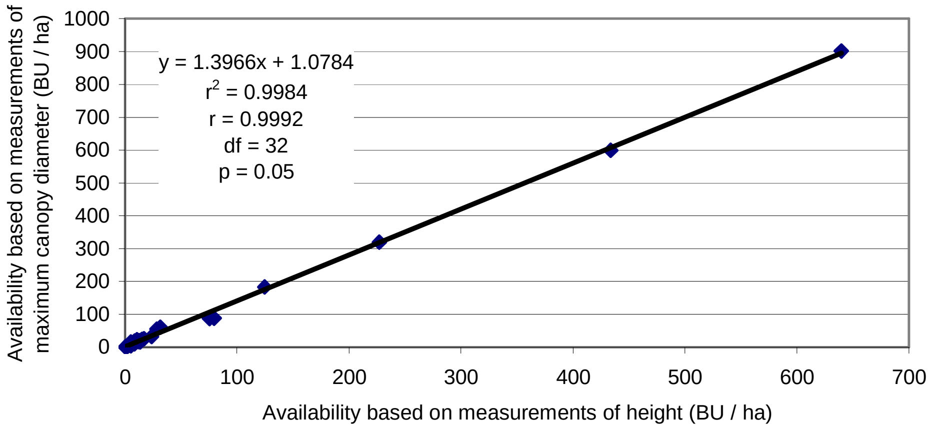


Figure 6.5. Availability estimates of woody species based on height of plants regressed against availability estimates based on maximum canopy diameter of plants in Short *Euphorbia* Thicket in the Great Fish River Reserve.

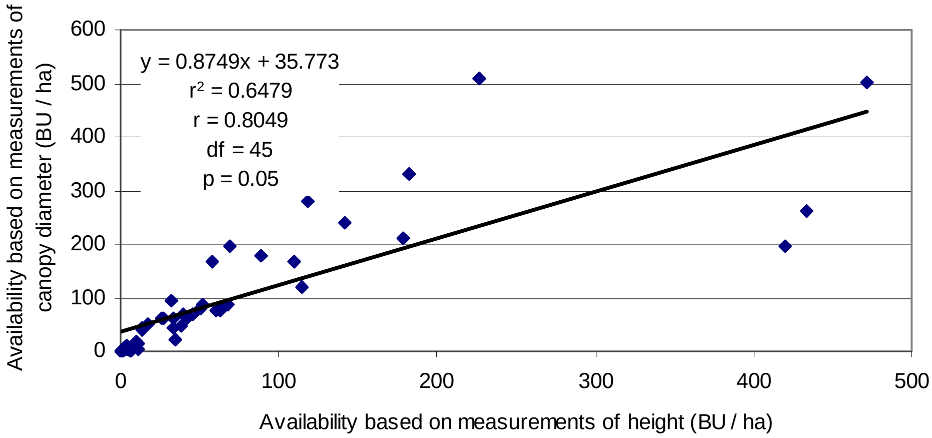


Figure 6.6. Availability estimates of woody species based on the height of plants regressed against availability estimates based on maximum canopy diameter of plants in Tall *Euphorbia* Thicket in the Great Fish River Reserve.

The high coefficients of determination indicate that either estimate of availability may be used. TET vegetation had the lowest coefficient of determination of the three vegetation types. This may be attributed to the typically elevated canopies of the taller vegetation. The result was that measurements of LBM were often high above the ground, giving reduced values for the estimates of availability based on height. For many of these species, the estimates of availability based on MCD were high because the canopies were often of large diameter. Because these canopies were often marginally lower than the upper height limit of 2m, they were included although they offered less browse than the results suggest.

6.4.3 Stratification of browsing

The stratification of browsing by the black rhino was determined from data on the number of bites taken in three discreet and one open-ended height category in the six vegetation types (Table 6.1). Across all vegetation types, more than 85% of bites were taken from vegetation that was <1m in height while only 5.5% of all bites were taken above 1.5 m

Table 6.1. Number of bites by black rhino in four different height categories in six vegetation types in the Great Fish River Reserve. n = number of bites

Vegetation type	0 - 0.5 m		0.51 – 1m		1.1 - 1.5 m		> 1.5 m	
	n	%	n	%	n	%	n	%
Bushclump Karroid Thicket	631	59.1	280	26.2	84	7.9	72	6.7
Dry Forest	1163	54.5	601	28.1	236	11.1	135	6.3
Medium *Portulacaria* Thicket	1966	49.6	1552	39.2	443	11.2	2	0.1
Riverine Acacia Thicket	659	80.1	122	14.8	19	2.3	23	2.8
Short *Euphorbia* Thicket	2490	56.6	1475	33.5	361	8.2	73	1.7
Tall *Euphorbia* Thicket	1190	47.5	791	31.6	135	5.4	389	15.5
Mean		57.9		28.9		7.7		5.5

Ganqa *et al*. (2005) and van Lieverloo and Schuiling (2004) both found that most browsing occurred below 1m in height in the GFRR thereby supporting this finding. The greatest contribution to the number of bites >1.5m came from the TET. These circumstances were exceptional, however, because this browsing was largely of *Euphorbia tetragona* and *E. triangularis* trees that were felled by the feeding rhino.

No discreet 1.5 – 2m category was used in this study, and the number of bites above 2m was unknown. Because the *Euphorbia tetragona* and *E*. *triangularis* trees were treated as exceptions in that the entire tree was considered available, the contribution of other browse above 2m would have been negligible. Buk (2004) assessed the contribution of browse to the diet of black rhino in 20cm height intervals on *Acacia mellifera* plants that were >2m in height and found that the preferred feeding height range was 1.01 – 1.50m and that 97% of all browse was below 2m. He maintained that this revealed the actual feeding height preference unbiased by species preferences and total vertical distribution of browse availability.

The data presented in Table 6.5 will allow for future comparisons of the number of bites consumed in each height category. As the number of black rhino increase in the area, it may be that the intensity of browsing on the vegetation will also increase. Increased browsing intensity may translate to a lower availability of browse in the lower height categories – partly due to a 'hedged' growth form - and more browsing in the higher categories. Such changes could be valuable in revealing possible 'stress' in the population.

6.4.4 Forage factors

The mean preference ratio of each woody species was expressed as a forage factor that represented the value of the species as browse to the black rhino and could be equated to browse quality/suitability (Adcock 2000). The forage factors indicate that a number of potential browse species were of little value as browse to black rhino - 15 out of 56 available browse species had forage factors of zero because they were never recorded as browsed (Table 6.2).

Table 6.2. Forage factors based on preference ratios for black rhino of all woody species in the veld condition assessment sites in Medium *Portulacaria* Thicket, Short *Euphorbia* Thicket and Tall *Euphorbia* Thicket vegetation types in the Great Fish River Reserve.

Species	PR	Forage Factor	Species	PR	Forage Factor
Acalypha glabrata	*39.05	1.000	*Olea europaea*	0.53	0.053
Coddia rudis	10.01	1.000	*Hippobromus pauciflоris*	0.48	0.048
Buddleja saligna	6.78	0.677	*Opuntia ficus-indica*	0.48	0.048
Plumbago auriculata	4.47	0.447	*Euphorbia triangularis*	0.47	0.047
Sarcostemma viminale	3.87	0.387	*Euphorbia tetragona*	0.44	0.044
Pachypodium succulentum	3.63	0.363	*Leucas capensis*	0.40	0.040
Lycium ferocissimum	3.38	0.338	*Rhus refracta*	0.38	0.038
Euphorbia bothae	3.36	0.336	*Grewia occidentalis*	0.20	0.020
Maytenus peduncularis	3.23	0.323	*Gymnosporia polyacantha*	0.17	0.017
Ozoroa mucronata	3.09	0.309	*Putterlickia pyracantha*	0.17	0.017
Euphorbia mauritanica	3.08	0.308	*Ptaeroxylon obliquum*	0.13	0.013
Grewia robusta	2.51	0.251	*Gymnosporia buxifolia*	0.11	0.011
Carissa haematocarpa	2.22	0.222	*Phyllanthus verrucosus*	0.07	0.007
Euclea undulata	2.01	0.201	*Pappea capensis*	0.05	0.005
Secamone filiformis	1.94	0.194	*Ehretia rigida*	0.04	0.004
Jatropha capensis	1.75	0.175	*Portulacaria afra*	0.03	0.003
Azima tetracantha	1.52	0.152	*Aloe ferox*	0.00	0.000
Jasminum angularae	1.32	0.132	*Boscia oleoides*	0.00	0.000
Capparis sepiara	1.15	0.115	*Cassine crocea*	0.00	0.000
Asparagus species	1.05	0.105	*Diospyros lycioides*	0.00	0.000
Acacia karroo	0.97	0.097	*Diospyros scabrida*	0.00	0.000
Rhus longispina	0.93	0.093	*Dovyalis cafra*	0.00	0.000
Schotia afra	0.81	0.081	*Heteromorpha trifoliata*	0.00	0.000
Brachylaena ilicifolia	0.80	0.080	*Hibiscus species*	0.00	0.000
Rhoicissus species	0.76	0.076	*Unknown species*	0.00	0.000
Gymnosporia capitata	0.65	0.065	*Scolopia zeyheri*	0.00	0.000
Rhigozum obovatum	0.62	0.062	*Scutia myrtina*	0.00	0.000

Cussonia spicata	0.58	0.058	*Tecoma capensis*	0.00	0.000

*The PR for *Acalypha glabrata* was an exceptional outlier and omitted as the upper limit for determining Forage factors.

The forage factors (Table 6.2) were based on three vegetation types, and although these vegetation types yielded most of the data on the feeding of the black rhino in this study, the forage factors may be refined by similar research on browsing and browse availability in other vegetation types. Season influences the quantity and quality of food resources (e.g. Bothma *et al*. 2004), and forage factors are therefore dynamic entities. The forage factors in this study were determined from data covering a wet and early dry period and, although probably providing a reasonable indication of the value of the browse species, data from varying climatic periods, particularly a late dry period, would further contribute to an understanding of the value of these browse species to black rhino.

The forage factor seems to be ideally suited to denoting a value to a browse species and is superior to simply classifying browse species as palatable and unpalatable because the full range of palatability is not sufficiently captured by such simple classification. Table 6.2 reveals that there were few species for which the forage factor approached the upper limit of one. Those that do were species that were of low availability but invariably browsed when encountered. These species are likely to be sensitive to browsing by black rhino, and their likely value as indicator species is discussed below.

6.4.5 Assessment of the condition of three vegetation types

The condition of the three vegetation types was based on the sum of the acceptable BU's/ha of each species. For each vegetation type, the ten most potentially available species are presented (Table 6.3). The acceptable BU's/ha for all the other species may be found in Appendices 6 – 8.

Table 6.3. Acceptable BU's/ha of three vegetation types based on forage factors and potential BU's/ha of selected woody species in the Great Fish River Reserve.

Medium *Portulacaria* Thicket					
Species	n	Density	Potential BU/ha	Forage Factor	Acceptable BU/ha
Portulacaria afra	533	3504	1757	0.003	5.3
Grewia robusta	76	956	445	0.251	111.6
Jatropha capensis	72	1460	311	0.175	54.4
Rhigozum obovatum	90	533	297	0.062	18.4
Phyllanthus verrucosus	38	781	250	0.007	1.7
Brachylaena ilicifolia	56	480	223	0.080	17.9
Euclea undulata	94	454	207	0.201	41.6
Gymnosporia capitata	103	291	167	0.065	10.9
Euphorbia bothae	30	558	154	0.336	51.7
Asparagus spp.	13	267	112	0.105	11.7
Other species	287	1717	582	0.140	98
Total:	1392	11001	3922		422.6
Short *Euphorbia* Thicket					
Species	n	Density	Potential BU/ha	Forage Factor	Acceptable BU/ha
Euphorbia bothae	241	2171	640	0.336	214.9
Rhigozum obovatum	180	1008	434	0.062	26.9
Grewia robusta	127	464	227	0.251	57.0
Gymnosporia capitata	167	288	125	0.065	8.1
Gymnosporia polyacantha	51	288	80	0.017	1.4
Brachylaena ilicifolia	58	137	75	0.080	6.0
Schotia afra	47	38	31	0.081	2.5
Lycium ferocissimum	13	127	29	0.338	9.6
Portulacaria afra	28	45	24	0.003	0.1
Asparagus spp.	10	88	17	0.105	1.8
Other species	184	598	158	0.121	18.9
Totals:	1106	5253	1839		347.3
Tall *Euphorbia* Thicket					
Species	n	Density	Potential BU/ha	Forage Factor	Acceptable BU/ha
Ehretia rigida	156	1883	472	0.004	1.9
Euphorbia triangularis	179	306	433	0.047	20.4
Euphorbia tetragona	132	144	420	0.044	18.5
Azima tetracantha	83	648	227	0.152	34.4
Grewia occidentalis	73	1179	182	0.020	3.6
Phyllanthus verrucosus	37	712	179	0.007	1.3
Plumbago auriculata	35	617	142	0.447	63.3
Rhus refracta	66	492	118	0.038	4.5
Jatropha capensis	27	478	115	0.175	20.1
Asparagus species	32	613	110	0.105	11.5
Other species	628	3810	991	0.129	91.0
Total	1448	10882	3387		271.0

n = Total number of plants recorded in the veld condition assessment sites for that vegetation type
Density = plants per hectare
Forage factor = Preference ratio expressed in range from 0-1
Acceptable BU's/ ha = Forage factor x potential BU's/ha

6.4.5.1 Potential browsing units

Although MPT and TET each provided about twice the potential BU's/ha than did SET, SET had the second highest acceptable BU's/ha of the three vegetation types. This supports the findings of Adcock (2000) and Buk (2004) that it was not so much the total browse availability but rather the availability of principal and preferred browse species that influenced the suitability of habitat for black rhino. Although much of the vegetation may not provide suitable browse for black rhino, it does contribute to the structural heterogeneity and Buk (2004) found that habitat heterogeneity was a variable of high significance in his model of the suitability of habitat for black rhino. Although habitat heterogeneity may encompass a variety of factors, the vertical distribution of browse (Figure 6.7) may be considered one measure of heterogeneity that has direct implications for black rhino because it reveals the contribution of woody plants of various height categories to total availability.

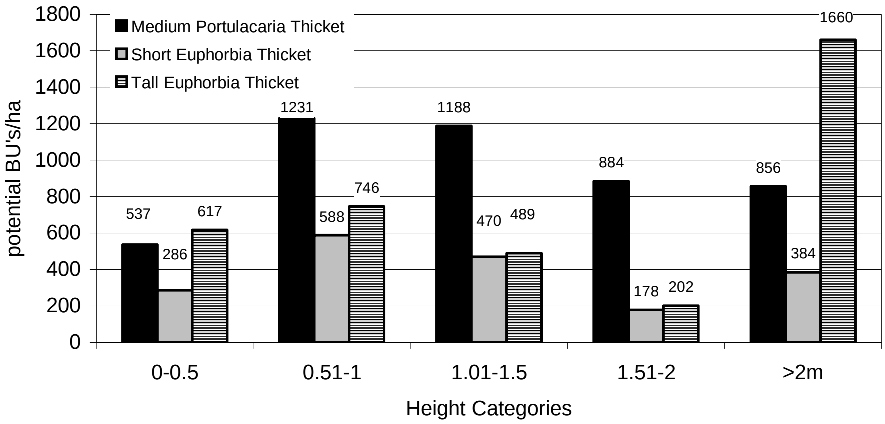


Figure 6.7. The number of potential BU's/ha contributed by plants in the 0.5 m height categories in three vegetation types in the Great Fish River Reserve.

The high contribution to potential BU's/ha of woody plants in the height categories >2m in TET reflects the abundance of taller vegetation, while the reverse applies to SET vegetation (Figure

6.7). If vegetation heterogeneity contributes to the suitability of a habitat for black rhino as suggested by Buk (2004) then TET may be more attractive in that respect than the other vegetation types. However, Buk (2004) studied black rhino in a significantly more arid area where the habitat heterogeneity may have been more important because of the scarcity of taller vegetation for providing shade.

Although the data on the number of potential BU's/ha in Table 6.3 will allow for change in total availability of each species to be detected over time, an indication of the vertical distribution of the woody browse in terms of the availability of potential BU's/ha in 0.5m height increments will give a clearer indication of what height class of plants have been impacted more than others over time, and in what vegetation types.

Given the complex nature of thicket, expressing availability in terms of BU's/ha is reasonably time efficient and may be the most practical method. However, while recognizing the varying physiognomy of thicket species, it will be important to determine the phytomass of the average BU such that comparisons may be made with other study areas regarding total browse phytomass available to black rhino.

6.4.5.2 Acceptable browsing units

The acceptable BU's/ha (Table 5.4) suggests that the amount of valuable browse in MPT was marginally greater than that in SET and distinctly greater than that in TET. Although the high forage factors of the highly available *Grewia robusta* and *Jatropha capensis* contributed positively to the acceptable BU's/ha of MPT, the very low forage factor of the characteristic and most available *Portulacaria afra* had a significant negative influence on the acceptable BU's/ha for this vegetation type. Contrary to the low forage factor of *P. afra* reported in this study, Hall-Martin *et al*. (1982) recognized the importance of *P. afra* in the late dry period in the Addo National Park. It is therefore possible that under certain prolonged hot and dry periods, *P. afra* may be of greater value as a browse resource in the GFRR than indicated in this study. It was primarily the high forage factors of *Euphorbia bothae* and *G*. *robusta*, the most available species, that dictated the high acceptable BU's/ha for SET. In TET it was the low forage factor of 0.004 of *Ehretia rigida*, the most available species, which contributed to the low number of acceptable BU's/ha of this vegetation type.

The optimal foraging theory (Pyke *et al*. 1977) suggests that black rhino would feed most efficiently in SET where the proportion of acceptable BU's/ha to potential BU's/ha was greater than the proportions in the other two vegetation types. The 'searching time' for suitable browse should be lower in SET, thereby maximizing energy intake. Therefore, although the current condition of MPT in terms of the total acceptable BU's/ha is better than SET and TET, the efficiency of feeding in SET is currently likely to be the highest. However, observations suggest that the condition of SET may be declining because this condition is strongly dependent on the viability of plants of *Euphorbia bothae*, a potentially sensitive species with a high forage factor as discussed later. Similarly, the felling of *Euphorbia tetragona* and *E*. *triangularis* trees by feeding black rhino suggests that TET is deteriorating in condition for black rhino. Indeed, black rhino are considered to control the population numbers of tree euphorbias (Heilmann *et al*. *in prep*, and Kamineth 2004).

Whether the number of acceptable BU's/ha determined for a vegetation type truly represents the number of complete BU's/ha that may be available for consumption is an unknown factor that is influenced by other factors such as season and populations of other browsers. Regardless, it does provide an indication of the condition of vegetation for black rhino, and also provides for comparisons in this regard assuming that the same methods are followed.

6.4.5.3 Browsing intensity

The % offtake on individually browsed plants by black rhino was estimated and considered to represent browsing intensity. Species with high % offtake values were species that would probably suffer under increased browsing pressure. TET had the greatest average % offtake while SET had the lowest (Table 6.4).

Table 6.4. The percent of total available browse removed by feeding rhino (%OT) from woody species in three vegetation types. Species where n≥10 are presented.

	MPT		SET		TET			MPT		SET		TET	
Species	N	%OT	N	%OT	N	%OT	Species	N	%OT	N	%OT	N	%OT
Acalypha glabrata	–	—	–	—	25	34	*Grewia robusta*	159	11	132	10	29	7
Asparagus species	51	28	58	36	35	25	*Jasminum angularae*	13	16	–	—	15	51
Azima tetracantha	18	19	22	12	24	7	*Jatropha capensis*	124	45	13	33	69	37
Brachylaena ilicifolia	16	9	20	10	–	—	*Lycium ferocissimum*	26	14	21	20	13	15
Capparis sepiara	11	5		—	–	—	*Gymnosporia capitata*	17	13	18	7	–	—
Carissa haematocarpa	–	—	–	—	10	12	*Gymnosporia polycantha*	–	—	10	25	–	—
Coddia rudis	37	41		—	17	22	*Phyllanthus verrucosus*	11	12	–	—	–	—
Euclea undulata	26	15	21	21	–	—	*Plumbago auriculata*	–	—	11	17	67	22
Euphorbia bothae	36	13	398	13	–	—	*Portulacaria afra*	15	13	–	—	–	—
Euphorbia tetragona	–	—	–	—	19	100	*Rhigozum obovatum*	24	5	15	3	–	—
Euphorbia triangularis	–	—	–	—	18	72	*Rhoicissus tridentata*	11	20	20	12	–	—
Grewia occidentalis	–	—	–	—	14	29	*Schotia afra*	14	4	11	3	–	—
							Average*		22		15		30

*= Average across all individuals of all species

The high average % offtake in TET can be attributed to the influence of the felling of *Euphorbia tetragona* and *E*. *triangularis* trees by feeding rhino where the % offtake values (100 and 72% respectively) reflect the subsequent mortality rather than amount removed by feeding. In SET, the low average % offtake was attributed to most of the forage on *E*. *bothae* plants being considered available. Therefore, it is the % offtake of the different browse species rather than the average % offtake of each vegetation type that is important to consider.

Highly preferred species are species that may be driven to extinction or near-extinction by a browser as has been documented for elephants (Cowling and Kerley 2002 and Johson *et al*. 1999) and black rhino (Buk 2004) and it is reasonable to assume that these highly preferred species would also be those with the highest % offtake values. A comparison between the forage factors (Table 6.3) and the % offtake values (Table 6.5) for the same species indicates that this relationship holds for *Acalypha glabrata*, *Coddia rudis*, *Jatropha capensis* and *Plumbago auriculata*, and these species should be considered early indicators of the impact of black rhino on the vegetation. *J*. *capensis* is a soft wooded unarmed shrub that, in the absence of information on its underground storage ability, seemed to be particularly susceptible to over-utilisation.

Although the response of the above species to heavy browsing pressure is of particular concern to maintaining the biodiversity of the vegetation types, the long-term response to browsing pressure of the more available and preferred species such as *Euphorbia bothae* and *Grewia robusta* to browsing pressure has direct implications for black rhino because these species contribute the most to the overall condition of the vegetation for black rhino.

Grewia robusta had an average % offtake distinctly less than the average for the vegetation types because rhinos typically fed on numerous individuals, taking small amounts off each. It seems that the hedged growth-form of *G*. *robusta* and certain other species such as *Schotia afra* and some *Pappea capensis* individuals may be maintained by regular browsing where small amounts were removed each time. The resulting hedged growth-form may resist heavy browsing pressure and *G*. *robusta* is therefore unlikely to be an early indicator of the impact of black rhino on MPT.

The rather low % offtake of *Euphorbia bothae* was deceptive in that, although some individuals were lightly browsed, the succulent-stemmed growth form meant that certain individuals could be very heavily browsed. The response of plants to such heavy browsing is an important question for future research because this is an exceptionally important species in determining the overall condition of the vegetation for black rhino. Observations indicate that, while some browsed stems tend to 'seal off' and produce lateral stems, others die.

The average % offtake for each vegetation type and for each woody species (Table 5.5) suggests a contrasting finding to that of a number of studies (Kruger 1994; Emslie and Adcock 1994; Von Holdt 1999 and Bothma *et al*. 2004) that browsers seldom use >10% of the standing browse in any area, and that ecological carrying capacity should be calculated by using <10% of the standing browse. However, the % offtake values not only reflect browsing of the more palatable species, but also of the more palatable individuals whereas the studies mentioned above consider all the available vegetation. Also, with the exception of the elephant, black rhino are capable of utilizing a greater proportion of a plant because they can remove thicker twigs than other browsers.

The type of vegetation further influences the proportion of the vegetation available for consumption. Contrary to the vegetation where the above studies were done, some of the vegetation types in the GFRR are dominated by succulent/semi-succulent plants (*Portulacaria afra* and *Euphorbia bothae* in MPT and SET respectively). These differing physiognomies suggest that the proportion of SET that may be browsed is greater than that of MPT and TET because of the dominance of the preferred and succulent *Euphorbia bothae*. This has implications for determining phytomass from estimates of availability based on BU's because different proportions of the BU's of species of different physiognomy will be used.

6.5 Conclusions

The method developed by Trollope *et al*. (2006) for assessing the condition of thicket determined botanical composition, density, and browse availability of the woody species effectively, and will facilitate comparisons of the change in the vegetation over time. Although the acceptable BU's/ha representing condition was highest for Medium *Portulacaria* Thicket, slightly less for Short *Euphorbia* Thicket and lowest for Tall *Euphorbia* Thicket, Short *Euphorbia* Thicket had the best ratio of acceptable BU's/ha to potential BU's/ha indicating that the efficiency of feeding was highest in Short *Euphorbia* Thicket. Observations suggest that the condition for black rhino of Tall *Euphorbia* Thicket is declining due to the felling of two tree *Euphorbia* species, while that of Short *Euphorbia* Thicket invites further investigation because of the dominance of *E. bothae*, a heavily browsed and potentially sensitive species. Detecting change in the vegetation over time may be inferred from data on the browsing stratification of black rhino. Changes in the percent of bites in various height categories suggest corresponding changes in the availability of browse in those categories. Similarly, data on the % offtake by feeding rhino on different woody species indicates species that may be sensitive to browsing pressure, and changes in the % offtake on various browse species will suggest corresponding changes in availability at the species level.

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CHAPTER SEVEN

GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

7.1 General discussion

The objective of the first experiment was to determine the principal species (contributing ≥5%) in the diet of the black rhino in the different vegetation types and across seasons by means of two methods that allowed for comparison. The two methods – species contribution in terms of dry mass and in terms of number of bites – were found to yield comparable results in most but not all cases. Determining the contribution of forage species to the diet of the black rhino in terms of number of bites is simple, but not always suitable for species with unusual growth form. Eighteen browse species were principal in the diet in terms of dry mass in at least one of the vegetation types. Yet, in five of the six vegetation types, the three most important principal browse species contributed more than 50% of the diet in terms of dry mass. Of these, *Grewia robusta* was principal in five of the six vegetation types and considering that this species appeared to be widespread and was principal throughout the duration of this study it was probably the most important principal forage resource for black rhino in the GFRR.

The knowledge of principal species in the diet of the black rhino is incomplete if it does not include information on seasonal change. The objective of the second experiment was therefore to determine the influence of season on the importance of browse species in the diet of the black rhino in three vegetation types. The overall diet of the black rhino changed significantly from one season to the next in Medium *Portulacaria* Thicket, but not in Short *Euphorbia* Thicket or Dry Forest. *Euphorbia bothae*, the most important principal browse species in the diet in SET, contributed a similar amount to the diet in both seasons. The trend for deciduous species to be selected more in the wet season and evergreen species in the dry season was supported by *R. obovatum* and *L. ferocissimum* for the deciduous species, and *J. capensis* for the evergreen species. *C*. *rudis*, also a deciduous species, was selected significantly more in the early dry season and was probably due to a slower response to rainfall.

Knowledge of the importance of forage species alone does not reveal much about the effect a herbivore may have on vegetation, even where it includes season. The objective of the third experiment was therefore to determine those forage species that were significantly preferred and those significantly rejected by two methods. The percentage of available browse removed by a feeding rhino was also recorded to reveal species possibly susceptible to browsing intensity. The estimates of preference based on the two different estimates of availability invariably determined the same species as significantly preferred although the rank order varied. This suggests that either method could be used to gain an understanding of the preference of various browse species for black rhino. The only species determined as significantly preferred based on one estimate of availability and significantly rejected based on the other were the succulent tree *Euphorbia tetragona* and *E*. *triangularis* where atypical feeding introduced complications. Significantly preferred species were usually also principal species and the average percent of available browse removed by a feeding rhino suggested that *Coddia rudis*, *Plumbago auriculata*, *Jatropha capensis*, *Euphorbia tetragona* and *E*. *triangularis* were more susceptible than others to pressure induced by browsing. *Grewia robusta* and *Rhigozum obovatum*, although significantly preferred and principal, were likely to be poor indicators of pressure induced by browsing.

The fourth experiment represents the practical application of the findings in the other experiments. The objective was to determine the condition of three well-utilized vegetation types for black rhino using the point centered quarter method adapted for thicket. This would provide data on the current condition of the vegetation for black rhino such that the trend in the condition could be determined from comparisons with subsequent sampling. Although the acceptable browse units per hectare (BU's/ha) representing condition were highest for Medium *Portulacaria* Thicket, slightly less for Short *Euphorbia* Thicket and lowest for Tall *Euphorbia* Thicket, Short *Euphorbia* Thicket had the best ratio of acceptable BU's/ha to potential BU's/ha indicating that the efficiency of feeding was highest in Short *Euphorbia* Thicket. Observations suggest that the condition for black rhino of Tall *Euphorbia* Thicket is declining due to the felling of two tree *Euphorbia* species, while that of Short *Euphorbia* Thicket invites further investigation because of the dominance of *E. bothae*, a heavily browsed and potentially sensitive species.

7.2 Conclusions

With few exceptions the contribution of different browse species to the diet of the black rhino was determined favourably both in terms of dry mass and in terms of the simpler approach of the number of bites. Although black rhino browsed a total of over 90 species, the bulk of the diet in each vegetation type was composed of a few principal species that contributed 5% or more to the diet. Of these, *Grewia robusta* was the most important of the principal species in the Great Fish River Reserve in terms of its total contribution to the diet. Some of the principal species displayed significant seasonal variation in the diet in Medium *Portulacaria* Thicket but not in Dry Forest. In Short *Euphorbia* Thicket it was only the succulent annual members of the Aizoaceae that displayed significant seasonal variation. Principal species were invariably also significantly preferred in at least one vegetation type. Some, however, exhibited markedly greater offtake of the total available browse by feeding rhino with the two tree *Euphorbia* species being extreme cases where the entire plants were often removed by felling before browsing. The technique developed by Trollope *et al*. (2005) for assessing the condition of thicket in terms of the number of acceptable browsing units (BU) per hectare was used in three of the six vegetation types and determined Medium *Portularia* Thicket to have the greatest number of BU's per hectare although Short *Euphorbia* Thicket had the best ration of acceptable BU's per hectare to potential BU per hectare. This suggested that Short *Euphorbia* Thicket provided for the most efficient feeding.

7.3 Recommendations

The diet of the black rhino in the different vegetation types was based on varying sampling intensity. Future work should focus on the more poorly sampled vegetation types and emphasis should be placed on sampling in the dry season. The estimate of the average bite of *Euphorbia bothae* is not suitable for wide application without further investigation. The photography of stems in the field proved extremely laborious and subject to chance encounters. Unless the chance is increased, this method is undesirable, and the average bite of *E. bothae* stems may best be determined through observations under captive conditions.

The absence of a vegetation map at the time meant that findings were not extrapolated to the entire reserve. The contribution of browse species to the diet of the black rhino in the six vegetation types should be interpreted with a practical vegetation map depicting these same vegetation types. This map should ideally also identify areas that may be regarded as degraded versions of the recognised vegetation types.

The information of the diet of the rhino in the GFRR will be of greater value if corresponding information is obtained on the diet and feeding behaviour of kudu (*Tragelaphus strepsiceros*), the most abundant browser. This will reveal areas of dietary overlap and therefore competition that would influence the management of the rhino population.

Nothing is known about seasonal feeding in three of the six vegetation types considered in this study. Investigations of feeding across all seasons, particularly the late dry season, will greatly contribute to an understanding of the influence of season on browse utilization.

The variation in the intensity of utilization of the vegetation types should be determined because certain vegetation types may be utilized more intensively at times of resource scarcity (dry season). Determining vegetation utilization is difficult in dense vegetation however, and will probably require a combination of methods such as transecting to record middens and/or signs of browsing and aerial censuses to record the number of animals per vegetation type. Determining vegetation utilization also relies on a suitable vegetation map of the area such that the areas of the vegetation types are known. This information will allow for comparisons between the intensity of utilization of the vegetation types and the condition of those vegetation types for black rhino.

Although the sample sites used in this study are permanent and can be used to obtain valuable information for future comparisons of the condition of vegetation and associated change, the value of exclusion sites in providing visual evidence of change cannot be over emphasized, and exclusion sites should be established adjacent to each of these sites used in this study. Sites should be established in this arrangement in representative examples of other vegetation types. The value of the exclusion sites is also in determining change in the vegetation induced specifically by the suite of animal species that are excluded from the site.

The ability of the various browse species to respond to browsing has important implications for the condition of the vegetation in the long-term. Preferred species that have high productivity will be more valuable than preferred species of low productivity because productive species provide more forage and should be more resilient to browsing pressure. It will be especially important to determine the productivity of those species contributing the most acceptable browse units to a vegetation type. Productivity also varies seasonally, and work in this regard should recognize this.

Browse availability is frequently estimated by volume and to facilitate comparisons with other studies, it will be necessary to determine the volume of browse provided by a BU and the phytomass of this volume. Considering the varying physiognomy of browse species in thicket, it would be necessary to select species of differing physiognomy to determine the differences between the phytomass of BU's of these species and to obtain a meaningful average. An understanding of the phytomass provided by a BU will provide an estimate of the number of BU's required to sustain a black rhino over a given period of time.

APPENDICES

Appendix 1

Recording sheet for backtracking of black rhino

SPECIES	ASS. SPECIES[5]	FEEDING HEIGHT[1]				TWIG DIAMETERS (in mm)				NO OF STEMS[2]	TOT HT.	WASTEAGE[4]	WASTAGE ESTIMATE[3]	TOT % OFFTAKE	DIST.
		2-3	3-4	4-5	>5	11-15	16-20	21-25	>25						
		0-0.5	0.5-1.0	1.0-1.5	1.5-	0-3	4-6	7-10	>10						

Appendix 2

Percent contribution of browse species to the diet of the black rhino in terms of number of bites (bites) and dry mass (DM) in Bushclump Karroid Thicket, Dry Forest and Medium *Portulacaria* Thicket. Nomenclature follows Germishuizen and Meyer (2004).

		Bushclump Karroid Thicket					**Dry Forest**					**Medium *Portulacaria* Thicket**				
		Frequency					**Frequency**					**Frequency**				
Species	**Family**	**Plants**	**Bites**	**%**	**DM**	**%**	**Plants**	**Bites**	**%**	**DM**	**%**	**Plants**	**Bites**	**%**	**DM**	**%**
Acanthaceae species	Acanthaceae	3	3	0.3	3.2	0.0	11	32	1.5	65.6	0.3	8	20	0.5	83.0	0.2
Aizoaceae species	Aizoaceae	0	0	0.0	0.0	0.0	6	6	0.3	13.6	0.1	29	40	1.1	303.0	0.8
Achyropsis leptostachya	Amaranthaceae	14	15	1.4	51.2	0.5	0	0	0.0	0.0	0.0	0	0	0.0	0.0	0.0
Rhus incisa	Anacardiaceae	1	3	0.3	1.8	0.0	2	12	0.6	74.7	0.4			0.0		0.0
Rhus longispina	Anacardiaceae			0.0		0.0	4.0	9.0	0.4	55.2	0.3	2.0	7.0	0.2	54.0	0.1
Rhus refracta	Anacardiaceae	1	1	0.1	8.9	0.1	3	6	0.3	53.2	0.3	4	19	0.5	76.0	0.2
Ozoroa mucronata	Anacardiaceae			0.0		0.0	2	25	1.2	279.5	1.4	4	160	4.3	1283.0	3.3
Carissa haematocarpa	Apocynaceae			0.0		0.0	2	4	0.2	5.6	0.0	3	17	0.5	96.0	0.2
Pacchypodium succulentum	Apocynaceae			0.0		0.0			0.0		0.0	4	4	0.1	307.0	0.8
Ceropegia ampliata	Apocynaceae			0.0		0.0			0.0		0.0	6	6	0.2	15.0	0.0
Cussonia spicata	Araliaceae			0.0		0.0			0.0		0.0			0.0		0.0
Fockea edulis	Asclepiadaceae			0.0		0.0			0.0		0.0			0.0		0.0
Sarcostemma viminale	Asclepiadaceae			0.0		0.0			0.0		0.0	1	1	0.0	14.0	0.0
Secamone filiformis	Asclepiadaceae	1	1	0.1	0.9	0.0	2	3	0.1	5.0	0.0			0.0		0.0
Bulbine frutescence	Asphodelaceae			0.0		0.0			0.0		0.0	1	1	0.0	1.0	0.0
Brachylaena ilicifolia	Asteraceae	7	76	7.1	906.8	9.2	8	33	1.5	324.5	1.6	39	172	4.7	1572.0	4.1
Chrysocoma ciliata	Asteraceae			0.0		0.0	9	16	0.7	45.6	0.2	1	1	0.0	3.0	0.0
Euryops tenuissimus	Asteraceae			0.0		0.0	2	2	0.1	5.6	0.0			0.0		0.0
Helichrysum rosum	Asteraceae			0.0		0.0			0.0		0.0	1	1	0.0	1.0	0.0
Venidium species	Asteraceae			0.0		0.0			0.0		0.0			0.0		0.0
Verbecena encelioides	Asteraceae			0.0		0.0			0.0		0.0	12	12	0.3	70.0	0.2
Rhigozum obovatum	Bignoniaceae			0.0		0.0			0.0		0.0	99	411	11.2	3257.0	8.5
Tecoma capensis	Bignoniaceae	3	5	0.5	67.6	0.7			0.0		0.0			0.0		0.0
Ehretia rigida	Boraginaceae	5	19	1.8	366.4	3.7	3	4	0.2	22.3	0.1	4	10	0.3	139.0	0.4
Cadaba aphylla	Brassicaceae			0.0		0.0			0.0		0.0			0.0		0.0
Opuntia ficus-indica	Cactaceae			0.0		0.0	2	1	0.0	Excluded	Excluded			0.0		0.0
Schotia afra	Caesalpiniaceae	1	2	0.2	31.8	0.3			0.0		0.0	22	81	2.2	484.0	1.3
Capparis sepiara	Capparaceae	2	6	0.6	42.5	0.4	11	24	1.1	334.3	1.7	12	30	0.8	362.0	0.9
Gymnosporia buxifolia	Celastraceae	2	14	1.3	108.7	1.1	6	23	1.1	187.9	0.9			0.0		0.0
Gymnosporia capitata	Celastraceae	18	65	6.1	556.0	5.7	16	41	1.9	362.3	1.8	26	129	3.5	1165.0	3.0
Gymnosporia polycantha	Celastraceae			0.0		0.0	21	86	4.0	573.9	2.9	1	3	0.1	10.0	0.0
Maytenus peduncularis	Celastraceae			0.0		0.0			0.0		0.0			0.0		0.0
Putterlickia pyracantha	Celastraceae	1	1	0.1	4.5	0.0	5	22	1.0	160.1	0.8			0.0		0.0
Commelina africana	Commelinaceae			0.0		0.0	1	1	0.0	0.3	0.0	1	1	0.0	0.0	0.0
Crassula perfoliata	Crassulaceae			0.0		0.0			0.0		0.0	1	1	0.0	18.0	0.0
Crassula species	Crassulaceae	1	1	0.1	0.6	0.0			0.0		0.0			0.0		0.0

Kalanchoe rotundifolia	Crassulaceae			0.0		0.0			0.0		0.0			0.0		0.0
Sanseveria hyacinthioides	Dracaenaceae	2	5	0.5	0.0	0.0			0.0		0.0	3	4	0.1	0.0	0.0
Diospyros lycioides	Ebenaceae	6	29	2.7	169.0	1.7			0.0		0.0			0.0		0.0
Diospyros scabrida	Ebenaceae			0.0		0.0	1	1	0.0	8.9	0.0			0.0		0.0
Euclea undulata	Ebenaceae	3	19	1.8	216.7	2.2	20	166	7.8	3851.4	19.3	37	274	7.4	5037.0	13.1
Acalypha glabrata	Euphorbiaceae	19	76	7.1	754.7	7.7			0.0		0.0	2	17	0.5	75.0	0.2
Croton rivularis	Euphorbiaceae	28	55	5.2	231.3	2.4	7	16	0.7	18.2	0.1			0.0		0.0
Euphorbia mauritanica	Euphorbiaceae	1	1	0.1	23.4	0.2	1	2	0.1	4.7	0.0	6	8	0.2	12.0	0.0
Euphorbia bothae	Euphorbiaceae			0.0		0.0			0.0		0.0	17	34	0.9	230.0	0.6
Euphorbia pentagona	Euphorbiaceae			0.0		0.0			0.0		0.0	1	0	0.0	0.0	0.0
Euphorbia tetragona	Euphorbiaceae			0.0		0.0			0.0		0.0			0.0		0.0
Euphorbia triangularis	Euphorbiaceae			0.0		0.0			0.0		0.0			0.0		0.0
Jatropha capensis	Euphorbiaceae	5	47	4.4	211.5	2.2	24	90	4.2	446.0	2.2	119	409	11.1	1824.0	4.7
Phyllanthus verrucosus	Euphorbiaceae	1	3	0.3	31.5	0.3	3	3	0.1	14.5	0.1	11	22	0.6	207.0	0.5
Indigofera hedyantha	Fabaceae	1	1	0.1	23.5	0.2			0.0		0.0			0.0		0.0
Indigofera sessilifolia	Fabaceae			0.0		0.0			0.0		0.0	2	3	0.1	22.0	0.1
Scolopia zeyheri	Flacourtiaceae	1	1	0.1	0.3	0.0	1	1	0.0	4.7	0.0			0.0		0.0
Dietes vegeta	Iridaceae			0.0		0.0	1	2	0.1	Excluded	Excluded	1	4	0.1	0.0	0.0
Leucas capensis	Lamiaceae			0.0		0.0	5	11	0.5	9.1	0.0	4	4	0.1	6.0	0.0
Asparagus species	Liliaceae	9	11	1.0	22.8	0.2	29	43	2.0	74.6	0.4	52	78	2.1	218.0	0.6
Asparagus striatus	Liliaceae	8	14	1.3	21.0	0.2	13	19	0.9	30.7	0.2	15	22	0.6	94.0	0.2
Buddleja saligna	Loganiaceae	2	8	0.7	33.2	0.3	3	9	0.4	36.5	0.2			0.0		0.0
Viscum rotundifolia	Loranthaceae	2	3	0.3	6.2	0.1			0.0		0.0			0.0		0.0
Abutilon sonneratianum	Malvaceae			0.0		0.0	0	4	0.2	2.9	0.0			0.0		0.0
Hermannia gracilis	Malvaceae			0.0		0.0			0.0		0.0	1	3	0.1	2.0	0.0
Pavonia pravescence	Malvaceae			0.0		0.0			0.0		0.0			0.0		0.0
Mesembryanthemaceae spp.	Mesembryanthemaceae	4	5	0.5	16.3	0.2	11	27	1.3	344.6	1.7	41	76	2.1	714.0	1.9
Acacia karroo	Mimosaceae	2	3	0.3	6.2	0.1			0.0		0.0	4	15	0.4	124.0	0.3
Jasminum angularae	Oleaceae	5	13	1.2	42.7	0.4	10	37	1.7	271.1	1.4	14	38	1.0	155.0	0.4
Olea europaea	Oleaceae			0.0		0.0	3	3	0.1	14.5	0.1			0.0		0.0
Plumbago auriculata	Plumbaginaceae	14	69	6.5	483.9	4.9	56	327	15.3	2168.5	10.9	3	13	0.4	107.0	0.3
Panicum maximum	Poaceae			0.0		0.0	1	1	0.0	4.5	0.0	1	1	0.0	0.0	0.0
Portulacaria afra	Portulaccaceae			0.0		0.0	1	2	0.1	70.3	0.4	19	40	1.1	3617.0	9.4
Ptaeroxylon obliquum	Ptaeroxylaceae			0.0		0.0	5	6	0.3	58.8	0.3			0.0		0.0
Scutia myrtina	Rhamnaceae			0.0		0.0	4	56	2.6	579.6	2.9			0.0		0.0
Coddia rudis	Rubiaceae	35	199	18.7	2683.6	27.4	51	289	13.5	3646.9	18.2	37	253	6.9	4768.0	12.4
Azima tetracantha	Salvadoraceae	4	45	4.2	290.7	3.0	23	182	8.5	1587.8	7.9	18	111	3.0	925.0	2.4
Allophylus decipiens	Sapindaceae	1	3	0.3	23.2	0.2			0.0		0.0			0.0		0.0
Hippobromus pauciflorіs	Sapindaceae			0.0		0.0			0.0		0.0			0.0		0.0
Pappea capensis	Sapindaceae	1	1	0.1	4.7	0.0	4	5	0.2	19.9	0.1	1	2	0.1	27.0	0.1
Selago geniculata	Scrophulariaceae			0.0		0.0			0.0		0.0	1	5	0.1	9.0	0.0
Lycium ferocissimum	Solanaceae	11	25	2.3	147.5	1.5	5	8	0.4	34.9	0.2	30	144	3.9	716.0	1.9
Solanum coccinium	Solanaceae			0.0		0.0			0.0		0.0			0.0		0.0
Solanum rigidum	Solanaceae			0.0		0.0			0.0		0.0			0.0		0.0

Gnidia cuneata	Thymeliaceae			0.0		0.0			0.0		0.0			0.0		0.0
Gnidia thessioides	Thymeliaceae			0.0		0.0	43	73	3.4	563.8	2.8			0.0		0.0
Grewia occidentalis	Tiliaceae	4	22	2.1	239.0	2.4	30	169	7.9	1271.1	6.4	2	5	0.1	40.0	0.1
Grewia robusta	Tiliaceae	32	190	17.8	1964.3	20.0	33	190	8.9	2193.5	11.0	173	944	25.7	10200.0	26.5
Lantana rugosa	Verbenaceae			0.0		0.0			0.0		0.0	2	2	0.1	5.0	0.0
Priva cordifolia	Verbenaceae	4	5	0.5	11.0	0.1	9	12	0.6	21.8	0.1			0.0		0.0
Rhoicissus species	Vitaceae	2	2	0.2	0.6	0.0	4	6	0.3	18.7	0.1	16	21	0.6	75.0	0.2
Unknown species		0	0	0.0	0.0	0.0	9	24	1.1	43.3	0.2	1	1	0.0	0.0	0.0
Total		**267**	**1067**	**100.0**	**9809.4**	**100.0**	**526**	**2134**	**100.0**	**19985.0**	**100.0**	**915**	**3680**	**100.0**	**38522.0**	**100.0**

Appendix 3

Percentage contribution of browse species to the diet of the black rhino in terms of number of bites (B) and dry mass (DM) in Riparian *Acacia* Thicket, Short *Euphorbia* Thicket and Tall *Euphorbia* Thicket. Nomenclature follows Germishuizen and Meyer (2004).

		Riparian *Acacia* Thicket					**Short *Euphorbia* Thicket**					**Tall *Euphorbia* Thicket**				
		Frequency					**Frequency**					**Frequency**				
Species	**Family**	**Plants**	**Bites**	**%**	**DM**	**%**	**Plants**	**Bites**	**%**	**DM**	**%**	**Plants**	**Bites**	**%**	**DM**	**%**
Acanthaceae spp.	Acanthaceae	30	175	21.2	339.4	5.3	4	20	0.4	64.2	0.2	33	72	2.9	278.1	1.4
Aizoaceae spp.	Aizoaceae	21	28	3.4	212.0	3.3	30	73	1.4	316.3	0.8	9	10	0.4	94.2	0.5
Achyropsis leptostachya	Amaranthaceae	0	0	0.0	0.0	0.0	0	0	0.0	0.0	0.0	10	11	0.4	38.6	0.2
Rhus incisa	Anacardiaceae			0.0		0.0			0.0		0.0			0.0		0.0
Rhus longispina	Anacardiaceae	1.0	1.0	0.1	4.5	0.1	7.0	41.0	0.8	373.7	1.0	4	8	0.3	60.9	0.3
Rhus refracta	Anacardiaceae	1	2	0.2	17.8	0.3	6	35	0.7	178.6	0.5			0.0		0.0
Ozoroa mucronata	Anacardiaceae			0.0		0.0	9	174	3.2	1292.1	3.3	5	30	1.2	208.6	1.1
Carissa haematocarpa	Apocynaceae			0.0		0.0	3	18	0.3	248.5	0.6	10	66	2.6	480.7	2.5
Pacchypodium succulentum	Apocynaceae			0.0		0.0			0.0		0.0	7	11	0.4	247.5	1.3
Ceropegia ampliata	Apocynaceae			0.0		0.0	5	10	0.2	23.5	0.1	2	2	0.1	0.6	0.0
Cussonia spicata	Araliaceae			0.0		0.0			0.0		0.0	4	9	0.4	Excluded	Excluded
Fockea edulis	Asclepiadaceae			0.0		0.0	1	2	0.0	0.3	0.0			0.0		0.0
Sarcostemma viminale	Asclepiadaceae			0.0		0.0	1	7	0.1	39.8	0.1			0.0		0.0
Secamone filiformis	Asclepiadaceae			0.0		0.0			0.0		0.0	2	2	0.1	26.8	0.1
Bulbine frutescence	Asphodelaceae			0.0		0.0			0.0		0.0			0.0		0.0
Brachylaena ilicifolia	Asteraceae			0.0		0.0	27	101	1.9	662.3	1.7			0.0		0.0
Chrysocoma ciliata	Asteraceae	1	6	0.7	16.2	0.3			0.0		0.0			0.0		0.0
Euryops tenuissimus	Asteraceae			0.0		0.0	2	5	0.1	80.0	0.2			0.0		0.0
Helichrysum rosum	Asteraceae			0.0		0.0			0.0		0.0			0.0		0.0
Venidium sp.	Asteraceae	1	1	0.1	0.9	0.0			0.0		0.0			0.0		0.0
Verbecena encelioides	Asteraceae	125	231	28.0	2372.0	37.3			0.0		0.0			0.0		0.0
Rhigozum obovatum	Bignoniaceae			0.0		0.0	19	68	1.3	357.6	0.9	1	1	0.0	4.5	0.0
Tecoma capensis	Bignoniaceae			0.0		0.0			0.0		0.0			0.0		0.0
Ehretia rigida	Boraginaceae			0.0		0.0	1	7	0.1	88.6	0.2	5	6	0.2	110.9	0.6
Cadaba aphylla	Brassicaceae	1	1	0.1	0.9	0.0			0.0		0.0			0.0		0.0
Opuntia ficus-indica	Cactaceae	1	1	0.1	0.0	0.0	1	3	0.1	Excluded	Excluded	1	1	0.0	Excluded	Excluded
Schotia afra	Caesalpiniaceae			0.0		0.0	11	75	1.4	693.9	1.8	1	2	0.1	20.3	0.1
Capparis sepiara	Capparaceae			0.0		0.0	3	7	0.1	48.8	0.1	4	14	0.6	214.8	1.1
Gymnosporia buxifolia	Celastraceae	1	4	0.5	19.9	0.3	1	3	0.1	10.1	0.0	2	2	0.1	6.8	0.0
Gymnosporia capitata	Celastraceae			0.0		0.0	19	114	2.1	777.7	2.0	4	14	0.6	124.1	0.6
Gymnosporia polycantha	Celastraceae	5	13	1.6	91.7	1.4	10	22	0.4	40.9	0.1			0.0		0.0
Maytenus peduncularis	Celastraceae			0.0		0.0			0.0		0.0	4	50	2.0	342.0	1.8
Putterlickia pyracantha	Celastraceae			0.0		0.0			0.0		0.0	5	13	0.5	51.6	0.3
Commelina africana	Commelinaceae			0.0		0.0	1	2	0.0	0.9	0.0			0.0		0.0
Crassula perfoliata	Crassulaceae			0.0		0.0			0.0		0.0			0.0		0.0
Crassula species	Crassulaceae			0.0		0.0			0.0		0.0			0.0		0.0

Kalanchoe rotundifolia	Crassulaceae			0.0		0.0	1	3	0.1	4.7	0.0			0.0		0.0
Sanseveria hyacinthioides	Dracaenaceae			0.0		0.0	1	2	0.0	Excluded	Excluded			0.0		0.0
Diospyros lycioides	Ebenaceae			0.0		0.0			0.0		0.0			0.0		0.0
Diospyros scabrida	Ebenaceae			0.0		0.0			0.0		0.0			0.0		0.0
Euclea undulata	Ebenaceae			0.0		0.0	27	210	3.9	4047.2	10.4	5	30	1.2	365.3	1.9
Acalypha glabrata	Euphorbiaceae	6	35	4.2	384.5	6.0			0.0		0.0	25	104	4.2	689.3	3.6
Croton rivularis	Euphorbiaceae			0.0		0.0			0.0		0.0			0.0		0.0
Euphorbia mauritanica	Euphorbiaceae			0.0		0.0	6	27	0.5	132.3	0.3			0.0		0.0
Euphorbia bothae	Euphorbiaceae			0.0		0.0	424	2719	50.5	15100.4	38.9			0.0		0.0
Euphorbia pentagona	Euphorbiaceae			0.0		0.0	5	24	0.4	87.9	0.2	2	5	0.2	41.7	0.2
Euphorbia tetragona	Euphorbiaceae			0.0		0.0			0.0		0.0	19	191	7.6	1576.5	8.2
Euphorbia triangularis	Euphorbiaceae	2	22	2.7	123.1	1.9			0.0		0.0	18	208	8.3	1323.9	6.9
Jatropha capensis	Euphorbiaceae			0.0		0.0	15	40	0.7	148.8	0.4	69	341	13.6	2138.5	11.1
Phyllanthus verrucosus	Euphorbiaceae			0.0		0.0			0.0		0.0	4	8	0.3	26.9	0.1
Indigofera hedyantha	Fabaceae			0.0		0.0			0.0		0.0			0.0		0.0
Indigofera sessilifolia	Fabaceae			0.0		0.0			0.0		0.0			0.0		0.0
Scolopia zeyheri	Flacourtiaceae			0.0		0.0			0.0		0.0			0.0		0.0
Dietes vegeta	Iridaceae			0.0		0.0			0.0		0.0	1	5	0.2	0.0	0.0
Leucas capensis	Lamiaceae	9	20	2.4	40.2	0.6	4	11	0.2	14.8	0.0	8	15	0.6	19.7	0.1
Asparagus spp.	Liliaceae	3	4	0.5	20.2	0.3	49	136	2.5	251.6	0.6	32	46	1.8	124.4	0.6
Asparagus striatus	Liliaceae			0.0		0.0	19	52	1.0	81.3	0.2	3	9	0.4	26.6	0.1
Buddleja saligna	Loganiaceae			0.0		0.0	1	3	0.1	23.4	0.1	2	11	0.4	76.4	0.4
Viscum rotundifolia	Loranthaceae			0.0		0.0			0.0		0.0			0.0		0.0
Abutilon sonneratianum	Malvaceae			0.0		0.0			0.0		0.0			0.0		0.0
Hermannia gracilis	Malvaceae			0.0		0.0	8	20	0.4	22.4	0.1			0.0		0.0
Pavonia pravescence	Malvaceae			0.0		0.0			0.0		0.0	1	1	0.0	4.5	0.0
Mesembryanthemaceae spp.	Mesembryanthemaceae	0	0	0.0	0.0	0.0	29	87	1.6	577.0	1.5	4	4	0.2	61.7	0.3
Acacia karroo	Mimosaceae	21	39	4.7	166.7	2.6			0.0		0.0			0.0		0.0
Jasminum angularae	Oleaceae			0.0		0.0	2	8	0.1	28.2	0.1	6	21	0.8	126.4	0.7
Olea europaea	Oleaceae			0.0		0.0			0.0		0.0	3	18	0.7	91.1	0.5
Plumbago auriculata	Plumbaginaceae	15	165	20.0	1966.0	30.9	11	47	0.9	209.8	0.5	67	656	26.2	5992.5	31.1
Panicum maximum	Poaceae			0.0		0.0	1	3	0.1	1.2	0.0			0.0		0.0
Portulacaria afra	Portulaccaceae			0.0		0.0	5	16	0.3	644.9	1.7			0.0		0.0
Ptaeroxylon obliquum	Ptaeroxylaceae			0.0		0.0			0.0		0.0	2	10	0.4	97.5	0.5
Scutia myrtina	Rhamnaceae			0.0		0.0			0.0		0.0			0.0		0.0
Coddia rudis	Rubiaceae			0.0		0.0			0.0		0.0	17	150	6.0	1820.8	9.4
Azima tetracantha	Salvadoraceae	9	39	4.7	218.4	3.4	26	182	3.4	1313.2	3.4	24	121	4.8	741.0	3.8
Allophylus decipiens	Sapindaceae			0.0		0.0			0.0		0.0			0.0		0.0
Hippobromus pauciflorus	Sapindaceae			0.0		0.0			0.0		0.0	1	1	0.0	4.5	0.0
Pappea capensis	Sapindaceae			0.0		0.0	1	2	0.0	0.6	0.0	1	2	0.1	18.4	0.1
Selago geniculata	Scrophulariaceae	1	2	0.2	18.4	0.3			0.0		0.0			0.0		0.0
Lycium ferocissimum	Solanaceae	6	6	0.7	48.9	0.8	22	97	1.8	575.7	1.5	13	35	1.4	156.6	0.8
Solanum coccinium	Solanaceae			0.0		0.0			0.0		0.0	1	2	0.1	10.1	0.1
Solanum rigidum	Solanaceae			0.0		0.0			0.0		0.0	1	1	0.0	4.5	0.0

Gnidia cuneata	Thymeliaceae			0.0		0.0	2	12	0.2	36.3	0.1	5	10	0.4	52.4	0.3
Gnidia thessioides	Thymeliaceae			0.0		0.0			0.0		0.0			0.0		0.0
Grewia occidentalis	Tiliaceae	3	17	2.1	209.4	3.3			0.0		0.0	14	32	1.3	297.6	1.5
Grewia robusta	Tiliaceae			0.0		0.0	141	835	15.5	10091.6	26.0	29	124	5.0	1023.5	5.3
Lantana rugosa	Verbenaceae			0.0		0.0			0.0		0.0	1	1	0.0	5.0	0.0
Priva cordifolia	Verbenaceae	2	2	0.2	36.2	0.6			0.0		0.0	6	8	0.3	12.4	0.1
Rhoicissus species	Vitaceae	0	0	0.0	0.0	0.0	22	52	1.0	79.2	0.2	3	6	0.2	15.1	0.1
Unknown species		7	8	1.0	23.6	0.4	2	6	0.1	1.2	0.0	4	5	0.2	16.0	0.1
Total		**272**	**822**	**100.0**	**6330.7**	**100.0**	**985**	**5381**	**100.0**	**38771.1**	**100.0**	**504**	**2505**	**100.0**	**19271.5**	**100.0**

Appendix 4

Dominant woody species in number of plants/ha for three vegetation types. Only species contributing ≥ 50 plants/ha are presented.

Medium *Portulacaria* Thicket

Species	Density	Species	Density
Portulacaria afra	3504	*Ptaeroxylon obliquum*	167
Jatropha capensis	1460	*Coddia rudis*	164
Grewia robusta	956	*Ozoroa mucronata*	162
Phyllanthus verrucosus	781	*Schotia afra*	152
Euphorbia bothae	558	*Ehretia rigida*	127
Rhigozum obovatum	533	*Jasminum angularae*	85
Brachylaena ilicifolia	480	*Azima tetracantha*	67
Euclea undulata	454	*Carissa haematocarpa*	64
Gymnosporia capitata	291	*Capparis sepiara*	62
Asparagus species	267	*Gymnosporia buxifolia*	62
Rhoicissus species	231	*Pappea capensis*	60

Short *Euphorbia* Thicket

Species	Density	Species	Density
Euphorbia bothae	2166	*Lycium ferocissimum*	127
Rhigozum obovatum	1006	*Leucas capensis*	97
Grewia robusta	463	*Asparagus species*	88
Gymnosporia polycantha	287	*Jatropha capensis*	78
Gymnosporia capitata	287	*Ehretia rigida*	52
Brachylaena ilicifolia	137		

Tall *Euphorbia* Thicket

Species	Density	Species	Density
Ehretia rigida	1870	*Lycium ferocissimum*	179
Grewia occidentalis	1173	*Rhus lucida*	154
Phyllanthus verrucosus	709	*Grewia robusta*	138
Azima tetracantha	641	*Euphorbia tetragona*	137
Plumbago auriculata	614	*Coddia rudis*	118
Asparagus species	611	*Schotia afra*	116
Rhus refracta	487	*Gymnosporia buxifolia*	111
Jatropha capensis	476	*Olea europaea*	111
Leucas capensis	472	*Brachylaena ilicifolia*	103
Euphorbia triangularis	338	*Capparis sepiara*	103
Gymnosporia polycantha	290	*Diospyros scabrida*	100
Pappea capensis	264	*Rhoicissus species*	89
Ptaeroxylon obliquum	226	*Rhigozum obovatum*	64
Gymnosporia capitata	205	*Cussonia spicata*	62
Putterlickia pyracantha	203	*Euclea undulata*	61
Hibiscus sp	197		

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Appendix 5

The Bonferroni confidence intervals[1] and forage ratio (FR) values for the utilization of woody browse species in the diet of the black rhino in Medium *Portulacaria* Thicket where availability is determined from plants adjacent to browsed individuals on backtracks.

MPT					Bonferroni Interval			
Species	**f_1**	**p_1**	**f_2**	**p_2**	**lower**		**upper**	**FR**
Acacia karroo	4	0.005	15	0.008	-0.002	≤ p ≤	0.013	0.67
Asparagus species	**52**	**0.067**	**153**	**0.078**	**0.040**	≤ p ≤	**0.093**	**0.85**
Azima tetracantha	**18**	**0.023**	**26**	**0.013**	**0.007**	≤ p ≤	**0.039**	**1.74**
Brachylaena ilicifolia	**38**	**0.049**	**108**	**0.055**	**0.026**	≤ p ≤	**0.072**	**0.88**
Capparis sepiara	**12**	**0.015**	**20**	**0.010**	**0.002**	≤ p ≤	**0.028**	**1.50**
Carissa haematocarpa	3	0.004	21	0.011	-0.003	≤ p ≤	0.010	0.36
Coddia rudis	**37**	**0.047**	**40**	**0.020**	**0.025**	≤ p ≤	**0.070**	**2.32**
Ehretia rigida	4	0.005	16	0.008	-0.002	≤ p ≤	0.013	0.63
Euclea undulata	**37**	**0.047**	**77**	**0.039**	**0.025**	≤ p ≤	**0.070**	**1.20**
Euphorbia bothae	**17**	**0.022**	**32**	**0.016**	**0.006**	≤ p ≤	**0.037**	**1.33**
Euphorbia mauritanica	**6**	**0.008**	**31**	**0.016**	**-0.002**	≤ p ≤	**0.017**	**0.49**
Grewia robusta	**173**	**0.222**	**286**	**0.146**	**0.177**	≤ p ≤	**0.266**	**1.52**
Gymnosporia capitata	**26**	**0.033**	**75**	**0.038**	**0.014**	≤ p ≤	**0.052**	**0.87**
Gymnosporia polyacantha	1	0.001	11	0.006	-0.003	≤ p ≤	0.005	0.23
Jasminum angularae	**14**	**0.018**	**51**	**0.026**	**0.004**	≤ p ≤	**0.032**	**0.69**
Jatropha capensis	**119**	**0.152**	**162**	**0.083**	**0.114**	≤ p ≤	**0.191**	**1.84**
Leucas capensis	4	0.005	30	0.015	-0.002	≤ p ≤	0.013	0.33
Lycium ferocissimum	**30**	**0.038**	**43**	**0.022**	**0.018**	≤ p ≤	**0.059**	**1.75**
Ozoroa mucronata	4	0.005	18	0.009	-0.002	≤ p ≤	0.013	0.56
Phyllanthus verrucosus	**11**	**0.014**	**36**	**0.018**	**0.002**	≤ p ≤	**0.027**	**0.77**
Portulacaria afra	**19**	**0.024**	**276**	**0.141**	**0.008**	≤ p ≤	**0.041**	**0.17**
Ptaeroxylon obliquum	0	0.000	8	0.004	—	—	—	0.00
Rhigozum obovatum	**99**	**0.127**	**235**	**0.120**	**0.091**	≤ p ≤	**0.162**	**1.06**
Rhoicissus tridentata	**16**	**0.020**	**89**	**0.045**	**0.005**	≤ p ≤	**0.036**	**0.45**
Rhus refracta	**5**	**0.006**	**12**	**0.006**	**-0.002**	≤ p ≤	**0.015**	**1.04**
Schotia afra	**22**	**0.028**	**65**	**0.033**	**0.011**	≤ p ≤	**0.046**	**0.85**
Acalypha glabrata	2	0.003	2	0.001	-0.003	≤ p ≤	0.008	2.51
Boscia oleoides	0	0.000	1	0.001	—	—	—	0.00
Ellusine crocea	0	0.000	2	0.001	—	—	—	0.00
Euphorbia pentagona	1	0.001	1	0.001	-0.003	≤ p ≤	0.005	2.51
Grewia occidentalis	2	0.003	3	0.002	-0.003	≤ p ≤	0.008	1.67
Pappea capensis	1	0.001	3	0.002	-0.003	≤ p ≤	0.005	0.84
Plumbago auriculata	3	0.004	4	0.002	-0.003	≤ p ≤	0.010	1.88
Putterlickia pyracantha	0	0.000	4	0.002	—	—	—	0.00
Rhus longispina	1	0.001	2	0.001	-0.003	≤ p ≤	0.005	1.25
Total	781	1	1958	1				

[1] where $\alpha = 0.05$, $k = 35$, $Z_{\alpha/2k} = 2.982698$, $n = 197$

Species in bold: $np_1 \geq 5$ and $n(1-p_1) \geq 5$; species above line: availability ≥ 5; Species shaded grey: difference at 0.05 level of significance

f_1: number of individuals recorded in diet — p_1: proportion of species in the diet

f_2: number of individuals recorded as available — p_2 expected proportion of species in the diet

Appendix 6
An assessment of the condition of Medium *Portulacaria* Thicket for black rhino in the Great Fish River Reserve.

Species	n1	Density	%	Potential BU / ha	Forage Factor	Acceptable BU / ha
Grewia robusta	76	956	8.7	445	0.251	111.6
Jatropha capensis	72	1460	13.3	311	0.175	54.4
Euphorbia bothae	30	558	5.1	154	0.336	51.7
Euclea undulata	94	454	4.1	207	0.201	41.6
Coddia rudis	8	164	1.5	29	1.000	29.2
Ozoroa mucronata	78	162	1.5	92	0.309	28.5
Rhigozum obovatum	90	533	4.8	297	0.062	18.4
Brachylaena ilicifolia	56	480	4.4	223	0.080	17.9
Asparagus spp.	13	267	2.4	112	0.105	11.7
Gymnosporia capitata	103	291	2.6	167	0.065	10.9
Schotia afra	38	152	1.4	99	0.081	8.0
Carissa haematocarpa	6	64	0.6	28	0.222	6.1
Portulacaria afra	533	3504	31.8	1757	0.003	5.3
Jasminum angularae	7	85	0.8	36	0.132	4.7
Rhoicissus tridentata	17	231	2.1	58	0.076	4.4
Azima tetracantha	10	67	0.6	29	0.152	4.4
Lycium ferocissimum	3	42	0.4	10	0.338	3.5
Plumbago auriculata	2	41	0.4	8	0.447	3.5
Capparis sepiara	3	62	0.6	16	0.115	1.8
Phyllanthus verrucosus	38	781	7.1	250	0.007	1.7
Euphorbia mauritanica	1	21	0.2	3	0.308	0.9
Maytenus peduncularis	3	2	0.0	2	0.323	0.5
Ptaeroxylon obliquum	12	167	1.5	34	0.013	0.4
Leucas capensis	2	41	0.4	8	0.040	0.3
Rhus refracta	3	23	0.2	8	0.038	0.3
Cussonia spicata	5	44	0.4	4	0.058	0.3
Pappea capensis	52	60	0.5	36	0.005	0.2
Ehretia rigida	11	127	1.2	43	0.004	0.2
Gymnosporia buxifolia	3	62	0.6	13	0.011	0.1
Gymnosporia polyacantha	6	6	0.1	4	0.017	0.1
Opuntia ficus-indica	1	1	0.0	1	0.048	0.0
Grewia occidentalis	1	21	0.2	1	0.020	0.0
Putterlickia pyracantha	1	1	0.0	1	0.017	0.0
Boscia oleoides	7	5	0.0	0	0.000	0.0
Cassine crocea	3	22	0.2	8	0.000	0.0
Diospyros scabrida	2	41	0.4	11	0.000	0.0
Scolopia zeyheri	2	2	0.0	1	0.000	0.0
Total:	**1392**	**11001**	**100**	**4504**		**422.6**

n1 = number of plants recorded in the veld condition assessment sites
Density = number of plants per hectare
% = percent occurrence of each species
Potential BU/ha = Number of browsing units per hectare available to black rhino irrespective of palatability
Forage Factor = browse value of a woody species based on the Preference Index and ranging between 0 and 10
Acceptable BU/ha = Number of browsing units per hectare available and acceptable to black rhino

Appendix 7

An assessment of the condition of Short *Euphorbia* Thicket for black rhino in the Great Fish River Reserve.

Species	n1	Density	%	Potential BU / ha	Forage Factor	Acceptable BU / ha
Euphorbia bothae	241	2171	41.33	640	0.336	214.9
Grewia robusta	127	464	8.83	227	0.251	57.0
Rhigozum obovatum	180	1008	19.19	434	0.062	26.9
Lycium ferocissimum	13	127	2.42	29	0.338	9.6
Gymnosporia capitata	167	288	5.48	125	0.065	8.1
Brachylaena ilicifolia	58	137	2.61	75	0.080	6.0
Euclea undulata	24	42	0.80	15	0.201	3.0
Euphorbia mauritanica	5	31	0.58	8	0.308	2.6
Schotia afra	47	38	0.73	31	0.081	2.5
Plumbago auriculata	3	29	0.56	5	0.447	2.4
Jatropha capensis	8	78	1.49	10	0.175	1.8
Asparagus spp.	10	88	1.68	17	0.105	1.8
Jasminum angularae	5	40	0.75	12	0.132	1.6
Ozoroa mucronata	10	6	0.12	5	0.309	1.6
Carissa haematocarpa	12	8	0.14	7	0.222	1.6
Gymnosporia polyacantha	51	288	5.48	80	0.017	1.4
Azima tetracantha	10	25	0.47	7	0.152	1.1
Pachypodium succulentum	1	10	0.19	2	0.363	0.6
Leucas capensis	10	98	1.86	13	0.040	0.5
Rhus longispina	10	6	0.12	5	0.093	0.5
Rhus refracta	20	12	0.23	11	0.038	0.4
Rhoicissus tridentata	9	15	0.28	5	0.076	0.4
Acacia karroo	4	12	0.22	4	0.097	0.4
Opuntia ficus-indica	7	4	0.08	3	0.048	0.2
Phyllanthus verrucosus	5	49	0.93	12	0.007	0.1
Portulacaria afra	28	45	0.85	24	0.003	0.1
Putterlickia pyracantha	2	20	0.37	4	0.017	0.1
Ehretia rigida	10	52	0.99	15	0.004	0.1
Pappea capensis	16	28	0.53	9	0.005	0.0
Cussonia spicata	2	10	0.20	0	0.058	0.0
Aloe ferox	5	21	0.41	2	0.000	0.0
Boscia oleoides	5	3	0.06	2	0.000	0.0
Diospyros lycioides	1	1	0.01	0	0.000	0.0
Totals:	**1106**	**5253**	**100**	**1839**		**347**

n1 = number of plants recorded in the veld condition assessment sites
Density = number of plants per hectare
% = percent occurrence of each species
Potential BU/ha = Number of browsing units per hectare available to black rhino irrespective of palatability
Forage Factor = browse value of a woody species based on the Preference Index and ranging between 0 and 10
Acceptable BU/ha = Number of browsing units per hectare available and acceptable to black rhino

Appendix 8

An assessment of the condition of Tall *Euphorbia* Thicket for black rhino in the Great Fish River Reserve.

Species	n1	Density	%	Potential BU / ha	Forage Factor	Acceptable BU / ha
Acacia karroo	10	13	0.12	10	0.097	0.96
Acalypha glabrata	2	40	0.36	2	1.000	1.98
Asparagus species	32	613	5.64	110	0.105	11.54
Azima tetracantha	83	648	5.95	227	0.152	34.43
Brachylaena ilicifolia	9	104	0.96	33	0.080	2.67
Capparis sepiara	8	104	0.95	27	0.115	3.11
Carissa haematocarpa	2	21	0.20	9	0.222	2.00
Cassine crocea	12	12	0.11	9	0.000	0.00
Coddia rudis	6	119	1.09	10	1.000	9.59
Cussonia spicata	30	63	0.58	11	0.058	0.63
Diospyros scabrida	6	100	0.92	35	0.000	0.00
Dovyalis cafra	9	45	0.41	11	0.000	0.00
Ehretia rigida	156	1883	17.30	472	0.004	1.89
Euclea undulata	44	64	0.58	26	0.201	5.31
Euphorbia tetragona	132	144	1.32	420	0.044	18.50
Euphorbia triangularis	179	306	2.81	433	0.047	20.35
Grewia occidentalis	73	1179	10.83	182	0.020	3.64
Grewia robusta	8	139	1.28	63	0.251	15.82
Gymnosporia buxifolia	34	113	1.04	33	0.011	0.36
Gymnosporia capitata	78	211	1.94	88	0.065	5.74
Gymnosporia polycantha	25	292	2.69	60	0.017	1.02
Heteromorpha trifoliata	1	2	0.01	1	0.000	0.00
Hibiscus sp.	10	198	1.82	46	0.000	0.00
Hippobromus pauciflorus	5	42	0.39	2	0.048	0.12
Jatropha capensis	27	478	4.39	115	0.175	20.08
Leucas capensis	24	474	4.36	51	0.040	2.02
Lycium ferocissimum	10	180	1.65	40	0.338	13.40
Maytenus peduncularis	21	46	0.42	13	0.323	4.25
Olea europaea	15	112	1.03	33	0.053	1.74
Opuntia ficus-indica	2	40	0.36	4	0.048	0.18
Ozoroa mucronata	18	39	0.36	17	0.309	5.29
Pappea capensis	78	269	2.47	69	0.005	0.34
Phyllanthus verrucosus	37	712	6.54	179	0.007	1.25
Plumbago auriculata	35	617	5.67	142	0.447	63.31
Portulacaria afra	1	1	0.01	0	0.003	0.00
Ptaeroxylon obliquum	38	228	2.10	42	0.013	0.54
Purple leaved spp.	1	20	0.18	1	0.000	0.00
Putterlickia pyracantha	14	204	1.88	68	0.017	1.15
Rhigozum obovatum	6	64	0.59	14	0.062	0.86
Rhoicissus tridentata	14	90	0.83	38	0.076	2.86
Rhus longispina	24	179	1.64	52	0.093	4.82
Rhus refracta	66	492	4.52	118	0.038	4.48
Schotia afra	55	119	1.10	58	0.081	4.70
Scolopia zeyheri	4	42	0.38	5	0.000	0.00
Scutia myrtina	3	4	0.03	4	0.000	0.00
Tecoma capensis	1	20	0.18	6	0.000	0.00
Total	**1448**	**10882**	**100**	**3387**		**271**

n1 = number of plants recorded in the veld condition assessment sites
Density = number of plants per hectare
% = percent occurrence of each species
Potential BU/ha = Number of browsing units per hectare available to black rhino irrespective of palatability
Forage Factor = browse value of a woody species based on the Preference Index and ranging between 0 and 10
Acceptable BU/ha = Number of browsing units per hectare available and acceptable to black rhino