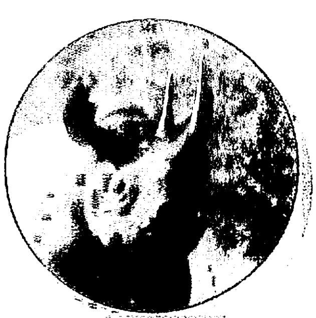
Feeding behaviour of the black rhinoceros *(Diceros bicornis)* in Great Fish River Reserve, South Africa

By Cecilie Ausland & Anne Marie Sveipe 2000



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Acknowledgements

The first intention of this study was to use goats as study animals. But suddenly our supervisor Jan Raats gave us black rhinos instead! We could not resist, even if our supervisor in Norway had some worries about what his students was getting into. And we do not regret that we chose the charming black rhinos as study animals. A special thanks to our rhino friends in the reserve for being there at the right time, and Boris; thank you for being so kind and give us the front side picture. Without help from the brave field rangers this study could not have been done. By sharing your knowledge with us and be patient during the long days in the field, we were able to do this study.

We would like to express gratitude to Prof. Jan Raats at Fort Hare University in South Africa, for all the help during the stay in South Africa. Jan's family, and especially Susan, also deserves warm thanks for hospitality and for sharing their home with us. Our supervisor at the Agricultural University of Norway Dr. LarsOlav Eik, should have applause for being with us all the way despite rhinos. We also got very good help from Dr. Øystein Holand, a man not knowing the word "no". Your constructive criticism and valuable advices were always very helpful to us. Dr. Tormod Ådnøy was our guardian angel when questions about the statistics were brought up, which they often were.

We would like to express our deepest gratitude to Mr Brad Fike, manager of the reserve, who provided all the help we needed during the fieldwork. Thanks also to Brad's wife Mary and their guard dogs. This thesis is made for you and your rhinos, Brad!

At this stage it is also time to thank each other for a first-class cooperation and hopefully a good piece of work. We have both learnt at least more about cooperation, but most about black rhinos! And thanks to all of you out there for being there for us.

Ås, December 2000

Cecilie Ausland　　　　　　　　　　Anne Marie Sveipe

Summary

As part of the conservation plan of the threatened black rhinoceros, several animals have been translocated to new conservation areas. The Great Fish River Reserve supports a population of 46 black rhinos, which have been moved from Kwazulu-Natal. The reserve is situated on the south side of the Great Fish River in the Eastern Cape, South Africa. The objective of this study was to describe the feeding ecology of these rhinos.

The reserve is covered by Valley bushveld thicket, which consists of densely wooded vegetation, about 2-3 m high. The rhino is a browser and is recognized to be dangerous to human on foot. Due to the dense vegetation type a plant based method was found to be adequate in this study. The fieldwork was conducted from February to April 2000, and the results therefore describe the summer diet of the rhinos. The main method used for the fieldwork was a tracking method where fresh feeding tracks of rhinos were examined. Measurements taken on each of the 662 plants browsed by rhino were scientific name of plant, distance between each browsed plant, feeding height, number of browsed twigs, number of bites, utilisation level, browsing level (previous) and height of plant. A different measurement technique was used for stem succulents and data on height of the stem succulent, browsing level (previous) and utilisation level was recorded.

To be able to determine preferred plant species of the rhino, availability studies were done at 20 of the 22 feeding tracks. The four most preferred species eaten by the rhinos, together with two rejected species, were sampled in order to do chemical analyses. A harvesting index was used for estimating the amount of plant material consumed of each plant by the rhinos.

Results show that the rhinos browsed 45 different plant species from 22 families during the six weeks of fieldwork. Four species contributed to 60 % of the total diet, and the succulent *Euphorbia bothae* contributed alone to one third of the diet. This succulent contains strong toxicants, but it does not seem to affect the rhinos in the reserve. The rhinos selected highest number of twigs with diameter between 0-5 mm, while twigs eaten with diameters between 6-10 mm contributed mostly to the total amount of harvested material removed from the plant. Distances between browsed plants seemed to be affected by preferred species. Previously browsed plants were preferred, and the largest proportion of bites was taken below 1 m at the plants.

Three ranking methods of plant species were used, based on the different measurements done. The rankings were done according to 1) number of plants browsed, 2) preferred plant species based on a preference index, and 3) browse material harvested from each plant based on a harvesting index. When comparing the different ranking methods of plant species, we found that the plant species ranking highest are similar on all three lists, however not in the exact same order. This indicates that the least time consuming method may be used in a similar study, and also that the rhinos have many of the preferred species in their habitat.

Chemical analyses show that there were few significant differences of dry matter (DM) content per twig, leaf-DM per twig, leaf:stem ratio, crude protein levels and neutral detergent fibre levels between the preferred species and the rejected species. These results were discussed in relation to optimal foraging theory, but we were not able to confirm that rhinos were selecting food items according to this theory. Our results indicate that the factors considered here are not the major factors influencing the preferences of food plants. Based on our results, it was not possible to explain why the rhino prefer to eat large amounts of *E. bothae* in this study area. However, we could reject the previously used theory of rhinos selecting *Euphorbia spp.* because they need water.

Sammendrag (summary in Norwegian)

Som en del av forvaltningsplanen for den truede arten svarte neshorn, har flere neshorn blitt flyttet til nye områder. I Great Fish River reservatet finnes en populasjon med 46 svarte neshorn som er flyttet fra Kwazulu-Natal. Dette reservatet ligger sør for elven Great Fish i Eastern Cape, Sør-Afrika. Formålet med oppgaven var å beskrive beiteatferden til neshornene.

Vegetasjonen i reservatet er dekket med en vegetasjonstype som kalles Valley bushveld, og denne består av tett skog/buskas som er ca 2-3 m høy. Neshornet er en "browser" (kvist-og konsentratbeiter) og er kjent for å være aggressiv mot mennesker. På grunn av den tette vegetasjonen ble det besluttet at en plantebasert metode den mest hensiktsmessige i dette studiet. Feltarbeidet ble utført mellom februar og april 2000, og beskriver derfor bare sommerdietten til neshornet. Hovedsaklig metode ved studiet bestod i å spore ferske beitespor av neshornene, og gjøre undersøkelser av all vegetasjon langs dette sporet. Målinger på hver enkelt av de 662 plantene som ble funnet beitet var: vitenskapelig navn på planten, distanse mellom hver beitet plante, beitehøyde, antall spiste kvist, antall bitt, utnyttingsgraden av planten, grad av tidligere beiting og høyde på planten. For sukkulenter ble det brukt en annen måleteknikk, der høyde på planten, grad av tidligere beiting og utnyttingsgrad av planten ble målt.

For å kunne estimere preferansen av plantearter hos neshornet ble det gjort bestemmelse av tilgjengelighet av arter på 20 av totalt 22 spor. Det ble tatt planteprøver fra fire av de mest prefererte planteartene til kjemiske analyser, sammen med to av de lite spiste artene. Estimering av det totale plantematerialet som ble fjernet fra hver plante etter beiting av neshornet, ble gjort ved hjelp av en "harvesting index".

Resultatene viser at neshornene beitet på 45 forskjelige plantearter fra 22 familier i løpet av det seks uker lange feltarbeidet. Fire arter bidro med 60 % av den totale dietten, mens sukkulenten *Euphorbia bothae* alene utgjorde en tredjedel. Sukkulenten inneholder sterke plantegifter som ikke ser ut til å påvirke neshornet. Det høyeste antallet spiste kvist var mellom 0-5 mm, mens størst inntak av plantemasse ble utgjort av kvist med størrelse mellom 6-10 mm. Prefererte plantearter ser ut til å påvirke neshornets distanse mellom spiste planter. Planter som viste tegn til å ha blitt beita på før ble preferert. Flest bitt av plantene ble gjort under 1 m.

Basert på de forskjellige metodene som ble brukt, ble tre ulike måter å rangere resultatene på sammenlignet. Rangeringsmetodene baserte seg på 1) antallet planter som var beitet på, 2) prefererte arter basert på en preferanseindex og 3) plantemasse fjernet fra plantene etter beiting, beregnet ved hjelp av en "harvesting index". Ved sammenligning av disse metodene, kan det ses at de samme planteartene finnes på toppen av alle tre lister, om ikke i den samme rekkefølgen. Dette kan tyde på at man ved fremtidige lignede studier kan velge den metoden som er minst tidkrevende, og at neshornet har god tilgang på sine mest prefererte arter i deres nåværende habitat.

De kjemiske analysene viser at det er få signifikante forskjeller i tørstoff (TS) innhold pr kvist, løv-TS pr kvist, løv-stamme forhold, protein innhold og fiber innhold mellom de prefererte og de ikke-prefererte artene. Disse resultatene ble diskutert i forhold til optimalitetsteorien, uten at vi kunne bekrefte at neshornene selekterer planter ut fra denne teorien. Våre resultater indikerer at det finnes andre faktorer enn de som er undersøkt her, som er med på å bestemme neshornets valg av arter. Basert på våre resultater er det ikke mulig å fastslå grunnen til at neshornene i dette området velger å spise store mengder av *Euphorbia spp.*. Likevel er vi stand til å avvise teorien om at neshornet velger disse plantene ut fra liten mulighet til annen vanntilgang.

1 Introduction

The black rhinoceros, *Diceros bicornis*, hereafter referred to as "black rhino" or only "rhino", is classified as Critically Endangered in the International Union for the Conservation of Nature (IUCN) 1996 Red List of Threatened Animals. It is known as one of the most charismatic megaherbivores left on our planet and has become a flagship species for international conservation.

In the early 19th century it was reported that several hundred thousand animals of black rhinos roamed the African continent from central-west Africa to the slopes of Table Mountain in the far south (Skinner & Smither 1990, Emslie & Brooks 1999). During the 19th century, the black rhino was hunted relentlessly across most of central-west and eastern Africa (Emslie & Brooks 1999). According to Skinner & Smither (1990) the last black rhino in the Cape Province was shot at Graaf Reinet in 1880. The proclamation of the Hluhluwe and Umfolozi Game Reserve in Natal in 1897 and the Mkuzi Game Reserve in Zululand in 1912 came just in time to save the black rhino in southern Africa from extinction. In Emslie & Brooks (1999) it is reported that probably over 100 000 black rhinos were still roaming Africa in the 1960s, while the number in 1997 were 2 600 animals. This large decrease came as a result of poaching during the 1970s and 1980s. For the first time since the compilation of continental statistics began, the black rhino numbers in the wild are now showing a slight increase.

The black rhino, once occurring virtually throughout the entire African continent, does today remain only in small, isolated populations in protected wildlife areas, primarily in Kenya, Tanzania, Zimbabwe, Namibia and South Africa (Stuart & Stuart 1997). Emslie & Brooks (1999) emphasize that the future of the black rhino depends on the development and operation of effective conservation strategies. Programs and action plans for the conservation of black rhino exist at international, continental, regional and national level. The common objectives of rhino conservation strategies are to develop and conserve genetically viable populations of each subspecies and to support captive breeding programmes.

There are five species of rhinoceros in the world, namely black, white, Sumatran, Javan and Indian rhinoceros. The two African species are the black and the white. The African Elephant and Rhino Specialist Group of IUCN recognises four subspecies of black rhinoceros, which occur in different areas (Skinner & Smither 1990, Emslie & Brooks 1999). The subspecies are the western (*Diceros bicornis longipedes*), the eastern (*Diceros bicornis michaeli*), the south-western (*Diceros bicornis bicornis*) and the south-central (*Diceros bicornis minor*). The *Diceros bicornis minor* is the most numerous of the black rhino subspecies, and is the subspecies historically occurring in the area of this study (Emslie & Brooks 1999).

The name "black" rhino is confusing, as the skin colour not is black but dark grey. The other common name; "hook-lipped", is more appropriate, referring to the pointed, triangular-shaped prehensile upper lip (Stuart & Stuart 1997). The black rhino is a browsing non-ruminant and require a habitat providing adequate shrubs and young trees up to about 4 m high, including well developed woodland or thickets in which to shelter during the heat of the day (Skinner & Smither 1990). Rhinos show a regular feeding rhythm with peaks in dawn and dusk (Joubert & Eloff 1971, Mukinya 1977), and resting periods in the middle of the day (Skinner & Smither 1990).

Black rhinos have a well-developed acoustic perception and smell but are still vulnerable to man, mostly because of their poor eyesight (Schenkel & Schenkel-Hulliger 1969). They are renowned for their unpredictability and aggressive charges, towards both vehicles and humans on foot (Schenkel & Schenkel-Hulliger 1969, Owen-Smith 1988, Skinner & Smither 1990). This can make free-ranging rhinos difficult to study, particularly in vegetation lacking tall trees to climb!

The Great Fish River Reserve is home to a relative large population of *Diceros bicornis minor*. The reserve is situated in Eastern Cape and is divided by Great Fish River. The river is the historic boundary between the former Ciskei "homeland" to the north-east and the old Eastern Cape Province to the south-west. The former Sam Knott Nature Reserve, Andries Vosloo Kudu Reserve and Double Drift Game Reserve together form the complex of Great Fish River Reserve, which we hereafter will refer to as "the reserve". In the Great Fish River Reserve Management Plan (Hahndiek *et* al. 1998) it is described that Andries Vosloo Kudu Reserve was established in 1973 on land that had been previously used exclusively for pastoral agriculture. More land has been added to the reserve since then, due to donations of previous farmland. Sam Knott Nature Reserve was founded in 1987. On the former Ciskei side of the Great Fish River, Double Drift Game Reserve was established in 1982.

According to Fike (1999) the first black rhinos were reintroduced into the reserve in 1986 and subsequent introductions have taken place in 1989, 1990, 1991 and 1997. Prior to year 2000, all the rhinos have been released on the southern side of the river and are staying there permanently, not known to move across the river. In May - August 2000 twenty animals were introduced to the Double Drift section of the reserve (Fike, pers. comm. 2000). The reintroduction of *D. b. minor* into Great Fish River Reserve is in agreement with the national conservation plan for the species, which includes the policy of only introducing each subspecies into their former range (Brooks 1989).

Achieving and maintaining a high population growth rate for rhinos can only be done if the area is not overstocked. This in turn depends on an estimate of the ecological carrying capacity of the land. Research into rhino feeding ecology is needed when estimating carrying capacities (Emslie & Brooks 1999). The rhino population in the reserve shows a very high reproductive performance (Fike, pers.comm. 2000), indicating adequate habitat quality. Very little is known about black rhino feeding ecology in the vegetation of the reserve. The intention of this study was to describe and obtain a better understanding of the feeding ecology of the black rhinos in the reserve. This research will hopefully be a helping factor for a sound and sustainable management of the to rhino population in the reserve and in other conservation areas.

The specific objectives of this study were:

- Examine the feeding behaviour of the black rhino in the reserve, with regards to important and preferred plant species, feeding heights, twig diameters, movement patterns between browsed plants and some characteristics of the browsed plants.

- Investigate the nutrient values of some food plants of rhino and see whether these factors are influencing the preferences and selection of plant species and plant parts.

2 Material and methods

2.1 Study area

Fieldwork was carried out between February and April 2000 in eastern part of the 45000 ha Great Fish River Reserve in Eastern Cape Province of South Africa (Figure 2.1). The study was limited to the Andries Vosloo Kudu Reserve, which is situated on the south side of the Great Fish River (Figure 2.2). This part is approximately 6500 ha in size, and is located between 33° 04' and 33° 09' S and 26° 37' and 26° 49' N, 35 km from Grahamstown (Palmer *et* al.1988). The altitude varies from 183m to 548m above sea level (Palmer 1981). Presently, the study area is protected from most human interference by high electric perimeter fences.

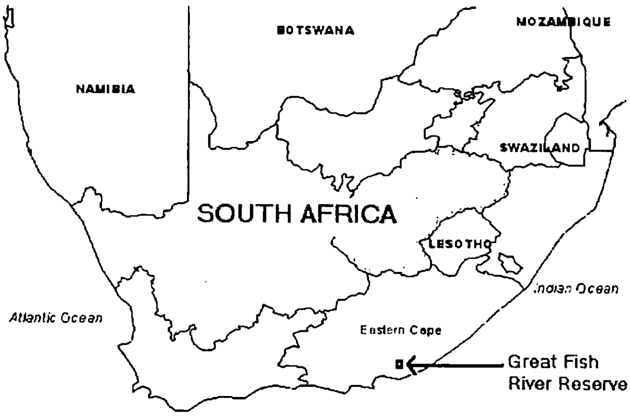

Figure 2.1. Location of study area.

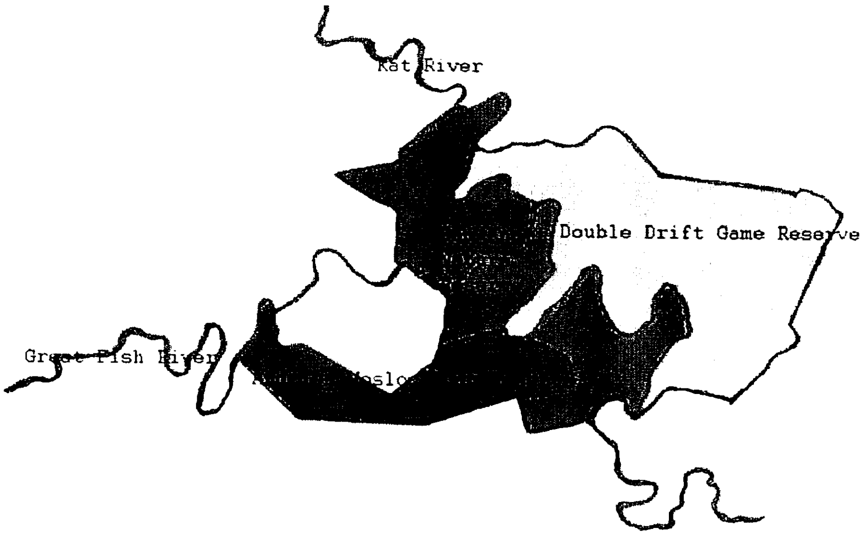

Figure 2.2. Map of Great Fish River Reserve. Study area in red colour.

2.1.1 Climate and geology

The region in which the reserve falls is generally considered to be semi-arid, with rainfall varying from 500 mm/annum in the high laying areas to 250 mm/annum in the low laying parts (Hahndiek *et* al. 1998). Mean annual rainfall in the Andries Vosloo Kudu Reserve is 435 mm, with monthly peaks in March (autumn) and October (spring) and dry winters. Temperature ranges are great with maximums in summer exceeding 40°C and winter minimums as low as 0°C (Palmer 1981).

Water is a limiting factor in the area, but there are numerous dams and waterholes throughout the reserve, and this provides for the immediate water requirements of the animals (Fike, pers. comm. 2000).

Geologically the area comprises the Middleton formation (Adelaide subgroup of the Beaufort group, Karroo supergroup) and consists predominantly of grey and "red" mudstone and sandstone (Johnson & Keyser 1976). According to Hartmann (1988) soils in the study area are predominantly weakly developed and solonetzic soils interspersed with red clays. These soils tend to be hard setting when dry, and possess a high portion of fine and very fine sand.

2.1.2 Vegetation

The vegetation in the reserve is classified by Acocks (1975) as Fish River Scrub of the Valley Bushveld. The term Valley Bushveld refers to the densely wooded vegetation found in the major river valleys of the eastern part of South Africa. It is known as a vegetation type with a semi-succulent thorny scrub, about 2-3 m high. Overgrazing in this vegetation type by cattle, gives an invasion of prickly pear (*Opuntia ficus-indica*) and *Euphorbia bothae* (Acocks 1975).

According to the classification of Everard (1987) of plant communities, the majority of the vegetation of the study area falls into xeric succulent thicket, which is a suborder of the kaffrarian succulent thicket. The dominating plants are evergreen sclerophyllous shrubs and succulents of karroid affinity. The thicket has an average total cover of 63 % with approximately 14 % forbs, 30 % succulents, 40 % woody components, 10 %

graminoid components and 6 % geophytes. Species richness is relatively low, although diversity is comparable with other thicket types in the eastern Cape.

The vegetation is not uniform throughout the reserve, mainly due to varied historical land use practices and variations in climate and soil. Evans *et* al. (1997) described three different plant communities within the reserve: short succulent thicket, medium succulent thicket and mesic bushclump savanna. Short succulent thicket is a very dense, sometimes impenetrable thicket, between 1 m and 2 m tall, and important/common species in this vegetation are *Euphorbia bothae, Rhigozum obovatum and Portulacaria afra.* Medium succulent thicket is a vegetation type between 2 and 2.5 m with important/common species like *P. afra, Euclea undulata and Grewia robusta.* Mesic bushclump savanna is a plant community with dense bushclumps, consisting of up to eight different species, and the bushclumps are separated by small patches of open grassland. The height of these bushclumps is above 2.5 m. *Scutia myrtina, Acacia karoo, Digitaria eriantha, Sporobolus fimbriatus and Holicrysum dregeanum* are important/common species in this vegetation type.

Due to the limited and sparse grass cover, fire is unknown in the arid areas in the reserve (Raats, pers. comm. 2000).

2.1.3 Other browsing animals in the study area

In addition with rhino the study area also supports a wide variety of other animals. The browsing species that represent the highest biomass in the reserve is the kudu (*Tragelaphus strepsiceros),* which, according to the game count numbers have an estimated density of 11-16 hectares/animal (Fike, pers.comm. 2000). As the kudu during the year moves freely across the border fences, the numbers may fluctuate. Other browsers and mixed feeders are eland (*Taurotragus oryx*), steenbok (*Raphicerus campestris*), springbok (*Antidorcas marsupialis*), grey duiker (*Sylvicapra grimmia*) and bushbuck (*Tragelaphus scriptus*). They are present in relatively small amounts in terms of biomass (Fike, pers. comm. 2000).

2.2 Study animals

The rhino population of the entire reserve consisted at the time of fieldwork of 46 animals, of both sexes and different ages (Fike, pers. comm. 2000). They move freely in the part of the reserve which is situated south of the river and comprise an area of 23 000 hectares. Due to logistics and limited resources during the field study, the observations were limited to the Andries Vosloo Kudu Reserve-part, in which about 33 of the 46 animals are permanently staying.

The Field Ranger Unit in the reserve is responsible for the surveillance of the rhino population, which is a continuous ground-based monitoring of individually identifiable rhinos. The rangers identify the animals by their earmarks, size, sex and age. Each observation of an identified rhino is recorded, and the observation includes the position on a map using an alphanumeric grid system. This system helps the reserve to monitor the continuously changing number of rhinos and their movements in the area.

2.3 Planning of field research

We recognized several constraints of the field research. They included:

1. Difficult study animals that do not allow close observations because they are shy and dangerous.
2. Dense vegetation that makes it difficult to locate and observe the study animals.
3. Limited equipment, i.e. no radio-collars or airplanes that would have helped located the rhinos.
4. Limited time for the fieldwork.

It was conducted a literature review on previous work done on the subject of rhino feeding ecology and a proposal together with the supervisors was made. The proposal was discussed in a workshop prior to start of the fieldwork. The researchers attending the meeting were Dr E. A. Boomker, specialist in animal physiology, University of Pretoria, Prof. A. R. Palmer, specialist scientist, ARC-Range & Forage Institute, Rhodes University, Grahamstown, Dr P. C. Lent, retired biologist from the U.S. Fish and Wildlife Service, Prof. W. Trollope, fire ecologist, University of Fort Hare, Dr P. F. Scogings, ecologist, University of Fort Hare, Dr L. O. Eik, Agricultural University of

Norway, Prof. J. Raats, University of Fort Hare, B. Fike, manager of Andries Vosloo Kudu Reserve/Sam Knott Nature Reserve and L. E. Dziba, previous master student at the University of Fort Hare. Everybody joined a very fruitful discussion.

We also visited Prof. G. I. H. Kerley, zoologist, at University of Port Elizabeth, who gave important information and comments on the study design along with some of his PhD students. Prof. N. Owen-Smith, specialist in African ecology, University of Witwatersrand, Johannesburg, was also contacted and gave us valuable advice.

The information obtained from the literature, from discussions and advices from scientific experts was used for making the following conclusions about methods for the fieldwork:

Diet composition of browsers may be estimated in several ways. (1) Analysis of ingesta or faeces of animals, (2) direct observation of feeding, and (3) the measurements of previously browsed vegetation (plant based methods) (Barnes 1976). The analysis of ingesta was not possible in this study as it requires capturing or killing of animals and is time consuming. In the past, direct observations of foraging black rhinos has been successfully applied (Goddard 1968 & 1970, Joubert & Eloff 1971, Mukinya 1977, Loutit *et* al. 1987), but this method was considered too dangerous due to the dense vegetation and limited equipment. A plant-based method, with measurements of previously browsed vegetation, was seen as the most advantageous method for this study. The technique used relied on the characteristic way in which the black rhinos browse, mainly due to their characteristic "pruning" of vegetation (Joubert & Eloff 1971, Skinner & Smither 1990, Dierenfeld *et* al. 1995). When rhinos are feeding on trees and bushes, this gentle type of browsing gives the end of branches a characteristic neatly pruned appearance, which is easily recognizable.

This method does also have some limitations (Kotze & Zacharias 1993). 1) Certain plant species, particularly succulents from the *Euphorbia* genera, can sometimes not be considered because they are not browsed the characteristic way. However, in this study a method of recording rhino feeding on these succulents was developed, see page 12. 2)

Black rhinos may browse non-thorny species by running their lips over the twigs (Joubert & Eloff 1971, Owen-Smith 1988). Consequently, off-take from species browsed in this manner would be underestimated. 3) Small plants and especially forbs may be underestimated, as they are not browsed in the recognisable way. 4) It is difficult to tell by looking at a plant exactly when the browsing occurred, but here an estimation of the age of bite marks was done, and old bite marks were thus not recorded.

It was also decided to estimate harvesting index per plant species, using the method as described in Chapter 2.5.4, to estimate preferences by using availability data and analyse plant material from some plants eaten by the rhinos.

2.4 Preliminary studies on local knowledge

We also interviewed seven rangers in the Field Ranger Unit of the reserve about the feeding behaviour of the black rhinos in the reserve, by using a list of pre-planned questions. The complete list of questions is to be found in Appendix 1. An interpreter was used, as many of the rangers speak only the local language Xhosa. The field rangers also pointed out the most important food plants of the rhino.

2.5 Feeding track observation method

The fieldwork was conducted in the late summer, and approximately 45 days were spent out in the field. In total 662 plants browsed by rhinos were examined during this period. The rainfall was somewhat higher than normal during the study period (Fike, pers. comm. 2000). As a consequence the vegetation contained a higher amount of grass and herbs than normally at this time of the year.

2.5.1 The method in general

A tracking method similar to those employed by Hall-Martin *et* al. (1982), Oloo *et* al. (1994) and Atkinson (1995) was applied. Rhinos and fresh tracks of rhinos were searched for from a small truck and by experienced field rangers who assisted us during the fieldwork. The search started early in the day, i.e. approximately 0630. If a rhino was located, its path of feeding was followed on foot at a safe distance. In areas where it could be unsafe to follow the rhino (because of wind direction, dense vegetation, topography etc.), the rhino track was followed in the opposite direction, i.e. backtracked. Occasionally the fresh tracks of a rhino were observed without any detection of the actual rhino.

By examining the tracks and the bite marks on the vegetation the field rangers were able to tell approximate the age of the track. If the track was estimated to be fresher than 8-10 h, it was followed. The tracking and examination of the vegetation could last from 1 to 4 hours for each track. Most of the tracking was done in the morning prior to the heat. A few recordings were undertaken in the afternoon as well.

The foot impressions of the rhinos were generally clearly visible on the ground together with bite marks and other damage to plants such as marking of territory, resting sites and scratch marks on trees and termite mounds along the track. In cases where footprints of the rhino could not be observed by the field rangers, no recordings were made. When a clear feeding track of a rhino was found, evidence of browsing were started searching for.

2.5.2 Measurements

Each track was assigned a number and information about date, hour, weather, temperature, position of the track on a map (grid system) and the GPS position at start- and end-point was stated. If identification of the actual rhino was possible, the name of it was added to the information.

Feeding on plants was quantified by counting the number of freshly browsed twigs. A browsed twig could be due to a single bite or to several bites, but in order to estimate the bite size, the same definition of a bite as described by Hall-Martin *et* al. (1982) was used. In this study a bite is defined when a single twig or several twigs were cut at the same level within a hypothetical circle of 10 cm diameter.

At each plant where fresh bite marks were found, data was collected on plants species (scientific name), plant groups, number and diameters of twigs browsed, number of bites and the height above the ground of bites, utilisation level, browsing level and total height of plant (see Appendix 3).

The plant species were classified into four groups (woody plants, dwarf shrubs, succulents and herbs). Woody plants included trees and shrubs with woody stems, dwarf shrubs included Karroid shrubs, herbs included all small herbaceous species, and succulents included both stem and leaf succulents. Utilisation level was defined as the percentage of total browsable material on the plant that had been removed by the rhino. Browsing level was defined as the level of previous browsing by any other animal on the plant. As in Hjeljord *et* al. (1990), the previous browsing was quantified on a subjective scale from 1 (not browsed) to 4 (heavily browsed). Twig diameters were categorized in classes; 0-5 mm, 6-10 mm and >10 mm, but the diameter of the thickest cut twig was always measured exactly. Heights of bites were also categorized in classes; 0-0.5 m, 0.5-1.0 m, 1.0-1.5 m and >1.5 m.

Samples of plant species that could not be identified on the spot, were collected for later identification either using the Great Fish River Reserve Herbarium or the Selmar Schonland Herbarium, Grahamstown.

The distance between each plant browsed was recorded in meters. During the tracking of the rhinos, the direction of the track was not always recorded. The plant associated with the distance from one browsed plant to the next, may therefore be either the plant that the rhino was walking to, or the plant that the rhino had just been foraging on.

2.5.3 The technique used for stem succulents

The characteristic pruning of twigs is not evident when rhinos feed on stem succulents and no quantification of the volume consumed by rhino was possible. Therefore a modified technique was applied for succulents. This was done in close cooperation with the field rangers in the reserve. The stem succulents in the study area included *Euphorbia spp.* and *Opuntia ficus – indica*, with *E. bothae* being the main plant of these stem succulents known to be browsed by rhinos.

In order to verify that rhinos, and no other animals, had browsed the actual stem succulent, several factors were considered. Firstly, the tracks of a rhino had to be located on the ground close to the plant. Secondly, some knowledge about the differences in bite-mark characteristics on *E. bothea* between rhino and kudu (which is the only other animal in the reserve known to browse *E. bothae*) was established (Figure 2.3 and Figure 2.4). The kudu nip off the upper tip (the shoot) of the *E. bothae* and leave only a small and fine cut on the remaining plant. The rhino, on the other hand, browse a larger part of the stem. The stems are torn off the main plant and parts of the stems are often found left on the ground. Thirdly, in a recently browsed *E. bothae*, which contains a white latex, this substance would not have dried or undergone any colour changes (Figure 2.5).

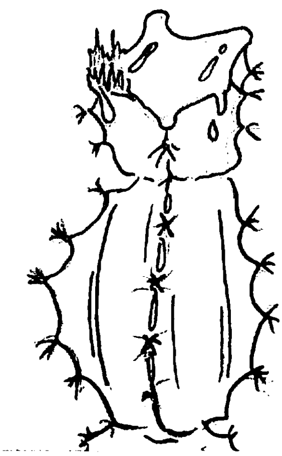

Figure 2.3.Illustration of Euphorbia bothae stem browsed by rhino. The unclean cut is typical for rhino browsing. Illustration by Heidi Nilsen.

Figure 2.4.Illustration of Euphorbia bothae stem browsed by kudu. The upper part of the stem has been gently nipped off. Illustration by Heidi Nilsen.

We found that feeding on stem succulents was not possible to quantify, due to the candle-like stems of the plant. The measurements done on the browsed stem succulents included only browsed stems as a percentage of total number of stems on the plant, the average height of the remaining stems, together with previous browsing level. The previous browsing level was estimated as with other plant species. See Appendix 4 for the recording form used.

Figure 2.5. A Euphorbia bothae stem recently browsed by rhino. The white poisonous latex is still not dried. Photo by authors.

2.5.4 The method used for estimating harvesting index

Hobson (1988) found an exponential relationship ($y = ae^{bx}$; $r = 0{,}93$) between twig diameter at point of browsing and twig mass distal to point of browsing. Mapuma *et* al. (1996) determined the relationship between twig diameter and twig mass for eight bush species in the False Thornveld of the Eastern Cape Province (South Africa) and concluded that for the range from 5 to 15 mm, twig diameter alone is a suitable predictor of twig dry mass (DM). In the absence of suitable regression equations to predict DM from twig diameters for most of the 45 bush species that were browsed by rhinoceros in this study, it was decided to use the cross sectional area of twigs as an indicator for the amount of DM harvested per plant and referred to as "harvesting index" or dry matter intake (DMI). Since the twigs browsed by rhinos in this study would be categorised into diameter classes, it was decided to use the diameter in the middle of each class in order to estimate the dry matter harvested.

2.6 Plant preferences

In order to determine the preferred food plants of the rhinos, the availability of the plant species in the environment were assessed. According to Petrides (1975) a "preferred food species" is one which is proportionally more frequent in the diet of the animal than it is in the available environment. In consequence, the different plant species available for consumption and their frequencies, along each feeding track was estimated. This was done by walking along a line between the GPS start and end point of the feeding track, recording the plant species present along the line. In order to save time, only the 100 first plants were recorded. Due to logistic and limited time it was not possible to get availability data on track 9 and 10.

It was decided to categorise the preferred food plants according to Emslie & Adcock (1994). Preferred species have preference indexes (PI's) greater than 1.25, while intermediate species are food plants that were likely to be neither preferred nor rejected, and have PI's between 0.80 and 1.25. Rejected species are defined as those with PI's less than 0.80.

2.7 Plant analyses

Plant samples were collected in March and April. The four most frequently eaten plant species during the field period were sampled for analyses. Two plant species that were abundant and seemed to be rejected by the rhinos were also sampled.

A field monitoring programme was started for the reserve during 2000 and about twenty sites were surveyed. The sites are described in terms of plant species composition. Five of these sites were chosen for the plant sampling. Together these five sites represent different vegetation types within the reserve where there is rhino activity. One plant of each of the six plant species was picked randomly at each of the five sites. From each plant a number of twigs of each diameter class were cut and leaf and stem separated, keeping the material from the different diameter-classes separate as well. All fresh material of each of the components collected, were placed in plastic bags and kept in a deep freezer until processing. The stem succulent *E. bothae* was collected only at two sites as it was not found at the other sites. Thus, it was sampled three plants of *E.bothae* from each site. In order to keep the number of samples low (due to high analyse-expenses), only twigs of a diameter between 6-10 mm was collected for the two less preferred species.

Dry matter was determined by freeze-drying the samples over a period of three days. Crude protein determinations were carried out by standard Kjeldahl method using a 2300 Kjeltec Analyser Unit (Tecator) following wet ashing. The samples for neutral detergent fiber analyses were freeze dried, milled with 1mm sieve and analysed with an ANKOM 200/220 Fibre Analyser according to the procedures as described in the Operator's Manual (ANKOM Technology, NY).

2.8 Statistical analysis

It was considered that the longer distances between browsed plants were not associated with feeding. The distances over 25 m (average distance + standard deviation) were therefore removed from the data set. The remaining data set was subjected to an analysis of variance according to the general linear models (GLM) of the computer software Statistical Analysis Systems Institute (SAS 1996). The model used was:

Distance between browsed plants = plant species + vegetation type

The data on feeding height and twig diameter selection was analysed using descriptive statistics. Statistical significances between the proportions of bites at different heights and between the proportions of twigs browsed in the different diameter classes were determined using chi-square tests (SAS 1996).

The data on dry matter intake was analysed using the GLM procedure. The procedure was used to test for the effects of plant species and height of the browsed plant on the amount dry matter harvested per plant. The model used was:

Dry matter intake per plant = plant species + height of browsed plant

All parameters from the chemical analyses of plant material were analysed using the GLM procedure. The procedure was used to test for the effects of plant species and twig diameter on the different parameters. The models used were:

Dry matter content per twig = plant species + twig diameter class

Dry matter content in leaves per twig= plant species + twig diameter class

Leaf:stem ratio = plant species + twig diameter class

Levels of neutral detergent fibre (NDF) = u + plant species + twig diameter

Levels of crude protein (CP) = plant species + twig diameter

When the results are presented as least squares means ± standard error (SE), the means are calculated using the LSMEANS statement in the GLM procedure of SAS (1996). The PDIFF statement was used for obtaining p-values for differences of the LSMEANS (LSMEAN (i) = LSMEAN (j))

3 Results

3.1 Plant species selection

From the 662 plants that were recorded as browsed by rhinos during the field period, 45 different plant species from 22 families were identified. The total number of bites recorded was 1785, and 7446 twigs were counted as browsed. The number of plant species found to be utilised by the black rhinos throughout the period was plotted against the increasing sample size as indicated in Figure 3.1.

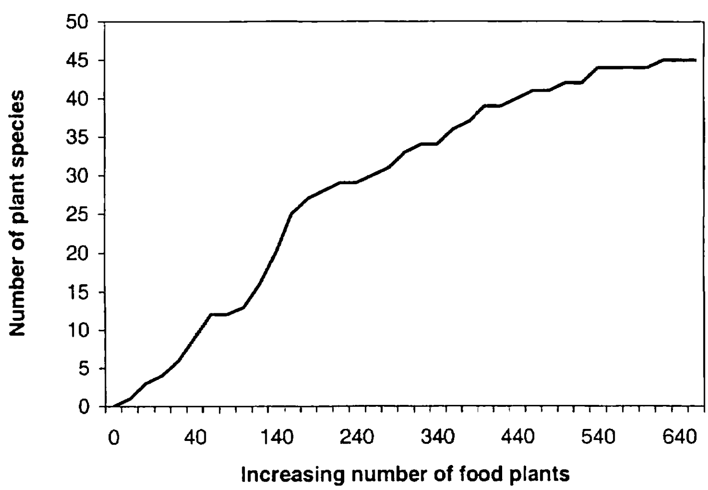

Figure 3.1. The relationship between plant species diversity and the increasing sample size as represented by the number of food plants examined.

Towards the end of the observation period, new plant species were still being recorded as utilised by the rhinos, which explains the curved graph.

Woody plants and succulents together, constituted about 70 % of all browsed plants. The respective contributions by the different categories of plants are shown in Figure 3.2. The four most commonly browsed plant species (*Euphorbia bothae, Jatropha capensis, Grewia robusta, Euclea undulata*) during the collection period, accounted for about 60 % of all the browsed plants. A complete list of the plant species recorded during the fieldwork is presented in Appendix 4.

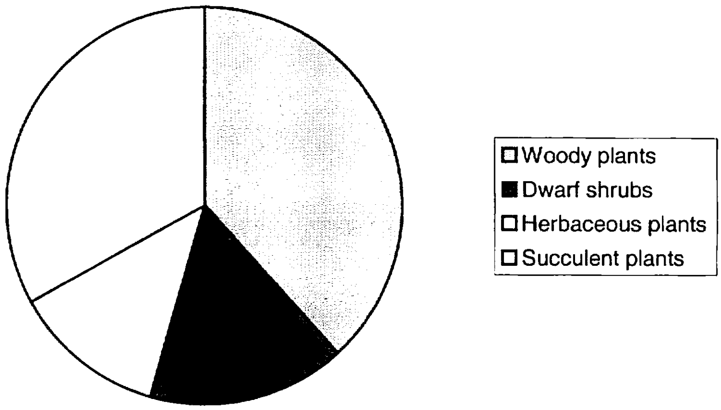

Figure 3.2. Distribution of browsed plants.

3.2 Distance between browsed plants

On average, the mean distance between browsed plants was 4.13 m (± 0.22 m). Plant species had a significant effect ($P < 0.01$) on the distance between browsed plants and vegetation type showed a tendency to have an effect on the distance ($P = 0.097$). Longer distances (6.01 m) between feeding sites were associated with *E. bothae* as indicated in Table 3.1.

Table 3.1. Mean distance (m) associated with the most frequently utilised plant species. Values are shown as least square means (LSmeans) ± SE.

Plant species	Distance[1]
Euphorbia bothae	6.01 (± 0.58)
Euclea undulata	3.96 (± 0.95)
Grewia robusta	4.95 (± 0.56)
Jatropha capensis	3.05 (± 0.65)
Other species	3.54 (± 0.35)

[1] Means corrected for vegetation type

The effect of vegetation type on the distance between browsed plants is shown in Table 3.2. The average distance between browsed plants tends to be shorter (3.51 m) in the short succulent thicket compared to the 4.35 m and 5.05 m recorded in the bushclump savanna and medium succulent thickets, respectively.

Table 3.2. Mean distance (m) between browsed plants in the different vegetation types. Values are shown as least square means (LSmeans) ± SE.

Vegetation type	Distance[1]
Short succulent thicket	3.51 (± 0.40)
Medium succulent thicket	5.05 (± 0.59)
Bushclump savanna	4.35 (± 0.44)

[1] Means corrected for plant species

3.3 Feeding heights and twig selection

The proportion of bites recorded in the different height classes varied significantly ($P < 0.001$). In the 0-0.5 m browse height class 56 % of the total bites were recorded, while 33 % and 10.2 % of the bites were recorded at heights of 0.5-1 m and 1-1.5 m, respectively. Only five bites were recorded at a height above 1.5 m of the ground. The highest bite was recorded on a *Maytenus capitata* plant at a height of 1.7 m.

The proportion of twigs browsed in the different diameter classes varied significantly ($P < 0.001$). The diameters of the majority (83 %) of twigs selected were between 0 and 5 mm while the rest (17 %) of selected twigs had a diameter larger than 5 mm (Table 3.3). The twig with the highest diameter (16 mm) recorded in this study appeared on a *J. capensis* plant. The average number of twigs that the rhino browsed per plant was estimated for each plant species and classified according to diameter of twig at point of browsing. The four plant species with the highest number of browsed twigs were compared with the average for the other species, as indicated in Figure 3.5.

Figure 3.3. Thin twigs selected by rhino at low levels above the ground from a Plumbago auriculata plant. Photo by authors.

Figure 3.4. Remnants of a Jatropha capensis plant browsed by rhino. Photo by authors.

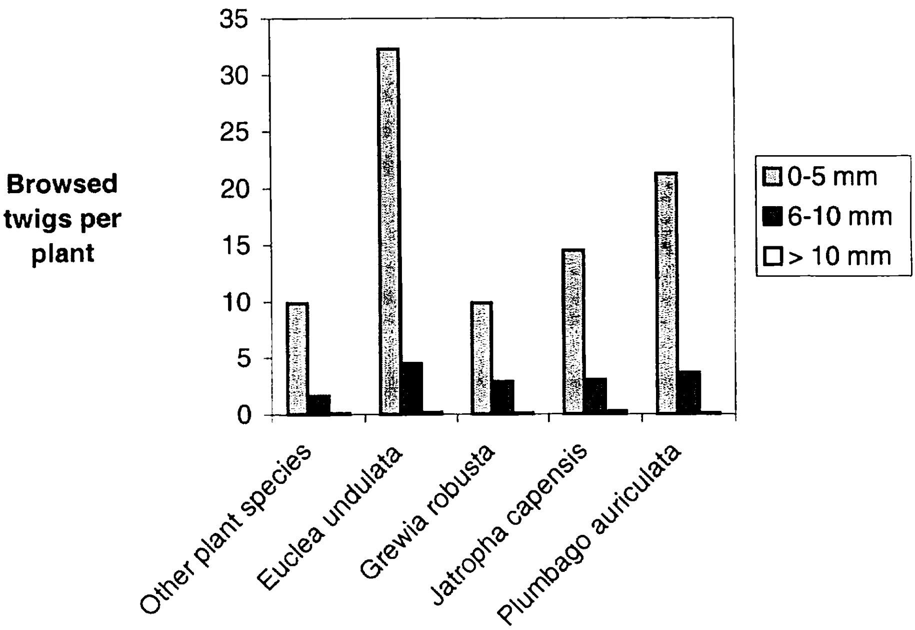

Figure 3.5. Average number of browsed twigs in each diameter class of important food species.

Figure 3.6. Typical bite mark by rhino on a twig of Azima tetracantha. Photo by authors.

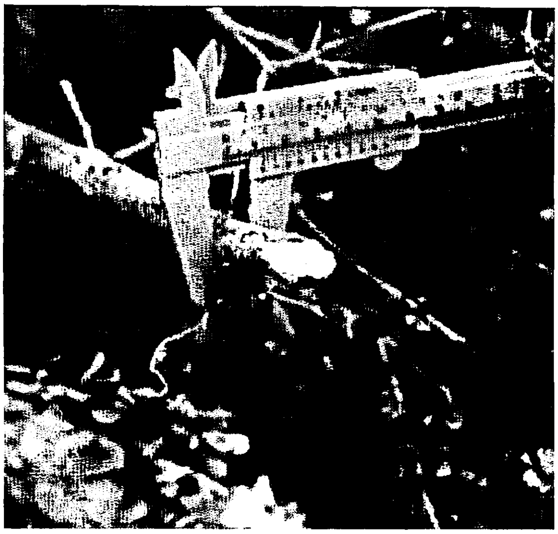

Figure 3.7. Ttwig of Euclea undulata browsed by rhino. The twig was measured to 12 mm.Photo by authors.

3.4 Quantification of plant material harvested

The amount of dry matter removed by rhino per plant and per plant species during the collection period was estimated by the total cross-sectional area of twigs at point of browsing and expressed as a harvesting index (see "2 Material and methods").

Plant species and height of the browsed plant had a significant effect on total amount dry matter harvested per plant ($P < 0.001$). On average, the largest amount of browsable material removed per plant was from *E.undulata* (381.2 mm^2), followed by *Plumbago auriculata* (281.4 mm^2), *J. capensis* (242.6 mm^2) and *G. robusta* (187.7 mm^2). When considering the other species as one group, only 133.1 mm^2 total twig diameter was removed per plant (Figure 3.8).

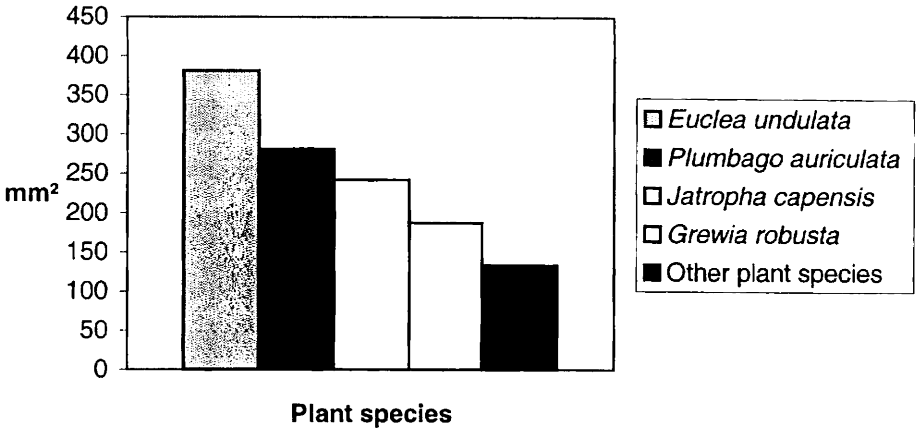

Fig. 3.8. Amount of browse harvested per plant of important plant species for rhino.

By adding the harvested amount of dry matter for all twigs within each species, a ranking of the species according to proportions of material harvested could be made (Table 3.5). When considering the harvested amounts of dry matter according to twig diameter, the majority of dry matter (58 %) was harvested from twigs between 6 and 10 mm in diameter (Table 3.4).

Table 3.4. Browsed twigs and harvested amount of dry matter recorded during the fieldwork in the different diameter classes.

Twig diameter	Browsed twigs	Harvested amount of plant material
0-5 mm	83.16 %	33.42 %
6-10 mm	15.98 %	57.81 %
> 10 mm	0.86 %	8.77 %

3.5 Previous browsing

The majority of the plants selected by rhinos were lightly (17 % of plants), moderately (40 % of plants) or heavily browsed (26 % of plants) prior to the start of this experiment. A total of 18 % of the selected plants showed no signs of previous browsing.

3.6 Preferences

The estimates of the preference indexes for the plants species browsed by rhinos showed that 11 of the food plants were preferred (Table 3.5), and 21 food plants seemed to be rejected by rhinos.

3.7 Ranking of plant species

A ranking of importance of plant species as food plant for rhinos was done according to (1) number of browsed plants, (2) preference index and (3) estimated harvested amount of plant material as shown in Table 3.5.

Table 3.5. Importance of different plant species according to the number of browsed plants and preference- and harvesting- indexes.

Plant species	*Plants browsed* (% of total)	Plant species	Preference index	Plant species	*Amount browse harvested*[1] (% of total)
Euphorbia bothae	27.2	*Lycium campanulatum*	14.6	*Grewia robusta*	22.3
Grewia robusta	16.5	*Asparagus sp.*	5.2	*Jatropha capensis*	19.9
Jatropha capensis	11.3	*Jatropha capensis*	4.1	*Euclea undulata*	15.0
Euclea undulata	5.4	*Plumbago auriculata*	3.2	*Plumbago auriculata*	7.7
Plumbago auriculata	3.8	*Euclea undulata*	2.8	*Coddia rudis*	3.3
Mestoklema sp.	3.2	*Euphorbia bothae*	2.6	*Schotia afra*	3.2
Coddia rudis	3.0	*Capparis sepiaria*	1.8	*Lycium campanulatum*	3.1
Schotia afra	2.6	*Grewia robusta*	1.7	*Mestoklema sp.*	2.8
Maytenus polyacantha	2.4	*Carissa haematocarpa*	1.6	*Azima tetracantha*	2.6
Azima tetracantha	2.3	*Azima tetracantha*	1.6	*Maytenus polyacantha*	2.1

[1] *Euphorbia bothae* is not present at the list of harvested amount dry matter due to difficulties with recording stem succulents (see "2 Material and methods").

3.8 Chemical composition of browse

The chemical analyses of the twigs sampled from the six plant species show that plant species and twig diameter class accounted for 84 % of the variation in dry matter (DM) content per twig. 75 % of the variation in DM content of leaves per twig (leaf-DM) and 76 % of the variation in the leaf:stem ratio. Plant species and twig diameter class accounted for 80 % of the variation in content of neutral detergent fiber (NDF) and 79 % of the variation in content of crude protein (CP).

By comparing LSmeans of DM content per twig, leaf-DM per twig, leaf:stem ratio, CP levels and NDF levels, some significant differences among means were found (Figure 3.9 and Figure 3.10). Mean DM content per twig, leaf-DM per twig, leaf:stem ratio, CP levels and NDF levels of *E. bothae* could not be compared with the other plant species due to unknown twig diameter classes of the samples. *E. undulata. G. robusta* and *R. obovatum* contained significant higher levels of dry matter per twig than did *J. capensis* and *P. afra* ($P < 0.05$). *E. undulata* had significant higher DM content in leaves than the other species ($P < 0.05$). *G. robusta* and *R. obovatum* had significant lower leaf:stem ratios than did the other species ($P < 0.05$).

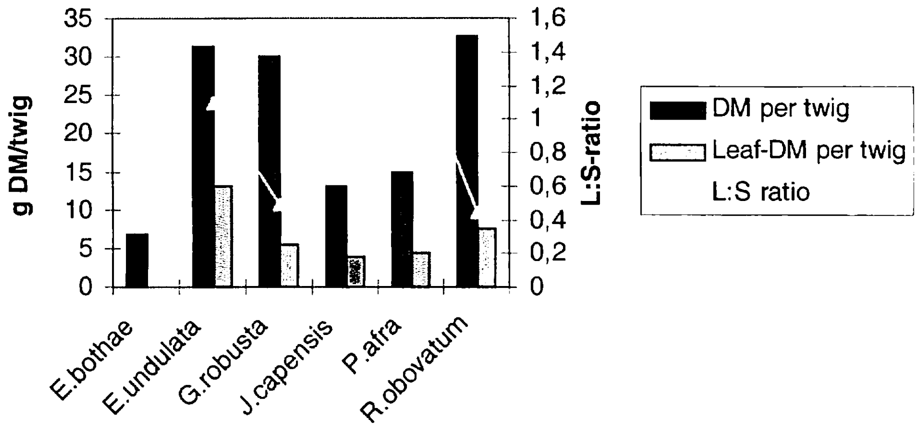

Figure 3.9. Some characters related to quantity of plant material. expressed as dry weight per twig, leaf-DM per twig and leaf:stem ratio. P. afra and R. obovatum are plant species that were rejected by rhinos. the other species were preferred. Values are shown as least square means (LSmeans).

G. robusta had significant higher NDF content than the other species ($P < 0.05$). *E. undulata* and *P. afra* had significant lower values of CP than the other species ($P < 0.05$).

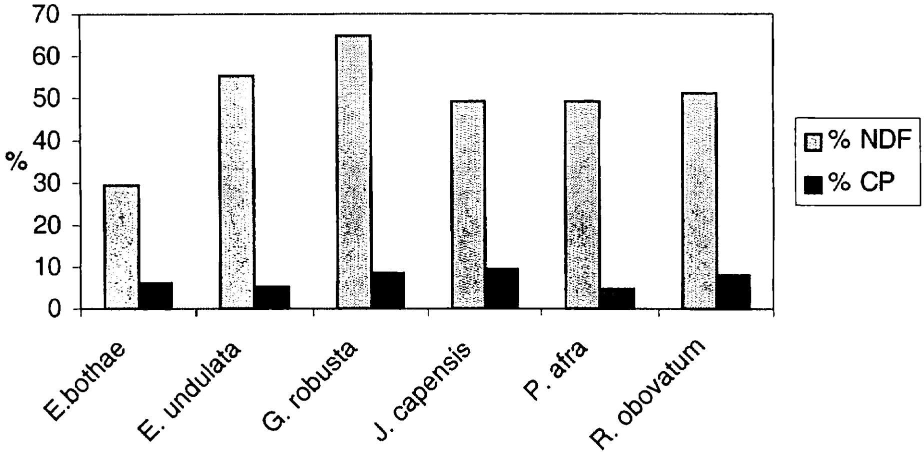

Figure 3.10. The quality of the sampled plant species expressed as neutral detergent fiber (NDF) and crude protein (CP) in % of dry matter. P. afra and R. obovatum are plant species that were rejected by rhinos, the other species were preferred. Values are shown as least square means (LSmeans).

The effect of twig diameter on the quality of the plant material was not as distinct as the effect of plant species, as indicated in Figure 3.11 and Figure 3.12.

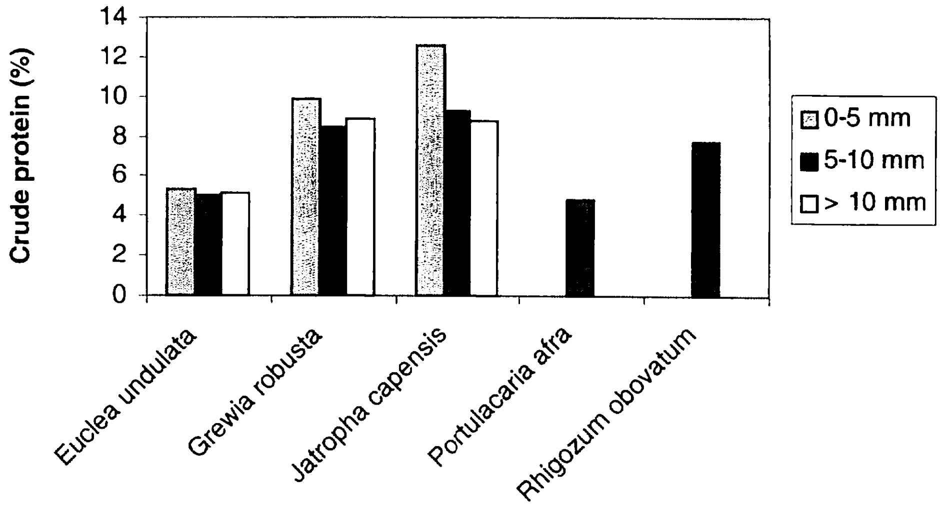

Figure 3.11. The quality of the sampled plant species and twig diameters expressed as crude protein (CP) in % of dry matter. P. afra and R. obovatum are plant species that were rejected by rhinos. the other species were preferred. For P. afra and R. obovatum samples were only taken in the intermediate twig diameter class.

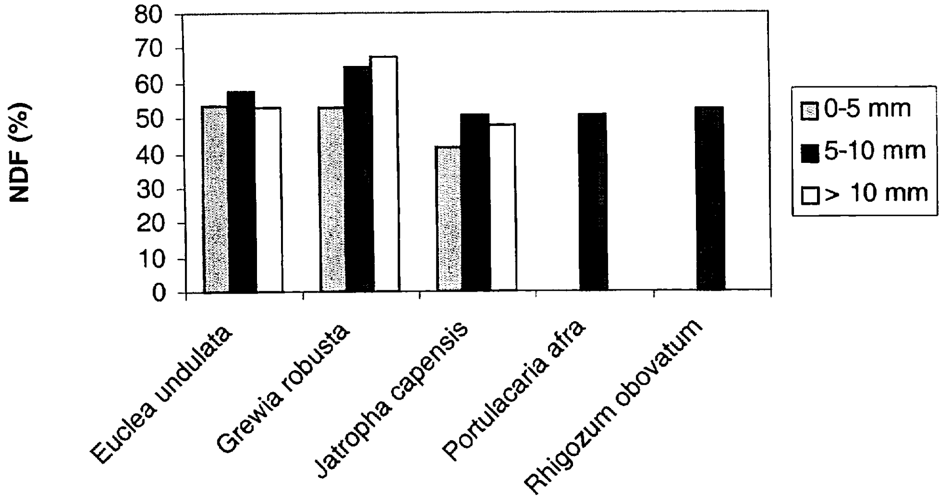

Figure 3.12. The quality of the sampled plant species and twig diameters expressed as neutral detergent fiber (NDF) in % of dry matter. P. afra and R. obovatum are plant species that were rejected by rhinos. the other species were preferred. For P. afra and R. obovatum samples were only taken in the intermediate twig diameter class.

The average NDF content in leaves is 42.31 % (±1.10 %). which is significantly lower than the average NDF content in stem (66.75 % ±1.16 %). The average CP content in leaves is 10.29 % (± 0.33 %). which is significantly higher than the average CP content in stem (3.79 %. ± 0.34 %).

4 Discussion

4.1 Plant species selection

When studying free-ranging animals' utilisation of plant species, it is important to get an indication as to whether the sample size is adequate to describe the full plant diversity of the animals' diet. For this purpose, the number of plant species found to be utilised by the black rhinos throughout the period was plotted against the increasing number of feeding tracks as shown in Figure 3.1. If the number of browsed plants recorded is large enough, the curve should flatten out (Hall-Martin *et* al.1982). The present curve seems to be close to reach a plateau, which indicates that only a small number of plant species are potentially utilised by the rhino, but not recorded. The decreasing number of new plant species found during the field period also indicates that the main diet is described, and that it is likely to assume that all the important species are included. Supporting this assumption is the fact that of the 45 different species, four species (*E. bothae, G. robusta, J. capensis* and *E. undulata*) contributed to more than 60 % of the total diet.

Black rhinos are known to utilise a wide variety of plant species (Schenkel & Schenkel-Hulliger 1969, Skinner & Smither 1990). During the six-week period of this study, the rhinos were found to feed on 45 different plant species from 22 different families. A study in similar vegetation as the present study area was carried out by Hall-Martin *et* al. (1982) and they found that the rhinos in Addo National Elephant Park utilised 111 plant species (35 families). Studies over longer periods from other vegetation types generally refer to a higher number of browsed plants, from 70 to 190 different plant species (Goddard 1968 & 1970, Joubert & Eloff 1971, Mukinya 1977, Hall-Martin *et* al. 1982, Loutit *et* al. 1987, Kotze & Zacharias 1992 & 1993, Emslie & Adcock 1994, Oloo *et* al. 1994, Atkinson 1995).

An overall comparison of studies done in eastern and southern Africa on black rhino gives some consistent findings. The tendency of the black rhino to concentrate on a few preferred species that form the bulk of its diet, although it feeds on a wide spectrum of plant species, is referred to by several authors (Joubert & Eloff 1971, Hall-Martin *et* al

1982, Oloo *et* al. 1994). This is in agreement with the results of this study, i.e. that a large number of species are consumed in smaller quantities and do not have a marked effect on the quantitative dietary intake. The reason for consuming such a wide variety of plants is however, not clear. It is possible that these species do have some qualitative features that are needed by the rhino. In Stephens & Krebs (1986), sodium was proposed as a likely nutrient constraint, as this is the only nutrient besides than water for which a specific hunger has been demonstrated, and the fact that this nutrient often are scarce in plants.

4.2 Plant species in relation to vegetation type

Valley bushveld or xeric succulent thicket is a vegetation type that is recognised to have relative low species richness (Everard 1987, Low & Rebelo 1996) compared to other vegetation types in South Africa. The vegetation type contains a high proportion of succulent plants and endemics but few herbs and grasses (Everard 1987). It is therefore difficult to compare the diets of black rhino in different vegetation types as presented in the literature. The studies are also often done at different times of the year. This study only gives data on the summer diet of the rhino.

In the current study, no evidence of grazing by the rhinos was found, even if this is recorded to some extent in other studies (Skinner & Smither 1990). Hall-Martin *et* al. (1982) found in their analysis of faeces of rhinos in Addo National Elephant Park, that grass was underestimated as a component in the diet of the rhinos when using a similar tracking method as is done in our study. Percentage grass material in faeces varied from approximately 2-10 % in the study of Hall-Martin et al. (1982). There is also a possibility for herbs to be underestimated because of the small size and not very striking bite marks.

The present population of black rhinos in the reserve originated from a group of 22 animals that were trans-located over a period of 11 years (1986-97) from Kwazulu-Natal province, South Africa (Fike, pers. comm. 2000) where the vegetation is of Coastal Thornveld type (Acocks 1975), which is different from the Valley bushveld vegetation type. Since the rhino population in the reserve has an exceptionally high reproductive rate (Fike, pers. comm. 2000) it can be concluded that the rhinos have adapted well to the predominantly vegetation. In this respect Hall-Martin *et* al. (1982), Loutit *et* al. (1987) and Skinner & Smither (1990) stated that black rhinos usually feed on a wide variety of species and shift their feeding preferences according to circumstances and abundance of plants in their environment. During the adaptation period of rhinos kept in captivity, Maddock *et* al. (1995) offered some of the plant species occurring in the reserve in a cafeteria test. Most of these plants do not occur in Kwazulu-Natal and it was found that the rhinos rejected all the succulents offered to them, where *E. bothae* and *P. afra* were two of them. It was suggested that these species were rejected because they were new to the rhinos and not sufficient time was allowed for the rhinos to familiarise themselves with the succulents. Maddock *et* al. (1995) did also indicate that it was unnecessary for the rhinos to eat succulents as a water source, since they already had water provided *ad libitum* during this study.

4.3 Distances between browsed plants

Highly preferred forage plants are likely to effect the movements of the rhinos when searching for food (Joubert & Eloff 1971). Results from the present study indicate that the rhinos were willing to walk further to get to *E. bothae* plants than other plants, suggesting high preference for this plant. For the other most frequently eaten species the distance between each eaten plants was shorter than for the *E. bothae*. The distance between browsed plants in different vegetation types was shorter in the short succulent thicket. *E. bothae* is mostly found in this vegetaion type, which indicates that the rhino walked longer distances in order to get to the highly preferred food plant *E. bothae* than to the other plants in this vegetation type. At several occasions it was observed that rhinos search for *E. bothae* in areas where the plant was scarce. Other researchers have also found indications of rhinos searching for Euphorbiaceae species (Goddard 1968, Joubert & Eloff 1971, Oloo *et* al. 1994). The longer distances associated with *E. bothae* may also be due to longer distances walked by rhino *after* feeding on this plant. It is therefore possible that the rhino need more time to finish eating *E. bothae* before it is ready to feed on the next plant.

4.4 Feeding heights

Because of differences in body size, different animal species feed at different levels in the vegetation. Only a few studies have focused on the competition between black rhinos and other browsing animals in relation to feeding height. In a study by Du Toit (1990) only giraffe is clearly different from other African browsing ruminants in feeding height stratification. This indicates, even if the black rhino is a non-ruminant, that in our study area no feeding height stratification should exist between the browsing species. We found that the majority of bites were taken below 1 m and only five of the bites were taken above 1.5 m. This shows that the rhino prefers to feed at a relatively low height. Du Toit (1990) found kudu to allocate half of their feeding time below 1.2 m, while 30 % of the time was spent feeding at a range 1.2-1.7 m. Emslie & Adcock (1994) found in their studies in Hluluhwe-Umfolozi that the black rhinos were highly selective for both species and size class, which they grouped and called "spize". It is of great importance when assessing habitat suitability to work at a "spize" level rather than simply a species level. Plants should not be regarded as available to the rhinos in an area if they are out of reach for the animals. Emslie & Adcock (1994) show that Acacia spp. smaller than 2 m were highly preferred by rhinos and that higher species of the family were less preferred or rejected. In our study area the bulk of the vegetation is less than 2.5 m, and this may be the reason why plant size was not found to be an important factor.

4.5 Twig diameters selected

It is not easy to find other studies where measurements of twig diameters browsed by rhinos have been used. Joubert & Eloff (1971) found rhinos to browse twigs up to one centimetre in diameter, but more details about frequencies of twig diameters browsed are not given. Cocroan (1994) did measure diameters of twigs browsed by rhinos, but the data material is small and some of the measurements are done on rhinos held in captivity. The results are thus expected to differ somewhat from results from free-ranging animals.

The majority of twigs (83 %) browsed in this study were between 0 and 5 mm, and the thickest twig that was found browsed by a rhino was 16mm. This is in agreement with the theory of optimality. However, when looking at the results of dry matter harvested by the rhinos, the largest amount of plant material (57 %) was browsed from twigs between 6 and 10 mm in diameter. This shows that although the minority of browsed twigs was from this diameter class, the thicker twigs contributed with the largest amount of dry matter to the diet of the rhinos. We found only 9 % of the harvested amount of dry matter to come from twigs thicker than 11 mm. The tendency of thin twigs to have a higher leaf:stem ratio and thus a lower fibre content than twigs with larger diameter showed by Vivås & Sæther (1987), was confirmed in this study.

Optimal foraging theories are based on the principle of maximum energy intake with a minimum of energy used and time spent (Owen-Smith & Novellie 1982, Senft *et* al. 1987). In the field an animal is being confronted with a spectrum of possible food items because they face a complex and constantly changing environment (Van Wieren 1996). The physiological and morphological manufacturing of the plants forces the animal to decide whereas to eat or not to eat the plant, and which, and how thick, plant parts to choose (Shipley *et* al. 1999). Intake of dry matter is strongly related to the architecture of woody plants (Owen-Smith & Novellie 1982, Senft *et* al. 1987). Rapid rates of dry matter intake can be achieved by taking larger bites, but this strategy normally results in food which is relatively low in nutritive quality, compared to higher quality but smaller bites taken from leaves or twigs near the growing points of the plant (Shipley *et* al. 1999). The higher fibre content in thick twigs decreases the digestibility of plant tissue, and hence the total amount of energy gained (Vivås *et* al. 1991). Fibre also increases the time required to pass through the digestive tract (Demment & van Soest 1985). Thus, on the basis of time-energy consideration, browsing smaller twigs takes longer time (g DM ingested/minute or bite) but provides a higher quality diet, and the plant material consumed has shorter retention time (Senft *et* al. 1987). The high proportion of thin twigs in the diet of rhinos in this study strongly indicates that the rhinos in the reserve are well provided with their preferred thickness of twigs.

The plant's morphology should be considered when comparing twig diameters selected from different plant species. As shown in our results, the largest number of twigs browsed per plant was on plants of *E. undulata*. This plant species have an exceptionally well-developed branch structure (large number of small twigs), compared with other species. When estimating the amount of dry matter consumed by rhino per plant, the highest amount of browse material was removed from plants of *E. undulata*, followed by *P. auriculata* and *J. capensis*.

4.6 Plant preferences

During the field period it is obvious that the rhino showed a preference for certain plant species and rejected others. According to Petrides (1975) principal foods of an animal are those that it eats in greatest quantities, and they may or may not be those that are preferred by the forager. According to Newman *et* al. (1995) the difference between preference and selection should be distinct. The diet preference is for the animal an underlying ecological need that is more important than selection of plants to eat in the preferred habitat. This subject is also important for the nutritional status of the population of the animals. If the population is reproducing well, and do not suffer from sickness of any kind, this may indicate that the population is feeding on food plants that are preferred and nutritional sufficient for the animals. Decrease in population size and signs of sickness may be a warning that the animals have to eat other plants than preferred because preferred food is not available, and that these plants are not providing the sufficient nutrients. If a plant is abundant in an area, this may make it more advantageous to browsers to consume this species rather than spend time and energy searching for more preferred species (Stephen & Krebs 1986). This highlights the distinction between preferred and principal food. In this study the five most frequently eaten plant species were all to be found at the list of the preferred species, which is strongly indicating that the rhinos is well provided with their preferred food.

4.7 Previous browsing

This study shows that a high proportion of the plants selected by the rhinos were browsed (moderately to heavily) prior to the study or during previous years. At least two factors can explain this result. One possibility is that very high proportions of the plants in the reserve are already utilised, i.e. the browsing pressure in the area is high. However, based on several game counts and a few botanical surveys, indications are found that the optimum carrying capacity for browsing animals in the reserve is not reached. Another explanation may be that the rhinos prefer previous browsed plants. This is in agreement with the findings of Hjeljord *et* al. (1990) in a study of summer feeding sites for moose in Norway, where previous browsing on the vegetation was measured subjectively. Moose browsed more on trees that had been heavily browsed during the previous summers than on lightly browsed trees, which is also confirmed in similar studies by Bergstrøm & Hjeljord (1987) and Danell *et* al. (1994). This preference for previously browsed trees may be related to the induced changes in morphology, though no uniform response of woody plants to browsing by large mammals could be found except that shoot size decreases after summer browsing (Danell *et* al. 1994). Yet, the rhino's gentle type of browsing that gives the end of branches a characteristic neatly pruned appearance (Skinner & Smither 1990, Dierenfeld *et* al. 1995) may lead to the formation of new shoots (Joubert & Eloff 1971). This is in contrast to Murray & Illius (2000) who suggest that herbivory by one species can modify the vegetation in a way that makes it less profitable for competing species. However, if browsing by rhinos can give the vegetation new shoots, this is obviously positive for other browsing animals in the area.

4.8 Chemical analyses

The crude protein levels (5-10 % of DM) and the content of neutral detergent fibre (30-65 % of DM) found in the plants that were analysed in our study were quite comparable to values reported from other studies. Generally one can expect a tendency to an increase in crude protein and crude fibre levels during spring and summer compared to other seasons (Joubert & Eloff 1971, Hall-Martin *et* al. 1982). Our study does only give the content of samples taken during late summer, but this should imply tendencies.

We did not find generally lower levels of CP or higher levels of NDF in browse from species that were rejected by rhinos, and this indicates that these factors are not major factors influencing preferences of rhino. Crude protein contents were generally higher and the fibre content lower in thin twigs for all species. Significantly lower levels of fibre in leaves than in twigs and significantly higher levels of CP in leaves than in twigs were also found. This supports the suggestion that rhinos select plant parts according to browse quality.

Although fibre is generally considered a negative index of feed quality, ruminant and non-ruminant herbivores such as the rhinos derive a major portion of dietary energy from the fermentation of cell wall constituents (Van Soest 1994). Our results show that some of the plant species that are important in the rhino's diet contain high levels of NDF (*G. robusta* and *E. undulata*) and low leaf:stem ratios (*G. robusta* and *J. capensis*). This is in agreement with Loutit *et* al. (1987) and Hall-Martin *et* al. (1982) that found that several plant species consumed by the rhino had a high crude fiber content.

It is of great importance not to judge forage quality by a single criterion (Haschick & Kerley 1997). According to Cooper *et* al. (1988), palatability of woody plant foliage to browsing ruminants is not controlled by any single chemical factor. Haschick & Kerley (1997) suggest that forage preferences could be influenced by protein as a limited factor, avoidance of secondary compounds, plants structural characteristics and the animals' sensitivity for taste of various compounds. Our study indicates that dry matter, fibre and protein content partly influence the selection of plant parts but that other qualities of browse than the ones analysed in this study, seems to influence the preferences for certain plant species.

4.9 The preference for *Euphorbia spp.*

Members of the Euphorbiaceae family have often been reported as being preferred by rhinos (Goddard 1968, Emslie & Adcock 1994, Oloo *et* al. 1994), but not to the same high extent as in this study. Although it was not possible to quantify the contribution of *E. bothae* in terms of dry matter intake (DMI, as estimated from the harvesting index), it was found that the stem succulents of which *E. bothae* was the most important, accounted for one third of all the eaten plants. It is considered that the marked preference for the succulent latex-bearing *Euphorbia spp.* may be an adaptation to obtaining water from the environment (Goddard 1968, 1970, Hall-Martin *et* al. 1982). In the dry season in northern Tanzania (Goddard 1968) it seemed that rhinos could survive without free water due to these plants. Although *E. bothae* has relatively high moisture content (contains only about 5 g DM/twig), no evidence was found in this study to support this hypothesis, primarily because the present study was conducted during the wet season with abundant water in dams and waterholes. Furthermore, the distances from the feeding tracks to the nearest water points were never more than 2 km. These findings suggest that the browsing done by the rhinos on *E. bothea* has got other explanations than browsing for water. This is supported by the study of Loutit *et* al. (1987) from the desert of Namibia where they found that rhinos had a high preference for *Euphorbia virosa*. When analysing *E. virosa* water appeared to not markedly influence selection.

Black rhinoceros are known to be able to utilise plant species that are unacceptable to many herbivores due to the plants morphological and chemical defence. (Cooper & Owen-Smith 1986, Loutit *et* al. 1987, Skinner & Smither 1990). Members of the

Euphorbiaceae family often contain white milk called latex that is highly toxic. The toxicity of this substance shows severe clinical signs, which in Cheeke (1998) is referred to cause gastrointestinal necrosis and death. In the reserve, kudu and rhino are the only animals known to feed on *E. bothea* (Fike, pers. comm. 2000). In addition to the latex, *E. bothea* is further protected by numerous spinescence that covers the whole plant and seemingly act as an effective anti-herbivore defence mechanism. This may lead to restricted bite size, even if some animals can compensate for this defence by extending feeding duration per encounter (Cooper & Owen-Smith 1986). Rhinos often browse and utilise whole twigs or plants that include spines and thorns (Skinner & Smither 1990). Thus, for rhinos this physical defence of plants does not seem to affect their preference or feeding method on these plants.

Browsing animals show anatomical and physiological features that distinguish them from grazers (Hofmann 1988, Owen-Smith 1988, Van Soest 1994). It was suggested that this may enable them to neutralise plant toxins in general or cope with their effects somewhat better than grazers. Digestion of herbage takes place in the voluminous sacculated caecum in black rhinos, as they have a single stomach (Owen-Smith 1988, Skinner & Smither 1990). The preference for tannin rich species may be influenced by the fact that certain animals, e.g goat, are adapted (physiologically) to cope with these toxins and normally have larger salivary glands with proline-rich salivary proteins, and large livers to decrease the effect (Owen-Smith 1993). Among woody plants phenolic chemistry patterns are commonly represented (Cooper & Owen-Smith 1986). The highest leaf concentrations of condensed tannins have been recorded among species in the Anacardiceae family (*Ozoroa spp.*), Caesalpinioideae family (*Schotia spp.*) and Ebenaceae family (*Euclea spp.*) (Owen-Smith 1993), which include many of the species the rhinos feed on in the reserve.

4.10 Rejected / preferred plants

In contrast to the findings that the rhinos utilise plants that are not readily eaten by other animals, there is also strong evidence that rhinos reject forage plants that are highly preferred by other animals. In the present study, no evidence could be found that rhinos browse *Acacia karoo* and it browsed only small amounts on *P. afra*, which are relatively abundant and known to be utilised extensively by many animal species, including kudu (Oloo *et* al. 1994). Emslie & Adcock (1994) concluded from many rhino studies that *Acacia spp.* are key dietary items. The importance of *E. undulata* in the diet of rhino is another interesting result from the reserve, as Emslie & Adcock (1994) found in several studies that *Euclea spp.* were rejected. By numerous authors it is argued that *Grewia spp.* routinely make up a small proportion of the diet, although in drier and more nutrient poor areas they can become a very important food source and highly preferred species. The importance of *G. robusta* in the diet of the rhinos in this study is therefore likely to be due to the arid nature of the vegetation. There is probably a limit to the amount of a certain species a black rhino may choose to eat (Emslie & Adcock 1994), or that certain individuals of this of this species may contain excessive amounts of anti-nutritional factors (Cooper *et* al. 1988).

4.11 Plant ranking methods

Three methods of ranking important plant species in the diet of rhino were compared. One found that the different ranking methods gave very similar results, and this indicates that in later studies the least time consuming method can be used, i.e. recording number of plants browsed. It is also important to have in mind that using one method may give some misleading results. An example in this study is the *L. campanulatum*, which has got a very high preference index. This species was only found to be eaten and available at one feeding track, and because of this small data amount, the preference index is uncorrect high. *L. campanulatum* is not represented at the two other lists, which highlights the importance of different methods used. As mentioned before, it was not possible to estimate amount harvested of *E. bothea*, but it is very likely that the amount harvested from this stem succulent is large. *G. robusta* is the species which is browsed in largest quantities, and it is number two on the list of total plants browsed. Because *G. robusta* is not among the highest preferred species, this suggests that this plant is a principle food plant for the rhino.

4.12 Vegetation monitoring

Valley bushveld is recognised as being vulnerable to degradation and desertification due to overgrazing (Furstenburg *et* al. 1996). According to Acocks (1975), excessive grazing pressure results in the invasion of plants like *E. bothea* and *O. ficus* in this vegetation type. In an undamaged state, the valley bushveld is an extremely dense thorny shrub vegetation but when overgrazed it has a high percentage of open ground. During our period in the reserve no signs of severe defoliation of the vegetation was observed. Large areas of the reserve have earlier been grazed by cattle (Fike, pers. comm. 2000). In the absence of browsers, it is likely that large numbers of cattle would have had a marked effect on the vegetation (Low & Rebelo 1996). However, there are many indications for the vegetation in the reserve is returning to its previous state and that the vegetation generally is in a good condition. No complete vegetation survey has been conducted in the reserve, but in year 2000 the Department of Livestock and Pasture Science, University of Fort Hare has started an extensive vegetation survey.

To be able to manage the vegetation in the reserve it is of great importance that the monitoring of the area continues. These results would help the management to estimate the carrying capacity of the reserve, and be in front of possible changes to the vegetation. Our results that focus on the vegetation used by rhino may be useful to compare with results from a similar done study in some years. If the rhinos have changed their diet, or if their intake of unpalatable species has risen, this may be a indicator of that the animals are likely to be overstocked, or will soon be.

5 Conclusion

In this study it was managed to describe in detail some of the aspects concerning the feeding ecology of the rhinos in the Great Fish River Reserve. It was found that the rhinos have preferences for certain plant species and that a few of these species make up the bulk of their diet. The large amounts of *E. bothae* found to be eaten by rhinos was a quite surprising result, as this species is rejected of most other browsing animals, due to the strong toxic components it contains. The previous theory that *Euphorbia spp.* are selected because of high levels of water, was not supported in this study, as the rhinos had the needs for water already provided.

Our results do not support the optimal foraging theory of herbivores selecting diets that tend to maximise their rate of intake with minimum of energy used and time spent. Other factors than the factors that we investigated in this study might explain the rhino's preferences and selection of food items.

At the present there are not seen indications at the vegetation of overstocking of the area. The densities of rhinos are still very low and they seem to be provided with a preferred habitat.

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List of Appendixes

Appendix 1.

Questionnaire used for interviewing field rangers working in the Great Fish River Reserve in a preliminary study.

Name of ranger:
Age:
Interpreter:
Area of growing up:
Education:
Previous working experience:
Duration of employment as field ranger in this reserve:
Responsibility area in the reserve:

Question 1.

Which plants have you observed rhinos in the reserve feeding on in summer?

Question 2.

Which five plants do you mean are the most important for rhinos in summer?

Question 3.

Which plant species, if any, are rhinos feeding on in winter but not in summer?

Question 4.

Do you know any plant species that are eaten by rhinos but not of any other animals in the reserve?

Question 5.

Do you know any plant species that are NOT eaten by rhinos but of other animals in the reserve?

Appendix 2.

Complete list of plant species recorded as food plants for black rhino during collection period.

Plant family and name	Plant group[1]	Number of recorded plants browsed	% of all browsed plants	% of all bites	% of all twigs browsed
Acanthaceae					
Justicia cuneata	sh	9	1,4	1,5	3,8
Anacardiaceae					
Ozoroa mucronata	w	1	0,2	0,5	0,7
Rhus longispina	w	9	1,4	3,0	2,2
Apocynaceae					
Carissa haematocarpa	w	8	1,2	1,3	1,0
Asteraceae					
Brachylaena ilicifolia	w	7	1,1	0,9	0,5
Euryops sp.	sh	1	0,2	0,1	0,1
Felicia filifolia	sh	1	0,2	0,2	0,3
Bignoniaceae					
Rhigozum obovatum	sh	13	2,0	2,5	2,2
Boraginaceae					
Ehretia rigida	w	5	0,8	0,6	0,6
Cactaceae					
Opuntia ficus - indica	s	4	0,6	0,4	0,0
Caesalpinioideae					
Schotia afra	w	17	2,6	2,7	2,7
Capparaceae					
Capparis sepiaria	w	3	0,5	0,2	0,1
Celastraceae					
Cassine crocea	w	5	0,8	0,8	0,5
Maytenus heterophylla	w	2	0,3	0,2	0,1
Maytenus polyacantha	w	16	2,4	2,5	1,9
Ebenaceae					
Diospyros scabrida	w	2	0,3	0,3	0,2
Euclea undulata	w	36	5,4	15,3	17,9
Euphorbiaceae					
Euphorbia bothae	s	180	27,2		
Euphorbia mauritanica	s	3	0,5	0,1	0,0
Jatropha capensis	h	75	11,3	15,7	18,0
Phyllanthus verrucosus	sh	2	0,3	0,2	0,4
Lamiaceae					
Becium burchellianum	sh	1	0,2	0,6	0,9

[1] w = woody plants, sh = dwarf shrubs, h = herbaceous plants, s = succulents

Appendix 2. Continued.

Plant family and name	Plant group[1]	Number of recorded plants browsed	% of all browsed plants	% of all bites	% of all twigs browsed
Liliaceae					
Asparagus africanus.	sh	2	0,3	0,3	0,0
Asparagus racemosus	sh	1	0,2	0,1	0,1
Asparagus striatus	sh	5	0,8	0,6	1,6
Asparagus sp.	sh	3	0,5	0,2	0,1
Malvaceae					
Abutilon sonneratianum	h	2	0,3	0,2	0,1
Mesembryanthemaceae					
Delosperma calycinum	s	5	0,8	0,5	0,7
Mestoklema sp.	s	21	3,2	2,1	3,1
Ruschia sp.	s	2	0,3	0,4	0,0
Oleaceae					
Jasminum multipartitum	sh	11	1,7	2,5	2,3
Olea africana	w	2	0,3	0,3	0,7
Plumbaginaceae					
Plumbago auriculata	sh	25	3,8	8,8	8,4
Portulacaceae					
Portulacaria afra	s	3	0,5	0,4	0,3
Ptaeroxylaceae					
Ptaeroxylon obliquum	w	2	0,3	0,2	0,2
Rubiceae					
Coddia rudis	sh	20	3,0	3,4	1,6
Salvadoraceae					
Azima tetracantha	w	15	2,3	2,8	1,9
Sapindaceae					
Pappea capensis	w	2	0,3	0,1	0,1
Selaginaceae					
Walafrida geniculata	sh	1	0,2	0,1	0,5
Solanaceae					
Lycium campanulatum	sh	11	1,7	3,7	3,0
Lycium oxycarpum	w	11	1,7	1,8	1,4
Lycium sp.	w	1	0,2	0,1	0,2
Solanum coccineum	h	6	0,9	0,6	0,5
Thymelaceae					
Gnidia cuneata	sh	2	0,3	0,2	0,6
Tiliaceae					
Grewia robusta	w	109	16,5	20,8	18,8

[1] w = woody plants, sh = dwarf shrubs, h = herbaceous plants, s = succulents

Appendix 3.

Date: Time of day: Weather: GPS position start: Position on map:
Rangers: Name of rhino: Temperature: GPS position end: Age of track:

Plant no.	Distance[1]	Plant species	Feeding height[2]				Twig diameters[3]				U.L.(%)	B.L.[4]	Height
			0-0.5 m	0.5-1.0 m	1.0-1.5 m	>1.5 m	0-5 mm	6-10 mm	>10 mm	Max			

[1] Distance in meters from the previous browsed plant
[2] Number of bites in each feeding height class
[3] Number of twigs browsed in each twig diameter class
[4] Browsing levels: 1=not previously browsed, 2=lightly browsed, 3=moderately browsed, 4=heavily browsed

Appendix 4.

Date: Time of day: Weather: GPS position start: Position on map:
Rangers: Name of rhino: Temperature: GPS position end: Age of track:

Plant no.	Distance[1]	Average height[2]	Browsed stems (%)[3]	Previous browsing level[4]	Comments

[1] Distance in meters from the previous browsed plant
[2] Average height of remaining stems
[3] Browsed stems in % of total number of stems on the plant
[4] Browsing levels: 1=not previously browsed, 2=lightly browsed, 3=moderately browsed, 4=heavily browsed