R. H. EMSLIE

THE FEEDING ECOLOGY
OF THE
BLACK RHINOCEROS
IN
HLUHLUWE-UMFOLOZI PARK

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THE FEEDING ECOLOGY OF THE BLACK RHINOCEROS
(*Diceros bicornis minor*)
IN HLUHLUWE -UMFOLOZI PARK,
WITH SPECIAL REFERENCE TO THE PROBABLE CAUSES OF THE HLUHLUWE POPULATION CRASH

BY

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DECLARATION

I, the undersigned hereby declare that, except where otherwise indicated the work covered in this dissertation is my own original work, and has not previously, in its entirety, or in part, been submitted at any University for a degree.

Signed

ABSTRACT

Concern about the decline in the black rhino (*Diceros bicornis minor*) population in the Northern Hluhluwe area of Hluhluwe-Umfolozi Park from 1961-1986 was the main reason that led to the initiation of the Black Rhino 2000 (BR2000) research project, which this work formed a major part of.

This thesis seeks to increase knowledge of black rhino:habitat relationships and feeding ecology, to ascertain the causes of the Hluhluwe population decline, and in particular to determine whether habitat changes could have been the major cause of the population changes in the Park. It also seeks to determine the impact of management actions on black rhino.

Through studying the feeding ecology of the species, the project obtained an increased understanding of what constitutes good black rhino habitat in terms of the species and size structure of vegetation; how black rhino perceive and use habitat; and what key variables need to be measured when assessing black rhino habitat suitability. Black rhino showed marked species and size class selection, highlighting the need to assess rhino habitat on a spize (SPecies sIZE class) rather than species basis. In both Hluhluwe and Umfolozi the bulk of their diet was made up of a few key spizes. In particular, black rhinos highly favoured small *Acacias* (<1 m) and members of the *Euphorbiaceae* family (*Spirostachys africana* and *Acalypha glabrata*). Grass interference of browse was also found to significantly reduce browsing, and if their favoured small Acacias were hidden by tall grass, black rhinos were forced to eat more of less preferred taller *Acacias*. At a broad patch level very tall grass areas were avoided by black rhinos.

Contrary to the belief prevailing at the start of the project, burning in Hluhluwe-Umfolozi Park was found, on the whole, to benefit black rhino in both the short and long term. In Hluhluwe, feeding levels were significantly greater in burnt than in unburnt plots, and burnt *Acacias* were especially favoured. In the short term no burning or infrequent burning was found to negatively impact on black rhino by 1) allowing "*Acacias*" to grow into taller less preferred size classes; 2) allowing emerging seedlings of unpalatable fire sensitive later successional evergreen species to establish and grow; 3) not removing grass interference in wet years; and 4) not creating conditions conducive to the early season growth of palatable ground herbs. In the longer term, partial constrained spize ordinations indicated that past fire frequencies significantly influenced habitat composition and structure. Lack of fire in the 1950s and early 1960s was implicated as a major factor associated with a large decline in black rhino carrying capacity following the development of mature *Acacia nilotica* closed woodland, which it time further developed into lowland forest dominated by *Euclea racemosa* and *Berchemia zeyheri.*

While bush-clearing of "*Acacia's*" temporarily reversed woody plant succession; data strongly indicated that clearing was only effective in the shorter term; requiring follow up treatments to prevent the rapid development of mature "*Acacia*" woodlands. Of all the species, *Dichrostachys cinerea* was shown to be particularly resistant to clearing. Conditions immediately after the extensive clearing of Hluhluwe north in 1959-61 together with increased grass growth following culling of grazers and high rainfall is likely to have been a factor in the 1961 die off of black rhino in the area. However, by slowing successional development towards closed woodland and lowland forest communities in N.E.Hluhluwe, past *Acacia* clearing probably prevented an even bigger decline in black rhino carrying capacity from occurring in the medium term. Given that the effects of bush clearing are temporary and require intensive management in the form of frequent re-clearing to maintain open areas, the longer term success of the recent clearing operations is likely to depend on other factors like the interactive effects of fire and elephants. Regrowth of small *Acacias* on many recently cleared areas favoured black rhinos.

A comparison between the offtake volumes and spizes eaten following a remeasurement of plots first measured in 1969-71, clearly indicated that the northern Hluhluwe black rhino population around 1970 was under severe nutritional stress. The recorded increase in inter-calving intervals, age at first calving and adult mortality plus the likely high abortion/neonatal mortality during the decline are all consistent with and reflect a population under nutritional stress. Together with known removals, these factors can fully account for the scale of the Hluhluwe decline from the post 1961 die off period up to 1986. In reviewing probable and possible causes of the Hluhluwe decline it was clear that habitat changes had resulted in a steady and significant drop in carrying capacity from the late 1950s to mid 1980s, and that this was the primary cause of the Hluhluwe black rhino decline. The increase in numbers of black rhino in Umfolozi over the same period was also consistent with habitat changes. Poaching, fire, bush-clearing, demographic stochasticity, competition from other browsers and inbreeding depression were not implicated as major factors in the decline. The level of past predation of neonates by spotted hyena is unknown, and may or may not have contributed to the decline, although on its own neonatal predation could not have been the major cause of the decline.

SAMEVATTING

Kommer oor die afname in die getalle van die swart renoster (*Diceros bicornus minor*) bevolking van die noordelike gebied van die Hluhluwe-Umfolozi Park vanaf 1961 tot 1986 was die hoof rede vir die instel van die “Black Rhino 2000” of (BR2000) navorsing projek waarvan hierdie studie ‘n groot deel uitgemaak het.

Hierdie tesis poog om kennis van swart-renoster habitatsvereistes en voedingsekologie uit te brei en sodoende die redes vir die afname in getalle te ondersoek. Daar word veral gekyk of habitat verandering ‘n hoofoorsaak van bevolkings verandering kon gewees het. Die studie ondersoek ook die impak van bestuurs aksies op swart renosters.

Deur studie van die voedingsekologie van die spesies is ‘n goeie begrip van wat as goeie renoster habitat beskou kan word in terme van spesies en struktuur van plantegroei verkry; asook hoe swart renosters hul habitat ervaar en gebruik. Hieruit was dit moontlik om te bepaal wat die sleutel veranderlikes is wat gemeet moet word wanneer swart renoster habitatsgeskiktheid beoordeel moet word. Swart renosters het sterk spesies en groteklas seleksie openbaar wat die nodigheid beklemtoon dat renosterhabitat op ‘n spesie en grote basis (hiervoor is die engelse term “spize” uitgedink) eerder as slegs spesies beoordeel moet word. In beide die Hluhluwe en Umfolozi parke is hulle dieet saamgestel uit slegs ‘n paar sleutel “spize”. Swart renosters het ‘n sterk voorkeur vir klein (<1m) *Acacia* soorte en lede van die *Euphorbia* familie (*Spirostachys africana* en *Acalypha glabrata*). Gras het met blaarkos ‘n interaksie wat blaarvretery beduidend verminder het, veral wanneer hulle verkose jong *Acacia's* deur lang gras bedek is, dan is die swart renosters verplig om meer van die minder aanvaarbare langer *Acacia* soorte te vreet. Op ‘n breë skaal is langgras kolle deur swart renosters vermy.

In teenstelling met wat aan die begin van die projek geglo is, was brand in die Hluhluwe-Umfolozi Park voordelig vir swart renosters beide in die kort sowel as die lang termyne. In Hluhluwe is bevind dat beweiding meetbaar hoër was in gebrande persele, en gebrande *acacia's* het spesifiek voorkeur geniet. Ongebrande of min gebrande veld het ‘n negatiewe invloed op swart renosters omrede: 1) *Acacia's* uitgroei in minder aanvaarbare groteklasse; 2) Onsmaaklike soorte van later suksessie stadiums wat vuur sensitief is word kans gegee word om te vestig en uit te groei; 3) Gras bedekking nie in nat jare verwyder word nie; en 4) Omdat toestande vir vroeë seisoens groei van smaaklike kruide nie geskep word nie. In die langer termyn het gedeeltelike ordinasies van “spize” aangedui dat

habitats struktuur en samestelling beduidend deur vorige brand frekwensie beïnvloed is. Afwesigheid van vuur in die 1950s en vroeë 1960s is as 'n hoof faktor in die groot afname in swart renoster drakrag uitgewys as gevolg van die ontwikkeling van volwasse, geslote *Acacia nilotica* bosgroepe wat met tyd ontwikkel het in laeveld woud met dominansie van *Euclea racemosa* en *Berchemia zeyheri*.

Ontbossing van "*Acacia's*" het houtagtige suksessie tydelik omgekeer maar die data gee sterk aanduidings dat ontbossing slegs in die kort termyn suksesvol was, en dat opvolg behandeling nodig was om te verhoed dat snelle ontwikkeling van volwasse "*Acacia*" bosveld plaasvind. *Dichrostachys cinerea* was veral bestand teen ontbossing. Toestande na die omvattende ontbossing in Hluhluwe Noord vanaf 1959 tot 1961 saam met die welige grasgroei na die uitdun van grasvreters en verhoogde reenval was waarskynlik 'n faktor in die vrektes onder swart renosters gedurende 1961. Dit is egter ook waarskynlik dat die vertraging van ontwikkeling na geslote bosveld en laeveld woud gemeenskappe as gevolg van ontbossing in die verlede 'n self groter afname in swart renoster drakrag oor die medium termy verhoed het. Daar die resultate van ontbossing tydelik van aard is, en intensiewe opvolgbestuur vereis om oop areas te onderhou, sal die langtermyn sukses van ontbossing afhang van ander faktore soos die interaksie van olifante en vuur. Hergroei van *Acacia's* op baie van die onlangs skoongemaakte areas het swart renosters bevoordeel.

Vergelyking van die volumes en "spize" gevreet, wat gemeet is na 'n oorspronklike meting in 1969-79 dui daarop dat die Hluhluwe swart renoster bevolking gedurende ongeveer 1970 onder geweldige voedings stress verkeer het. Die aangetekende verhoging in tussenkalf periodes, ouderdom by eerste kalwing en volwasse mortaliteit asook die waarskynlike hoë voorkoms van aborsies en neonatale mortaliteit, dui alles op 'n bevolking onder uitermate voeding stress. Saam met die getal diere verwyder (bekend), kan hierdie faktore die volle bevolkingsafname verklaar, vanaf die vrektes na 1961 tot en met 1986. By oorweging van die moontlike en waarskynlike redes vir die afname op Hluhluwe was dit duidelik dat habitats veranderings 'n stelselmatige en beduidende afname in swart renoster drakrag tot gevolg gehad het vanaf die laat 1950s tot die middel 1980s en dat dit die primêre oorsaak van die afname in swart renoster getalle was. Die toename in swart renosters in Umfolozi in die selfde periode kon ook aan habitatverandering toegeskryf word. Stropery, vuur, ontbossing, demografiese stokastisiteit, kompetisie van ander blaarvreters en inteling kon nie as beduidende faktore vir die afname uitgewys word nie. Die geskiedkundige vlak van predasie op jong diere deur gevlekte hiena's is onbekend, en kon moontlik bygedra het tot die afname. Predasie op jong diere kan egter op sy eie nie 'n beduidende oorsaak van die afname gewees het nie.

DEDICATION

This Thesis is dedicated with much gratitude to my parents for all they have done for me and also to Keryn for all her friendship, support and encouragement.

I am just sorry I did not manage to complete this thesis before my mother died.

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✂ NOTE: In the interest of conciseness, with the exception of Chapters 10 and 21, chapter summaries, have been cut from the final degree copies of this dissertation. However all 23 chapter summaries are being released in a separate summary volume, and will be included in all other expanded versions of this thesis for wider distribution (available from the author). The symbol ✂ indicates the summaries that have been cut from this copy of the dissertation.

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THE FEEDING ECOLOGY OF THE BLACK RHINOCEROS
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INTRODUCTION

Chapter 1 - Project Rationale, Scope and Objectives, and a Guide to the Structure of the Thesis

CHAPTER 1:

PROJECT RATIONALE, SCOPE AND OBJECTIVES, AND A GUIDE TO THE STRUCTURE OF THE THESIS

INTRODUCTION

The background to the initiation of the BR2000 project was covered in detail in the original BR2000 project proposal (Emslie 1986). In brief, the world importance of South African black rhino populations increased dramatically over the last thirty years. While poaching reduced the world's black rhino population by an estimated 96% since 1970; South African black rhino numbers increased over the same period. By the end of 1995, South Africa had more black rhino than any other country (with 1,025 out of Africa's approximately 2,410 - Source: IUCN SSC AfRSG data - Emslie & Brooks 1996). This situation can be contrasted with 1970, when probably only about 4% of Africa's black rhinos occurred in South Africa. **The survival of the species is therefore becoming increasingly dependent on successful conservation in South Africa.**

However, not all black rhino populations in South Africa were performing well. Peter Hitchins estimated that the Hluhluwe-Umfolozi Game Reserve population had declined from about 330 in 1973, to an estimated 190 by 1985 (Hitchins & Brooks 1986). The translocation of 88 black rhino from the park during the same period only partially accounts for this decline. As a result of heavy poaching in other range States, **Hluhluwe-Umfolozi Park's black rhino population has increased in international importance to become the world's largest black rhino population. From a continental perspective the decline in Hluhluwe was therefore a major cause for concern.**

DIFFERENCES IN PAST POPULATION PERFORMANCE IN DIFFERENT AREAS OF HLUHLUWE-UMFOLOZI

Past population performances also differ markedly between different areas within Hluhluwe-Umfolozi Park (Hitchins & Brooks 1986). Table 1.1 presents the Hluhluwe-Umfolozi black rhino population estimates by area from 1933 to the 1991. As the boundaries of the areas estimated have changed over time, black rhino densities are also presented in the table to facilitate comparison of the data.

THE HLUHLUWE DECLINE

Prior to the 1961 "die-off", the Hluhluwe and Northern Corridor black rhino population was estimated at almost 300 (Deane 1961). This translates to a density of 1.03 black rhino/km^2. Of these animals, 59% occurred in north Hluhluwe at the very high density of 1.54 black rhino/km^2.

Forty six black rhino mysteriously died in Hluhluwe North in a three month period from the 11th of July to the 27th of October 1961 (Hitchins & Anderson 1983). The decline continued, and by 1973 the Hluhluwe population was only two thirds of peak levels (Hitchins & Anderson 1983), with densities around 0.84 black rhino/km^2. By 1991 it was estimated that black rhino densities in Northern Hluhluwe were only 17% of peak levels (0.26 black rhino/km^2).

THE UMFOLOZI INCREASE

In contrast to Hluhluwe, black rhino densities increased in the adjoining Umfolozi from only 0.03 black rhino/km^2 in 1933 to 0.29 black rhino/km^2 by 1991. Umfolozi densities have more than doubled over the last twenty years despite removals (Hitchins & Brooks 1986; Adcock *et al* 1991, Adcock 1995).

Table 1.1 shows that in 1967 densities in Northern Hluhluwe (0.906 rhinos/km^2) were more than ten times higher than those in Umfolozi (0.080/km^2). However densities continued to decline in Hluhluwe whilst numbers increased in Umfolozi and the Corridor, with the result that by 1991 densities were similar throughout the park (Northern Hluhluwe 0.261/km^{2}and Umfolozi 0.292/km^2). Thus, although densities were similar throughout Hluhluwe-Umfolozi Park in 1991, population performances and past densities have differed markedly between areas in the reserve.

TABLE 1.1 : Hluhluwe-Umfolozi black rhino population estimates and densities (n/Km^2) by area.

POPULATION ESTIMATES

AREA	km2	1933	1937	1948	1950	1952	1961	Post Die Off 1961	1962	1967	1971	1972	1973	1976	1982	1985min	1985	1990	1991
ORIGINAL HGR	160.79	65	115	160	190		279	233		201			199	100	135	69	87		
HLUHLUWE	230.67						146	100		75		67							
Brooks N.HGR	89.12						67			62		33							
Brooks E.HGR	54.99						20			16		20							
Brooks W.HGR	25.9						46			48									30
Brooks S.HGR	60.68						177	131		104									
N.HGR	114.78						97			102									
S.HGR	115.89						300	254		226	170								49
HGR & N.COR	292.34						123			122									
S.HGR & N.COR	177.56						67			73		79							
Brooks S.HGR & N.COR	122.35						21			25									67
N.COR = Brooks N.COR	61.67									26									
S.COR	201.86								30	51	53		69		66	41	52		
OLD COR	258.33																		
CORRIDOR	263.53																		64
UGR 1933	291.6	10																	52
W.UGR	313.05														80	81	102		
S.UGR	157.21					10				38	41	60	50						136
OLD UGR	477.54															191	241	303	262
UMFOLOZI	470.26											329	328						
HLUHLUWE-UMFOLOZI	964.46																		

POPULATION DENSITIES n/km2

AREA	km2	1933	1937	1948	1950	1952	1961	Post Die Off 1961	1962	1967	1971	1972	1973	1976	1982	1985min	1985	1990	1991
ORIGINAL HGR	160.79	0.529	0.715	0.995	1.182		1.210	1.010		0.871			0.683	0.622	0.585	0.299	0.377		
HLUHLUWE	230.67						1.638	1.122		0.842		0.752							
Brooks N.HGR	89.12						1.218			1.127		0.600							
Brooks E.HGR	54.99						0.772			0.618		0.772							
Brooks W.HGR	25.9						0.758			0.791									0.261
Brooks S.HGR	50.68						1.542	1.141		0.908									
N.HGR	114.78						0.837			0.880									
S.HGR	115.89						1.028	0.869		0.773	0.582								0.276
HGR & N.COR	292.34						0.693			0.687									
S.HGR & N.COR	177.56						0.548			0.597		0.646							
Brooks S.HGR & N.COR	122.35						0.341			0.405									0.332
N.COR = Brooks N.COR	61.67									0.129									
S.COR	201.86								0.117	0.199	0.201		0.282		0.336	0.156	0.197		
OLD COR	256.33																		
CORRIDOR	263.53																		0.268
UGR 1933	291.6	0.034																	0.331
W.UGR	313.05														0.168	0.170	0.214		
S.UGR	157.21					0.021				0.080	0.086	0.126	0.128						0.289
OLD UGR	477.54															0.198	0.250	0.314	0.292
UMFOLOZI	470.26											0.340	0.340						
HLUHLUWE-UMFOLOZI	964.46																		

[illegible] MacDonald 1983 and Hitchins 1967, 1971, 1969, Adcock & Emslie 1990, Adcock et al 1991, Potter 1933 and Brooks 1979

CONCERNS THAT LED TO THE INITIATION OF BR2000

For a number of years since the 1961 "die-off", the Hluhluwe segment of the population showed classic signs of a population at or near ecological carrying capacity : delayed sexual maturity, longer calving intervals and high adult and calf mortality (Hitchins & Anderson 1983). Despite removals, the Hluhluwe population showed no improvement in performance (Owen-Smith & Brooks 1985), suggesting that in this instance, Caughley's (1985) Partial Compensation Harvesting Model (which is the main theoretical paradigm on which regional black rhino conservation strategy is based) did not apply.

The Hluhluwe population decline and continuing poor performance was a cause of great concern to local managers and NGO's. Natal Parks Board staff on the ground identified the need for a Hluhluwe black rhino research project as early as 1984 (P.M. Brooks, R.Henwood & S.Pillinger pers. comm.). The process-based management workshop held at Masinda in 1985 also highlighted the need for further black rhino research (Knott & Wills 1985; Anon 1986). The level of concern increased further following the publication of the preliminary results of Peter Hitchins' 1985/86 black rhino census work. The Southern African Nature Foundation (SANF now WAF-SA) were also extremely concerned about the situation in Hluhluwe, and about the lack of a national black rhino conservation initiative at the time. Although an academic proposal to the SANF to do a black rhino project was unsuccessful in 1985, the SANF were convinced of the need for an applied research project on black rhino (R. Soutter pers comm.). The SANF then initiated the Black Rhino 2000 project (BR2000) with the Natal Parks Board (NPB); with SANF approaching and negotiating with me to undertake the project. The Endangered Wildlife Trust (EWT) and Total Oil became major sponsors of the project shortly afterwards. Later Ecoscot Consultancy Services itself became the fifth major sponsor.

Given the increasing global importance of Southern African Populations, SANF staff, and the SANF Scientific Advisory Committee were keen that the project work towards formulating a National Conservation Strategy for the species (F.Stroebel and R. Soutter pers comm). Both the EWT and Mr Van Der Walt of Total also indicated to the consultant that they were interested in the broader strategic conservation work; as was Ecoscot Consultancy Services.

The broader scale work of BR2000 (not discussed in detail in the Thesis) was concerned with regional and national monitoring and strategies for rhino conservation. With the development of the Conservation Plan of the black rhinoceros in South Africa, the TBVC States and Namibia (Brooks 1989), the broader scale work of BR2000 was channelled through both the Rhino Management Group (RMG) and IUCN SSC's African Rhino Specialist Group (AfRSG).

This included:

- determining information requirements for population monitoring and reporting to the RMG (Sandwith *et al* 1988, Emslie 1991a) ;
- improving rhino population estimation procedures, through addressing field data collection requirements, and devising and producing the tailor-made Bayesian Mark-Recapture analysis software package RHINO (Emslie 1993a);
- revising RMG black rhino ageing categories (Emslie *et al* 1993)
- synthesising and managing regional black rhino population data (1989-93), and producing the first two status report summaries for South Africa and Namibia (Emslie 1990b, 1991c)
- holding a workshop for the RMG to develop procedures for assessing property suitability for black rhino and for assessing carrying capacities (Emslie 1993c)
- attending RMG and AfRSG meetings in South Africa, Namibia, Zimbabwe and Kenya, and contributing to rhino conservation workshops in South Africa, Kenya and Tanzania.

While this broader scale work primarily focused on biological management issues, the crucial importance of community development, law enforcement and security in the successful conservation of black rhino is fully recognised.

The primary concern of the Natal Parks Board (NPB) was that the BR2000 project should focus on the Hluhluwe decline, and in particular black rhino-habitat relationships. This subject forms the basis of this thesis. This project was designed to enhance and build on Peter Hitchins' earlier work in the Park by focusing on areas where there appeared to be information gaps. In particular it was clear that there was an urgent need to obtain a more detailed understanding of black rhino feeding ecology in different areas. This would enable general principles about the factors influencing black rhino populations to be drawn; and shed light on whether habitat changes were the main cause of the Hluhluwe decline. Such knowledge would also prove valuable in improving estimates of the potential of different areas for supporting black rhinos.

INVESTIGATING THE CAUSES OF THE HLUHLUWE DECLINE

POSSIBLE CAUSES OF THE HLUHLUWE DECLINE

Prior to the start of BR2000, Hitchins & Brooks (1986) concluded that although a number of hypotheses to explain the causes of the Hluhluwe decline existed, the exact causes of the decline had not been established. Unfortunately in many cases there was limited evidence to evaluate alternative hypotheses; or the available evidence had not been synthesised.

One of the major aims of this project was therefore to examine key alternative hypotheses; and in particular to determine whether habitat changes in Hluhluwe were likely to have been the primary cause of the Hluhluwe decline.

The various hypothesised possible causes of the Hluhluwe decline at the start of the project were:

○ Habitat changes have greatly reduced the carrying capacity of the area for black rhino.

○ Past bush clearing by management may have caused or catalysed the decline by removing favoured black rhino browse.

○ Control burning by management has negatively affected black rhino by selectively removing palatable young browse plants (Hitchins - quoted in Anon 1988), and that more black rhinos could have been burnt in veld fires than previously thought (Hitchins & Brooks 1986).

○ Alternatively, infrequent past burning may have been detrimental to black rhino by negatively affecting habitat quality. (This hypothesis conflicts with the previous hypothesis and the speculative conclusion from a 1988 NPB meeting to discuss Peter Hitchins' management recommendations, that increased fire frequencies and competition with browsers may be the two factors that negatively impacted on the Hluhluwe black rhino population (Anon 1988)

○ Calf predation by spotted hyena and/or lion has increased

○ Genetic problems and inbreeding depression may be the cause of reduced performance.

○ Black rhinos may have suffered from increased competition for food with other browsers, and especially from nyala which increased in numbers tenfold between 1950 and 1972 (Anon 1988).

○ Poaching was greater than previously thought, especially around the Corridor road (Hitchins & Brooks 1986, Anon 1988).

○ A disease outbreak, prussic acid poisoning or haemolytic anaemia may have reduced numbers.

○ Heavy culling of grazers during the "agricultural" period of management in the early 1980s may have contributing to an increase in tall grass areas. Grass interference of browse in turn may have negatively affected black rhino by hiding preferred food plants.

○ Browsing of poisonous alien plants may have led to increased mortalities.

○ Stochastic demographic factors may have reduced performance.

○ The use of chemicals to control Tsetse flies and Harvester termites in the 1940s and early 1950s may have contributed to the decline.

○ The scale of the decline may have been overestimated because of variable undercounting biases in the population estimation methods.

It was also speculated that the exceptionally low rainfall in 1979-83 contributed to the decline, and that inter male fighting increased in Hluhluwe contributing to the decline.

Evaluating many of these hypotheses for the decline depends on a good understanding of:

1) Black rhino feeding ecology
2) Patterns of woody plant dynamics, and the factors that govern them.
3) Influence of management actions (burning, culling, bush clearing etc) on vegetation and hence black rhino habitat quality.

These three aspects became the key focus of the local component of the BR2000 project.

A CONCEPTUAL FRAMEWORK TO STUDY BLACK RHINO:HABITAT RELATIONSHIPS

Figure 1.1 illustrates how the three aspects mentioned above are inextricably linked together, and provide a conceptual framework to study black rhino: habitat relationships.

There are basically two sub-systems being studied, and these are represented by the two boxes.

The lower box represents the detailed study and understanding of black rhino woody plant selection and preferences (eg species and size class importances and preferences, and the influence of grass height on black rhino feeding).

The upper box illustrates changing woody plant structure and composition. The icons around the upper box represent key factors governing woody plant dynamics and current habitat structure and composition.
These variables can in turn be broken down into two groups.

o The first group of variables includes those factors that cannot be directly manipulated or controlled by management; namely:

PE: Physical Environmental factors such as soil type, underlying geology, distance from water, slope, aspect and altitude.

W: Weather

M: The influence of iron age man on the environment.

T: Time for successional processes to operate following key episodic events.

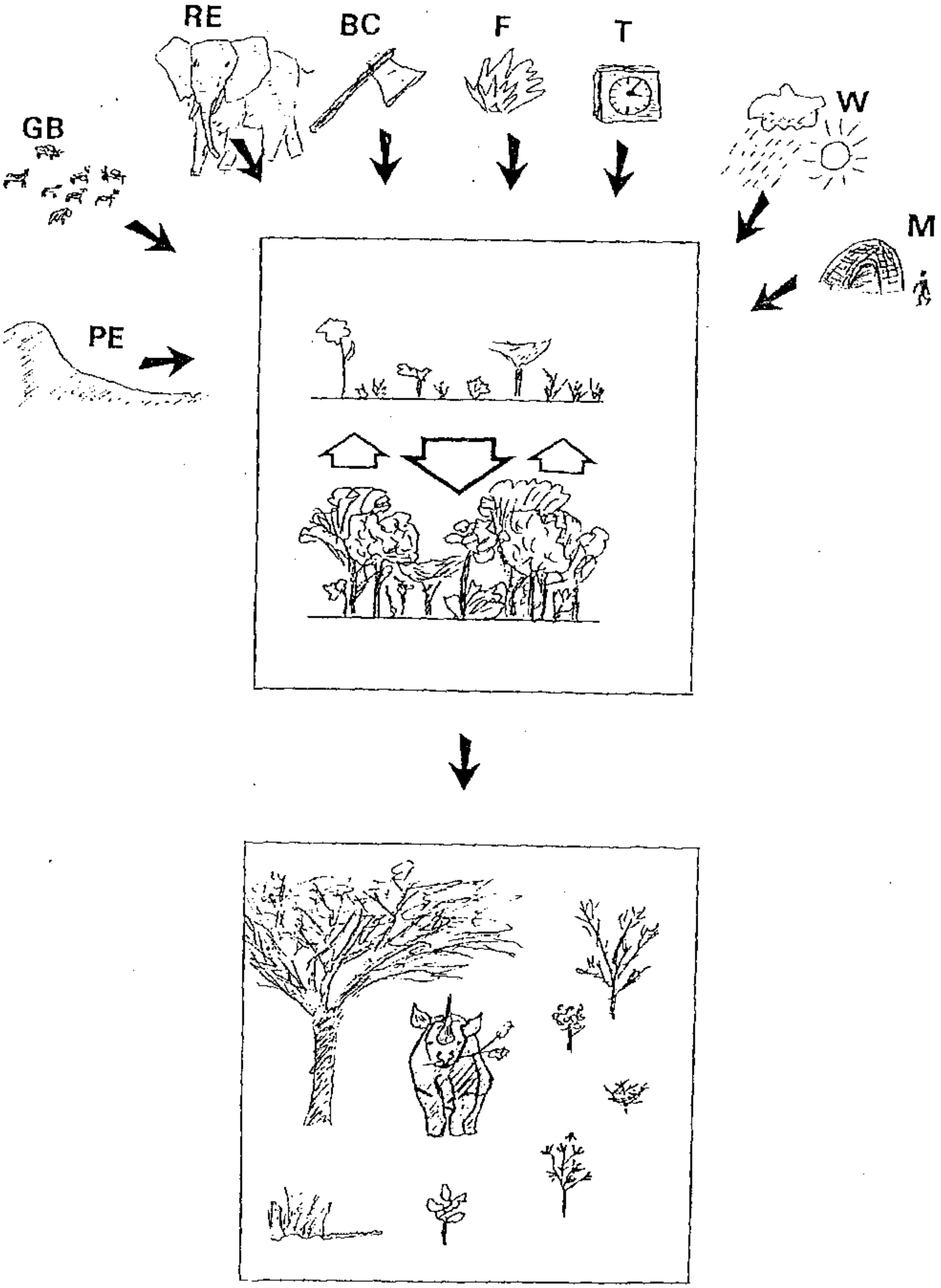


Figure 1.1 Illustration of the conceptual framework and different components of the BR2000 report. The two boxes represent the two main topics under study. The upper box depicts the study of woody plant composition and structure dynamics. The icons above it represent the various factors affecting habitat. These factors can be split into those that can be altered by management (GB: Grazer biomass RE: Reintroduction of elephant BC: Bush-clearing F: Fire); and those that cannot (PE: Physical environment T: Time after episodic events W: Weather M: Effects of Iron-age man). The bottom box depicts the study of black rhino feeding ecology. The arrows linking the two boxes show how the two main components are inter-related. The effects of any changes in habitat composition and structure on black rhino (Top box) can be inferred using the knowledge about black rhino feeding preferences and selection patterns (Bottom Box).

o The second group of variables that can be affected by management are of greater practical interest; namely:

GB: Large grazer biomass and species mixes

RE: Reintroduction of, and stocking policy on elephant

BC: Bush clearing

F: Fire frequencies, return periods and intensities

The arrow depicts how the two boxes are directly linked. It follows that if we have a good understanding of black rhino feeding ecology, then we are in a position to interpret what any observed changes in habitat will mean to black rhino.

By understanding how management actions influence habitat dynamics, we can infer the likely effects of our management actions on black rhino habitat quality. The rationale behind focusing on these habitat issues is discussed more fully below.

BLACK RHINO:HABITAT RELATIONSHIPS AND HABITAT CHANGES - THE MAIN FOCUS OF THIS THESIS

THE NEED FOR STUDIES OF BLACK RHINO FEEDING ECOLOGY IN HLUHLUWE-UMFOLOZI

To date most of our knowledge about black rhino habitat selection has come from studies in East Africa (Goddard 1967b, 1968, 1970 ; Frame 1980 ; Mukinya 1973, 1977 ; Brett 1986), Addo Elephant Park (Hall-Martin *et al* 1982), and Namibia (Joubert & Eloff 1971 ; Loutit *et al* 1987). Unfortunately the conditions in most of the areas studied differ from those in most of South Africa's black rhino reserves (East Africa has two rainy seasons and leguminous forbs are very abundant; conditions in Namibia are much more arid than in Zululand; and in the Addo Elephant Park succulents are abundant). **The results of these studies are therefore not directly applicable to Zululand conditions.**

Many of these studies had limitations. In particular most of the published black rhino feeding studies to date have made little or no attempt to quantify food availability. Such studies therefore can only be used to quantify dietary importance of different food items (but not preference and rejection levels). Some of the studies simply counted the number of plants browsed without taking cognisance of the size of the browsed plant, their settings, or the amount of foliage removed.

Prior to this project, detailed research on black rhino feeding patterns in Zululand was restricted to one study in three habitat types in N.E.Hluhluwe in 1969-71 (Hitchins 1979). Peter Hitchins (1969) also studied habitat use by comparing densities of known black rhino in two areas to the different proportions of broad physiognomic vegetation types in the two areas. This work was backed up by limited vegetation data from two transects per area.

However, at the outset of the project, the view that further research into rhino habitat selection was needed was not universally accepted (P.M. Brooks, pers. comm.). At least one conservationist at the time felt that "we already knew all we needed to know about black rhino habitat use". However, **the need for further work was clearly apparent when black rhino specialists visited the area of developing forest behind the Zincakeni dam early on in the project. Visual habitat suitability estimates of the same patch ranged from "Prime black rhino habitat" to "Poor"!** This was clearly not an ideal situation.

Given regional and national conservation goals for the species (Brooks 1989, Brooks & Adcock 1997), black rhinos are now being managed on a metapopulation basis. Translocation of black rhino to new areas forms a major part of this regional strategy. In turn, habitat suitability assessments form an integral part of the evaluation of potential new areas for reintroduction of black rhino.

Our ability to estimate carrying capacities of potential new parks would improve if our knowledge of black rhino habitat use improved. In particular, improved knowledge about black rhino feeding ecology should reduce the risk of overestimating potential carrying capacity.

The study of black rhino feeding ecology in two areas with differing past population performances would provide valuable information. This project therefore studied black rhino feeding in both Umfolozi and Hluhluwe. In Hluhluwe, feeding results could also be compared with Hitchins' findings two decades previously (1969-71) when black rhino densities in Hluhluwe North were approximately three times higher than they are today.

Another good reason to study feeding ecology in detail is that detailed knowledge of black rhino feeding patterns is needed to be able to assess the likely impact on black rhino of any natural successional or management induced changes in woody vegetation composition and structure.

EVALUATING THE *HABITAT CHANGE AS A MAJOR CAUSE OF THE HLUHLUWE DECLINE* HYPOTHESIS

While analysis of aerial photographs has revealed major changes in Hluhluwe woody vegetation cover and physiognomy since the 1930s (King 1987); detailed information on vegetation changes in Hluhluwe at a species size class (***spize***) level was limited (see definitions in Chapter 4). To evaluate the habitat change hypothesis, it was therefore necessary to determine as best as possible how woody vegetation composition and structure had changed in Hluhluwe. The rationale behind the study of succession is that provided one has a detailed knowledge of black rhino feeding preferences and selection patterns it is possible to estimate the likely effects of past changes in Hluhluwe woody species composition and structure on black rhino.

Fortunately a hypothetical successional sequence for woody vegetation in Hluhluwe had already been proposed by Whateley and Wills (1996); although academic referees of a draft of the paper had questioned some of the authors' conclusions about the causal processes operating. Although Nick King (1987) supported the Whateley-Wills successional model for Hluhluwe; he recommended that the Natal Parks Board should make a study to verify the proposed successional pathways a research priority.

THE NEED TO DETERMINE THE EFFECTS OF MANAGEMENT ACTIONS IN HLUHLUWE-UMFOLOZI ON BLACK RHINO

Management actions in Hluhluwe (control burning, bush clearing, culling and removal of large herbivores and re-introduction of elephant) can also affect habitat composition and structure. Particular concern was expressed about the possible negative impact of burning on black rhino at a Natal Parks Board meeting in 1988 (Anon 1988). Natal Parks Board managers were therefore keen to determine the likely impact of their management actions on black rhino.

This project therefore aimed to study how management actions have affected habitat conditions. Once again, the implications for black rhino of any identified man-induced vegetation changes can be inferred given detailed knowledge of black rhino feeding patterns. The short term effects of burning can also be determined by observing how black rhinos use burnt and unburnt areas after fires.

Four major difficulties arise in separating out the effects of management actions on habitat composition and structure (and hence rhino habitat quality):

- o Environmental and management effects are partially confounded requiring sophisticated statistical techniques to separate out the independent effects of key variables of interest[#1].

- o The ability to sort out the effects of past management impacts is only as good as the quality of the monitoring records of management activities, and the degree to which adaptive management is practised.

o The vegetation data are complex, bulky and noisy. Multivariate analyses were used to deal with some of these problems. In some cases software had to be written to prepare data prior to analysis[#2]. Interested readers who are not professional ecologists can read Appendix 4.1 for a non-technical explanation of what such multivariate techniques can do, and how to interpret the graphical outputs from such methods.

EVALUATING OTHER HYPOTHESES FOR THE HLUHLUWE DECLINE

A review of available literature and records for the area were in part used to evaluate the possibility of other factors (besides vegetation change) being responsible for the Hluhluwe problem. This covered factors such as genetics, competition with other browsers and predation. The possibility of variable bias in population estimation leading to an over-estimation of the Hluhluwe decline is also considered.

VORTEX (Lacy & Kreeger 1992, Lacy *et al* 1995) modelling was also used to evaluate the possible influence and relative importance of some hypothesised causes for the Hluhluwe decline. Factors affecting population performance that were modelled using VORTEX included neonatal calf mortality (related to poor nutrition/hyena predation), inter-calving intervals, adult mortality rates, age at first calving, maximum age of breeding, translocation of rhinos, inbreeding and loss of genetic heterozygosity, stochastic demographic factors, and occasional catastrophes such as adult predation by lion, poaching and animals being burnt in veld fires.

MAIN OBJECTIVES AND KEY QUESTIONS

The objectives of the thesis follow from the information gaps identified in the previous section. The thesis is primarily concerned with increasing our knowledge about black rhino:habitat relationships and feeding ecology, the impact of management actions on black rhino and the causes of the Hluhluwe population decline. It has three main objectives...:

1) To study black rhino habitat use and feeding ecology in areas with contrasting population performance (N.Hluhluwe & W.Umfolozi).

The work aims to obtain an increased understanding of:

○a What constitutes good and sub-optimal black rhino habitat in terms of species and size structure of the vegetation ? - Can general principles be drawn from findings in Hluhluwe-Umfolozi and other areas? (see Objective 1b)

○b How do black rhino perceive and use habitat? For example, do they select for patches of suitable habitat, or select at a finer species, spize (*sp*ecies s*ize* class) or resource level (spize and grass interference level); or alternatively do they select at a hierarchy of scales?

○c What key variables need to be measured when assessing habitat suitability ?

Given the concern about the reasons for the Hluhluwe decline it was necessary:

2) To determine why the Hluhluwe black rhino population has declined; and in particular to evaluate whether habitat changes have been the major cause of population changes in Hluhluwe (and Umfolozi).

To answer these questions one needs to meet objectives 1a and 1b above and:

○a To determine how the habitat has changed in Hluhluwe (and in particular evaluate the proposed successional model of Whateley & Wills).

○b To ascertain the likely effects of other factors (such as genetics, competition with other browsers, and predation) on population performance.

Management can affect habitat structure and species composition, and so it was necessary :

3) To determine the effects of management actions (fire, bush clearing, heavy culling, reintroduction of elephant) on black rhino habitat quality suitability.

Again this is a two step problem - Firstly determining how habitat is altered by management, and secondly interpreting this in the light of knowledge of black rhino feeding preferences. In addition to answering questions 1a and 1b above, key questions were:

○a What were the short and long term influences of fire on Hluhluwe vegetation and black rhino habitat suitability?

○b What have been the long and short term influences of bush clearing on the woody vegetation in Hluhluwe, and on black rhino habitat suitability?

oc What were the likely effects on black rhino habitat quality of the very heavy culling during the period of conservative "agricultural" management in Hluhluwe-Umfolozi in the early 1980s? In particular, how will the likely increase in grass interference of browse during the late 1980s have affected black rhino habitat quality? What does the increase in grazer densities following the replacement of the "agricultural" management paradigm in Hluhluwe-Umfolozi by Emslie, Wills and Goodman's "process-based" management paradigm hold for the black rhino?

Limitations of black rhino population estimation methods available at the start of the project, resulted in the original PhD project proposal having a fourth aim "*to develop an improved black rhino population estimation technique that could be used in the field*". This aim was achieved by developing the necessary statistics to improve estimation of black rhino population sizes using field sighting/re-sighting data, and then writing a software application, "RHINO" (Emslie 1993a) to enable field biologists to use the derived statistical methods. This formed part of the broader scale work of BR2000 and has been fully written up (Emslie 1993a). However in order to reduce the size and scope of the thesis to a more manageable level it was decided not to include this work in the thesis.

This introductory chapter provides a route map through the thesis chapters, which are split into 4 main sections:

I Black rhino feeding ecology and habitat use : Methods and Analyses (Chapters 2-5).

II Black rhino feeding ecology and habitat use : Results (Chapters 6-13)

III The influence of environmental factors and management actions on black rhino habitat quality (Chapters 14-19)

IV Probable and possible causes of the Hluhluwe decline: Discussion and Recommendations (Chapters 20-23)

A ROUTE MAP TO THE THESIS

STYLE OF THE THESIS

To aid the reader, chapter summaries are given in bold font at the beginning of each chapter (except in copies of the thesis submitted for the degree of PhD), and key points in the text have also been highlighted in bold font. Chapter notes (indicated by [#n] in the text) are appended to the end of each chapter, while Appendices follow the Refernces at the back of the disertation.

In order to reduce the size and scope of the thesis, my supervisor decided that the thesis should restrict its focus to just the first three aims dealing with the more local Hluhluwe-Umfolozi Park research. Despite excluding all the broader scale work of BR2000, this thesis still covers a wide range of research topics. Following further discussions with my supervisor, it was decided that in order to cut the size of the thesis, but still present the full picture and scope of the Hluhluwe-Umfolozi research, only a chapter summaries for chapter 10-14, 19 and 21 would be included in the Thesis. However in the interest of conciseness, all chapter summaries, with the exceptions of Chapters 10 and 21 have been removed from the final copy of the thesis submitted for the degree of PhD. However, all 23 chapter summaries are included in both a shortened summary version of the thesis, and all other copies of an expanded version of the thesis for wider distribution. Additional detail relating to Chapters 16 and 18 and the final applied recommendations of BR2000[#4] presented to, and considered by the Natal Parks Board at a BR2000 recommendations meeting in February 1995 (Emslie 1995) can be found in the BR2000 reports lodged with the Natal Parks Board (now KZNNCS). Many of the latter were concerned with broader strategic conservation management issues and this document was also written primarily for park managers not scientists.

Results summaries have for the most part been included as Tables. The many large tables may be a bit off-putting to the casual reader. For this reason, the salient points to emerge from these tables have either been discussed in point form in the text, or been illustrated graphically. The tables have been included primarily for other researchers who may be interested in specific details of the results. Those with limited time need only glance at the tables.

The analytical approaches, field techniques and software used are described in Chapters 2,3,4 and 5. **Readers not overly concerned with methodological and analytical details should just read the summaries of Chapters 2,3, 4 and 5; and the definition of terms in Chapter 4.**

Similarly, the results and key findings from the Formal Inference-based Recursive Modelling (FIRM) are also discussed in point form in the text. An optional edited 84 page summary of key FIRM results (Appendix 9.1) is available to examiners on request and formed part of the BR2000 report to the Natal Parks Board.

Those readers who are unfamiliar with the constrained ordination methods and the interpretation of canonical correspondence analysis biplots can consult Appendix 4.1 for a non-technical explanation.

STRUCTURE OF THE REPORT

Chapters with only chapter summaries have not been shaded

SECTION I - BLACK RHINO FEEDING ECOLOGY AND HABITAT USE

The four chapters (2-5) outline the methods and analyses used to study black rhino habitat relationships.

CHAPTER 2 - *Methods I: How does one measure black rhino feeding ?*

CHAPTER 3 - *Methods II: Black rhino feeding:habitat studies*

CHAPTER 4 - *Methods III: Black rhino feeding:habitat data preparation and analysis*

SECTION II - BLACK RHINO FEEDING ECOLOGY - RESULTS

The following eight chapters (6-13) present the results of these analyses, ending with comparison of the results with those of other areas. Observations of feeding behaviour of a boma'd rhino are also listed. Chapters 6 to 9 are included in full as they deal with results from the pilot, grid and post-burn surveys. Only chapter summaries are included for chapters 10-13.

These chapters provide answers to the following questions:

> What are the levels of browse availability in the two study areas ? Such data are required to be able to assess dietary *preference* and *rejection*. What are the key species and spizes in the habitat in terms of density, available browse bottles and canopy cover ?. These data provide a baseline against which future vegetation changes can be measured.
>
> What are the most *important*, *preferred* and *rejected* species in black rhino diets in Hluhluwe and Umfolozi ?
>
> What are the effects of tree size class on both preference and importance values for key woody species in both study areas ?
>
> What woody plant communities are black rhino selecting for, and which are they rejecting?

At what level were black rhinos selecting their food - at a plot, species, spize and/or resource level ?

What are the differences in food and habitat selection patterns between Hluhluwe and Umfolozi ?

How do black rhino diets vary at different seasons ?

Do black rhino change their habitat or species selection because of burns? In particular, are black rhinos forced to seek unburnt patches or forest patches to feed in after burns?

What are the effects of burn severity on black rhino habitat suitability ?

What were the feeding patterns of black rhino immediately after burns and before the post-burn/early growing season vegetation flush period ?

What were the feeding patterns of black rhino during the post-burn/early growing season vegetation flush period ?

How important were forbs in the Hluhluwe black rhino diet ? Which were the key species?

Were browsing levels influenced by the degree of grass, thicket and forb interference of browse, and if so how ?

Do black rhino preferentially feed along paths ?

Have feeding selection patterns changed in NE Hluhluwe since Peter Hitchins measured black rhino feeding in 1969/70 ?

How do the results compare with findings elsewhere? Can general principles be drawn?

CHAPTER 6 - *Black rhino feeding patterns I: Pilot Survey results*

CHAPTER 7 - *Black rhino feeding patterns II: Grid survey results - Part I: Important, preferred and rejected communities, species and spizes*

CHAPTER 8 - *Black rhino feeding patterns III: Grid survey results - Part ii: Effects of grass interference and grass height on black rhino feeding*

CHAPTER 9 - *Black rhino feeding patterns IV: Results of Post-burn surveys*

CHAPTER 10 - *Black rhino feeding patterns V: Remeasurement of Hitchins' 1969-1971 transects in the bush cleared areas of Hluhluwe North* **(Summary only)**

CHAPTER 11 - *Black rhino feeding patterns VI : Forb Use* **(Summary only - Excluded from PhD examination copies)**

CHAPTER 12 - *Black rhino feeding patterns VII: Comparison of Hluhluwe-Umfolozi results with other areas* **(Summary only- Excluded from PhD examination copies)**

CHAPTER 13 - *Black rhino feeding patterns VIII: Boma feeding observations* **(Summary only - Excluded from PhD examination copies)**

SECTION III - INFLUENCE OF ENVIRONMENTAL VARIABLES AND MANAGEMENT ACTIONS ON BLACK RHINO HABITAT QUALITY

The next six chapters (14-19) examine the influence of various environmental and especially management actions (fire, bush clearing, stocking rate policy) on black rhino habitat quality.

CHAPTER 14 - *Hluhluwe Woody species : Environment relationships* **(Summary only - Excluded from PhD Examination copies)**

CHAPTER 15 - *The effects of management actions on black rhino habitat quality I: Short term effects of fire*

CHAPTER 16 - *The effects of management actions on black rhino habitat quality II: Long term effects of fire*

CHAPTER 17 - *The effects of management actions on black rhino habitat quality III: Short term effects of bush clearing*

CHAPTER 18 - *The effects of management actions on black rhino habitat quality IV: Long term effects of bush clearing*

CHAPTER 19 - *The effects of management actions on black rhino habitat quality V: Game introductions and removals* **(Summary only - Excluded from PhD examination copies)**

SECTION IV - PROBABLE AND POSSIBLE CAUSES OF THE HLUHLUWE DECLINE

The next four chapters (20-23) review the probable and possible causes of the Hluhluwe decline and assess whether habitat changes have been the primary causes of the Hluhluwe decline. Recommendations to stem directly from the research relating to the local management of Hluhluwe-Umfolozi are also briefly discussed in Chapter 23[#4].

CHAPTER 20 - ***The nature of past habitat changes in Hluhluwe and their impact on black rhino***

CHAPTER 21 - ***The use of VORTEX PVA modelling to examine the possible causes of the Hluhluwe***

(Summary only - Included in PhD Thesis)

CHAPTER 22 - ***A review of other possible causes of the Hluhluwe decline***

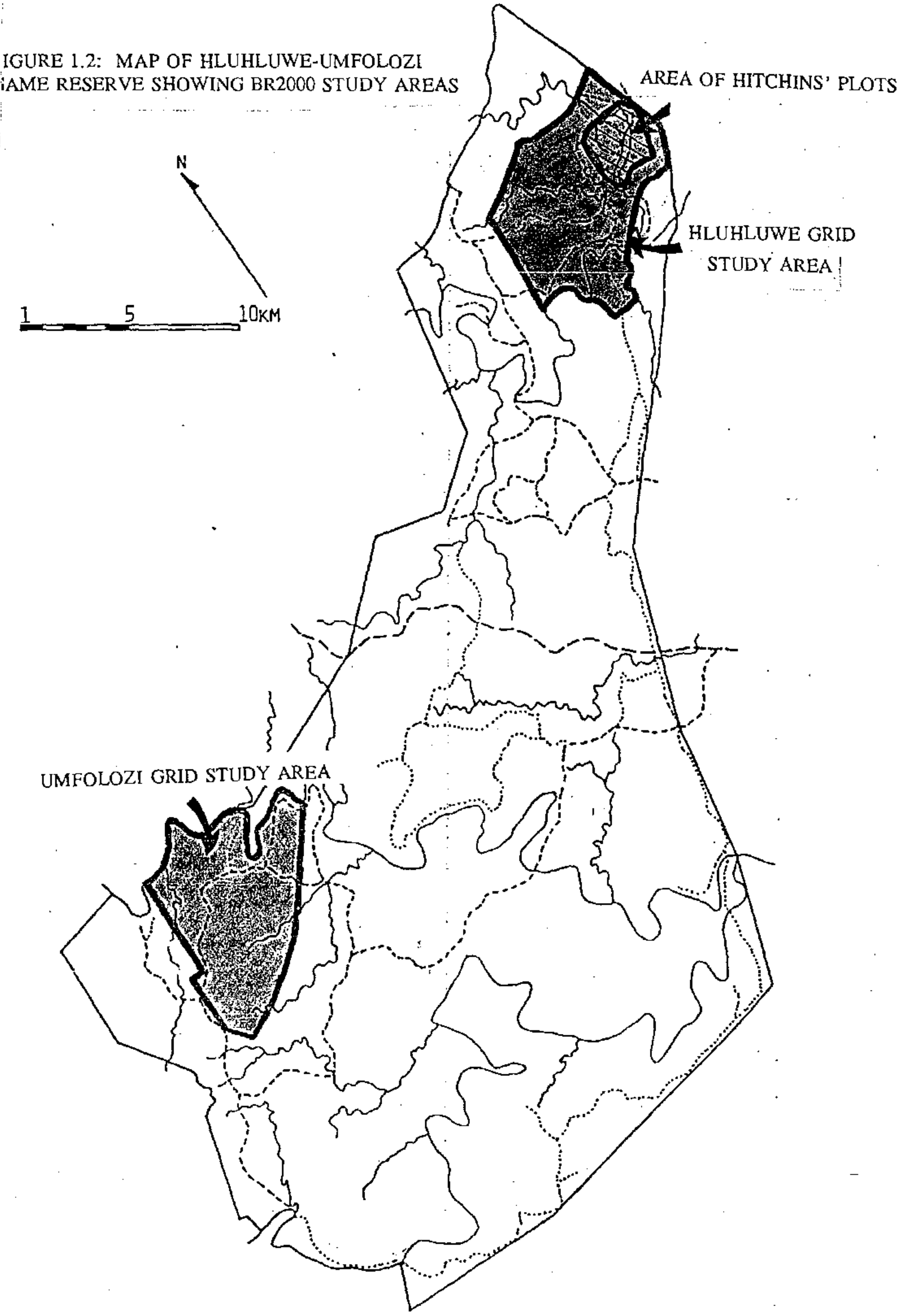
CHAPTER 23 - ***Conclusions on the causes of the Hluhluwe decline***

HLUHLUWE-UMFOLOZI PARK

Hluhluwe-Umfolozi Park is situated in Zululand in the province of KwaZulu-Natal in South Africa and is 96,453 Ha. Readers who are unfamiliar with Hluhluwe-Umfolozi Park, and who require more background information, should consult either Whateley & Porter 1983, Brooks & Macdonald (1983) or King (1987).

Figure 1.2 shows the locations of the two main study areas in N. Hluhluwe and W. Umfolozi.

IGURE 1.2: MAP OF HLUHLUWE-UMFOLOZI
AME RESERVE SHOWING BR2000 STUDY AREAS



CHAPTER 1 - NOTES

#1: For example, fire frequency is in part a function of altitude, slope and aspect. In other words, certain areas have environmental conditions and microclimates that are more predisposed to growing tall grass; and higher fire frequencies usually occur in such tall grass areas. This is a "chicken and egg" problem. The approach adopted to deal with this problem was to firstly statistically remove the effect of the environmental variables on the vegetation. (A spin-off is that this analysis also contributes to an understanding of woody:environment relationships.) The next stage, was to determine whether fire variables significantly explained any of the remaining variation in the vegetation data (ie the variation not already explained by the environmental variables). This approach relied on the assumption that not all areas with the same environmental conditions experienced identical management treatments (in this case fire regimes). See Figure 4.1

#2: For example, as one is interested not only in species, but also size classes, one needs to describe habitat in terms of abundance levels of 250 to 300 species-size classes (or spizes). The effects of grass interference further complicates matters. The human brain cannot readily deal with habitat descriptions in 300 dimensions. Therefore the approach taken to deal with this was either to use multivariate techniques to condense data down to a few derived composite variables describing the main vegetation gradients; or to study feeding preferences on individual species and spizes one at a time.

#3: With the benefit of hindsight and current knowledge, the 1980 density estimates of 0.7 rhino/km2 for Hluhluwe and Northern Corridor, and slightly higher than 0.1/km2 for Umfolozi (Brooks et.al. 1980), were likely to be over and underestimates respectively. Bayesian re-analysis of Peter Hitchins' 1985 data using the method of Zucchini & Channing (1986) indicated that the population estimate of 190 in Hitchins & Brooks (1995) was a biased underestimate and that the true population was probably closer to 240 animals. The 1995 estimate of 405 is based on RHINO analyses of mark-recapture data.

4: This document was written for park managers and contains a total of 65 recommendations and suggested matters for the Parks Boards manangement teams attending the workshop to consider under the headings of removals, fire, bush clearing, predators, genetics, potential competitors and especially nyala, grazer stocking levels, elephants, game capture, habitat assessments, vegetation monitoring, black rhino monitoring, research, scientific communications, socio-politics, lobbying by NGO's and the problem of surplus males. Many of the BR2000 recommendations were also concerned with broader strategic metapopulation management issues. A copy of this document is lodged with the Natal Parks Board (now KwaZulu-Natal Nature Conservation Service).

THE FEEDING ECOLOGY OF THE BLACK RHINOCEROS (*Diceros bicornis minor*) IN HLUHLUWE -UMFOLOZI PARK, WITH SPECIAL REFERENCE TO THE PROBABLE CAUSES OF THE HLUHLUWE POPULATION CRASH

PART 1

BLACK RHINO FEEDING ECOLOGY AND HABITAT USE: METHODS AND ANALYSES

CHAPTER 2

METHODS I : HOW DOES ONE MEASURE BLACK RHINO FEEDING ?

ALTERNATIVE APPROACHES TO MEASURE BLACK RHINO BROWSING

There are three broad approachers to assessing the diet of browsers like black rhino (Barnes 1976, Kotze 1990):

1: Analysis of ingesta or faeces.

2: Direct observation of feeding animals

3: The measurement of browsed vegetation (plant-based methods)

ANALYSIS OF INGESTA OR FAECES

The analysis of ingesta (by way of fistulas or stomach content analysis) was not an option for black rhino for obvious reasons.

A major advantage of faecal analysis is that the feeding sampled in the dung covers the full 24 hour period. However, faecal analysis has a number of well known limitations. The contribution of less digestible or easily identifiable material is likely to be overestimated (Goddard 1968, Kotze 1990). In addition the effect of leaf shape on the probability of individual fragments being sampled under the microscope is unclear (Bruce Page pers. comm) #1

Given the above problems with faecal analysis, one cannot reliably quantify how much of each species is represented in the dung sample. At best one can simply conclude that an item is present or absent in a dung sample, and quantify the frequency with which individual species occur in a number of dung samples. .

The other less commonly articulated, but major shortcoming with using dung analysis to study black rhino woody plant diet, is that it is not possible to determine the size of the plant, and where on the plant, the material in the dung sample came from. The feeding patch woody species composition and physiognomy, and grass structure, also remains unknown - Yet this is just the information we need to understand rhino habitat selection.

However, despite its limitations, faecal analysis is currently the most suitable method to study forb use in densely bushed areas where direct observations cannot be made.

DIRECT OBSERVATION

Goddard successfully used direct observation to study black rhino diet in Ngorongoro, Olduvai (Goddard 1968) and Tsavo (Goddard 1970). The docility of individual rhino and the open terrain allowed much of the fieldwork to be done from a Land Rover. In some cases Goddard was able to observe feeding rhino from only ten metres or less. Conditions were less favourable in Tsavo although Goddard found he could successfully follow rhino on foot in most habitats. In all these studies Goddard used a feeding station method. The number of stations where a species was eaten was expressed as a percentage of the total number of stations recorded. Goddard (1968) concluded that his method provided an indication of the relative importance of the various plant species in the diet, rather than a precise bulk or volumetric measure.

Mukinya (1977) used a Land Rover to find rhinos, and then also successfully used direct observation to measure browsing along rhino feeding tracks. He estimated the proportion of a plant eaten by comparing measurements of the browsed remnant with the total height of an uneaten plant of the same species close to the remnant.

Hall-Martin et al. (1982) also successfully used the feeding track technique to measure black rhino feeding in a 210 ha paddock in Addo Elephant National Park. Approximately 5,550 plants were examined in this study. The densities of the rhino in the paddock for the 15 years before the study ranged from 1.3 to 5.2 rhinos/ km^2, and thus were far greater than the maximum densities recorded elsewhere (Emslie & Adcock, 1988). The artificially high densities explained the high amount of feeding recorded.

Hitchins (1979) attempted direct observation over a period of 8 days in Hluhluwe, but with limited success. The nature of the terrain and its effect on wind direction and local turbulence together with the dense vegetation made it almost impossible to maintain visual contact with a feeding black rhino for more than 15 minutes. By way of comparison, in more open East African terrain Goddard threw out any observations made if it was not possible to watch the animal for at least one hour. The Kenyan and Tanzanian method of using a Land Rover to find rhino was not an option in Hluhluwe-Umfolozi because of the thicker bush, more rugged terrain and because driving off roads is generally not permitted in the Park as it damages the veld. **Hitchins therefore rejected direct observation methods, and instead chose to use indirect plant-based methods in his feeding study in Hluhluwe.**

Field trials in Umfolozi also showed that the hilly terrain limited the effectiveness of using radio-tracking to locate feeding animals quickly and efficiently. The use of a null-peak aerial system improved tracking, but not to a sufficient degree to make it a practicable field tool [#2].

Data collected by Hitchins during fieldwork in 1985, indicated that when sampling a large area (i.e. not just when visiting the most favourable areas), black rhinos were seen between every 23.5 to 39.2 kilometres walked. The overall rate of encounter for the Hitchins' 1985 surveys was 32 km/ black rhino group encountered. Comparable rates of encounter during BR2000 fieldwork were: 48.6 km and 18.6 km for the Hluhluwe and Umfolozi Grid surveys respectively; and 11 km and 12.1 km for the two Hluhluwe Post-burn surveys. No black rhino were encountered during the Umfolozi Post-burn Survey.

Thus even if it was possible to observe animals for long periods; the low rate of encountering rhino means that direct observation in thick Zululand conditions would be very inefficient.

However, the major problem with direct observation techniques, is that direct black rhino feeding measurements are likely to be strongly biased.

Firstly, most black rhino movement occurs during the evening and night (Hitchins 1971, Hillman 1982). Direct observations during the day may reflect the need for thermoregulation by lying up in thick bush or near pans and on ridge tops and therefore could produce a very biased sample. The point is - **daytime feeding areas may differ from night-time feeding, and ideally one needs a technique that will sample feeding throughout 24 hours in an unbiased way.**

Although highly idiosyncratic, many black rhinos are shy, and some individuals may therefore choose to browse in open areas or near roads during the night. For example, we were watching an adult black rhino bull ("Harvey") at the Hlaza saddle near Hilltop in Hluhluwe. He was trying to move up slope through open country, and appeared to be intending to cross the main tourist road at the Hlaza saddle. However, every time he heard the noise of a vehicle pass by on the road, he turned back and hid in a patch of thick bush.

Certain rhinos do become more habituated to humans. For example the male "Ugodo" and female "Cadbury" have both been watched resting in the grass very near to noisy human activity at Game Capture and the Hluhluwe Tennis Courts respectively, without any sign of concern. In all these cases the rhinos were out of the direct sight of the people making the noise. However in Zululand, individuals like these may be the exception rather than the rule. (By way of contrast many of the black rhinos in the open areas of Nairobi National Park, Kenya and Ngorongoro Crater, Tanzania, appear to be completely habituated to vehicles.)

Many of our daytime "sightings" of radio horned rhino in Umfolozi occurred in the very thick donga dissected *Euclea undulata / Schotia capitata / Brachylaena ilicifolia / Maytenus nemorosa / Olea europaea / Carissa bispinosa* dominated dense hillslope bush. The Pilot feeding survey and Grid Surveys recorded limited feeding in such areas, with only *Maytenus nemorosa, Schotia capitata* and *Dovyalis caffra* being regularly eaten along paths. Black rhinos therefore appear to use these areas more for thermoregulation than feeding during the day. By way of contrast, Umfolozi's black rhinos are less commonly seen during the day in open short grass areas with small "*Acacia*'s" near tourist roads. However the plants in these areas often show signs of extensive browsing, suggesting that much of the feeding in these areas occurs at night. These observations corroborate the concern that feeding levels in open areas near human disturbance were likely to be lower during the daytime.

Radio-tracking of black rhino in Pilanesberg by Hillman (1982) also revealed a similar pattern of differential habitat use between night and day. Hillman (1982) also found that at night black rhinos spent proportionately more time feeding in more open grassland areas, and in areas with lower woody canopy cover. This was also supported by her observations of browsed vegetation; and that in areas of Pilanesberg far from human disturbance, black rhinos were more often seen in open areas.

Differential visibility and availability of nearby climbable trees (given that black rhino can be dangerous) in different habitats, would further bias direct observations in Zululand.

PLANT-BASED METHODS

Plant-based methods rely on monitoring feeding signs. When browsing woody plants black rhino characteristically bite branches and twigs (Schenkel & Schenkel-Hullinger 1969) leaving a neat angled cut surface that looks like pruning, as shown in Figure 2.1. This differs from the "toothbrush fraying" of branch ends eaten by elephant. Elephants tend to be more destructive in their feeding and may strip bark.

In Namibia, Joubert and Loutit also ruled out direct observation because of the low sighting frequency of rhino in their study areas, and instead studied feeding by following a rhino's tracks, and noting all species that were eaten (Joubert & Eloff 1971; Loutit *et al* 1987). Loutit *et al* (1987) compared feeding data to measures of available browse made in 20m diameter circles after every 200m of feeding track, while Joubert used samples of 100 trees along randomly sited transect lines to determine preference (Joubert & Eloff 1971). On these transects Joubert recorded the number of trees browsed, and used these data to categorise the amount of browsing on a tree as *Heavy* or *Moderate* depending on the number of twigs eaten. Unfortunately no indications of sample sizes were given.

In both studies, this work was occasionally supplemented by direct observation (Joubert & Eloff 1971; Loutit *et al* 1987). The success of the feeding track method in Namibia was in part due to the more favourable conditions for following spoor and availability of expert trackers.

Hitchins (1979) used a black rhino browse index, where each tree in a plot was examined for browse and scored either 0 (no black rhino feeding signs), 1 (1 bite), 2 (2 bites) or 3 (More than two bites). He summed the total browsing scores for each species, and expressed the results as a percentage of the maximum points possible for each species. **Hitchins' browsing index was therefore an improvement on simple binomial eaten/not eaten feeding preference assessments.**

TECHNIQUES USED TO MEASURE FEEDING

THE BROWSE BOTTLE VOLUMETRIC ASSESSMENT METHOD

THE METHOD

A standard volumetric unit of browse was defined called a *browse bottle* (or BB) [#3]. The volume of leaf material was the primary variable considered when assessing browse bottles.

The browse bottle measure was designed to improve upon the method developed by Hitchins (1979). The aim was to provide an approximate volumetric browse measure, allowing one to assess *both* browse availability and use, on a range of woody species and size classes, without being prohibitively time consuming to apply.

Figure 2.2 shows how much one browse bottle represents for each of five different species, and serves as a photographic standard. The browse bottle measure and photographic standard were also used in Itala by Kotze (1990)[#4]. Estimates of the number of browse bottles available were usually made using a geometric doubling scale with mid points (ie. ½, 1, 1½, 2, 3, 4, 6, 8, 12, 16 BB's, etc.). The same geometric scale with midpoints was used to estimate browse offtake in the pilot survey. During the grid surveys, browse offtake per tree was estimated to the nearest ½ browse bottle.

Figure 2.1. Characteristic "pruning" of woody browse by black rhino.

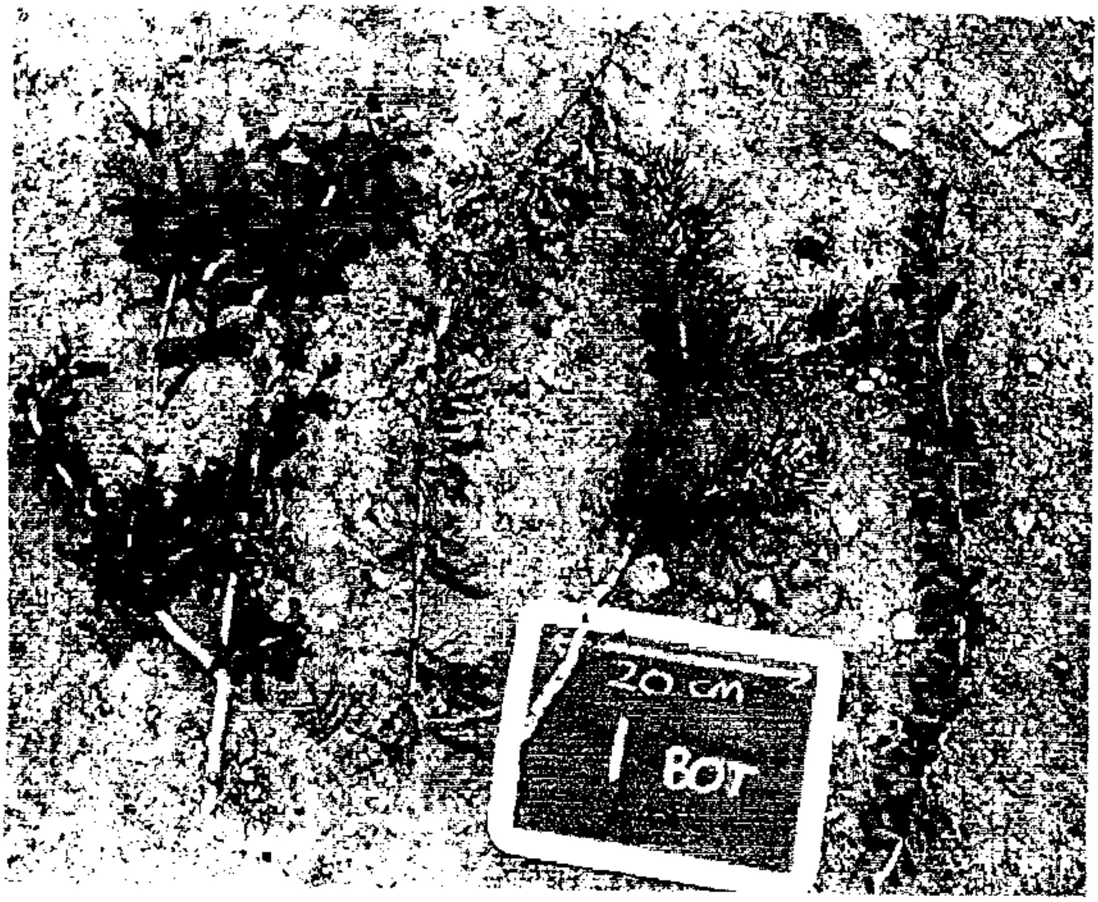


Figure 2.2. Browse bottle standards.

On other occasions, where slightly cruder measures of browsing were required (the rapid post-burn surveys, and when walking between grid transects), the total offtake browsed in each transect was ranked using a 5-point scale (with class boundaries defined using browse bottles).

There is a trade-off between the level of measurement precision attainable in a single plot versus the number of plots that can be sampled in a given time. The pilot survey indicated that large samples would be needed in the Grid surveys to deal with the high spatial variability inherent in both savanna habitat composition and structure, and black rhino feeding patterns. Because of this high variability, better understanding would come from larger sample sizes, rather than from using more precise but time consuming methods in fewer plots.

The browse bottle technique was designed to provide a volumetric measure that could be consistently applied to give approximate estimates of browse abundance, was quick to use, and could be used by different observers. Its ball-park resolution, was also in the right order of magnitude to be appropriate for data analysed using multivariate ordination methods (Gaugh 1982).

PILOT TRIAL OF METHOD

Many vegetation monitoring techniques are notoriously subject to inter-observer variability. Visual techniques to estimate browse use have not escaped serious observer biases (Pitt & Schwabb 1990). It was therefore of primary importance to us to determine whether the eye-balling browse bottle method was repeatable. Hobson (1989) has shown that an eye-balling technique (he called it ocular estimation!) was for a given sample size more precise and more accurate in estimating browse offtake on *A.karroo* bushes than objective techniques. A trial to assess the browse bottle method was undertaken in Itala.

Before the trial one individual acted as a black rhino, and "browsed" eight trees using pruning shears. The harvested twigs were then removed and hidden from the observers. The observers (Adcock, Emslie & Kotze) were shown the browsed bushes, and each estimated how many browse bottles had been "browsed" from each bush

(Missing Browse). No conferring was allowed between observers who independently wrote down their assessments. After estimating the "Missing Browse" the observers were shown the "Browsed Twigs", and again asked to assess the number of browse bottles per sample. Results are given in figure 2.3.

A One-Way ANOVA was initially used to analyse the trial data. There was no difference between observers in their offtake estimates when looking at the "Missing Browse" (F= 0.015 df:2,21 p=0.9849). Similarly there was no difference between observers' offtake assessments when looking at the "Browsed Twigs" (F=0.030 df:2,21 p=0.9702). In both cases, plots of the residuals against predicted values were examined to ascertain whether the key assumption of residual homoscedasticity had been violated. Heteroscedasticty was not present, validating the analyses.

As there was no difference between observers, data were pooled to examine whether offtake estimates based on the "Missing Browse" differed from those based on looking at the "Browsed Twigs". Again no significant differences were found between the estimated compared to actual offtake levels (Paired t=0.299 Pair n=24 p=0.766).

Although not an exhaustive trial, the observers were satisfied that the technique was suitably robust, and could be used by different observers. The trial also showed that it was possible to estimate browse offtake reliably while only looking at a browsed tree.

The three trial observers (Adcock, Emslie & Kotze) also undertook all the rhino habitat:feeding assessments in the Hluhluwe, Umfolozi and Itala black rhino feeding/habitat studies. This facilitated comparison of results. Moreover, the apparent robustness of the technique allowed two field teams to work concurrently during the Hluhluwe and Umfolozi grid surveys.

Figure 2.3 a. Offtake estimated from looking at the branch ends remaining on plants after "browsing"

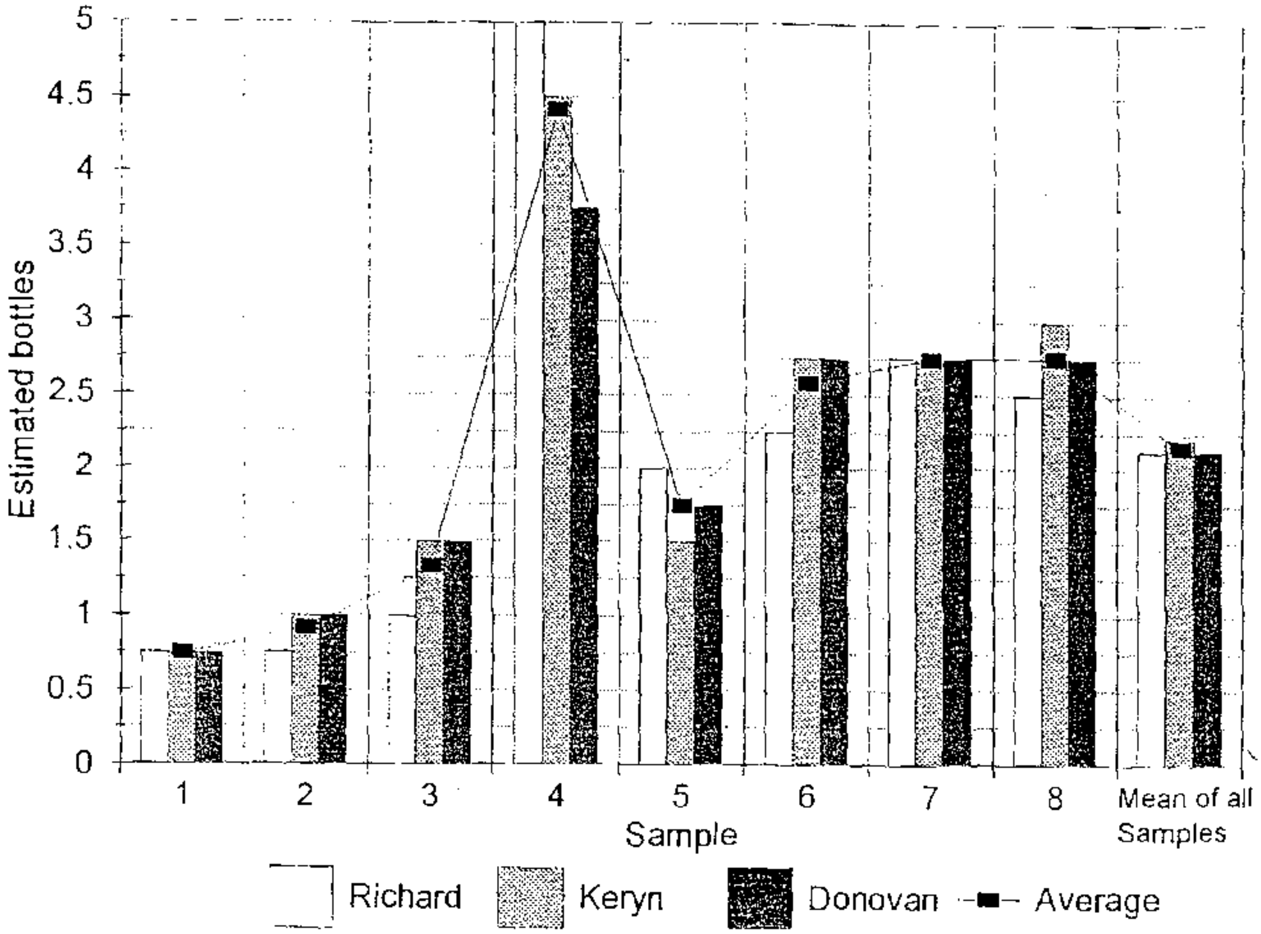
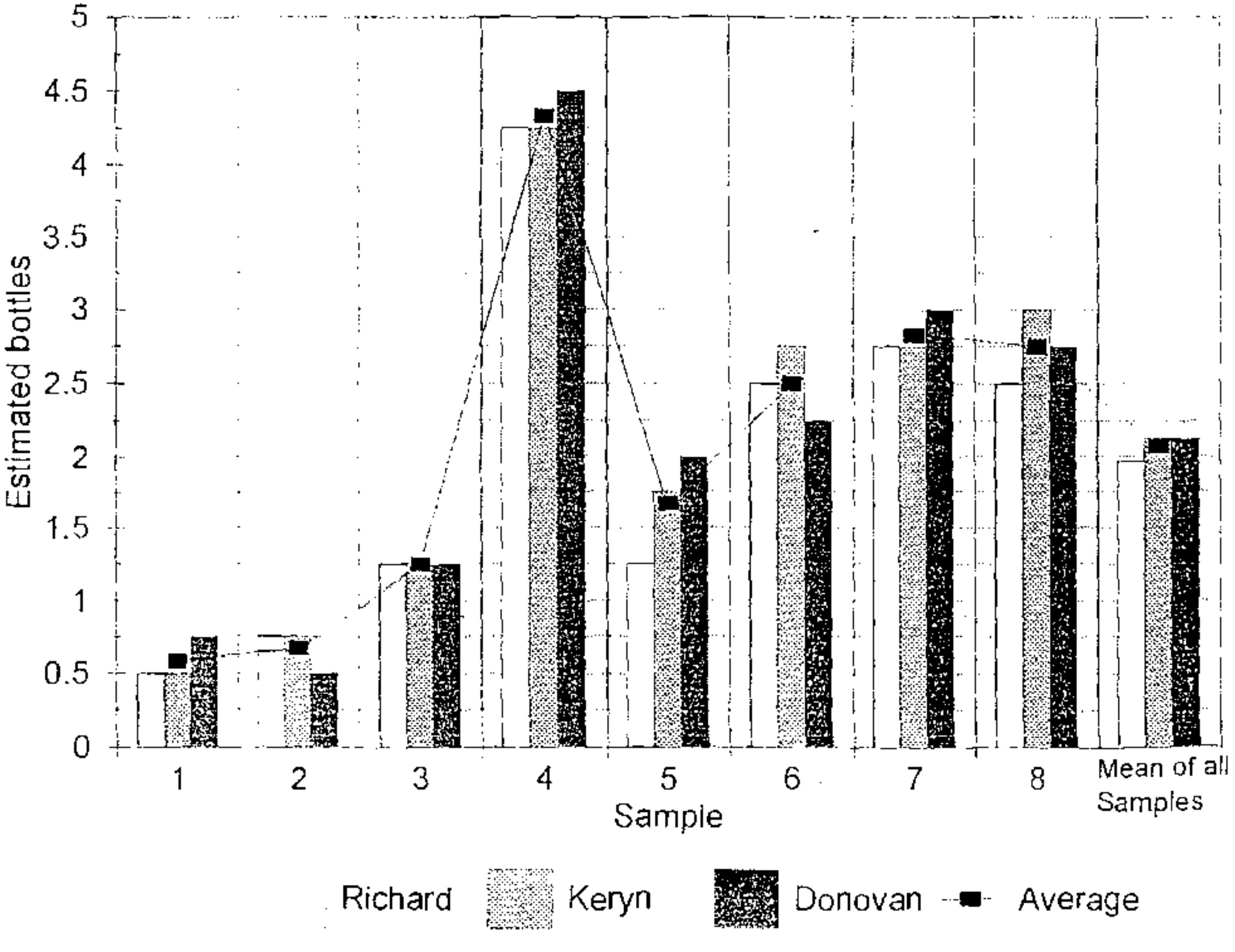


Figure 2.3 b. Offtake estimated from looking at the branches ("bites") removed by "browsing"



PROBLEMS WITH THE BROWSE BOTTLE METHOD

It must be stated that the Browse Bottle plant-based technique was not without its problems. In short these were:

o Black rhinos do not always browse woody plants in their characteristic "pruning" way. For example, we observed black rhinos after burns nibbling the tips of freshly coppicing *Acacia* shoots soon after a burn. Looking only at the feeding signs on such a plant, it would have been impossible to tell what species had browsed it.

o It is difficult to assess browse bottle offtake on certain soft or thin stemmed species/spizes (eg. *Lippia javanica, Euclea crispa, Chromolaena odorata, Hippobromus pauciflorus,* and small *Celtis africana*). If a number of adjacent stems had been neatly browsed it was usually easy to tell whether they were likely to have been taken in one or more big bites. If this was the case then the browsing was ascribed to black rhino. If not, the browsing was not recorded.

o The inability to determine which species browsed small thin seedlings also meant that these had to be excluded from the study.

o The BB values from very large leaved species like *Dombeya burgessiae* may not be exactly comparable with BB values for other smaller leaved species. Calibration of key species BB's could easily be used to solve this shortcoming if it was ever felt to be a real problem. In practice, BB estimates are still a marked improvement on simple binomial present/absent or eaten/not eaten measures. In addition, a major advantage of the browse bottle method was that browse availability and browse offtake assessments were directly comparable within a species, provided browse availability was also quantified in BB's.

o The morphology of certain succulent species (*Aloes* and *Euphorbia's*) and most forbs, makes it impossible to assess these species using this method. Visual observations of browsing of *Euphorbia's* (M.Ward pers. comm.) and the presence of *Aloe* fragments in Itala (D.Kotze pers comm.), Hluhluwe-Umfolozi, and Pilanesberg (K.Adcock pers.comm.) black rhino dung indicate that black rhinos eat these plants.

o By looking at the end of the branches it is only possible to estimate approximately when browsing took place. In this study "new" and "old" browsing was distinguished primarily by the colour of the browsed shoot ends. New browse still retained some of the wood's pale creamy yellow/orange colour at the bite site, while old browse was grey and lacking colour at the bite site.

o It was not possible to use this method to study whether feeding differed between different age/sex classes of black rhino.

o Whilst I share Schenkel and Schenkel-Hullinger's (1969) confidence that in almost all cases it was possible to distinguish correctly between elephant and black rhino browsing; under some conditions the usually clear difference between elephant "toothbrush fraying" and black rhino "pruning" can be blurred. Fortunately in the majority of such cases, other bites can be inspected to decide which species did the browsing. We erred on the side of caution, and did not record browsing unless we were sure it was done by a black rhino.

o Black rhinos have been observed to strip leaves (like giraffe) from species like *Grewia's*. However, *Grewia's* are also browsed in the typical black rhino pruning way.

o In areas with eland, some misclassification of black rhino browsing is more likely. In this study, eland were not present in either study area.

ELECTRON MICROSCOPY

As mentioned above, a major drawback with the browse bottle method is that it cannot be used to study forb (non-grass herbaceous plant) use.

Initially radio-tracking was used to help find individual rhino with the intention of then attempting to use direct observations to locate feeding paths. These could then be examined more closely for signs of forb use. A trial of this approach was not successful, although some of the technical developments used have proved useful elsewhere [85]. In conclusion, despite its limitations, faecal analysis was probably the best way to study forb use in Hluhluwe.

DEVELOPMENT OF REFERENCE COLLECTION

Collaborative research was initiated by Black Rhino 2000 and Bruce Page of the Department of Biological Sciences in Durban. Before using scanning electron microscopy to identify leaf fragments in black rhino dung, a descriptive reference collection of all the common woody species and forbs in Hluhluwe had to be built up.

Fortunately a number of reference electron micrographs already existed for a limited range of woody species in Hluhluwe (Ward 1982 and Blakeway 1985). However the majority of the commoner woody species in Hluhluwe and all the common forb species still had to be studied. Black Rhino 2000 therefore prepared a list of the all the common woody species in Hluhluwe for which reference electron micrographs photographs did not exist.

On a field trip to Hluhluwe we toured round the study area with the three University of Natal third year students (Craig Haskins, J.Raubenheimer and Keren Pearman) who undertook the project. Specimens of most of the missing common woody species were collected. Additional samples from a few of the already described species were also collected to allow comparison of results with previous work. Samples of a number of the more dominant forb species were also collected. A total of 73 different species were sampled from nine different areas within the project's Hluhluwe Study Area. Thirty of these were herbaceous species (Raubenheimer 1989). Voucher specimens were collected in every case. Plant samples were preserved in a cooled sodium cacodylate solution (2.5% gluteraldehyde in O.1M sodium cacodylate buffered to pH 7.2).

The three students then used a scanning electron microscope (SEM) to describe the surface features of leaf fragments of each species. A photographic reference collection was built up showing the distinctive leaf surface features for each species (or in some cases a group of species).

DUNG ANALYSIS

Five fresh dung samples were collected in March and May 1989 and sent to Durban for analysis by the three students. Very fresh samples were required so that decomposition and fungal hyphae did not cover or obscure the surface characteristics of the fragments. Dung samples were also preserved in a cooled sodium cacodylate solution (2.5% gluteraldehyde in O.1M sodium cacodylate buffered to pH 7.2).

Each student then independently identified the species present in sub-samples of the five dung samples. Full details of the methods used are listed in the three appended project reports (Appendices 11.1, 11.2 and 11.3).

PROBLEMS WITH METHOD

For some reason (unbeknown to me, or their University supervisor), the existing reference photographs of Ward (1982) and Blakeway (1985) were not consulted by the students during dung fragment investigation. Thus a number of the common woody species were not represented in the reference collection. However, as the primary goal of this analysis was to study the herbaceous diet of black rhino this omission was not too serious.

The number of samples the students could analyse was limited as most of their time was spent building up the reference collection of photographs and identification key. It had been hoped that in subsequent years other third year students would analyse a greater number of black rhino dung samples using the reference collections. This would have allowed the study of feeding in different seasons and areas. Unfortunately that year, the University of Natal chose to scale down the third year projects and so this was no longer possible.

CHAPTER 2 NOTES

#1: A joint Honours project to examine these questions was initiated by Black Rhino 2000 and the Department of Biological Sciences in Durban. For one week the amounts of browse species with different leaf morphologies fed to a boma'd black rhino was measured, and dung samples were collected at regular intervals and preserved. The fresh samples were preserved in a cooled sodium cacodylate solution (2.5% gluteraldehyde in 0.1M sodium cacodylate buffered to pH 7.2). Unfortunately the Honours student who was to do the project quit varsity before being able to complete the project. No results can therefore be presented. All the dung samples are still lodged with the University of Natal.

#2: The radio aerial was mounted vertically up the horn. In the field it was found that as the rhinos moved their heads the polarity, and hence strength, of the signal constantly changed. This made it very difficult to take an accurate bearing. The use of a null-peak aerial system built by Garth Lee according to the specifications of Rowan Martin solved the problem, improving direction finding, but at a cost of reduced range.

#3: The term Browse Bottle (BB) originated in the field, the day the method was developed. Andrew and Rachel Cunningham (Irish visitors), suggested the volume of browse I had selected as one browse unit looked equivalent to the amount of foliage that would balance nicely and make a good arrangement when placed in an imperial pint milk bottle! From that time onwards, I decided to refer to my standardised visual browse unit as a Browse Bottle or BB. The term Browse Bottle (BB) has been used rather than using the term Standardised Browse Volume (SBV)both on historical grounds, and because there is no possible way that a Browse Bottle could ever be confused with anyother visual browse assessment measure.

#4: Kotze referred to the Browse Bottle (BB), as a Standardised Browse Volume (SBV).

#5: Although radio-tracking proved unsuccessful in this study, experience gained during the project was able to help other researchers.

CHAPTER 3

METHODS II : BLACK RHINO FEEDING:HABITAT STUDIES

INTRODUCTION

Black rhino feeding ecology and habitat selection was studied by jointly measuring habitat structure and composition together with estimates of browse offtake by rhino on transects and plots. Four distinct types of black rhino feeding:habitat survey were undertaken:

Four distinct types of black rhino habitat:feeding surveys were carried out:

1: **Pilot** Surveys in both Hluhluwe and Umfolozi (1988)

2: Large scale **Grid** Surveys in Hluhluwe and Umfolozi (1989)

3: Rapid **Post-Burn** Surveys in Hluhluwe and Umfolozi (1989)

4: Remeasurement of **Hitchins'** 1969/70 Hluhluwe plots (1990)

This chapter details the sampling strategies and field methodology used in these surveys.

PILOT STUDIES

PILOT PLOT SAMPLING DESIGN

A stratified sampling design was used in the pilot survey to obtain measures of replicate variation in both the amount of black rhino feeding and plot vegetation composition and structure. A total of 21 different "habitat" strata were chosen for the Pilot rhino habitat:feeding study. Nine of the strata were in Hluhluwe, with 12 in Umfolozi. Initially a truly replicated design was planned, but the techniques proved so time-consuming that only three replicate plots were measured per habitat stratum. Thus the eventual design was psuedoreplicated (Hulbert 1984).

The plots were measured in late summer 1988, and so reflected feeding over the 1987/88 growing season and late winter 1987.

LOCATION OF PILOT PLOTS

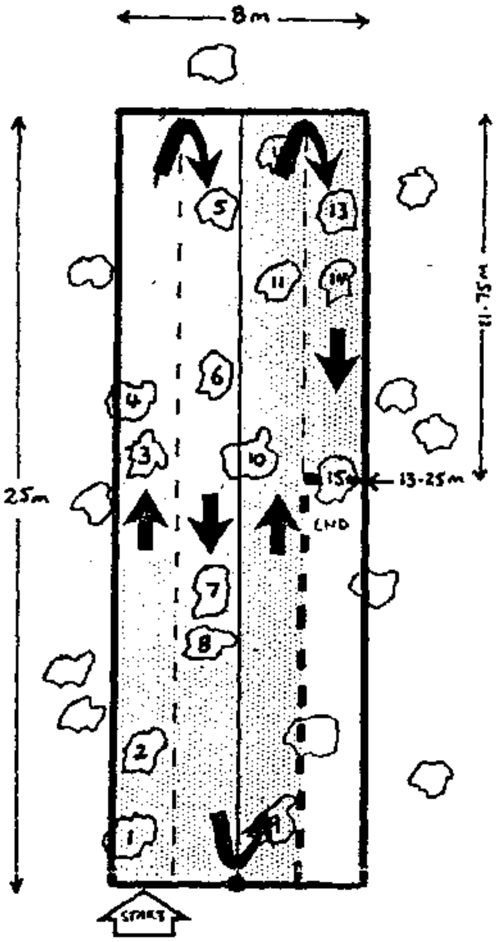
Three pocket-computer-generated random numbers were used to locate each plot within a patch of suitable habitat. The first two random numbers supplied the distance and bearing to the plot origin (up to 50m). The third random number was used to set plot direction. Replicate transects were located up to a maximum of 50m away. The process of plot location and alignment was repeated whenever random numbers put plots in very different habitats to the strata being surveyed. This sampling method therefore ensured that replicate plots were close together in similar broad habitat types. Apart from the initial choice of area, subjective biases in plot location were therefore minimised.

PLOT DIMENSIONS AND MEASUREMENT

The Pilot survey used a variable plot size that was computer-controlled in the field. Plots were up to 25 metres long by 8 metres wide (Figure 3.1). Plots were sampled in up to four parallel 2m wide strips proceeding from left to right. A 25m tape measure was laid out down the centre of the plot from the plot origin in the specified direction. A second 25m tape was laid out parallel to the first tape, but 4 metres to the left.

Plot measurement started in the bottom left of the plot. Measurement took place in two metre wide strips. The second tape demarcated the left hand edge of this strip, while a two metre long pole was used to demarcate the

Figure 3.1. Diagram illustrating layout of Pilot survey plots, and method for the calculation of plant densities. For simplicity only one size class of tree is illustrated. The dot in the middle of the bottom of the plot represents the randomly located starting point. The direction of the plot was also selected using random numbers. Plots were up to a maximum of 25m long and 8m wide (maximum plot boundary shown by thick solid black line). The plot was measured from left to right going up and down 2m wide strips (arrows show direction of measurement). The 2m strips were demarcated by a tape measure on one side (shown as solid vertical lines) and the edge of a 2m pole carried by the observer on the other (shown by vertical dashed lines). For each of size classes 1,2, and 3 a maximum of 15 trees were measured. 15 trees was also the maximum sample size for the taller size classes 4.5 and 6 combined. The shaded area represents the area sampled in our example (173.5m^2 = 86.75% of maximum). In this example the density of trees was calculated as 836/Ha (14½ trees in area sampled). See text for a more description of how tree densities were estimated.



right hand edge of the strip. Only trees that had more than half of their trunks/stems inside the strip were sampled. After 25m, sampling continued back down the second of the four 2m wide strips; but this time using the first tape-measure to demarcate the left edge of the strip. The plot continued up the third strip and then down the fourth strip. The second tape was moved 8 metres to the right to demarcate the left hand edge of the fourth strip.

The maximum number of trees measured in each of size classes 1, 2 and 3 was 15. The maximum sample size was also 15 for sizes 4,5 & 6 combined. Thus, up to 60 trees could be measured per plot. This sampling strategy was devised to obtain a more equitable distribution of sample sizes for trees of different sizes.

Field data collection was computerised with all data being recorded onto a Sharp 1500A pocket computer. The following descriptive information was stored per plot:

1) Habitat strata
2) Replicate number
3) Slope (using an integer scale from 0-5) and Aspect if Slope was greater than 0.
4) An estimate of Canopy Cover (using an integer scale from 1-5)
5) An estimate of Impenetrability (using an integer scale from 1-5). This variable measured how difficult it was to move throughout the plot.
6) Topographical information on slope position and closeness to water.

Six size classes (1-6) were used to sample woody plants. These were:

1: < 0.75m, but big enough to be able to detect black rhino feeding (i.e. excluding small thin saplings).

2: 0.75 - 1.24m

3: 1.25 - 1.74m

4: 1.75 - 2.49m

5: 2.50 - 3.99m

6: ≥ 4.00m

When the fifteenth tree of a size class or size class group was sampled, the computer automatically prompted the operator for the lane number (1-4) and tape measure reading. Plot measurement continued either until 15 trees had been sampled from each of the four size groups, or when the whole plot (200m^2) had been sampled. In between data logging, the computer displayed how many trees of each size class were still required.

On every sampled tree the total number of available browse bottles (see Chapter 2) was assessed using a geometric doubling scale with mid points (½, 1, 1½, 2, 3, 4, 6, 8, 12, 16, 24, 32, etc.). If the tree had been browsed by black rhino, the estimated number of browse bottles eaten was also recorded using the same scale. Feeding was split into "new" and "old" browsing depending on the colour of the browsed stems. The percentage of browse interference was scored on a rank scale. If there was interference, its type (Grass, Forb, Thicket, or a mixture of these types) was also recorded.

Tree densities for each of the six size classes were calculated and stored automatically by the pocket computer as follows:

> The program initially calculated the plot area sampled for each size class or size class group. In the simplified example in Figure 3.1 only one size class of tree is shown. In this case the fifteenth tree was located in the fourth lane, and the tape measure reading was 13.25m. This gives a total area sampled of 2m by 86.75m (25+25+25+(25-13.25)) = 173.5m^2.
>
> The next stage was to work out the area per tree sampled for each size class or size class group. To avoid overestimating densities, it was assumed that only half of the fifteenth tree fell inside the sampled area. The area per tree in Figure 3.1 was therefore calculated as: *area sampled/14.5*. If fewer than 15 trees were recorded for a size class, the area sampled was set at 200m^2 (the maximum plot area). In the example in Figure 3.1 the area/tree = 73.5/14.5 or 11.9655 m^2. This gives an estimated density of 836 trees/Ha (10,000/11.9655). When less than 15 trees were sampled per size class or size class group, the area per tree in m^2 simply equals 200/n where n = the number of trees sampled.

In the special case of size class 4, 5 or 6 trees, the lumped size class 4,5&6 density was multiplied by the sample number for an individual size class (e.g. 4) divided by the total number of size class 4, 5 and 6 sampled. For example if size 4,5&6 density was 800/Ha and 9 out of the 15 trees sampled were size 4 then the size 4 density would be estimated at 800*(9/15) = 480/ha.

Additional information was also collected in three 2m^2 quadrats per plot. The following information was recorded per quadrat:

1: Grass Modal Height - Measured to leaf tips and not to the odd flower head.

2: Grass Biomass - Using a linear ranking scale from 0 to 9. This scale was originally set up and calibrated in Umfolozi using estimation, clipping and weighing. Calibration proved to be essential for two reasons. Firstly, initial biomass estimates tended to be biased. The biomass of shorter stoloniferous grasses was usually underestimated, while the biomass of some tall grass patches was often overestimated. Secondly, calibration was needed to ensure that the derived rating scale was linearly related to biomass.

3: The three dominant forb species or genera together with a rough measure of abundance for each species/genus on an integer scale.

In the case of both grass measures, the pocket computer only stored the mean value for all three quadrats to save memory.

The variable plot size sampling for each size class group, the laying out of the tape measures, and the recording of detailed measurements for each tree - contributed towards making this method very time consuming. Individual plots commonly took over 2 hours to lay out and complete.

THE 1989 HLUHLUWE AND UMFOLOZI GRID SURVEYS

INTRODUCTION

Lessons from the Pilot study strongly guided field technique development and sampling design for the main grid surveys.

The pilot survey results indicated that grass interference was particularly important, and so a measure of grass interference was required in the main grid surveys.

In Umfolozi, we found it was more difficult to classify habitat types. Exploratory Discriminant function analysis of plot ordination axis scores did not always correctly classify Pilot plots according to habitat strata sampled. This was one of the reasons why an a-priori stratified design according to habitat type was ruled inappropriate for the main grid surveys. The continuum model of vegetation was more appropriate for describing habitats in Hluhluwe-Umfolozi. We therefore decided to let the data itself describe habitat types in the Grid surveys.

Most importantly the very high variability in black rhino feeding between the replicate Pilot plots made it imperative that many more plots be sampled in the main Grid surveys. The number of plots required would have been impossible to achieve using the Pilot survey method as it was so time consuming. A more rapid technique needed to be developed. A compromise was needed whereby sufficient detail was obtained, yet a large number of plots could still be measured.

One of the main objectives of the Grid surveys was to cover a complete range of rhino habitats, and to provide abundance estimates for the whole population of trees in each study area.

The systematic sampling design adopted for the Grid survey ensured that inferences could reliably be made

about the population of trees throughout a whole area. The sampled population was therefore quite different from the more usual population of trees in "representative" plots nearer roads. The importance of this sampling design is discussed in more detail in Chapter 7. The systematic grid sample design started from a randomised placement of the most South-West plot in each study area. Plots were located every 450m in all four compass directions throughout a 4,900 Ha Central and North East Hluhluwe Study Area, and every 500m throughout a 4,675 Ha North-West Umfolozi study area. A total of 242 and 187 plots were measured in Hluhluwe and Umfolozi respectively. The locations of the plots, and study area boundaries are shown in figures 1.2, 3.2 and 3.3.

Plot placement was marked in onto 1:10,000 orthophotos before fieldwork. To locate plots, bearings were continuously taken while walking through the bush. A Suntu compass was used (accurate to about ½ a degree). The 5m contours, small drainage lines and visible patches of thicker bush on the orthophotos, were particularly useful navigation aids.

Accurate navigation through dense bush in lowland closed woodlands and thicket was slow using the more traditional methods used in the grid surveys. It was essential to regularly take bearings, and concentrate on counting paces while walking through the bush. Portable GPS's (Geographical Positioning Systems) would have been preferable if they had been available, and all the planned satellites had been operational at the time.

A lack of suitable background data on vegetation structure and composition over time was identified as a major information gap. **The grid surveys were therefore designed to also provide baseline data against which woody habitat changes could be measured in future.** In this way the project could provide the kind of data for future managers and researchers, that we wished had been available to us at ten year intervals since the 1930s.

One of the regional project objectives was to determine how one should measure black rhino habitat. This could be split into two main questions:

- What does one measure?
- What measurement resolution is required?

Descriptions of habitat which give weight to the taller dominant trees in a community may be the ideal; even though such tall trees contribute little to rhino browse availability. For this reason, the contribution to Canopy Cover of each spize (species size class) was assessed using a modified Braun-Blanquet scale. Alternatively tree densities, or total browse bottle* and free browse bottle* availability may be better descriptors of black rhino habitat (* terms defined in Chapter 4). Spize availability was also estimated using these three descriptors.

Which measurement descriptor is the most suitable depends on how a black rhino perceives its habitat. It was therefore necessary to undertake analysis at a range of levels from area to patch to species to spize through to resource (spize with a given level of grass interference).

It was therefore deliberately decided to describe available habitat in as much detail as possible using different abundance variables. With this design, browse bottle and density data could be converted to cruder values at a later date. Analysis could then be repeated. The comparison of results of analysis, with those obtained using the original more detailed data could then be used to indicate what level of measurement resolution was required.

FIELD METHODS

Given the need to simplify the field method and speed up measurement a number of changes were made to the Pilot method:

Traditionally field data collection has been geared towards getting as accurate measures of vegetation abundance as possible. However **considering the aims of the grid surveys, excessive detail was not required**. By moving a plot two metres to the right the detail may change, but practically this is not important. What was needed in our case was to obtain an approximate measure of the abundance of each spize. We needed to know whether there were 5, 40, 125, 300 or 1200 bottles/ha available, not whether there were 561.2 or 583.9 bottles/ha. For practical purposes the latter two figures are the same. **What was required was a method that could quickly and reliably** produce ball-park abundance values that were of the correct order of magnitude. A further justification for this level of resolution came from Will's provisional finding in Hluhluwe that too much measurement detail may obscure some of the broader scale vegetation patterns one is searching for (Wills personal communication) - a case of not seeing the wood for the trees.

For similar reasons, it did not matter much in practice whether plots were all exactly 30 metres long. In the Pilot surveys setting out tape measures was time consuming, and this was especially the case in thick bush. As a 29 or 31 metre long transect would produce similar ballpark figures as an exact 30m transect; it was decided to save time by dispensing with a tape measure. After training, it proved to be possible to gauge transect distance to within 5% over 90% of the time. To achieve this level of accuracy the main observers needed to calibrate their paces over different types of ground. An ability to mark out 10 metres by eye proved useful in thick bush. The time required for calibration training was more than made up for in the bush.

Measuring browse availability and interference on every individual tree proved to be very time consuming on the Pilot survey. It was therefore decided to record only the estimated average number of available browse bottles/tree per spize on each transect. In practice this was achieved by the observer shouting out the number of bottles on a sample of trees for the commoner spizes. In between recording information, the recorder mentally calculated approximate running averages of browse availability per tree for those spizes (i.e. 2.5 rather than 2.617).

For the rare spizes, browse availability per tree was recorded on each individual as before.

A slightly smaller plot size of 30m x 5m was chosen to allow a greater number of plots to be measured. Grid survey Plot direction was standardised at magnetic North to save more time.

The use of six size classes in the Pilot study was also time consuming and for the grid surveys these were reduced to four:

1: small, < 1.00m, but big enough to be able to detect black rhino feeding (i.e. excluding small thin seedlings and saplings).

2: medium, 1.00 - 1.99m

3: intermediate, 2.00 - 3.99m

4: tall, ≥ 4.00m

When **densities** of common size 1 and/or size 2 spizes were high, numbers of these spizes were only sampled and counted in the 2m wide central strip of the plot [#2]. The totals for the common spizes were then multiplied by 2.5 to give estimates of total plot densities. The whole plot was surveyed for size 1 and 2 spizes of rarer species. All larger size class 3 and 4 trees were recorded in each plot.

All trees in the plot were examined for signs of browsing; and both **new* and old* browsing** was recorded as in the Pilot study (* terms defined in Chapter 4).

A "default" mean percentage **grass interference** was estimated for both size 1 and size 2 trees on the transect. This involved assessing what proportion of a plant was obscured by grass material, and averaging this for each spize class. Should mean grass interference levels for some plants radically differ from the default value for that spize, alternative percentage interference values were recorded against those spizes on the data form. All other spizes were assumed to have the mean (default) interference levels for their height class (1 or 2). The need for alternative grass interference values most commonly occurred when a plot crossed over a boundary between open tall grassland into forest with very short grass. In other cases, the only individual of a spize may have occurred at the edge of a path in an otherwise very tall grass area. In this case that particular spize would receive a lower grass interference rating than the default.

The modal **grass height** was also recorded for each plot.

In addition the number of black rhino **dung piles** [#3] and the **amount and type of feeding signs were recorded when walking between transects**. The walk between two plots was split in half. Data for the first half were allocated to the recently measured plot and data from the second half to the new plot. Values for each plot were averaged.

Elephant browsing was also noted on the data forms.

Although we would have saved at least two months work (data capturing and checking) if the Psion Organiser had been used during field work, attempts to computerise data collection were abandoned[#4]. A pen and a piece of paper proved to be much quicker and more flexible to use in the field[#5]; and this was important because the major limiting factor was time for fieldwork. This was because all the transects had to be completed in as short a period as possible to allow comparison between early season and late season feeding patterns.

Capture onto PC of the grid survey data and subsequent error checking was (as expected) a time consuming affair, made worse by inadequate software and hardware.

Given that all transects had to be measured in as short a period as possible, fieldwork averaged about 9 hours a day for 7 days a week, for most of the three months from Mid January 1989 to Mid April 1989. For much of the surveys two teams worked concurrently. We are extremely grateful to the late Joe Venter for the loan of technical assistants Welcome Dube, and Vincent Shongwe from the Natal Parks Board, and for the help of Paul Cuthbert during this period. It would have been impossible to put two teams into the field without their support.

Ecologists may be concerned that measuring vegetation for such extended periods, day in day out, might have adversely affected data quality due to fatigue. It is generally accepted that between four and six hours of vegetation monitoring is about the maximum possible, before data quality starts to suffer as a result of fatigue. Some ecologists also advise taking at least a one week break from vegetation monitoring every two weeks.

However, given the need to measure a large number of grid survey plots in as short a time as possible, it was necessary to undertake fieldwork for longer than this - usually between 8 and up to 14 hours a day. For similar reasons the key observers could not afford the luxury of week breaks from fieldwork, although as a number of different field recorders and assistants were used they were able to take breaks from fieldwork. Such long periods of fieldwork were essential, if the teams were to be able to cover the ground and measure the required number of plots in the required time, and meant that the grid surveys were completed in less than half the time Natal Parks

Board staff would usually have taken (A.J.Wills pers.comm.).

The two key observers (Adcock & Emslie) did most of the work (looking for and assessing rhino browse, species identifications, shouting out plot measurements, laying out plots, navigating between plots including pace counting, taking bearings and map reading).

It was therefore especially important that they made every effort to minimise fatigue. However, for a number of reasons, **both key observers felt confident that data quality did not suffer as a result of the long fieldwork hours** [#6]; although by the end of the grid surveys the observers were exhausted, couldn't walk anywhere without counting paces and even dreamt of measuring trees! It is fair to say that by the end of the grid surveys neither observer would relish the idea of repeating the grid surveys any time during the next few years. Undertaking such grid surveys is not something that can be done annually; and it requires particular people with lots of enthusiasm, drive, interest, dogged perseverance, commitment and a little madness! The team for a 1999 re-survey would therefore need to be picked carefully - it is not a task that could be done by just anybody .

GRID STUDY AREAS

The Grid study areas were chosen to:

o cover as wide a range of habitats as possible from hill slope forest down to the thickest riverine bush.

> Ease of accessibility to sites was of minimal concern in the choice of grid survey study areas. By using roads and management tracks in the study areas, all sites could be accessed on foot. In a similar approach to the Park's line-transect distance-sampling herbivore monitoring programme, a measurement team was sometimes dropped off early in the morning, to eventually pick up a vehicle that had been left many kilometres away in the afternoon. Careful planning and the use of two teams made this possible. This approach differs radically from traditional vegetation

sampling which has tended to concentrate on easily accessible sites that are usually near tracks and roads. The latter sampling approach does not allow inferences about the population of trees throughout a study area to be drawn. In addition, such a sampling strategy, introduces possible biases when monitoring black rhino feeding due to the potential effects of increased human disturbance near roads on black rhino behaviour. In addition vegetation next to roads is often different because of increased run off or the deposition of dust thrown up by traffic. Sometimes rhinos also use roads as paths. It was therefore important that the sampling strategy used in the grid surveys minimised these biases as much as possible.

o include as much of the bush cleared area in Hluhluwe North in the Hluhluwe study area as possible.

o ensure that the study areas included areas of differing past black rhino population performances - preferably within study areas as well as between them.

For example, the Hluhluwe Study area included both the N.E.Hluhluwe area - where most of the bush clearing and the major population decline had taken place - and part of the Nomagetje, Sisuze area where black rhino densities were higher (Hitchins & Brooks 1986).

o ensure the study areas were of a sufficient size so that the influence of boundary location on browse availability assessments was minimised.

o cover a large enough area to encompass a full range of past fire regimes, underlying geologies, soil types, altitude, slope, aspects, etc..

o include areas in the Umfolozi study area that were close to and further away from water, so that seasonal use in relation to water availability could be studied.

Figures 3.2 and 3.3 show the study areas selected and the locations of the 429 grid survey feeding/habitat transects.

The exact locations of the transects are marked on orthophotos which cover the study area.

HLUHLUWE STUDY AREA

The North East and Central Hluhluwe study area covered 4,900 ha, and encompassed an altitudinal range of 375 metres. The Hluhluwe Study area boundary stretched from the top of Gontshi hill; down to the Gontshi turn-off; then up over Mahwanqana and Qolwana; then down into the Mzini valley; and back up to the top of Qololenja; changing direction down through part of the Mpongo forest into the Manzimnyama valley; before continuing up Hlaza and crossing the main tourist road on the Hlaza saddle near hilltop (near the new Hilltop camp bypass road turn-off) ; before going almost due south down the other side of Hlaza, across the Fuzula steam and down to the west of the Chibilezangoma bend in the Hluhluwe river; then following the river eastwards just round the tip of the Sisuze peninsula; then crossing the river and proceeding for one and a half kilometres in the direction of the top of Nhlayinde; before going almost due east to the Nomageje stream; changing direction to follow this stream down to eventually cross the Hluhluwe river about 500m east of Maphumulo picnic Site; and from there going in a straight line to the eastern most spur of Magwanxa; then up to the top of Magwanxa following the high ground till hitting the boundary fence; then following the fence to the N.E. Mgodlo corner of the reserve; continuing down to Memorial Gate; and then finally following the fence back up to the top of Gonthsi Hill.

The Hluhluwe study area therefore includes Hidli, Magangeni, Ngqunqulu, Most of the Manzimbomvu, Manzimnyama and Mzini valleys, Zincageni, Nkwankwa, Sisuze, the Kubi ridge, and the Oncobeni and Ngumela valleys.

UMFOLOZI STUDY AREA

The North Western Umfolozi study area covered 4,675 ha, and encompassed an altitudinal range from the black Umfolozi river to the top of Mbulunga. The Umfolozi Study area boundary bisected the Sontuli Loop. It stretched from the middle bend of the Black Umfolozi river on the Sontuli loop; proceeding south west over Ntabayamaphiva

Figure 3.2. Map showing the approximate position of plots in the 1989 Hluhluwe Grid Survey. Plots are spaced 450m apart Scale 1:50 000

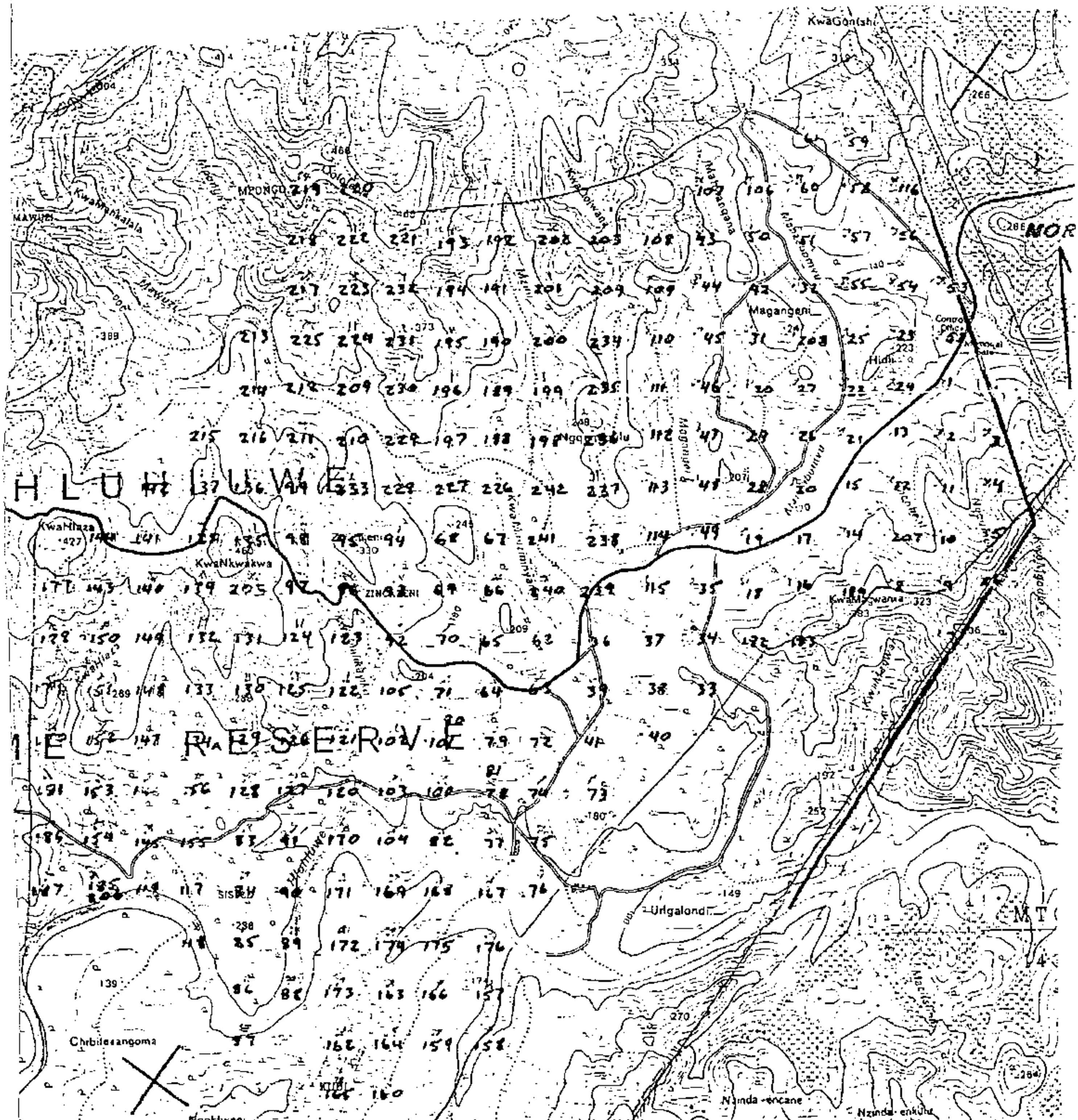
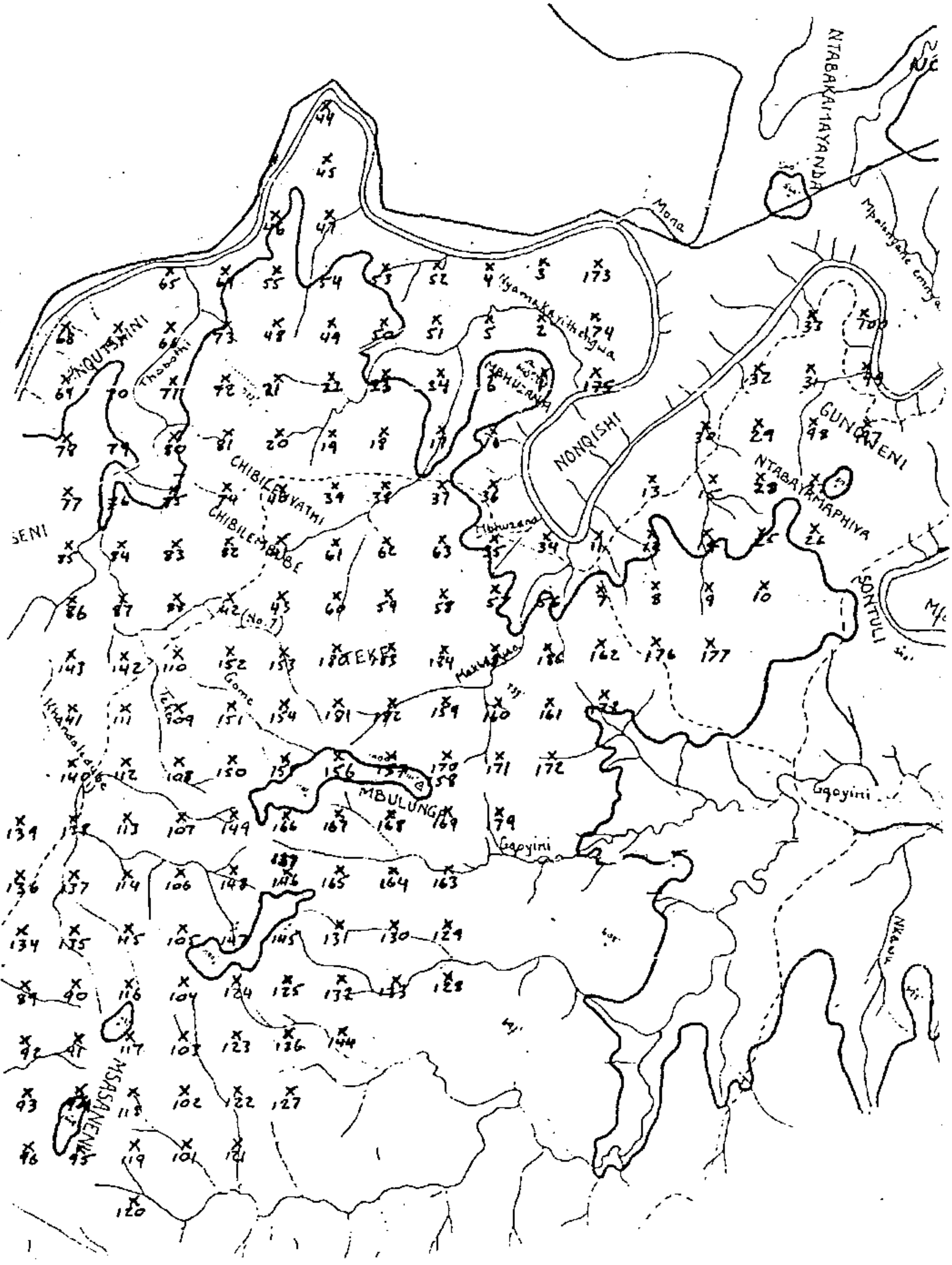


Figure 3.3 Map showing the approximate position of plots in the 1989 Umfolozi Grid Survey. Plots are spaced 500m apart Scale 1:50 000



continuing to cross the tourist road; then up to the quarry continuing in a south west bearing through Gqoyini up to the T junction where the Gqoyini management track meets the Sokwezele-Mantiyane track (which has since been opened up as a tourist road); then following the latter track westwards to hit the tourist road at the base of Sokwezele; then proceeding almost due north to hit the Black Umfolozi at Nqutshini east of the guard camp; then following the river downstream back to the middle of the Sontuli loop.

The Umfolozi study area included Mbhuzane, Nyamakayithengwa, Thobothi, the Nqutshini bottomlands, Chibilenyathi, Chibilembube, Teke, Gome, Khandaledube, the Masasanenei range, Mbulunga, much of Gqoyini basin and half of the Sontuli loop.

We initially had hoped to include a third study area in the Corridor, but time and personnel constraints made this impossible.

1989 HLUHLUWE AND UMFOLOZI POST-BURN SURVEYS

OBJECTIVES

The objectives of the Post-Burn surveys were to determine the feeding patterns of black rhino immediately after burns, before vegetation flush; and during the post-burn vegetation flush. The main aim of the Post-Burn surveys was to find out if black rhinos changed their habitat or species selection because of burns.

THE 1989 BURNS AND THE STRATEGY FOR THE FEEDING SURVEY

Previous surveys indicated that black rhino feeding is extremely patchy and variable in intensity, and unless large numbers of "patches" are sampled, results may not reflect true feeding patterns. This problem was compounded because the amount of post-burn feeding would be limited compared to the feeding sampled in the Pilot and grid surveys (as only a month or so of feeding would have occurred). Therefore to obtain sufficient data on post-burn feeding, large areas had to be covered quickly. To do this, a rapid post-burn survey technique was then developed Although I was involved in the initial post burn survey planning and design, and wrote Psion software to automate post-burn data collection, Keryn Adcock and Rupert Nanni deserve most of the credit for developing the rapid post-burn survey technique. While Keryn and Rupert collected the raw post-burn data for BR2000, I analysed and wrote up all the Post-burn Survey data with the exception of Table 9.1 and Figure 9.7 which was the work of Keryn Adcock. The work reported on in Chapter 9 should therefore be considered as jointly authored by Adcock, Emslie & Nanni.)

During the post-burn survey, strip plots 50m long were assessed sequentially along walked routes, which were spaced to cover the burnt area evenly. Because of the rapid nature of this survey, the absolute amounts of feeding detected were not comparable to those of the grid survey, although the relative proportion of feeding on different species and in different areas was comparable. The term *rapid survey* was apt. To have measured the same number of post-burn plots using the original Pilot survey method would have taken 4 years 9 months of continuous fieldwork working 8 hours a day!

Three sets of Post-Burn surveys were conducted:

1: HLUHLUWE North early survey: 1 month post burn - covering areas burnt from 16 August 1989 to 22 August 1989.

2: UMFOLOZI West survey: 1-2 weeks post-burn - covering areas burnt from 16 August 1989 to 24 August 1989

Figure 3.4. First Post Burn Survey: map showing the routes walked in Hluhluwe (1989)

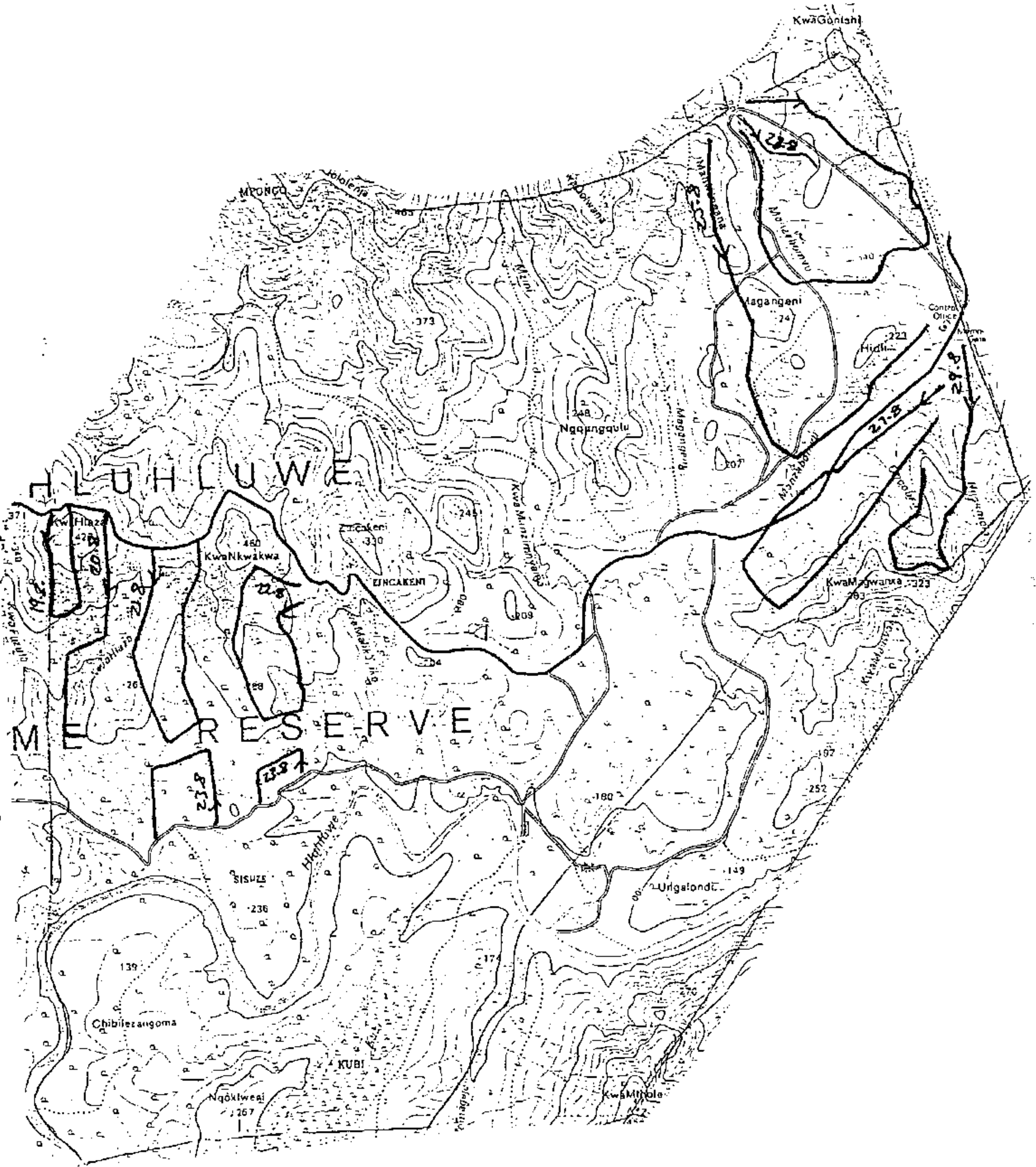


Figure 3.5. MAP SHOWING ROUGHLY THE ROUTES WALKED IN THE 1989 POST-BURN SURVEY IN UMFOLOZI WEST

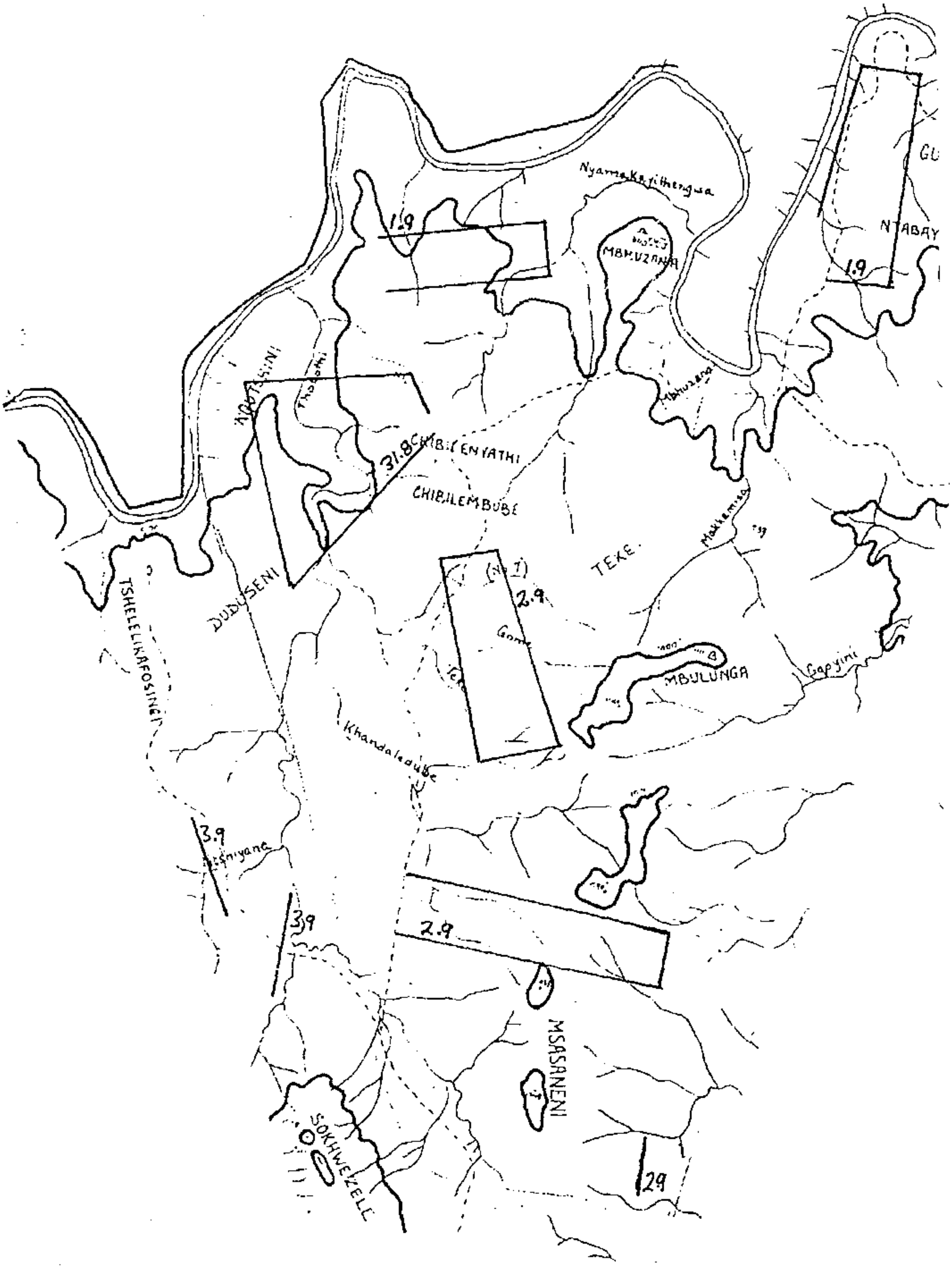
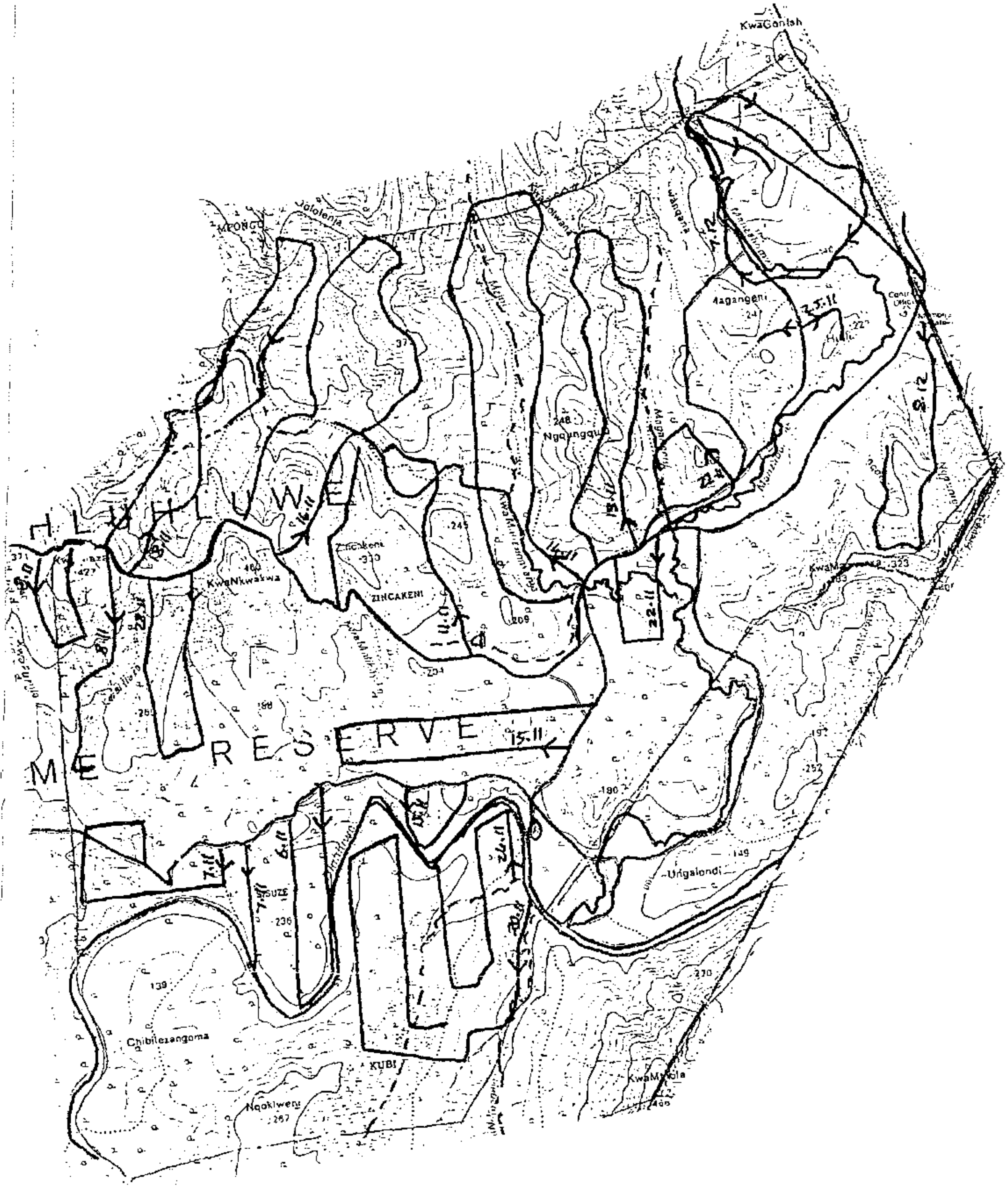


Figure 3.6. Second Post Burn Survey: map showing the routes walked in Hluhluwe



3: HLUHLUWE North late survey: 2½ months post burn - covering the whole study area, and assessing feeding both immediately post-burn (old feeding: older than 1½ months); and during the post-burn flush (new feeding, up to 1½ months old.

Figures 3.4, 3.5 and 3.6 show the routes walked in the post-burn surveys. Maps of the 1989 burns are available at Hluhluwe Research Centre.

FIELD METHODOLOGY

Plots of 50m by 8m were assessed in the post-burn surveys. Only post-burn feeding was noted. In the first Hluhluwe and Umfolozi surveys, all browsing was recorded as "new". In the main Hluhluwe survey "old" feeding was recorded as that which had probably occurred 1½ months or less after the burns; while "new" feeding occurred more than 1½ months after the burns during the post- burn flush. Feeding was aged based on observations of feeding signs of known age.

In practice, spotting feeding signs in unburnt dense bush was more difficult than in burnt areas, and effective plot widths may have been slightly less in these areas compared to in open or burnt areas. Attempts were made to minimise this problem by both walking much more slowly, and searching more carefully in such areas (ie. when compared to burnt areas where the visibility was good).

Plots were rated for the following:

BURN INTENSITY - 0=unburnt, 1=lightly/poorly burnt, 2=burnt well but some tufts not fully burnt, 3=intensely burnt - all visible biomass burnt.

PLANT DENSITY :refers to the zone up to 4 metres on either side from the imaginary walked transect line; 0=no woody plants, 1=a few widely spaced shrubs or trees, 2=woody plants frequent, but not impeding visibility, 3=abundant woody plant matter, often impeding visibility/movement; 4=thicket/dense stand of woody plants were visibility and movement are impeded. In practice, no plots were rated as a 0.

PHYSIOGNOMY (this was described separately for 0-2m vegetation and that greater than 2m.) classes were (synonyms used in FIRM analyses in brackets):

0-2m: Open Grassland (O), Open Scrub (L), Scrub (M), Closed Scrub (S), Thicket (T).

>2m: Scattered trees (S); None (N), Woodlands: either Open (O) , Medium (M) or Closed (C); Forest (F), or Forest Margin (FM).

DRAINAGE LINES were noted

SPECIES: The three dominant species were noted in both the 0-2m and > 2m size classes respectively.

PATHS: The degree to which the 50m section of walked route followed or crossed game paths was rated: 0 = no paths, 1 = less than 1/3 paths, or crossed one or two paths; 2 = > 1/3 but < 2/3 of the route involved paths, 3 = > 2/3 of the route was on paths.

BLACK RHINO EATING: The AMOUNT of feeding (on all woody species) in the 50m section was rated on an almost linear scale of 0-5: 0 = none, 1 = 1-4 bottles, 2 = 5-10 bottles, 3 = 10-15 bottles, 4 = 16-20 bottles, 5 => 20 bottles

The PLANTS EATEN were assessed as to SPECIES, SIZE CLASS, PERCENTAGE CONTRIBUTION TO TOTAL AMOUNT OF FEEDING, whether the plant was BURNT, and whether it was on a PATH or not. Data were recorded for all species eaten along the transect. During the post-burn flush surveys, NEW browse (younger than ~6 weeks) was distinguished from or OLD browse (post-burn, but older than ~6 weeks).

DUNG: The number of OLD and NEW black rhino dung piles in each transect was also noted.

All parts of the HLUHLUWE study area were covered in the main Hluhluwe Post-Burn Survey (thus some routes were walked for the second time).

REMEASUREMENT OF HITCHINS" 1969/70 PLOTS

FIELD METHODOLOGY

Peter Hitchins' original belt transects were located by reference to two maps made by Hitchins giving the location of the plots, and by him showing the two observers (Emslie & Adcock) their position on the ground. As some transects were marked in different positions on the two maps, Hitchins was asked which of the maps was the correct one. Figure 3.7 shows the location of the re-surveyed Hitchins' plots.

As the original plots were not permanently marked, the remeasured plots are not in exactly the same place as before. Three transects were repeated to crudely assess the effects of slightly different transect positions on recorded spize density and feeding. **Appendix 3.1 shows that the differences in species composition between years ('70 and '90) was greater than that between replicate sites.**

Every attempt was made to duplicate Hitchins' methodology as closely as possible including using imperial units during the resurvey of Hitchins' plots.

The transects were 100 yards long and 6 feet wide (167.3 square metres).

Figure 3.7. Map showing the position of Hitchins' 1969-1971 plots in the bush-cleared area of NE Hluhluwe. Landscape/vegetation types used in analysis are also shown.

	HT	Hill tops
■	ACS	Acacia caffra slopes
■	BCB	Bush cleared bottom lands
░	HV	Hidli vlei
	F	Forest patches
■	ES1	Eastern slopes 1
■	ES2	Eastern slopes 2
▒	ES3	Eastern slopes 3
■	WS	Western slopes
▨	NG	Ngungulu

Table 3.1.

BUSH CLEARING HISTORIES UP TO 1990, OF THE TRANSECTS IN THE HITCHINS 1969-71/EMSLIE 1990 SURVEY OF BLACK RHINO FEEDING IN NORTHERN HLUHLUWE GAME RESERVE

	1st CLEARIN		2nd CLEARING		3rd CLEARING		4th CLEARING	
TRANS	DATE	SPECIES	DATE	SPECIES	DATE	SPECIES	DATE	SPECIES
1a	1960	A.karroo	1985	general	1989	A.karroo		
1b	1960	A.karroo	1985	general	1989	A.karroo		
2	1960	A.karroo	1985	general	1989	A.kar,D.cin		
3	1989	A.karroo						
4	1962	A.karroo	1975	M.senegalensis	1987	A.karroo	1988	M.senegalensis
5	1989	A.kar,D.cin						
6	1960	A.karroo	1977	A.kar,D.cin				
7	1960	A.karroo	1977	A.kar,D.cin				
8	(never cleared - forest patch)							
9	1962	A.karroo	1985	A.kar,D.cin	1988	M.senegalensis		
10	1962	A.karroo	1984	A.kar,D.cin	1989	M.senegalensis		
11	1962	A.karroo	1984	A.kar,D.cin	1989	M.senegalensis		
12	1960	A.karroo	1988	A.karoo				
13	1960	A.karroo						
14	1960	A.karroo	1985	A.karroo	1988	A.karroo		
15	1960	A.karroo	1985	M.senegalensis	1988	A.karroo		
16	1975	A.karroo	1987	A.karroo				
17	**(Uncleared)**							
18	1989	A.karroo						
19	1959	A.karroo	1962	A.karroo	1984	D.cinerea		
20	(uncleared)							
21	(uncleared)							
24	(never cleared - forest patch)							
25	1962	A.karroo	1975	M.senegalensis	1987	A.karroo	1989	M.senegalensis
26	1962	A.karroo	1975	M.senegalensis	1987	A.karroo	1989	M.senegalensis
27	(never cleared - forest patch)							
28	(never cleared - forest patch)							
29	1960	A.karroo	1987	A.karroo				
30	1960	A.karroo						
31	1960	A.karroo						
32	1962	A.karroo	1984	D.cinerea				
33	1960	A.karroo						
34	1960	A.karroo						
35	1960	A.karroo	1987	A.karroo				
36	(never cleared - forest patch)							
37	1962	A.karroo						
38			1990	tall Acacias				
39	1962	A.karroo						
40	1960	A.karroo	1988	A.karroo				
41	1960	A.karroo	1988	A.karroo				

The species and height class of all woody plants were noted. Height classes were in 1 foot (30.48cm) intervals until 6 feet (1.289m), then 6-10 ft (1.289-3.048m), 10-15 ft (3.048-4.572m) and > 15 ft (4.572m).

Plants were examined for signs of black rhino feeding, and browse severity was allocated as follows: low - one branch bitten on the plant, medium - two branches bitten; high - more than two branches bitten.

The cover-density board was used to assess lateral plant cover (8 readings were taken from regularly spaced perpendicular points 1 chain (20.12m) away from the transect.

Modal grass height was also noted at each cover board position (not measured by Hitchins in 1969-70).

(The summary Chapter 10 discussing the re-measurement of Hitchins' plots should be considered as jointly authored by Keryn Adcock, Peter Hitchins and myself. Peter undertook the original survey, supplied the 1970 baseline plot monitoring data and helped locate some of the plots in the field prior to re-measurement. While I queried the raw survey data to contrast the proportional contribution to the diet of different species in the two periods, and the proportion of individual trees of each species browsed in the two surveys, more detailed graphical analyses of the Hitchins plot data were undertaken by Keryn Adcock. The latter formed part of the BR2000 report submitted to the Natal Parks Board. A summary of Adcock's main findings of these analyses as they relate to bush-clearing history is included in Chapter 18. Table 3.1, Figure 3.7 and Appendix 3.1 relate to the re-measurement of Hitchins' plots and were also produced by Keryn Adcock.)

BUSH CLEARING HISTORIES OF HITCHINS' TRANSECTS

The bush clearing history of the area of Hitchins' plots in HLUHLUWE North was found to be extremely complicated. There was almost no replication of treatments. Virtually all the valleys (and a few lower slopes) were cleared, and effectively no controls (uncleared patches) were left. Roddy Ward had left two control patches near

Magangeni (Alf Wills pers.comm.). However, these were not marked on the ground and were not part of the Hitchins survey. Unfortunately these apparently were cleared by accident sometime between 1988 and 1990). The only uncleared areas were forest patches and upper slopes/hilltops, ie areas with different vegetation to begin with. Thus no assessment of the effectiveness of any one type of bush clearing could be made.

If the chemicals used in bush clearing were included as part of the bush clearing treatments, then each of the 35 cleared plots would have had a unique clearing history since the 1960s. Ignoring chemical treatments 10 different bush clearing regimes occurred on the Hitchins transects. Table 3.1 details the bush clearing histories of the plots.

SAMPLE SIZES

The number of plots or transects, and woody plants, examined during the different surveys of black rhino project, are given overleaf.

The extremely high spatial variation in feeding means that feeding importance and preference values from the Pilot survey should be treated as rough approximations. Using first principles, output from One-Way ANOVA was used to calculate an overall coefficient of variation in the amount of browsing within Pilot survey stratums. Very high variability in browsing occurred with coefficients of variation of 93.1% for Hluhluwe and 92.0% for Hluhluwe. Kotze (1990) also recorded coefficients of variation in browsing of over 100%.

The results from the much more extensive grid and rapid Post-burn surveys are drawn from a much larger sample size and therefore more confidence can be put in the results. The number of transects and trees assessed for browsing in the different studies were as follows:

Number of Transects/plots	**Hluhluwe**	**Umfolozi**
Pilot Study(excl Strata 16&17)	27	30
Grid Survey	242	187
First Post-Burn	694	550
Main Post-Burn	1,687	-
BR2000 re-survey of Hitchins' plots	40	-

Number of Woody plants Assessed	**Hluhluwe**	**Umfolozi**
Pilot Study(excl. Strata 16&17)	1,451	1,163
Grid Survey	25,623	7,098
First Post-Burn	196,000	56,000
Main Post-Burn	476,000	-
Hitchins' survey 1969-71	(7,631)	
BR2000 re-survey of Hitchins' plots	3,954	

Total Area of all Transects (ha)	**Hluhluwe**	**Umfolozi**
Pilot Study(excl Strata 16&17)	0.54	0.60
Grid Survey	3.63	2.81
First Post-Burn	27.76	22.00
Main Post-Burn	67.48	-
BR2000 re-survey of Hitchins' 1969-70 plots	0.67	-

BR2000 examined 700 000 odd trees for browsing in the five Hluhluwe Surveys; while in Umfolozi just over 64 000 trees were assessed in three surveys.

SPECIES IDENTIFICATION

The majority of species were identified using Moll (1981) and Coates-Palgrave (1977, 1990). The authors also made up a portable mini-herbarium on record index cards [#6]. This proved very useful when learning the species at the outset of the project.

Naming followed the 1990 revised second edition of Coates-Palgrave; then Von Breitenbach & Von Breitenbach 1990. Pooley (1993) was also consulted for new names, although it was too late to change any names in the text. Species whose names have changed in recent years are listed in Appendix 3.2.

Unfamiliar old species names found in old papers were translated into their current names using Ross (1972) and Von Breitenbach & Von Breitenbach (1990).

As is usual in extensive ecological surveys the odd similar species may have been confused. If observers were not sure, or could not identify a species it was given a temporary name, and part of the plant was labelled and put into a rucksack for identification later that day back at base[#7].

Grewia and *Rhus* species can be difficult to tell apart, and as an aid to correct identification the observers carried keys to those species with them in the field.

The bulk of the *Ehretia* observed was *E.rigida*. However as an occasional *E.amoena* may have been wrongly classified, it was decided to lump data for these two species.

Diospyros dichrophylla was not recorded in the surveys, and it may have been confused with *D.simii* (Pooley 1993). In addition *D.lyciodes* is a very variable species (Pooley 1993) and some plants may have been wrongly identified.

All *Solanums* were lumped together for analysis. This was unfortunate as the tall *S.giganteum* and more common *S.panduriforme* had differing distributions; with the former favouring forest margin habitat, and the latter more open grassland areas. Palatability also varied between species. Occasionally patches of *S.giganteum* were heavily browsed; while *S.panduriforme* was highly rejected.

The scrambling *Acacias*, *A.ataxacantha* and *A.schweinfurthii*, were also lumped together.

Spiny Forest *Maytenus*' (that were obviously not *M.senegalensis* or *M.heterophylla*) were usually classified as *M.nemorosa*. It is possible that some of the trees classified as *M.nemorosa* may have been *M.mossambicensis*.

CHAPTER 3 NOTES

#1: With only 22 Kb of memory available programming the Sharp PC1500A required routines to be written to convert data into alphanumeric codes that took up less space. One alphanumeric code was used to store values for up to three different integer variables. Special interfacing software was written to down load the data onto a PC and translate the alphanumeric codes back into their original values. Data were exported to PC in ASCII format which could then be parsed after being imported into a spreadsheet. In Umfolozi, data had to be downloaded onto cassette tape for later transfer to PC back at Hluhluwe. Unfortunately, checkbit errors occurred when attempts were made to reload the data from two strata from tape to the pocket computer. The tape failure meant that data from six plots in two strata (16 & 17) could not be retrieved.

#2: When densities of some spizes were high, sheep-counters were occasionally used to count the common trees. The total tree number was then proportionally allocated between the common spizes. For example, let us suppose that 47 sized 1 *Acacia karroo* and *Acacia gerrardii* were counted in the central 2m strip of a plot using the sheep counter. If about two thirds of these trees were *Acacia karroo*, then the plot densities of the two species would be estimated at 78 (47*.667*2.5) and 39 (47*.333*2.5) respectively. In practice this procedure was not used much. It proved easier for the observer to shout out "gerrardii1, 3karroo1's, karroo2, bezey1, karroo1, etc." and the recorder to record each tree as a dash. Dashes were entered on the page in groups of five, with every fifth being diagonally superimposed on four vertical dashes to make a "gate". The use of dash gates made final counting much easier.

#3: In hindsight I should have recorded perpendicular distances to the dung piles. As we walked on a straight compass bearing between plots it would then have been possible to correct for visibility difference and estimate the density of dung piles using distance sampling (Burnham et. al. 1993).

#4: In practice the small non-standard keyboard and display on the Psion Organiser proved difficult to use; although in contrast to the Sharp, downloading of data from the Psion was quick, easy, accurate and error free. The technology of the memory modules also meant that the data captured by the Psion were secure.

#5: Paper was also chosen over the Psion Organiser for data capturing on the simpler rapid post-burn surveys as it was easier and most importantly quicker in the field. The two experiences with using poacket computers to capture data in the filed showed that only simple techniques appear to lend themselves to traditional pocket computer capture in the field (e.g. Dry Weight Ranking). However, the use of sets of bar codes and a bar code reader might have solved many of the problems experienced and make pocket computers a better option in future for electronic data recording.

#6: Probably the most important fact was that both key observers (Richard Emslie and BR2000 research assistant Keryn Adcock) were highly motivated. Keryn and I were convinced that data quality would almost certainly have suffered if the surveys had been carried out by others simply as a job for a third party employer. For this reason, no other field assistant worked for the full period. It simply would have been unreasonable to expect non-project members to work in the bush for such long hours, and for such a long period.

The grid survey programme was a once-off project that the two observers would not have to repeat in a hurry. Therefore it helped that the two key observers were able to get into a "Comrades marathon" frame of mind, and see the whole exercise as big challenge to be completed successfully also helped. This attitude helped both key observers cope with the heat in the middle of the day. Observers with different personalities and characters may not have been able to do this, and data quality or sample sizes may have suffered as a result.

Given the desired total number of plots to be measured in the surveys; daily targets simply had to be achieved in order to complete the surveys in the required time. The knowledge that one couldn't afford to slip behind schedule was a stimulus to keep at it despite flagging enthusiasm.

Observers measured plots as fast as possible as this was found to reduce fatigue - probably because the plots took less time, and also because key observers were so busy there was no time to think about how monotonous and boring the field-work was.

Although plot measurement was time consuming, this work was interspersed with half kilometre walks through the bush to travel to the next plot. Navigating between plots involved map reading, counting all paces taken, and regularly taking bearings. In addition rhino browsing was also assessed while moving between plots. Moving between plots therefore involved more work introducing more fatigue. However, the repeated changing from plot to navigation mode throughout the day at least introduced variety, and helped break the monotony of plot measurement. Fortunately the simple pleasures of game viewing and seeing new areas on foot while navigating through the bush helped reduce fatigue.

#7: The mini-herbarium would have horrified any professional herbarium botanist but worked well as an aid to field ecologists.

#8: The observers had no time for the niceties of botanical plant collection. Identification of unknown specimens had to be done the same evening before they dried up. There were a few rare species that I was not able to identify.

CHAPTER 4

METHODS III : BLACK RHINO FEEDING:HABITAT DATA PREPARATION AND ANALYSES

INTRODUCTION

- To critically interpret and evaluate the BR2000 results, professional quantitative ecologists require details of the methods of data analyses . This chapter provides this information.

- However, many readers will primarily be interested in the results and conclusions[#1]. Readers who are not professional ecologists should probably skip all of this chapter except for the following section on definitions of terms (pages 83-86).

- Those **readers unfamiliar with spize-based ordination methods, but who would like a non-technical review of what they can do, and how to interpret their outputs (ordination diagrams and biplots) should refer to Appendix 4.1** for a layman's guide to these methods.

DEFINITION OF TERMS USED IN ANALYSES

Before proceeding with details of the analyses a number of terms need to be defined...

SPIZE AND RESOURCE

The term *spize* was coined as a shorthand way of saying species size class.

A *resource* is defined as a further subdivision of a common spize according to the amount of grass interference. For example - small *A.karroo* (<1m) is a spize, while small *A.karroo* (<1m) with high grass interference (>50% of the foliage hidden) is a resource.

IMPORTANCE, PREFERENCE AND REJECTION OF FOOD ITEMS

An *important* species is one which contributes a high proportion of the total diet.

A *preferred* species occurs in the diet in a greater proportion than it occurs in the habitat; while a *rejected* species occurs in the diet in a lower proportion than it occurs in the habitat.

Preference Indices were always calculated as the percentage contribution of species, spize or resource X to the diet divided by the percentage contribution of X in the habitat (i.e. an importance:abundance ratio).

Standardised preference and rejection symbols have been used throughout this and subsequent chapters to aid interpretation. Stars (*) and minuses (-) have been used to denote preferred and rejected items respectively: the more symbols the greater the preference or rejection.

Highly preferred items (***) had Preference Indices (PI's) greater than or equal to 2.75.
Preferred items (**) had PI's greater than or equal to 2, but less than 2.75.
Slightly preferred items (*) had PI's greater than or equal to 1.25, but less than 2.00.
Intermediate items ( ) which were likely to be neither preferred nor rejected were defined as having PI's greater than or equal to 0.80, but less than 1.25.

To facilitate comparison, rejection class boundaries were simply defined as the reciprocals of preference class boundaries:

Highly rejected items (---) were defined as those with PI's less than 0.36.

Rejected items (--) had PI's greater than or equal to 0.36, but less than 0.50.

Slightly rejected items (-) had PI's greater than or equal to 0.50, but less than 0.80.

"ACACIAS"

Unless otherwise stated the term "*Acacias*" (ie. in inverted commas) is defined as including the Acacia- like *Dichrostachys cinerea* (a member of the sub family Mimosoideae of the family Leguminosae) along with true *Acacias*.

YES, NO, AYE AND NAE PLOTS

Plots where feeding was recorded were termed *YES* plots, and plots with no feeding *NO* plots.

Plots where Species or Spize X occurred, and which contained feeding, were called *AYE* plots. Those where Species/Spize X occurred without feeding were *NAE* plots.

TOTAL, FREE, HIDDEN, OLD, NEW AND ALL BROWSE BOTTLES

The basic volumetric browse unit was the ***browse bottle*** or *BB* (see Chapter 2).

Total available bottles measured the amount of browse bottles within rhino reach. Foliage above about 2 metres on tall trees was not included in the assessments of total available browse bottles. The exception to this rule was when foliage occurred on taller spindly trees which black rhino could easily push over (e.g. some 2-4m high *Spirostachys africana* and tall spindly *Acacia karroo* trees). Foliage above 2 metres on these trees was included in total bottle assessments as it was effectively available to black rhino.

In the Pilot surveys ***Free available bottles*** represented the total available bottles on trees of less than 2 metres not hidden by grass, forb or thicket interference (i.e. Total minus ***Hidden bottles***)

In the Grid surveys ***Free available bottles*** represented the total available bottles on trees of less than 2 metres not hidden by grass interference (i.e. Total minus ***Hidden bottles***).

The term ***New bottles*** refers to the estimated recent browse offtake by black rhino, measured in browse bottles. The points of New browsing did not show signs of decomposition or discolouration.

The term ***Old bottles*** refers to the estimated offtake after the last burn, but yet had occurred some time previously (ie. > 1½+ months ago). In contrast to New browsing, the points of Old browsing had lost their colour and turned greyish - sometimes with slight decomposition. Only browsing that was definitely done by black rhino was measured (see Chapter 2 for further details).

The term ***All bottles*** refers to all recorded browsing (i.e. both new and old).

TREE SIZES

Tree sizes in the grid survey were:

1: small, < 1.00m, but big enough to be able to detect black rhino feeding (i.e. excluding small thin seedlings and saplings).

2: medium, 1.00 - 1.99m

3: intermediate, 2.00 - 3.99m

4: tall, ≥ 4.00m

DATA PREPARATION

Raw encrypted data were transferred from the Sharp to PC using interfacing software written by the author in GW-BASIC. The coded data were unpacked and free browse bottles/tree, thicket interfered bottles/tree, and the bottles hidden by both grass and forbs/tree were calculated. Results were summarised by spize (species-size class) and expressed per hectare and as per tree.

Excluding the six lost plots, a total of 2,614 trees were sampled in the Pilot survey.

RELATIONAL QUERYING

Paradox relational database querying was used to summarise results. Queries were self explanatory, and so details need not be given here. Paradox was also used to export the data to other statistical analysis packages.

STANDARD STATISTICAL ANALYSES

Unless otherwise stated BR2000's standard statistical analyses were undertaken using Statgraphics, and later Statgraphics Plus version 5.0.

One way ANOVA's and Tukey's Honestly Significantly Different Multiple Comparison Testing were used to determine whether black rhino browsing significantly differed between the habitat patches sampled. The Sums of Squares in the derived ANOVA tables and Grand means were also used to manually calculate the pooled coefficients of variation in feeding between replicate plots per habitat patch for both reserves.

In cases where explanatory variable collinearity was marked, Ridge Regression (Draper and Smith 1981) was used to analyse data in preference to standard multiple regression. Ridge regression modifies the least squares procedure to help avoid problems caused by highly collinear independent variables. Resulting parameter estimates may be slightly biased, but are often more precise than those obtained using ordinary least squares, while estimated coefficients of *correlated* independent variables may be closer to their true values. The value of ridge regression's theta coefficient controls the extent of bias introduced. Where theta equals zero, results are the same as for ordinary least squares after all variables are standardised. As theta increases, usually remaining less than 1, bias increases but so does precision of the coefficients. A small value of theta beyond which the estimates change slowly, is appropriate. Details of the pilot-survey analyses are given in Chapter 6.

GRID SURVEYS

BASIC DATA MANIPULATION AND QUERYING

After importation of the original data from dBaseIV, almost all the basic data manipulation and querying were done using Dos versions of the Paradox relational database software package. All the necessary computer programs were written in PAL (Paradox Application Language). Quattro Pro was primarily used to enter environmental data onto the computer, and @ functions and cell equations were used to manipulate data and calculate new variables. Data were routinely transferred between these two packages without problem.

BUILDING OF HABITAT, BROWSING, ENVIRONMENTAL AND MANAGEMENT DATABASES

Past recording and mapping of fire and bush-clearing data by NPB staff allowed BR2000 to study the longer term effects of management actions as well as environmental variables on woody vegetation structure and composition. To undertake these analyses it was first necessary to build databases summarising environmental and management variables at both plot and plot-spize levels.

The databases used in Grid analyses consisted of raw data and simple calculated fields (e.g. Free Bottles/Plot). The databases also included data that had to be laboriously extracted for each plot, from the many Soil, Geology, Fire and Bush Clearing Maps in the Hluhluwe Research Centre.

The main Hluhluwe and Umfolozi Grid Study area datasets contained 306 different variables. This represented almost three hundred thousand datapoints that either had to be entered or calculated (Hluhluwe 198,306 Umfolozi 93,500). If one also included the hundreds of RESOURCE and CANOCO derived variables that were also used, the datapoints used in the Grid analyses numbered about half a million.

Some calculated variables were used to facilitate certain queries, even though they effectively duplicated information. Data for a number of variables were expressed in three ways: 1) per plot, 2) occasionally per hectare, and 3) per hectare divided by the number of plots in the study area. This technically made querying easier. The first format (the raw data) could, for example, be used for categorical analysis. Averaging queries using the second data format returned average values per hectare for the conditions specified. Summation queries using the third, returned average values per hectare for the whole study area for any given set of conditions.

The variables in the main databases could be spilt into five broad types:

A] **Habitat description variables for each of the** 4651 unique Hluhluwe and 2354 **unique** Umfolozi **Spize/Plot combinations**. These variables included woody spize data using a range of abundance measures from estimates of canopy cover to free browse bottle densities. Grass Interference data also formed part of the habitat descriptions.

B] Variables recording **browsing and habitat use data for each** of the 4651 **unique** Hluhluwe and 2354 unique Umfolozi **Spize/Plot combinations**.

C] **Summary habitat description variables for** the 242 Hluhluwe and 187 Umfolozi **plots**.

D] Variables recording **browsing and habitat use data summarised for each** of the 242 Hluhluwe and 187 Umfolozi plots. Variables that quantified the extent of black rhino browsing and sign in the areas surrounding each plot were also included in the Hluhluwe databases.

E] **Explanatory** databases with data for a suite of **environmental and management variables per plot** for each reserve. Environmental data ranged from physical information about plot location, altitude, slope and aspect to details of underlying geology and soil type. Management variables summarised fire and bush clearing histories for each plot.

Separate databases were built for each study area. In addition pooled databases containing data from both areas were built to allow pooled queries. All variables in the databases are described and listed in Appendix 5.2. A copy of these variables on disks, together with 1 hard copy, will be supplied to the Natal Parks Board.

Besides the habitat descriptor variables, whole suites of key species, spize and resource variables were derived for each plot using the RESOURCE software (Emslie 1991d). RESOURCE is a data preparation tool which automates the identification and lumping, making passive, or dropping of rare species, spizes, resources and plots. RESOURCE is fully described in the following chapter.

These data were converted into summary tables, with plots as rows and species, spizes or resources as columns. To do this, the RESOURCE generated ARKA compatible input files (i.e. arkain.dbf files), were simply imported into Paradox and cross-tabulated. The ARKA[#2] (Bodasing et al. 1989) software application was then used to automate the process of building the specialised FORTRAN format input files required by multivariate analysis packages like CANOCO (Ter Braak 1988a), TWINSPAN (Hill 1979b) and COMPCLUS (Gaugh 1979).

STATISTICAL ANALYSIS OF MULTIVARIATE ECOLOGICAL DATA

Ecological data are amongst the most intractable data for statistical analysis (W.Zucchini, pers comm.). The statistical analysis of multivariate ecological data is not simple, making model selection and analysis complicated and time-consuming. Examples of common statistical problems that were experienced included:

- Variable collinearity and non-normality.
- Non-Linear system responses.
- High data dimensionality.
- Failure to meet Parametric technique assumptions (e.g. residual non-normality and heteroscedasticity).
- Spatial and temporal autocorrelation.
- Non stationarity and variable anisotropy when attempting Kriging.
- Potentially more explanatory variables than plots.
- Limits to the number of variables and plots allowed in standard ecological FORTRAN statistical packages.
- Problems caused by rare species/spizes and aberrant sites.
- High levels of "noise" in the data.

Fortunately for ecologists, more and more techniques and software are being developed every year which are better suited to analysing ecological data than the traditional classical Parametric statistics. BR2000 was able to take advantage of some of these developments (eg Partial Constrained Ordination with Monte-Carlo Permutation testing, and Formal Inference-based Recursive Modelling).

STANDARD STATISTICAL ANALYSES

Many of the analyses in Chapters 7, 8 and 9 are self-explanatory (e.g. Relational database querying, ANOVA, Multivariate ANOVA (Johnson 1980), Multiple regression or Ridge regression analyses), and therefore need not be described in this chapter. Details of the aims of these analyses are instead presented together with the results in later chapters.

Paradox proved to be a superb software package, allowing very complex interrogation of the databases. It was an essential component that contributed greatly to the success of the analyses.

The rationale for using Ridge regression was outlined earlier in this chapter.

The so-called self-explanatory analyses were used to :

- examine baseline woody tree abundances;
- highlight habitat differences between study areas;
- determine the important, preferred and rejected species and spizes for each study area, (results being calculated using both bottle and count data);
- contrast differences between plots with feeding and those without;

○ examine the effects of grass interference and grass height on black rhino feeding; and

○ contrast the influence of grass in Hluhluwe versus Umfolozi, on the availability to rhino of <2m (small-medium) food *"Acacias"*.

The decomposition of multiple correlation coefficients was undertaken using the approach of Johnston (1980). In essence this analysis was akin to a simple version of Newton and Spurrell's Addititive Elements Analysis (Newton & Spurrell 1967a, 1967b; Whittaker 1984). The aim of such analyses was to quantify the unique effects and shared effects of selected correlated explanatory variables (in this case Grass Height and Grass Interference).

DETERMINATION OF THE LONG TERM INFLUENCES OF MANAGEMENT ACTIONS (BUSH CLEARING AND FIRE) ON WOODY HABITAT COMPOSITION AND STRUCTURE IN HLUHLUWE.

Determining the long term (3-30 years) effects of fire frequencies and bush clearing on black rhino habitat quality using multivariate analysis of the Grid survey data was a two step problem -

- Multivariate statistical techniques were firstly used to determine how the habitat composition and structure has been altered by management variables (e.g. fire frequencies at different periods since 1955). This was in itself a multi-stage process.

- The knowledge gained about the effects of management variables on habitat structure and composition was then interpreted in the light of knowledge about black rhino feeding preferences obtained from the feeding surveys.

The first stage of the analysis had to be split into a number of stages. This was primarily because past fire regimes and bush clearing histories were partially confounded with environmental variables.

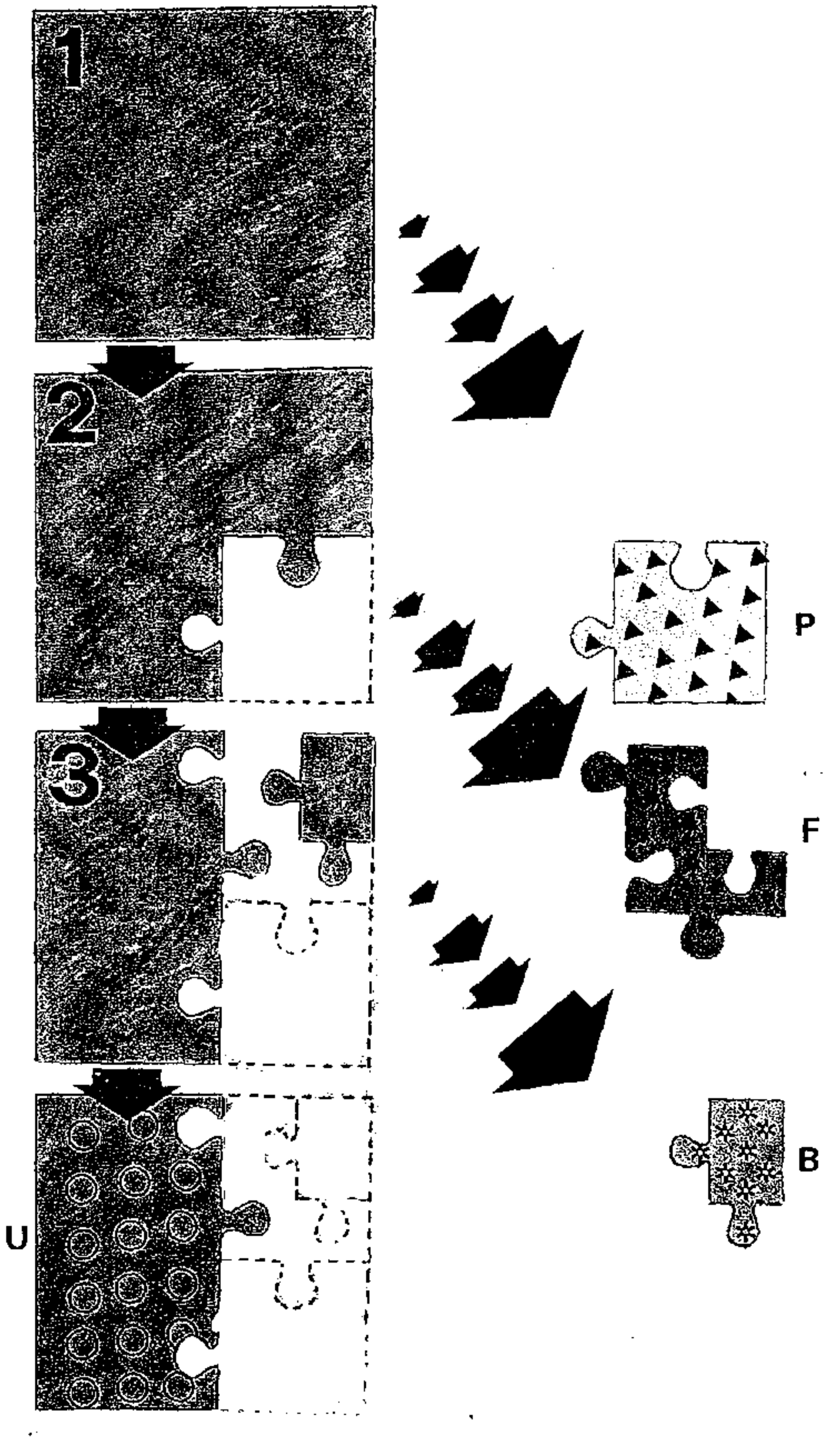
For example, fire frequency is in part a function of altitude, slope, soil type, geology and aspect. Analyses that include all these correlated variables at once, may show that fire histories are strongly correlated with community composition and structure. However, the problem is that such analyses will not indicate whether fire variables themselves uniquely explained some of the variation in habitat composition, that could not already be explained by other correlated environmental variables (altitude, slope, soil type, geology and aspect). Similarly, high frequencies of bush clearing were correlated with flat low lying areas in the Manzimbomvu valley, confounding interpretation.

Before examining the influence of management actions on woody vegetation composition, analyses concentrated initially on determining, and then statistically removing the effects of environmental variables on the vegetation. Available software was not dimensioned to handle all the environmental variables data were available for. It was therefore also necessary to select a key subset of environmental variables from all possible variables (see Chapter 14).

After the effects of the selected key environmental variables on species composition had been partialled out, analysis could proceed to the next stage. This was, determining whether firstly fire variables, and secondly bush clearing variables, significantly explained any of the residual variation in species composition and structure (See Chapters 15-18). Figure 4.1 illustrates the analytical approach taken. The square (1) represents the variation in woody vegetation data. The pieces P, F and B symbolise the variation accounted for by the environmental, fire and then bush-clearing variables. The piece U symbolises the remaining unexplained variation and noise.

The methodology adopted to select and determine the influence of a suite of key environmental variables is described in the following section. The knowledge gained during this stage of analysis represents a spin-off for the Natal Parks Board.

Figure 4.1. Illustration of successive analysis to study variation in habitat data. 1) First analyses determine variation in habitat structure and composition accounted for by physical and environmental factors (P ▲). 2) Second set of analyses determine the residual variation in habitat structure and composition accounted for by fire variables (F ✱). 3) The third stage determines variation of remaining variation in habitat structure and composition that can be accounted for by bush clearing treatments (B ✲). The remaining unexplained variation (U ○) is also shown. This will comprise of unexplained variation and noise.



ANALYSES TO DETERMINE THE INFLUENCES OF ENVIRONMENTAL VARIABLES ON HLUHLUWE WOODY VEGETATION

Given the bulky, noisy and complex vegetation data (eg 337 different spizes in 242 plots in Hluhluwe Grid survey), it was necessary to use multivariate ordination methods to determine the major patterns in vegetation composition and structure. This enables the main gradients in community composition to be described using a smaller number of variables. Although a little of the raw information is always lost in multivariate analyses, this is usually more than made up for by the overall gain in understanding which results (see Appendix 4.1).

Constrained Ordination methods were selected to derive the new vegetation structure and composition variables. Constrained ordination has the advantage that analysis can focus directly on the relationships between species and measured explanatory variables. Interpretation of derived ordination axes is also automated. Results can also be shown graphically using ordination diagrams and biplots. Biplots not only show the major patterns of habitat variation, but also the main relations between the species and each of the environmental and management variables under study. (Readers unfamiliar with interpreting ordination diagrams and biplots should consult Appendix 4.1 for a non-technical explanation of how to interpret them).

Model building

The aim of this modelling was to determine which key environmental variables influence woody habitat structure and species/spize composition in general, rather than just describing vegetation composition within black rhino reach. Braun-Blanquet (BBQ) cover abundance data were therefore chosen to be the basis of habitat analysis rather than density or bottle based data, because the former gives greater emphasis to physiognomically dominant big size classes, which have lower densities.

Both Species and Spize based RESOURCE analyses of Braun-Blanquet Cover Abundance data were undertaken. Chapter 5 gives full details on RESOURCE (Emslie 1991d). Rare species were identified and dropped using RESOURCE. In the Spize based analysis, optimal spize combinations of more common species were then determined by RESOURCE. Finally, aberrant site indices were calculated and aberrant sites identified so they could be made passive in subsequent analyses. RESOURCE output was then exported to ARKA 1.1 (Bodasing *et al.* 1989).

Subsets of the environmental explanatory variables were extracted from the main Hluhluwe dataset using Paradox. Data were then either translated immediately into a dBaseIV format file for direct input into ARKA; or were exported to Quattro Pro before subsequent transfer to ARKA.

Quattro Pro was used when 34 additional environmental explanatory variables, interaction product variables, or transformations were included. A total of 75 different environmental variables were considered in the analyses. Additional environmental variables used in the analyses are listed in Appendix 4.2. To avoid "data dredging", only additional variables which previous runs indicated should be examined and/or seemed intuitively reasonable were added.

ARKA 1.1 was used to build the two vegetation (species and spize) and six environmental data input files in the specialised FORTRAN format required for CANOCO multivariate analyses. Explanatory variable subsets were used to draw up the six different FORTRAN format input files [#3].

Basic environmental variables (altitude, aspect, slope, distance from water, soil type and texture and underlying geology) have a major influence on species distributions. Initial analyses therefore used the Species based Braun-Blanquet (BBQ) vegetation dataset.

The first major section of the analysis studied the relationships between basic physical variables and BBQ species data. The aim of this stage of the analysis was to determine the smallest possible subset of variables that significantly described as much of the species:physical environment relationships as possible.

Repeated runs were used to identify and drop superfluous variables that explained little more than could be explained by other variables. This approach enabled the number of explanatory variables to be reduced to a manageable level, and at the same time avoiding problems associated with variable collinearity. Full details of the various analyses are given in Chapter 14.

Detrended Canonical Correspondence Analysis (DCCA) was used at this stage of analysis in preference to straight Canonical Correspondence Analysis (CCA). This was because CCA could be expected to exhibit classic horseshoe effects as explanatory variables were collinear. Detrending by polynomials in DCCA was used to remove arch-effects. The majority of runs were Partial DCCA's (i.e. effects of covariables were partialled out before canonical ordination).

Factors guiding model selection

Model building was a complex process. In particular the decision of which variables to include and which to drop was not straight forward. Variable subset selections for each run were chosen after reviewing the results of previous runs.

The following list of factors was used to select variables for each run and assess model suitability. The list assumes a rudimentary knowledge of the use of CANOCO and its output. This is both for the sake of brevity, and because this thesis is not intended as a training manual in multivariate ecological statistics. For a full description of the details of the methods, and how to interpret and use output, interested readers are referred to the works of CajoTer Braak (1986; 1987a; 1987b; 1988, *et al;* 1988a; 1988b). I have however, endeavoured to provide enough detail so that professional ecologists can understand the approach taken to build and evaluate models.

The factors used to guide model selection and assessment were :

- Whether CANOCO detected collinearity and dropped variables before analysis.

- The size of the eigenvalues of derived canonical axes - The larger the better. Comparison between the size of eigenvalues of previous runs was useful [#4].

- Correlations between explanatory variables in the weighted correlation matrices - This was useful to get an overall picture of variable collinearity patterns.

- The inter- and intra-set correlations between explanatory variables and derived species axes. These were particularly useful in interpreting the canonical axes derived, and showed which variables worked in the same ways.

- The size of the species:environment correlations for each canonical axis.

- Variable Inflation Factors (VIF's) - The aim being to produce final models with low VIF's for all variables. VIF's proved to be very useful in guiding variable selection and identifying those variables with unique effects.

- The weighted means for each explanatory variable - Small weighted means indicated that these variables should probably be dropped in future runs. The variable to drop in a dummy variable or closed number set was usually determined by looking at means. The variable with the smallest mean was usually dropped.

- Graphical biplots of environmental variables were mentally superimposed onto plots of Species scores. Collinear variables which had been made passive were often also displayed on the biplots to aid interpretation. The length of the biplot arrows and angles between arrows were especially useful.

o Centroids of some dummy variables or fuzzy coded dummy variables were occasionally examined, and **Centroid plots** were mentally superimposed onto Graphical plots of Species scores.

o The size of the t values of the regression coefficients, and especially whether they were > 2.1 **(In practice, t values were not as useful in helping to select variable subsets as had been suggested by Ter Braak in the CANOCO manual.)**

o Occasionally the discrepancies between Canonical Coefficients and Inter-Set Correlations were used to determine the extent of Collinearity problems.

o The significance of the first Eigenvalue (and sometimes the Trace eigenvalue) was routinely determined using **Non-Parametric Monte-Carlo Permutations Testing**. This was **particularly useful in determining whether a model was spurious** (i.e. the variables being examined did not add anything to the model). In the majority of cases 99 permutations were undertaken so that significance could be determined at the p=0.01 level. This conservative level was chosen to avoid the "multiple-comparisons test spurious significance problem". In other words if you do enough different analyses, the chance of making a Type I error at some stage is greater with significance set at the traditional 5% level (where on average one can expect a spurious significance on average once every twenty runs).

o The magnitude of the differences between the first eigenvalue (and occasionally the trace eigenvalue) and subsequent Monte-Carlo permutation eigenvalues was used to give a further indication of the strength of the derived species:environment/management relationships.

o Sometimes the run stopped prematurely due to numerical overflow problems, caused by excessive collinearity amongst variables. In such instances, it was noticed that immediately before the run bombed, the screen very briefly showed the VIF table with some VIF's shown by a row of stars allowing the offending variables to be identified.

In summary, Eigenvalue sizes, Monte-Carlo Permutation Testing, Correlation Matrices, Variance Inflation Factors, Weighted Means and Biplots were of most use in guiding variable selection and future analyses. Results of these analyses are given in Chapter 13.

DETERMINING THE LONG TERM INFLUENCES OF FIRE ON HLUHLUWE WOODY VEGETATION COMPOSITION AND STRUCTURE

After the effects of the selected key environmental variables on species composition had been partialled out, analysis could proceed to determine whether fire variables significantly explained any of the residual variation in species composition and structure (see Figure 4.1). This approach was based on the likelihood that sites with similar environmental conditions had not experienced identical fire histories. If fire frequencies affected habitat conditions in their own right, one would therefore expect fire variables to still significantly explain some of the residual habitat variability (ie. variation in the data not already accounted for by the environmental variables). In practice this premise held when looking at the effects of fire on the Grid survey data. Monte-Carlo Permutations testing was used to test the significance of the derived relationships.

Tree size is a function of successional stage, which in turn can be influenced by management actions such as bush clearing and fire. Therefore this stage of analysis was undertaken using a spize based BBQ data set.

Although large areas were shaded as having been burnt on the burn maps, these areas included patches of riverine and other mature forest patches that would not have been burnt. An examination of the species composition and structure of each plot enabled those plots to be listed. When analysing to determine the effects of fire, these plots were therefore dropped from the analysis. As some riverine and mature evergreen forest plots were dropped from the analysis, the species weights from the first "fire" run were examined to identify further species that should also be made passive in future analyses.

Results of these analyses are given in Chapter 16, and this chapter also discusses the limitations of the fire data on the Park's burning maps.

MULTIVARIATE ANALYSES TO DETERMINE THE LONG TERM INFLUENCES OF BUSH-CLEARING ON HLUHLUWE WOODY VEGETATION COMPOSITION AND STRUCTURE

After the effects of the selected key environmental variables and fire variables on species composition had been partialled out, analysis proceeded to determine whether bush clearing variables significantly explained any of the residual variation in species composition and structure.

As will be discussed later, the partial constrained ordination approach failed when studying the effects of bush clearing. This was almost entirely due to the complete lack of adaptive management (ie virtually no controls) in the application of bush clearing treatments.

Besides the lack of adequate control treatments, the large number of different bush clearing treatments (species cleared, physical method used, chemicals applied, concentration of chemical solutions, whether diesel was applied, frequency of clearing, etc.) made it almost impossible to adequately assess the long term effects of bush clearing using the Grid survey data.

Problems with bush-clearing data

Short term experimental projects can be used to determine the short term effects of bush clearing operations on woody plants (e.g. King 1987, Konstant in prep). However, past mapped bush-clearing data have to be used when attempting to discern the longer term implications of bush clearing on woody species composition and structure. Such work was fraught with problems.

The most striking features of the early bush clearing operations in Hluhluwe have been 1) the large number of different bush clearing treatments and 2) the lack of adaptive management in setting up replicates of treatments together with uncleared controls. In other words the emphasis appears to have been almost entirely on clearing bush, with little thought of assessing the success or otherwise of particular treatments.

Roddy Ward was one notable exception who had the foresight to leave control plots during the early clearing. Sadly all these plots have since been cleared accidentally (A.J. Wills pers comm.).

Analysis of the bush clearing history of the 242 Hluhluwe Grid Plots revealed that of the plots that were treated up to 1988 :

Nine different sets of species were listed as being cleared.

Clearing was undertaken in 14 different years.

Ten different combinations of arboricide and diesel were applied in N.E.Hluhluwe between 1973 and 1990 (Garlon with diesel, Garlon Super with diesel - only after Grid survey, Tordon 101, Tordon 155 with and without diesel, Tordon Super with diesel, 2-4-5-T with and without diesel, Roundup, and application of diesel on its own.)

The application of chemicals in different strength solutions further increased the number of different chemical applications.

The number of different treatments imposed on the plots increased further when one also considers the frequency of clearing and the time since last clearing.

The huge number of different treatments, and lack of adequate replication made it impossible to analyse the bush clearing data in detail. **It was therefore necessary to simplify the bush clearing data before analysis to reduce the number of variables to a more manageable level.**

- It was decided to reduce the species cleared to three classes: *Acacias*, *Maytenus senegalensis* and *Euclea divinorum*.

- All chemical treatments were lumped as chemical treatments, although a separate variable was included to denote whether diesel had been applied or not.

- Similarly all physical clearing methods were lumped together as physical.

DETERMINING THE SHORT TERM INFLUENCES OF BUSH-CLEARING AND FIRE ON HLUHLUWE WOODY VEGETATION COMPOSITION AND STRUCTURE

The results from the short term bush clearing experiments of Nick King (1987) and more recently Tracy Konstant (*in litt.*) were interpreted in the light of knowledge gained on black rhino feeding patterns.

In addition, the influence and importance of the variables *Fire in 1988* and *Fire frequency in the 1980s* were studied on the fire constrained canonical ordination biplots (see above).

IDENTIFICATION OF POSSIBLE SUCCESSIONAL PATHWAYS USING GRID SURVEY DATA, INCLUDING THE EVALUATION OF THE HYPOTHESISED WHATELEY-WILLS MODEL OF SUCCESSION IN HLUHLUWE.

Past vegetation changes were pieced together using a number of different approaches:

KING'S ANALYSIS OF AERIAL PHOTOGRAPHS

King (1987) analysed old aerial photographs of Hluhluwe. His findings were reviewed based on ground truthing of his vegetation states based on our knowledge of the vegetation throughout the Hluhluwe Grid Study area. This work is discussed in both Chapter 16 and 20.

LITERATURE REVIEW

A literature review proved very useful. Older papers referring to the area in the 1930s and 1940s were searched for references to woody vegetation. The communities described by Whateley and Porter (1979) were closely examined to see if there were any differences in communities compared to 1989. Current theory on plant succession also proved valuable in reviewing the evidence for changes in various communities.

ANALYSIS OF OLD VEGETATION MAPS OF N.HLUHLUWE

The following old maps were located and examined following recorded changes in different parts of the Grid study area:

- J.S.Henkel's (1937) 1936 map of vegetation types of Hluhluwe Game Reserve *
- P.M. Hitchins' 1960 map of vegetation types mapped from aerial photos job 442 strip 8 *

- P.M. Hitchins' 1970 map of vegetation types mapped from 1969 aerial photos job 608 strips 11 and 12 plus field work *.
- P.M.Hitchins' 1970 map showing the extent of "dense vigorous scrub" in 1960 and 1970 based on his 1960 and 1970 maps *.
- P.M.Hitchins' 1973 vegetation base map *
- A.Whateley's 1975 map of vegetation communities of (written up as part of Whateley & Porter 1979 & 1983)*.
- R.N.Porter's 1975 map of wildlife management areas and associated veld problems for Hluhluwe Game Reserve and the northern Corridor.

A map study area was defined as the area of Hitchins' maps that occurred in the Grid study area and its boundaries are given in Figure 4. 2. The proportional contribution of the different vegetation units in each map were quantified using a point sampling grid overlaid on top of each map annotated with an asterisk* above. In the case of Hitchins's 1960, 1970 and 1973 maps the history of each sampling point was recorded.

USE OF A RESOURCE-BASED STATIC ORDINATION APPROACH

o A Spize-based ordination approach was used to study successional trends, as these reflect both species composition and vegetation structure. This has been termed a "static" ordination approach to studying succession (Austin 1977); in contrast to the "dynamic" ordination of repeated site measurements over time. Despite being successfully used by a few researchers (Goff & Zedler 1972, Enright 1982) the "static" ordination approach has largely been ignored as a method to study succession.

The past lack of use of "static" ordination approaches may in large measure have been due to the problems inherent in spize-based ordinations that RESOURCE was designed to sort out (see Chapter 5). RESOURCE was therefore used to prepare data prior to ordination to identify rare spizes and aberrant plots. RESOURCE also created composite spizes where necessary to ensure that valuable data were not discarded prior to ordination.

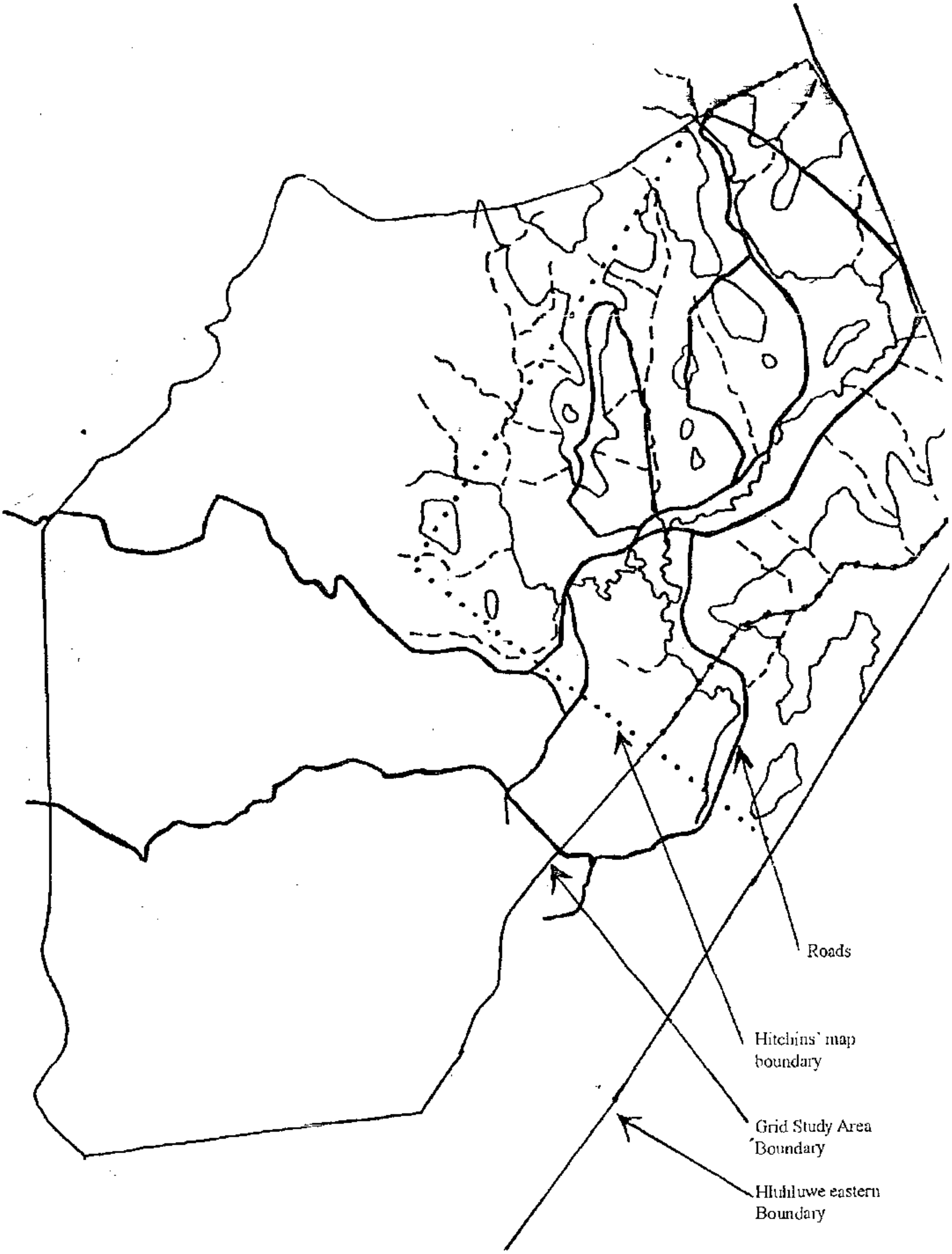


Figure 4.2. Area of Hitchins' 1960, 1970 and 1973 maps which fell inside the Grid Study Area and which was used to analyse Henkel's 1937, Hitchins' 1960, 1970, 1973 and Whateleys' 1975 vegetation maps.

The assumption behind this "static" approach was that each site represents a sequence in time; with the larger size classes representing the present successional stage of the site, and the smaller size classes the possible future composition (Enright 1982, Emslie 1991e). By following the path traced by the centroids of successively larger spizes of key species on ordination diagrams, successional patterns can be detected (Emslie & Adcock 1990, Emslie 1991e). However on standard ordination plots it is usually not clear whether plots placed near the origin are simply unaffected by the constraining variables, or genuinely represent a central position in the ordination. For this reason, and to make understanding easier, three dimensional interpolated species abundance data were plotted for many spizes in ordination space. The three dimensional plots also include much more information about spize distributions than simply looking at the position of centroids on an ordination plot. Time constraints meant it was not possible to draw plots for all key spizes. However, enough maps were drawn to clearly identify the main successional gradient and objectively evaluate the Whateley-Wills hypothesis (Whateley and Wills 1996).

A three dimensional plot of black rhino feeding levels in ordination space was also produced. By mentally superimposing this diagram onto the identified successional path in ordination space it was possible to determine the extent to which successional trends may have been detrimental to the rhino.

The three dimensional surface plots were drawn using an inverse distance squared interpolation algorithm [#5].

This approach provided a good objective test of the Whateley-Wills successional hypothesis (see Chapter 20 for more details), as the patterns were determined objectively by multivariate analysis. As mentioned it also enabled one to relate any detected successional pathways to rhino feeding levels.

ORDINATION OF DATA SUBSET

The Hluhluwe Grid Plots were examined and those plots that contained communities that had no part in the proposed Whateley-Wills successional model (eg riverine forest and true evergreen forest) were dropped. The remaining subset of the Hluhluwe Grid Plots was then subjected to a spize-based ordination, to further examine the proposed successional model.

TWINSPAN ANALYSIS

A spize based TWINSPAN (Hill 1979b) analysis was also carried out to further evaluate the proposed successional model. If the Whateley-Wills model holds, one would expect that *A.nilotica* would be identified by TWINSPAN as a pivotal species in the classifications. An examination of the associations of spizes in the detailed output file would provide additional evidence to evaluate the model. Once again this provided an objective assessment of the proposed model.

MEDIAN CLUSTERING

A median clustering algorithm was used to study patterns of association of key spizes.

CONSTRAINED ORDINATION BI-PLOTS

A number of causal processes were suggested by Whateley & Wills (1996). The examination of the constrained partial ordination biplots and in particular the fire constrained plot would be an objective test of the theory. Should lack of fire have been such a key factor as suggested, then one should expect the orderings of the key "Whateley-Wills" spizes to be organised in a logical sequence on the resultant biplot. However, should the theory not hold, no clear cut pattern should be apparent.

INTERVIEWS

Where possible past rangers and researchers were questioned about past vegetation structure and composition. Unfortunately in most cases memory was hazy as most people's interest in the past had been the animals and not the vegetation. However, Staff-sergeant Ncgobo, who was interviewed just before he retired in 1990, was a most useful mine of information and could talk about conditions in the mid 1970s in some detail. Before he died Dumisane Ngobese and an old long-retired Game Guard who had worked with Pete Hitchins in the 1960s were also interviewed in Kwa-Zulu and provided useful information on vegetation changes. BR2000 also toured the Hluhluwe study area with Doug Pheasant who put the first lighting-plant into Hluhluwe.

OLD PHOTOGRAPHS

The old photos at Hluhluwe Research were examined. Unfortunately very few were of much use, as animals or people were generally the main subject of the photographs and the exact location of the photos were not clear. Some old movie film was watched at Natal Parks Board Head Office, but again this proved not to be useful as the vegetation was never the subject of filming.

However, some photos were very useful. Attempts were made to re-find one location where photographs had been taken in 1949, 1974 and 1984 (Figure 20.4). Unfortunately Tony Whateley who had taken the last photo had emigrated and was not available to assist in finding the site in the field. Although we had a rough grid reference, attempts to relocate the site were unsuccessful. Indeed, it may have been that the area had recently been bush-cleared.

Roelf Attwell also kindly supplied the author with copies of some his photographs of Hluhluwe taken from 1939 onwards (see Chapter 20).

Unfortunately the fixed-point photographic monitoring programme was too recent to look at longer-term past vegetation changes. During the field work period, the planned retaking of these photographs by NPB staff unfortunately never took place. A comparison of recent pictures with old ones would still have been instructive. In time, the author is sure that the foresight of NPB staff, partticularly Ian Macdonald, to set up these fixed point photographs will be appreciated. However using a colour video may be more appropriate.

DETERMINATION OF HOW BEST TO MEASURE BLACK RHINO HABITAT:

The basic rationale used, was to study black rhino habitat use at 1) a hierarchy of scales (woody plot community structure and composition → woody plot community structure and composition within rhino reach → species → spize → resource level); and 2) using a range of descriptors (eg densities, cover abundance, total and free browse bottles within rhino reach).

The influence of grass interference and grass height on black rhino feeding was also studied.

The results from these studies could then be synthesised to predict how a black rhino perceives its habitat, and in particular to determine at which scale it selects its food. This knowledge is central to determining how best to measure black rhino habitat.

Ordination which was constrained by browsing data was also used to study key variables influencing habitat use.

In future, the effects of measurement resolution on conclusions could be studied to avoid sampling habitat in excessive detail. Time constraints did not allow for this work to be undertaken as part of this project.

POST-BURN SURVEYS

DATA PREPARATION

The vegetation type of post-burn survey plots was described by "key species" dummy variables, which characterized the main vegetation variation. If a "key species" was noted as a dominant species/spizes in a plot during the field survey, that dummy variable received a 1, else it remained 0. Similarly, if the plot fell within a "vegetation locality", that variable was scored 1, else it scored 0. Thus a plot could score 1 in one or more of these dummy variables, depending on its locality and spize composition. Dummy variables for these key species and spizes were created:

A.karroo > 2m
L.javanica
Rhus pentheri > 2m
Euclea racemosa >2m
Spirostachys africana
D.cinerea
A.caffra
A.nilotica >2m
Euclea divinorum

Dummy variables of the following "vegetation localities" were also created:

Forest
Forest margin
Drainage lines

Physiognomies of size classes 1 (<2m) and 2 (>2m) in each plot were categorized as:

Size < 2m:	**Size > 2m:**
Open grassland = 1	Scattered trees = 1
Open scrub = 2	Open woodland = 2
Scrub = 3	Medium woodland = 3
Closed scrub = 4	Closed woodland = 4
Thicket = 5	

Categories for fire intensity, black rhino eating, plot density and amount of paths, were coded as given in the field methods in Chapter 3.

RELATIONAL QUERYING

Paradox relational querying was used to generate the general feeding patterns and species compositions of the post-burn diet for all three Post-Burn surveys presented in Chapter 9. The queries were self explanatory and no details are required here.

The feeding data (see Chapter 3) were used to calculate estimates of the offtake (bottles\plot) from each of the spizes eaten (browse intensity mid-class (bottles) for each plot multiplied by the percentage contribution to the feeding of that spize).

FORMAL INFERENCE-BASED RECURSIVE MODELLING

More detailed patterns of feeding in relation to burns, paths and vegetation types, were investigated using Formal Inference-based Recursive Modelling or FIRM (Hawkins 1990) on the data from the second main Hluhluwe post-burn survey.

WHAT IS FIRM ?

For those that may be unfamiliar with FIRM, it is a largely assumption-free method of exploring the relationship between a dependent variable and a set of predictors (Hawkins 1990). The data set is partitioned into two to four groups defined by a range of values of one of the predictors. Each of the successor groups is in turn similarly partitioned into two or more groups defined by ranges of values of one of the predictors. The analysis continues until some termination rule indicates that none of the sub-groups can be split further. Each split is designed to create further nodes which are in some sense maximally internally homogeneous. Output is used to create a dendrogram. FIRM is ideally suited to discovering interactive effects in the data. If there are sufficient data it has the advantage that cross validation procedures are available to test the reliability of derived models.

There are a number of techniques for modelling based on recursive partitioning. FIRM differs from these in several respects - notably of varying the number of descendent nodes into which different nodes are split; and of using conservative (Neyman-Pearson) statistical inference for determining when to end analysis of each node (Hawkins 1990).

The predictors are on either the nominal (*Free*) or ordinal (*Monotonic*) scale. The dependent variable can either be on a categorical or interval scale of measurement. CATFIRM analysis is appropriate for the former, and CONFIRM for the later.

The data from the 1,687 main Hluhluwe post-burn survey plots were analysed using both Continuous and Categorical Formal Inference-based Recursive Modelling (CONFIRM and CATFIRM see Hawkins 1990).

THE NATURE OF DEPENDENT VARIABLES

Browsing was measured on a six point (Browsing Unit of BU) scale (with modal class intervals of 5 bottles per transect). As the browsing scale was almost linear it was decided to primarily analyse the data using CONFIRM (ie in effect treating browsing as a crude continuous dependent variable). CONFIRM analyses had the advantage over CATFIRM (treating browsing as a categorical dependent variable) as direct comparisons of group (node) means are possible. CATFIRM analyses were also undertaken for comparative and heuristic purposes.

ATTEMPTS AT MODEL VALIDATION

To determine how well the models held up when presented with new data, validatory CONBACK and CATBACK analyses were undertaken. To do this, the available data were split into two groups (odd and even numbered plots). One half was used to build the models, and the other half was used to verify their fit. While this did not make good use of the data from the point of statistical efficiency, it provides quite a searching test of the modelling approach.

If the F values in the splits of the validation sample are highly significant, there is a very strong formal inferential basis for the claim that the CONFIRM tree reflects real structure and not just chance.

The results of the validatory analyses indicated that a sample size of 844 plots was not big enough to validate most of the derived nodes apart from some of the main divisions. This highlighted the immense sampling problems caused by the high variability in black rhino feeding between plots. This was reflected in low R^2 values. Exploratory analyses using log transformed dependent data did not appear to be more appropriate, and will not be discussed further. The limited success of cross-validation attempts may in part have also been due to high collinearity amongst some of the predictors.

Despite the limited cross-validation in the CONBACK and CATBACK analyses, the models obtained from the full CONFIRM and CATFIRM runs can be expected to be substantially better as they were based on double the amount of data. Unfortunately, no reserve data were then available to validate these models, as all the data were used to build them.

RATIONALE FOR NOT ONLY CONSIDERING THE "BEST" STATISTICAL MODELS

In many ways FIRM analyses appear to suffer from the same problems of Stepwise multiple regression. From a heuristic point of view, the "best" statistical model may not be the most valuable. Due to the ordering in choice of predictors a whole suite of good models may be possible. In other words, given predictor variable collinearity, a consideration of a range of "good" models is likely to be more appropriate than just the "best". For this reason the edited output presented in an optional Appendix 9.1 in the BR2000 report lodged with Natal Parks Board (now KZNNCS) gives node split statistics for all significant predictors, and not just the best selected by the model. A copy of this Appendix will be made available to examiners on request.

RUN PARAMETERS SELECTED

The following run parameters were used on the initial CONFIRM run:

For a group to be analysed it had to contain at least 25 cases, and account for at least 0.004% (1/250) of the Starting Sum of Squared Deviations.

The minimum % Raw significance for a split was set at 5% and the minimum % Bonferoni significance for a split at 10%.

The analysis was set to stop after 75 groups had been formed.

The Pooled Anova Error Mean Square was used as the error variance.

The Split/Merge significance levels for all variables were set at 4.9% and 5% respectively.

Due to the limited cross validation obtained by using only half the data to build the model, and the desire to limit the chance of spurious divisions occurring by chance, it was decided to make the split rules more restrictive. The following run parameters were altered for the CONFIRM runs:

For a group to be analysed it had to contain at least 50 plots (instead of 25), and account for at least 0.001% of the Starting Sum of Squared Deviations.

The minimum % Raw significance for a split was set at 1% (instead of 5%) and the minimum % Bonferroni significance for a split was also set at 1% (instead of 10%). As there are 18 predictors the use of such small values minimise the chance of spurious splits - (ie. this is similar to the multiple comparison testing problem).

Although the use of the Pooled Anova Error Mean Square as the error variance brings more information to bear on tests, pooling may contaminate the good information for a particular pair of categories with bad information from other categories if the data contain outliers or exhibit heteroscedasticity (Hawkins 1990). Initial analysis revealed outliers. The pooled error variance of just the two groups being tested was therefore used instead. In practice changing the denominator variance did not affect the CONFIRM dendrogram.

DETAILS OF FOUR MAIN RUNS

The results of four main FIRM runs are presented and discussed in Chapter 16.

Two main CONFIRM runs were undertaken:

In the first, the variables for Burn severity, Tree density and Path were deemed *monotonic*. All remaining variables were classed as *free* predictors.

In the second, all variables were classed as *free* predictors. This approach may be more appropriate as we are primarily interested in modelling habitat importance. The lumping together of predictor extremes is not a problem when intermediate predictor values happen to be the most preferred by black rhino.

For heuristic purposes two CATFIRM analyses of the data were also undertaken. Significance and Bonferroni significance levels were again set at the conservative 1% level.

The simplest CATFIRM run used a binomial dependent variable - Eating found in the plot or not.

A more detailed CATFIRM run used three browsing categories. This analysis allowed the amount of feeding in browsed plots to be examined, as well as the frequency of plots with eating. All six BU categories were not used because exploratory analyses indicated that because heavy browsing was rare it was preferable to lump some browsing categories together. The three categories were :

0 - No feeding
1 - A little feeding (1 BU)
2 - More than a little Feeding (2,3,4 and 5 BU's)

Final splits which only identified outlier plots were ignored in all analyses.

RE-MEASUREMENT OF HITCHINS' 1969/70 PLOTS

PLANT DENSITY CHANGES SINCE c.1970: LONG TERM EFFECTS OF BUSH-CLEARING

Densities in Hitchins' survey were compared directly with the re-survey using Paradox's relational queries. Height classes from 1-6 feet were combined, and those greater than 6 feet were combined for analysis: given the high variability in the data and limited samples sizes, there were insufficient data to undertake between years comparisons at the fine scale of individual foot height classes.

However most of the detailed examination of these data were carried out by Keryn Adcock. She used the data to examine what species density changes since c.1970 were after combining transects with different **clearing frequencies** and **positions** in the N.E. HLUHLUWE. She also examined the data to see if any impacts of bush clearing could be discerned. However she found that there was insufficient data to provide a real comparison of all the different bush-clearing treatments, because of the compounding effects of different site positions (initial vegetation) on the treatments. Therefore transects that had been cleared the same number of times by 1990, were combined, irrespective of type of clearing and then compared. She also looked at vegetation changes in individual site positions in the study area, as each position had a different initial vegetation type, reflecting the influences of slope, aspect and soil moisture. These positions are shown in Figure 3.7.

RHINO FEEDING

Rhino feeding was compared between years in sites in different positions, and in sites cleared different numbers of times. Overall feeding patterns were viewed based on the number of trees with eating. Feeding in the Hitchins transects in 1990 was scarce, so a subset of the 1989 Grid survey data from plots in the Hitchins study area was used to provide additional comparisons between black rhino feeding patterns of c.1970 and 1989/90.

The following data were compared between feeding years:

- Species % contribution to total number of trees eaten
- Species % contribution to total number of trees available (present)
- The proportion of the available trees of each species that had eating
- Species preferences (proportion in the diet / proportion of the available plants).

DUNG AND BROWSE SAMPLE ANALYSES

Analysis of dung samples in the forb study was straightforward. Plant fragments were identified in five black rhino dung samples using a key and reference collection of electron micrographs of samples of common Hluhluwe woody plants and forbs. Results are given in Chapter 11 and the project reports of Haskins (1989), Raubenheimer (1989) and Pearman(1989) were included as Appendices in the BR2000 report submitted to the Natal Parks Board. Copies of these reports will be made available to examiners on request.

Chemical analysis of dung and browse samples was undertaken by Richard Eckard of Cedara using standardised procedures. The method of near Infra-red reflectance spectroscopy was, however, used to estimate nitrogen levels in both dung and plant samples (Eckard *et al.* 1988). As a comparison the more traditional Kjeldahl method was also used to estimate nitrogen of the plant samples. Percentage crude protein was taken as the standard 6.25 times percentage nitrogen.

Levels of the following chemicals were determined in a limited number of vegetation samples: crude protein, nitrogen, calcium, phosphorus, zinc, manganese, copper, molybdenum.

CHAPTER 4 NOTES

#1: - The technicalities of many of the statistical analyses undertaken are probably of little interest to most field conservationists who will assume that peer review of the methods will detect any problems with the methodology used to obtain the results.

#2: The author was the primary designer of ARKA with input from Keryn Adcock and Alf Wills. The dBase IV coding of the application was undertaken by Ashish Boadasing. The name ARKA stands for Ashish, Richard, Keryn and Alf.

#3: Multiple input files were needed because I) the version of CANOCO used was only dimensioned to handle a limited number of both variables and covariables, and ii) the need to add new variables only became apparent during analysis.

#4: Any axes with eigenvalues less than 0.02 were ignored.

#5: Given the heuristic objectives of the analyses, and the need to generate a large number of approximate maps, the inverse distance squared method was deemed appropriate. Variable anisotropy and non-stationarity also indicated that one would not be justified in Kriging the data over the whole ordination space. Building good semi-variograms (the cornerstone of successful Kriging) is also a very complex and time-consuming business.

CHAPTER 5

METHODS IV: PROCESSING OF RAW DATA USING "RESOURCE"$^{©}$ PRIOR TO SUBSEQUENT MULTIVARIATE ANALYSIS

INTRODUCTION

A suite of sophisticated multivariate analysis programs are currently available to analyse complex, noisy and bulky vegetation composition and structure data. Commonly used programs include DECORANA (Hill 1979a), SIMCA (Greenacre 1985), COMPCLUS (Gaugh 1979), TWINSPAN (Hill 1979b), and CANOCO (Ter Braak 1988a). However, a review of the use of these multivariate methods in ecology (Kent & Ballard 1988) concluded that little of the published work using these methods was of an applied nature. The review concluded that plant ecologists needed to direct more of the application of these methods towards the demands and needs of biological conservation, rather than simply using them to describe species composition (Kent & Ballard 1988).

Fortunately recent advances in multivariate statistics, have greatly increased the practical value of such multivariate analyses. The advent of Full and Partial Canonical Correspondence Analysis (CCA and PCCA) now enables a set of species to be directly related to a set of environment/management variables (Ter Braak 1986,1987a,1988b). These methods (available in CANOCO) can also be used to investigate specific questions about the response of species to particular environmental or management variables (Ter Braak 1987a,1988a,1988b, Ter Braak & Prentice 1988). Furthermore CANOCO's non parametric Monte Carlo permutations test allows one to statistically test whether the species are significantly related to the supplied explanatory variables (Ter Braak 1988a,1988b).

Despite these developments, a number of factors have limited their use in studying practical conservation problems. These problems can be split into two generic categories :

- o those caused by rare species and in particular by aberrant sites, and
- o the need for the development of alternatives to species based analysis.

RESOURCE was developed and written to address these problems.

THE PROBLEM OF RARE SPECIES AND ABERRANT SITES

To date, a general problem with the successful application of many of these multivariate methods - is that aberrant sites (where rare species are abundant and only a few common species occur) can dominate analyses and swamp the major patterns in composition one is trying to detect (Gaugh 1982, Ter Braak 1987a,1987b, Ter Braak & Prentice 1988). This is because rare species/spizes, and especially aberrant sites come to dominate the derived ordination axes. Incorporation of rare species also clutters up output. Ideally rare species, and aberrant sites in particular, need to be identified and dropped or made passive in such analyses (Ter Braak & Prentice 1988).

The downweighting option (Hill's Frequency/Balance weighting) in CANOCO and DECORANA can be used to identify rare species. However, the success of this downweighting option was evaluated using dummy datasets, and in practice was found not to effectively solve the aberrant sites problem - Aberrant sites continued to dominate analysis despite downweighting.

The first major development specification of RESOURCE was therefore to develop an improved method to identify and drop rare species and/or abberrant plots prior to subsequent multivariate analysis.

THE NEED FOR ALTERNATIVES TO SPECIES BASED ANALYSES

Multivariate community analysis to date has invariably been species based, yet from a conservation perspective this may often not be the most appropriate level of study. This is the case when the goals of analyses are concerned with identifying successional trends, studying woody vegetation structure in addition to species composition, or describing habitat from an animal's rather than a taxonomist's perspective.

The study and identification of successional processes is of particular concern to conservation managers of many African game reserves. This is because woody plant dynamics can markedly affect the carrying capacities for species of particular conservation concern like black rhino, and forest and thicket development can negatively affect game viewing and hence tourism. However, in order to detect and generate hypotheses about probable trends in vegetation change from a single dataset, one needs to ordinate at a *spize* (species/size class) based level instead of a species level. This has been termed a "static" ordination approach to studying succession (Austin 1977); in contrast to the "dynamic" ordination of repeated site measurements over time. Despite being successfully used by a few researchers (Enright 1982, Goff & Zedler 1972 op.cit.), the "static" ordination approach has largely been ignored as a method to study succession (Enright 1982). The assumption behind this approach is that each site represents a sequence in time with the large size classes representing the present successional stage of the site, and the smaller size classes the possible future composition (Enright 1982). By following the path traced by the centroids of successively larger spizes of key species on ordination diagrams, successional patterns can be detected (Emslie 1991d). By also reflecting vegetation structure in addition to species composition, Spize based ordinations have an advantage over species based ordinations.

Spize based analysis is also likely to be more appropriate if one aims to describe habitat from an animal's viewpoint. For example, different size classes of a species represent different quality food resources to the browsing black rhino, *Diceros bicornis* (see Chapters 6 & 7).

Given that black rhino are not botanists selecting only for Latin binomials, and the need to study woody plant patterns, structure and patterns of change; the second major development specification of RESOURCE was to develop data preparation techniques to facilitate spize-based ordination.

In the case of black rhino, grass interference has also been shown to have a major effect on habitat suitability and food selection (Chapter 8, Kotze 1990). Any description of habitat in terms of suitability for black rhino therefore needs to incorporate information on species composition, size structure information and grass interference.

Although grass interference, biomass or modal height can be added as an extra habitat variable in subsequent indirect habitat suitability modelling using spize based ordination scores; if grass interference could somehow be included directly into the ordination - and feeding data were also available for each plot, then constrained ordination methods could be used to study habitat selection directly. Therefore **the third development**

specification of RESOURCE was to facilitate improved multivariate habitat descriptions from a black rhino's perspective by directly incorporating grass interference into ordination analyses. *Resource* based ordination was developed to deal with this problem (Emslie 1991d). A *resource* by definition is simply a spize that has been further categorised into two classes, *low* (L) or *high* (H) depending on the degree of grass interference.

For example, small *A.niloticas* <1m make up the spize Acnil1, and if there are sufficient data this spize can be further subdivided into small *A.niloticas* <1m that have low levels of grass interference (the resource Acnil1L) and those that have high levels of grass interference (the resource Acnil1H). A simple rule, such as whether or not half of available browse is hidden by grass, is used to define resources.

In studies of black rhino habitat suitability, resource based ordinations should have an advantage over species and spize based ordinations as they reflect species composition, vegetation structure, and grass interference. This is tested in Chapter 8 using canonical correspondence analysis to contrast strengths of the relationships between black rhino browsing levels and alternative multivariate community descriptions based on species, spize and resource based abundance data (as indicated by eigenvalues and first canonical axis significance levels)[#1] .

DATA PREPARATION PROBLEMS PRIOR TO SPIZE BASED ORDINATION

Spize based analysis of the remaining data (ie for species not identified as rare) is however, not just a simple process of ordinating raw spize data for each species. This is because there may not be enough data to subdivide all of the remaining species into different spizes. In other cases there may be sufficient data to subdivide, but not enough data to treat each size class of a species separately. The number of spizes in a dataset also often exceeds the maximum number of species common PC based multivariate analysis programs have been dimensioned to handle.

To date spize based analysis has not adequately dealt with these problems as the choice has simply been to include or drop the rarer raw spize data from analysis. Such an approach is wasteful of data, and therefore not ideal. Therefore to avoid losing information, instead of simply including only those individual spizes with sufficient data, it would be preferable to lump adjacent size classes together to create new combination spizes or species which could then be used in subsequent analysis. For example, there are only few *Acacia caffra* trees in Hluhluwe that are over 4m high (size 4), and those that are, are just over 4m tall. Functionally size 3 and size 4 *A.caffras* represent the same thing - tall *A.caffra*. If one were simply to drop data for the rarer spize *A.caffra4* from analysis, one would be throwing away useful information. It makes better biological sense to make a new composite spize for tall *A.caffra* by pooling data by amalgamating size classes 3 and 4 to form the new spize - *A.caffra34*).

In other cases, there may only be enough data to describe a less common species at a species level. However, just knowing that a species is present may still provide some useful information about a stand. In such cases it makes better biological sense to amalgamate data from all size classes and simply use a species abundance value. For example, just knowing whether or not the forest species *Celtis africana* and *Scutia myrtina* are present in a patch of mature *Acacia nilotica* dominated woodland tells us something about the stage of successional development on that site.

Therefore a **fourth design requirement of RESOURCE was that whenever there was insufficient data to analyse each size class of a species separately, size classes should be pooled to form composite spizes (and in some cases species) prior to ordination.** Apart from facilitating subsequent analysis this should reduce the number of spizes in the final dataset to a more manageable number whilst at the same time minimising loss of valuable information.

As can be imagined the identification of which spizes/composite spizes should be used; and the generation of the new composite spizes from the raw data is a complicated and time consuming business that needs to be automated. For example, in the case of a species that has data for all four size classes, there are 8 possible size class combinations to consider, ranging from treating each spize separately (1,2,3,4 - the most preferred) through various composite spize combinations (1,2,34 1,23,4 12,3,4 12,34 1,234 and 123,4) to treating the data at a pooled species level (1234 - the least preferred).

In summary RESOURCE determines which composite species, spizes or resources to use in subsequent multivariate analyses. All records of rare species are also dropped from the data set by RESOURCE and aberrant sites are identified to avoid the problem of aberrant sites dominating ordinations. RESOURCE also determines which species have sufficient data to be subdivided on the basis of size class and which small spizes can be subdivided into resources. If subdivision is possible, RESOURCE objectively determines which size classes, pooled size classes or which resource should be selected out of the different possibilities. RESOURCE has therefore adopted a hierarchical filtering approach resulting in a dataset that does not only consist of raw spize data - but also includes resources, pooled spize combinations or simply species summary level data (a special case of pooling spizes). In this way the only data excluded from subsequent analysis are those records for rare species, and loss of information is minimised. Users can select either species based, spize based or resource based analysis of the raw data and have the option of transforming data prior to analysis.

To illustrate the effect of resource processing, let us examine the real world example of the Hluhluwe Grid survey (Appendix 5.1). 124 different species were recorded in the 242 plots. Four size classes were used, and a total of 337 different spizes were recorded. There were a total of 4651 unique plot/spize records in the raw data set. After a spize-based RESOURCE processing of the raw data, a total of 109 different spize/composite spize combinations of 47 of the more common species were included in the final dataset. The other 77 species were flagged by RESOURCE as rare. A total of 4072 records were selected out of a possible 15,404 spize combination records. Apart from dropping rare species and amalgamating rare spizes; RESOURCE recommended that data from 11 aberrant plots (4.5%) should be excluded from any subsequent ordination analyses.

Resources, spizes and pooled spizes in the final output database can occur at a hierarchy of resolutions from a broad species level through to a fine resource level. Examples of resources at each level of resolution from a broad to a fine level are :

1) Rare species dropped from the dataset (eg acbur - *Acacia burkea*)

2) Less common species which you are recommended to make passive in subsequent analyses (eg acger - *Acacia*

gerrardii)

3) Species for which there are sufficient data to be actively included in subsequent analyses, but not enough data to subdivide further on the basis of size class (eg chari - *Chaetachme aristata*).

4) Lumped spizes where data have been pooled for different size classes, but there are insufficient data to subdivide the data into their original size classes (eg accaf34 - Functionally tall *Acacia caffra*'s over 2m high).

5) Individual spizes (eg accaf1 - small *Acacia caffra*'s less than 1m high)

6) Individual resources (eg acnil1H - small *Acacia nilotica*'s less than 1m high with over half of the available browse hidden by grass [high grass interference])

The fifth and final design requirement of RESOURCE was to produce output compatible with the ARKA file building utility (Boadasing *et al* 1989) so that the lengthy process of creating the specialised FORTRAN format input files required by CANOCO and TWINSPAN could be automated.

RESOURCE DATA FORMATS AND METHODOLOGY

STRUCTURE OF RESOURCE Version 1.1©

The RESOURCE© software Versison 1.1 $^{\#2}$ that was used to process the Grid data is a modular application. RESOURCE analysis is undertaken by running a specific sequence of procedures from the main menu. The sequence of procedures selected depends on whether one is undertaking either a species, spize or resource based analysis.

Given the modular nature of the software it is appropriate to describe the methodology according to what the program does in each procedure. Before describing how RESOURCE processes raw datasets it is necessary to briefly describe the structure of the input data, choice of abundance data and the optional transformation of data available within RESOURCE.

INPUT DATA

RESOURCE requires there to be a separate record in the raw input database for each unique spize/plot combination (eg. one record for *Acacia nilotica* Size 3 in Plot 203); and that the database contains one or more abundance level for each record (eg number of trees, total bottles, free bottles, Braun-Blanquet value and or estimated % canopy cover)[#2].

RESOURCE was written to deal with four size classes [#3] although it is possible to use RESOURCE to analyse datasets with only 2 or 3 different size classes, or data collected at a Species only level [#4]. A single species therefore may have up to four records for one plot.

All species names must be 5 character long acronyms. This is because RESOURCE uses characters 6 up to 8 to store information about spize and resource type.

RESOURCE uses a five value scale similar to early Braun-Blanquet scales (Mueller-Dombois & Ellenberg 1974). Standard seven value Braun-Blanquet data can be converted to a five value scale simply by combining classes r and + with class 1. The Braun-Blanquet % canopy cover classes used by RESOURCE are... Class 0: 0%; Class 1: <5% ; Class 2: 5-25%, Class 3: 25-50%, Class 4: 50-75% and Class 5: >75%.

CHOICE OF ABUNDANCE DATA AND OPTIONAL TRANSFORMATIONS AVAILABLE

The user must first select one of the following abundance data type for analysis:

either .... Braun-Blanquet (5 value scale[#2]) or.......... Density (Number of trees/plot)

or.......... % Canopy Cover (Braun-Blanquet scale class mid-points)

or.......... Free Browse Bottles (not hidden by grass)

or.......... Total Browse Bottles available (within rhino reach)

Logarithm + 1 (LOG+1), Natural Logarithm + 1 (LN+1), and Square Root (SQRT) transformations are optionally available to transform raw data prior to RESOURCE analysis if required [#5].

SPECIES CALCULATION ROUTINE (All analyses)

This menu item must then be selected during each RESOURCE run, and summarises abundance data for each species in a separate species rather than a spize database.

In the special case of Braun Blanquet data (BBQ), the scores for different size classes cannot simply be added together as the scale is not linear. RESOURCE firstly transforms the BBQ values for each spize to appropriate % canopy cover class mid point values. These are (BBQ-%) 1-3% 2-15% 3-37.5% 4-62.5% and 5-87.5%. These values are then summed for each species per plot and the results are transformed back to the nearest BBQ class. For example, if Species A had BBQ values in Plot X of 1 for size class 1 and 2 for both size classes 2 and 3 the derived estimate of species canopy cover for A would be 33% (ie. 3+15+15). This value is >= 25% but < 50% and so the BBQ estimate returned for species A in plot X would be 3.

The procedure then examines each species in the dataset to determine which size classes are represented in the data set. A one or two character size combination code is given to each species. This code indicates to RESOURCE which size class combinations are possible for each species. The codes are used later by RESOURCE to ensure that abundance values for impossible combinations of sizes are not calculated, cutting down on computation time and the temporary hard disk storage space required.

RESOURCE has been written assuming there are four possible size classes, 1 2 3 and 4 (but can also analyse data collected at only a species level[#4] or 2 or 3 size classes[#3]). The four size classes can form 15 possible spize combinations in the dataset. These are :

Size Classes in dataset	Size Combination Code	Size Classes in dataset	Size Combination Code
1 2 3 4	x0	2 3	23
1 2 3	x4	2 4	24
1 2 4	x3	3 4	34
1 3 4	x2	1	1
2 3 4	x1	2	2
1 2	12	3	3
1 3	13	4	4
1 4	14		

Species summary names are then made up for the summed species values. The summed species abundance values are treated by RESOURCE as a special case of spize where all sizes are lumped together.

SELECTION OF WEIGHTING ALGORITHM (All analyses)

One of three alternative downweighting functions is then selected. These weightings are used in calculations to identify rare species and spizes and aberrant plots. RESOURCE offers the user a choice between:

either..	Frequency weighting
or..	(Hill's) Frequency/Balance weighting
or..	(Emslie's) Frequency/Balance/Abundance Combination weighting

FREQUENCY WEIGHTING

Frequency weighting refers to the downweighting obtained using Hill's (1979a) method on presence-absence data. A critical species frequency (FCRIT) is calculated at a fifth of the highest frequency recorded (FMAX). Let FREQj be the frequency of species j. Any species commoner than FCRIT (ie has a frequency FREQj which is >= FCRIT) is not downweighted and given a frequency weight (FDWTj) of 1. Species with FREQj's < FCRIT are given downweights = FREQj/FCRIT.

For example, let us assume the most common species occurred in 219 plots out of a total of 300 sampled plots, $species_p$ occurred in 74 plots and $species_q$ occurred in 36 plots.

It follows that...

FMAX = 73% (ie. 219/300)

FCRIT = 14.60% (ie. 73%/5)

FREQp = 24.67% (ie 74/300)

FREQq = 12% (ie 36/300)

As FREQp ≥ FCRIT ...

FDWTp = 1 (ie any species occurring in 44+ plots [≥ 14.6%] would receive a weight of 1)

However, as FREQq < FCRIT ...

FDWTq = 0.82 (ie. 12/14.6)

(HILL'S) FREQUENCY/BALANCE WEIGHTING

Hill (1979a) recommends that the simple frequency weighting outlined above needs to be modified for quantitative data. His downweight is a quantitative analogue of the number of times a species occurs, and reduces to true frequency for presence-absence data. Hill's weighting algorithm is used to downweight in DECORANA (Hill 1979a) and in CANOCO (Ter Braak 1988b).

To calculate Hill's downweights (HDWTj), let n = the total number of plots, ABUNij = the abundance of species j in plot i.

Hills frequency analogue (HILLj) is calculated as follows[#6]:

$$HILL_j = \frac{(\sum_{i=1}^{n} ABUN_{ij})^2}{\sum_{i=1}^{n} ABUN_{ij}^2 * n}$$

HCRIT is calculated as the maximum HILLj/5. The downweighting calculations proceed as before, except that HILLj is substituted for FREQj and HCRIT is substituted for FCRIT.

To take a simple example, the calculated value of HILLj for a species with abundance values 20 15 20 0 0 0 0 0 0 and 15 in a sample of 10 plots would be 39.2% (ie $[20^2 + 15^2 + 20^2 + 15^2] / [[20+15+20+15]^2 * 10]$ instead of 40% (FREQj). Assuming in this case that HCRIT was 19% then HDWTj would be 1.

The more equal the abundance values for a species in different plots are, the closer HILLj becomes to FREQj. In the special case when the abundance values for a species are the same in each plot it occurs in, then HILLj = FREQj. In the simple example above the abundances of species j do not vary much in each plot it occurs in, with the result that HILLj (39.20%) is close to FREQj (40%). However if the abundances in the ten plots were 60 5 2 0 0 0 0 0 0 3 instead, HILLj would be reduced to only 13.47% even though the total abundance of the species in all plots was still 70. Instead of recieving a weighting of 1 the downweighting would instead be 0.71 (ie 13.47/19.00)

(EMSLIE'S) FREQUENCY/BALANCE/ABUNDANCE COMBINATION WEIGHTING

The above example shows that Hill's weight (HDWTj) suffers from the problem that it only considers abundance in terms of the evenness of spread of abundance values. Using Hill's weighting 100 100 50 50 0 0 0 0 0 0 is weighted the same as 2 2 1 1 0 0 0 0 0 0 (HILLj = 36%) even thought the total abundance of the first species in all plots was 300 compared to only 6 of species 2.

Therefore if one wishes to include a measure of the overall abundance of a species in the calculation of downweights, Hill's weight needs to be modified. RESOURCE provides an alternative Combination weight that incorporates frequency and evenness of abundance as before, but also includes a measure of overall abundance.

The algorithm used by RESOURCE is as follows ..

A critical abundance value (ACRIT) is first calculated as the square root of the maximum sum of abundance values for any species. For example, if the maximum sum of the abundance values for any species in the dataset is 6084, then ACRIT will be 78.

A temporary abundance weight (ADWTj) is then calculated as before with ADWTj = 1 if the sum of the abundances for species j (SUMABUNj) >= ACRIT, and ADWTj = SUMABUNj/ACRIT if SUMABUNj < ACRIT.

Hill's weight (HDWTj) is also calculated and then decomposed into a frequency component (FREQj) and a Balance or Evenness of spread component (BALj). The latter component (BALj) is calculated as HILLj / FREQj.

BALj is then used to derive a temporary balance weight (BDWTj) for each species. If BALj is >= 0.5 then BDWTj is set at 1 otherwise BDWTj = BALj * 2.

A combination score COMBj is then calculated as FREQj * ADWTj * BDWTj. A critical combination score (CCRIT) is set at one fifth of the maximum value of COMBj.

Finally the combination weight (CDWTj) is set at 1 if COMBj >= CCRIT, otherwise CDWTj = COMBj/CCRIT.

In practice, Hill's weight does not often differ that much from the Combination weight. The RESOURCE manual (Emslie 1991d) gives the combination weight as the default, which should be used unless one is dealing with untransformed data with contains a few common species with exceptionally high abundance values. In the later case Hill's weight should be used on untransformed data. However, in such cases, one will probably need to transform the abundance data during subsequent analysis to prevent those species dominating subsequent analyses. The Combination weight was used as the default in the RESOURCE processing of Grid data analyses, unless otherwise stated.

It is recommended that either the Combination or Hill's downweight always be selected in preference to simple Frequency downweighting.

After the user has selected the weighting function, RESOURCE then calculates downweights for each species.

The method of weighting chosen is used consistently throughout the RESOURCE run as weights are recalculated later if spize or resource analysis is undertaken (as the critical values used in the weight calculations are likely to be lower for spize or resource level data compared to species based data).

SPECIES BASED OUTPUT (Selected only for a Species based analysis)

The Species menu option is then selected if performing an analyses at a Species only level.

Users are prompted by RESOURCE to enter a *Critical Species Drop Weight.* All species with downweights less than this critical value are flagged as rare and dropped from the final database. The number must be less than 1, and 0.25 is the suggested default value (that was used in the Grid analyses).

Users also are prompted to supply a *Critical Passive Weight.* The species which have downweights greater than the critical weight, but less than the passive weight are listed separately in the output file together with the numbers they will be given (by ARKA 1.1) in the specialised Fortran format input files used by other programs. The RESOURCE output file can be consulted during subsequent analyses to determine which species should be treated as Passive. For example you may want to drop unidentified species or make species that you may have wrongly identified passive in future analyses, but still display them in the results.

In a species based RESOURCE analysis the next procedure selected deals with aberrant site identification and handling and output.

SPIZE CALCULATION ROUTINE (Selected for Spize and Resource based analysis)

This procedure is selected when undertaking a spize or resource based analysis; and it deals with the problem of how to subdivide species data by size class, yet avoid having to drop valuable data - It addresses the questions: Which species can be sub-divided into spizes ?; If so - Can all the size classes for that species be treated separately, or do some need to be pooled ?; If pooling of spize data are required which size classes should be lumped ?

As in the species only analysis above, users are prompted to enter a *Critical Drop Weight* and a *Critical Passive Weight*. RESOURCE analysis of the Grid data used the default values of 0.25 and 0.4.

RESOURCE then examines the size combination codes, and makes up records for all possible size class combinations for each species. The size combination code is used to prevent impossible size class combinations being examined, reducing disk space and the time needed for processing. In the case of a species that has data for all four size classes there are 8 possible spize/pooled spize combinations (1,2,3,4 ; 1,2,34 ; 1,23,4 ; 12,3,4 ; 12,34 ; 1, 234 ; 123,4 ;1234). The latter combination (1234) in this case represents the data summarised for a species whilst the ideal (provided there are enough data) is to include all four spizes separately (1,2,3,4). Only adjacent size classes are allowed to be combined, as spize/pooled spize combinations like 13, 24 do not make biological sense.

RESOURCE then calculates new downweights for each possible spize/pooled spize combination for each species. RESOURCE then determines which combination of sizes for each species should be selected out of the range of options. For a particular combination of sizes to be considered, none of the size combinations for the species must have a weight less than the critical passive weight.

To be computationally more efficient RESOURCES uses an expert system to speed up selection of the spize/pooled spize combinations to select. For example if size class 2 in our example has a weight less than the critical passive weight, then RESOURCE will not consider 1,2,3,4 and 1,2,34 as possible spize combinations for that species. RESOURCE decides which one of the remaining possible combinations is the most preferable, based on the principle that keeping four separate spizes (1,2,3,4) representing each separate size class is the first choice option; and having to lump all the size classes together as a species (1234) is the least desirable option. Once the combination of spizes has been selected, all other possible size combinations for that species are then dropped from the database.

In our example above the first choice option of 1,2,3,4 would be rejected as size class 2 had a weight less than the critical passive weight. Let us suppose that the downweights indicated there were sufficient data for the next best option of pooling data for size classes 1 and 2 to create a combined 12 (small-medium) spize, then the final database would include the combined spize 12 together with the unchanged size 3 and size 4 spize data resulting in spize options 1, 2, 23, 34, 123, 234 and 1234 being dropped from the database for that species.

RESOURCE repeats this process for each species[#7].

The size class codes used in the spize or spize combination names in the RESOURCE output files are usually either 1 or 2 digits. Size class 34 for example refers to a pooled category for all trees over 2 m high (ie Size classes 3 and 4 combined). Sometimes this size class code is an x followed by a number. The x stands for "all size classes lumped together but eXcluding size ..". When the following number is 0 (ie x0) this refers to lumping of all four size classes (ie data pooled at the species level). The single character labels L or H are used to represent the degree of grass interference in a resource based analyses. A full resource name will then usually be either 6 (eg acnil4) or 7 (accaf34 or acnilL) characters long. Very rarely, resource names may have a maximum of 8 characters (eg facap12H). This use of a maximum size of 8 characters ensures that the Resource names generated by RESOURCE will always be appear in full in the ARKA generated FORTRAN format data input files.

SPIZE BASED OUTPUT (Selected only for Spize based analysis)

This menu option is selected only if undertaking a spize-based analysis.

In this procedure RESOURCE re-assess which species should be treated as passive in later analyses. It does this by adding the temporarily dropped species (those that were > than the critical drop weight and < the critical passive weight in a species only downweighting) to the newly created spize/spize combination dataset. Downweights are calculated as before using this dataset, and the same critical passive and drop weights are applied to the data. As a result some species that originally had weights below the critical passive weight may end up with weights just above the recalculated critical passive weight.

As in species based RESOURCE analysis the next procedure that should be selected when undertaking a spize based analysis deals with aberrant site identification and handling and output.

RESOURCE OUTPUT (Selected only for Resource-based analysis)

This menu selection is only selected whilst undertaking a resource based analysis. Analysis proceeds with output from the spize calculation routine and proceeds in a similar way to that described above with a spize-based output selection.

In this procedure, additional resource records are made up for both LOW (L) grass interference (<50%) and HIGH (H) grass interference (>=50%) for each remaining size 1, 2 or 12 size combination spize . Weights are then calculated for each of these resources. If the calculated weights for both H and L resources are greater than the critical passive weight, both resources replace the spize data in the final output. However if either H or L resources have weights less than the passive weight RESOURCE deems that there are not sufficient data to subdivide that particular spize further.

For example let us imagine that the spizes selected for species acnilL during spize calculations were acnil1, acnil2, acnil3 and acnil4. Resources acnil1L, acnil1H, acnil2L and acnil2H would then be created in addition to the existing four spizes. Resources are only made up for trees in size classes 1 and 2 (and very rarely the combination size 12). If the downweights calculated for these new resources were 1, 0.87, 0.67 and 0.27 respectively, and the critical passive weight was given as 0.4, the resources acnil1L, acnil1H, acnil2, acnil3 and acnil4 would appear in the final data set. In this case RESOURCE would conclude that there were insufficient data to warrant subdividing acnil2 further.

As in the spize based analysis, rare species that were identified and temporarily dropped from the dataset during the species calculation routine are added back to the updated dataset (including selected spizes/pooled spizes and resources) prior to downweighting the dataset again and re-evaluating whether they should remain passive or not in the final dataset.

ABERRANT SITE IDENTIFICATION AND HANDLING (All Analyses)

This procedure objectively identifies aberrant sites by calculating aberrant site indices for each plot. Deviant sites can then either be dropped or made passive in future analyses. Such statistics are not provided by packages like CANOCO and DECORANA, which only have a downweighting option which simulation modelling shows does not adequately handle the problems caused by aberrant sites. The principle behind the calculation of the aberrant site indices is a simple one and is based on the fact that for aberrant sites there will be a big discrepancy between the total abundance values in the plot compared to the total of downweighted abundance values for each plot. RESOURCE firstly calculates plot weights by summing the abundance values for all records in each site. RESOURCE calculates two alternative plot weights using 1) all data in the original data base and 2) only the data in the final output database (ie excluding rare species).

RESOURCE then calculates downweighted plot weights, by summing downweighted abundance measures for each site. Only records in the final output database are used. Weighted abundance measures are simply obtained by multiplying the abundance value for a species/spize/resource by its downweight. Weighted abundance values for species/spizes/resources are therefore unchanged if the downweight = 1.

By expressing the downweighted plot weight as a percentage of the plot weight one obtains an index of how aberrant a site is. RESOURCE gives you the choice of choosing which of the two plot weights to select. It is recommended that you answer Y at the prompt to select option 1) above. Results calculated using both plot weights are listed in the output file.

Users are prompted to specify a critical drop aberrant index value (a value from 0 to 100). It is suggested that you use 40 (ie 40%) as the default value and this value was routinely used in analyses of the Grid data.

Users are then prompted to specify whether they wish to drop all plots with an aberrant index less than this value from the output database, although it is strongly recommended that users choose not to drop aberrant plots. This is because:

1) Most multivariate ecological programs have an option to exclude plots from analyses, and any aberrant plots can be dropped at this stage.

2) If you do not drop aberrant plots in RESOURCE, the sample numbers produced by the ARKA file building utility will remain the same for both Explanatory and Vegetation databases. By dropping aberrant sites in RESOURCE, site numbers will change in the ARKA output files and may no longer match those in explanatory databases where data are usually recorded for each plot. In other words, if you drop 2 aberrant plots named 045 and 134 during RESOURCE, the plots named 048 and 242 will be numbered 47 and 240 (instead of 48 and 242) in the ARKA output file.

Finally RESOURCE prompts users to supply a critical passive aberrant site index. A number from 1 to 100 should be entered. The suggested default of 60 (ie 60%) was used routinely in the analysis of the Grid data. Any sites that have aberrant site indices less than the critical passive value but greater or equal to the critical drop value are listed separately in the output file.

There obviously are no hard and fast rules one can apply to decide when to make a plot passive or even drop it, but with RESOURCE output you can easily determine which plots are obviously aberrant (< critical drop Aberrant Index), and which plots may or may not be aberrant (<critical passive Aberrant Index).

Once analysis has been completed users can select to save output an ASCII file and/or send it to a Hewlett Packard Laserjet III printer. The final menu option allows users to translate the final RESOURCE output database into an ARKA 1.1 compatible dBase IV file to allow automated generation of both CANOCO and CORNELL compatible FORTRAN format input files.

An example of a RESOURCE output file is included as Appendix 5.1. Upon request, an optional Appendix containing the PAL program code and application structure can be supplied to examiners.

CHAPTER 5 NOTES

#1: Resource based CCA proved to be superior to Spize based CCA which in turn was an improvement on Species based CCA. For example the eigenvalue for the first canonical axis from resource based CCA of Umfolozi Braun-Blanquet vegetation and black rhino feeding data was almost double that of species only CCA. Significance levels for the first canonical axes were also higher for resource and spize based analyses. Analysis of Hluhluwe data revealed a similar pattern - See Chapter 8 for details.

#2: RESOURCE is available for sale from Ecoscot Consultancy Services, and is copyright protected by international treaty provisions. The primary concern of the author and developer was to write software to meet the design specifications outlined in the introduction as quickly as possible (as time was limited). RESOURCE was therefore written in a language familiar to the developer (Borland's PAL) and computational elegance and speed were therefore not of primary concern. RESOURCE was written in PAL as a Paradox 3.5 © application (which is supplied with Paradox 3.5 Runtime ©). RESOURCE requires the raw data to be in a specific Paradox database file (.db) format. The structure of the input database in is listed below.

Field Name	Field Type	Description of field type (example)
✓ Plot	A8	Plot name (eg. 021)
✓ Species	A8	Must be 5 digit acronym in all cases (eg ACNIL)
✓ Size	A1	Must be either 1, 2, 3 or 4. (eg 2)
✓ Spize	A8	= Species + Size (eg. ACNIL2)
✓ Resource	A8	Can be left blank or make = Spize (eg. ACNIL2)
● N/Plot	N	Tree density measure (eg 14)
✓ TB/Plot	N	Total browse volume measure = FB/Plot + HB/Plot (eg 24)
● FB/Plot	N	Free browse volume not hidden by grass (eg 16)
✓ HB/Plot	N	Browse volume hidden by grass (eg 8)
● BBQ	N	Braun-Blanquet measure from 1 to 5 [with rhino and + set as 1] (eg 2)
● Cover	N	% Canopy cover (eg left blank - not measured and non-essential field)

The fields marked with a tick must be included in the input database. Fields must have exactly the same field names as those listed above, and the data types must be the same as those listed above.

If you are only undertaking a Species level RESOURCE analysis the Spize, Resource, TB/Plot and HB/Plot fields can be left blank in your database.

Fields marked with a filled circle are optional and refer to different abundance measures that can be handled by RESOURCE.

To ensure that the original database is not corrupted, RESOURCE works on a copy of the original database rather than the original.

The fields TB/Plot and HB/Plot refer to Total Browse Bottles/Plot and Hidden Browse Bottles/Plot. The term *hidden* refers to the amount of browse on smaller size classes hidden by grass. These two fields can be used to supply abundance values. RESOURCE uses these fields to calculate % grass interference, and this is why they are compulsory.

If you do not have data for the fields TB/Plot and HB/Plot but have another grass measure, then you can still undertake a Resource based analysis. To do this you have to fool the program that you have TB/Plot and HB/Plot data. In this special case you first must decide on the critical cut off level which will be used to determine whether there is LOW or HIGH grass interference. Let us suppose you have measured plot modal grass height in centimetres and that you want any plots with grass over 70cm to be classed as a plot with HIGH interference. The cut off value RESOURCE actually uses is whether or not the sum of HB/Plot for a spize or species is greater than half of the sum of TB/Plot. In this example you could set TB/Plot to 3 in every record, and set HB/Plot either to 1 if grass height >= 70cm or else to 3 if less than 70cm.

If one wants to carry out a Spize based analysis and do not have data for the fields TB/Plot and HB/Plot, the value 1 must be entered in both fields.

All species names must be 5 character long acronyms (no more, no less). This is because RESOURCE uses characters 6 up to 8 to store information about spize and resource type.

The size class codes used in the spize or spize combination names in the RESOURCE output files are usually either 1 or 2 digits. Size class 34 for example refers to a pooled category for all trees over 2 m high (ie Size classes 3 and 4 combined). Sometimes this size class code is an x followed by a number. The x stands for "all size classes lumped together but eXcluding size ..". When the following number is 0 (ie x0) this refers to lumping of all four size classes (ie data pooled at the species level). The single character labels L or H are used to represent the degree of grass interference in a resource based analyses.

A full resource name will then usually be either 6 (eg acnil4) or 7 (accaf34 or acnilL) characters long. Very rarely, resource names may have a maximum of 8 characters (eg facap12H). This use of a maximum size of 8 characters ensures that the Resource names generated by RESOURCE will always be appear in full in the ARKA generated FORTRAN format data input files.

Braun-Blanquet data for use in RESOURCE are converted to integer numeric class values from 0 to 5. For RESOURCE analysis Braun-Blanquet classes rhino and + need to be combined with class 1 to produce a 5 point scale. The Braun-Blanquet class mid point values used by RESOURCE are as follows... Class 0: 0%; Class 1: 3%; Class 2: 15%, Class 3: 37.5%, Class 4: 62.5% and Class 5: 87.5%.

#3 When undertaking either a Spize or Resource bssed analysis, the program assumes that all four size classes are represented in the data set for at least one common species. If ones dataset has only three size classes, one needs to change the size of one record for a very common species from 3 to 4. In this way RESOURCE is fooled into thinking you have 4 sizes. One size 4 record is not enough to merit being treated as a separate spize, and so the record will be correctly lumped with the remaining size class 3 records for that species. (The only difference will be that this spize will now be called .....34 instead of .....3 .)

Similarly if ones dataset has only two size classes, one needs to change the size of one size class 2 record for a very common species to 3 and one other record to 4. In this way RESOURCE is fooled into thinking you have 2 sizes. One size 3 record and one size 4 record are not enough to merit being treated as separate spizes, and so the record will be correctly lumped with the remaining size class 2 records for that species. (The only difference will is that the spize will now be called .....234 instead of .....2 .)

#4 In Species only RESOURCE analysis. The value 1 should be entered in the Size field of every record

#5 Transformation can be selected if abundance data have very skewed distributions (Ter Braak 1987b). This can prevent a few large abundance values having an undue influence on the results, and reduces the influence that dominant species have on subsequent analyses (Gaugh 1982, Ter Braak 1986).

If data transformations are required they can be carried out either during RESOURCE analysis, or alternatively may sometimes be available as an option during subsequent multivariate analyses. SQRT, LN+1 and Piecewise linear transformation are available in CANOCO (Ter Braak 1988a). The latter is also available in DECORANA (Hill 1979a). SQRT, LOG+1, Octave, Presence/Absence and Sample Percentage transformations are available in COMPCLUS (Gaugh 1979) .

#6 The equation on page 15 of the DECORANA manual (Hill 1979a) is incorrect, as the last term (plot number) has been omitted. Presumably this was a typographical error.

#7 This is the most computationally intensive procedure in RESOURCE. In a dataset with about 50 non-passive species and 240 plots, RESOURCE may have to decide which records out of over 15000 possible spize/spize combination records to include in the final dataset. During this stage about 4000 spize records may be retained while the remaining 11000 will be dropped.

THE FEEDING ECOLOGY OF THE BLACK RHINOCEROS (*Diceros bicornis minor*) IN HLUHLUWE -UMFOLOZI PARK, WITH SPECIAL REFERENCE TO THE PROBABLE CAUSES OF THE HLUHLUWE POPULATION CRASH

PART II
BLACK RHINO FEEDING ECOLOGY AND HABITAT USE: RESULTS

CHAPTER 6

BLACK RHINO FEEDING PATTERNS I : PILOT SURVEY RESULTS

A WORD OF CAUTION

The Pilot surveys primarily provided:

Experience which could be used to design subsequent surveys.

Corroborative evidence to compare with the findings of the other surveys which were based on substantially larger sample sizes (transects and trees) and more systematic sampling designs.

It is important to understand that Hluhluwe and Umfolozi Pilot Summary data relate to the habitat patches sampled, and not to the whole population of trees in each of the study areas.

The techniques used in the Pilot surveys proved to be so time-consuming, that it was not possible to use a truly replicated sampling design, as had been originally planned. Readers should be aware that, due to the psuedoreplicated sampling design used, one can justifiably make statistical inferences about the patch of habitat X sampled, but not all patches of habitat X (Hulbert 1984). All one can hope is that the sampled plots within a patch of habitat X were representative of habitat X in general.

Due to the high coefficients of variation in browsing levels recorded between pseudo-replicate plots/habitat patch (Coefficients of Variation HGR: 92.0% UGR: 93.1%), and the lower sample sizes in the Pilot surveys - caution should be exercised when drawing conclusions from the Pilot data on patch and rare species selection and preferences.

In many instances it proved difficult to successfully pigeon-hole plots into discrete habitat types. Discriminant Function analyses of ordinated multivariate community data failed to correctly allocate all plots to their respective strata. Describing Hluhluwe-Umfolozi woody vegetation according to community continua was clearly preferable to discrete community descriptions. For future surveys one should therefore use a systematic sampling design and then use the resultant data to describe habitat types, rather than (as in the Pilot survey) stratify according to a-priori defined habitat types.

Despite the limitations of the Pilot study, broad conclusions about species groups and some key (abundant) species and spizes could be drawn. In addition, the influence of tree size and different kinds of browse interference on black rhino feeding could be examined, as six tree size class categories were used, and browse interference levels were recorded painstakingly for each individual tree.

IMPORTANT, PREFERRED AND REJECTED SPECIES

RIDGE REGRESSION ANALYSIS OF FEEDING LEVELS

Figure 6.1 graphically presents the results of a preliminary Ridge regression of the Pilot survey data. (The Y axis gives the ridge coefficients obtained at the value of theta where the ridge traces appeared to have stabilised). As ridge regression coefficients are based on standardised data, this has the added advantage that explanatory variables measured using different units can be directly compared.

o Total browsing levels (New & Old) measured in late summer were positively related to the amount of browse bottles of *"Acacia"* species and *Spirostachys africana.*

o Feeding levels were negatively related to the density of *Euclea, Maytenus* and *Rhus* species.

FIGURE 6.1

PILOT STUDY RIDGE REGRESSION: Theta=.25
LOG (TOTAL BOTTLES BROWSED +1)

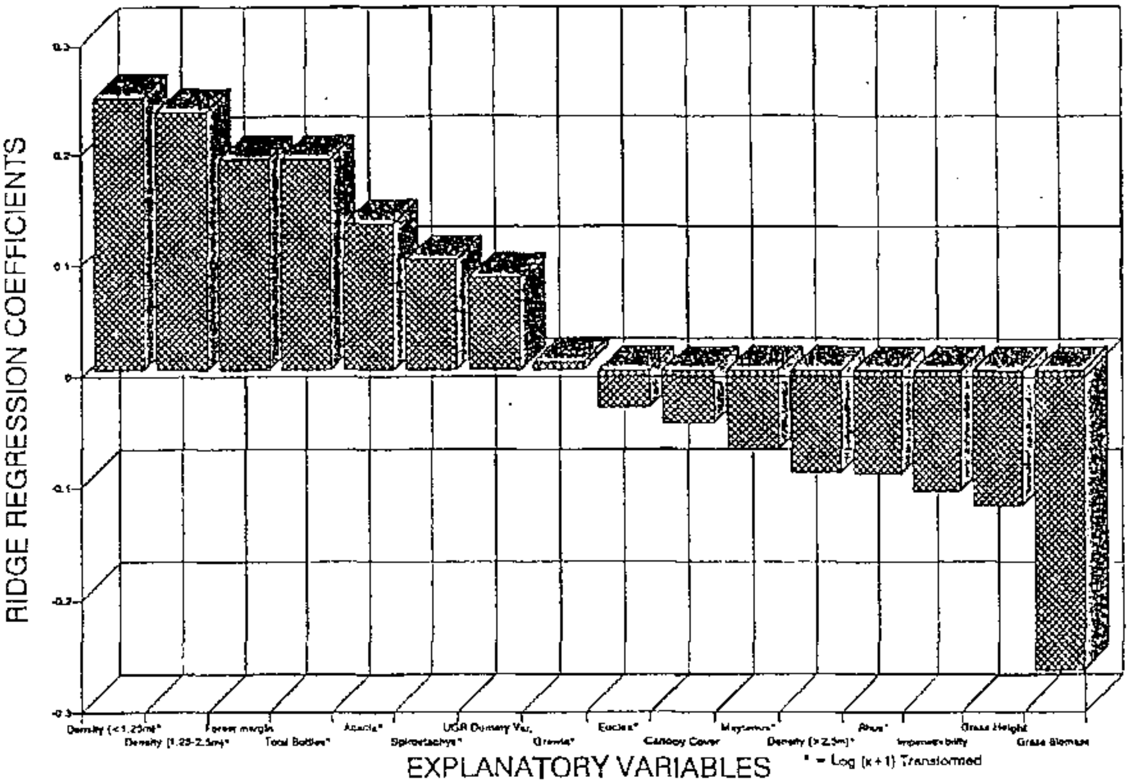
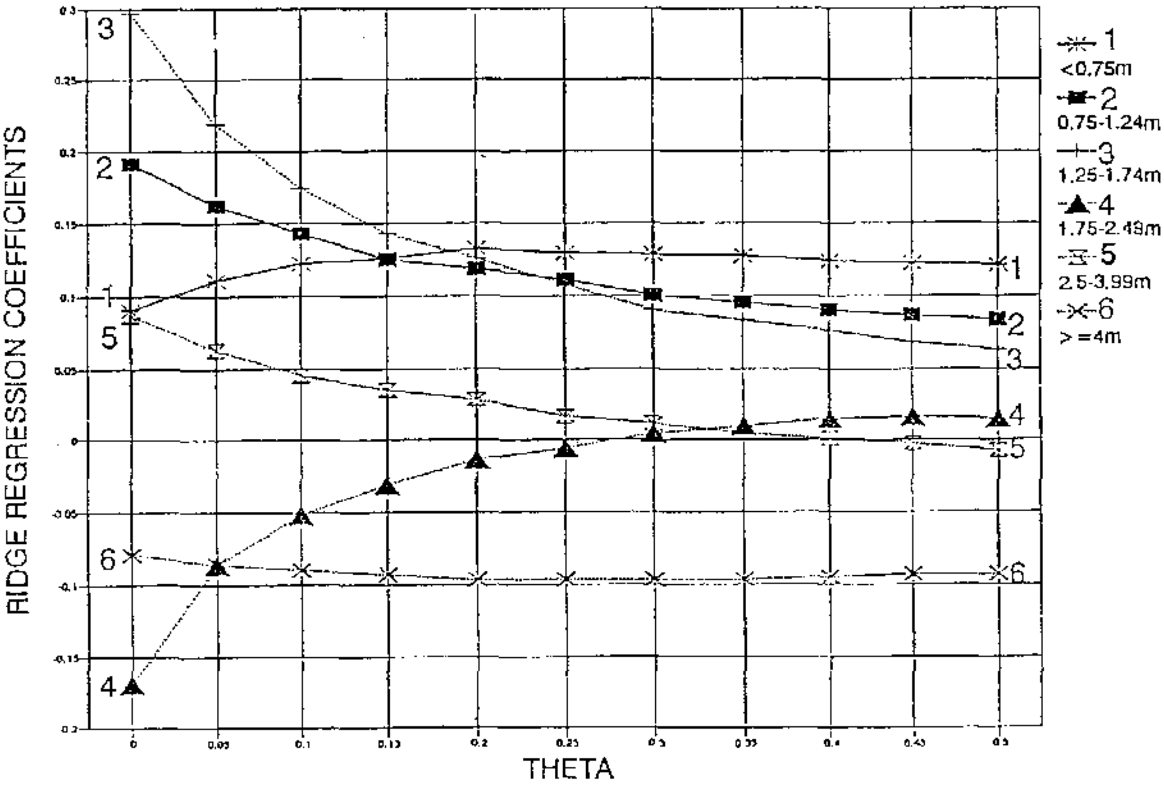


FIGURE 6.2

RIDGE REGRESSION TRACE OF AMOUNT OF
ACACIA BROWSING vs DENSITIES/SIZE CLASS



SUMMARY RESULTS FROM POOLED DATASETS

Species summary data on browse availability, importance and selection have been pooled for all strata and are presented in Tables 6.1 (Hluhluwe Pilot Plots) and 6.2 (Umfolozi Pilot Plots)

HLUHLUWE GAME RESERVE

○ *Dichrostachys.cinerea, Acalypha glabrata, Maytenus nemorosa, Diospyros lyciodes, Dombeya burgessiae, Acacia karroo, Acacia caffra, Acacia gerrardii* and *Acacia nilotica* were the most important contributors to the diet in the Hluhluwe Pilot survey.

○ The high amount of feeding recorded on *Solanum* species in Hluhluwe occurred primarily in one high density patch of *S.giganteum* in Forest margin habitat. The overall dietary importance of *Solanums* may therefore have been over-estimated by the Pilot survey. Interestingly no part of *S.giganteum* has been found to be poisonous (Pooley 1993).

○ Of those species in the Hluhluwe Pilot survey that contributed at least 3% of all recorded Free bottles: *A.caffra, A.nilotica, A.glabrata, M.nemorosa, A.gerrardii, Solanum giganteum.* and *D.cinerea* were preferred; while *A.karroo*, and *D.lycioides* were rated as intermediate in acceptance.

○ Of the rarer species in Hluhluwe, *D.burgessiae* and *Scutia myrtina* appeared to be highly preferred. The limited data also suggests that the "hard" forbs *Justicia sufritescens* and *Indigofera natalensis/cylingorica* may also be highly preferred. More data are required to substantiate these results.

○ No feeding was recorded on *Euclea* species in Hluhluwe, which made up 18.58% of Free available bottles. *Cordia caffra* and *Kraussia floribunda* contributed a further 4.75% of Hluhluwe Free bottles and were also uneaten.

TABLE 6.1a HLUHLUWE PILOT SURVEY - POOLED SPECIES AVAILABILITY, IMPORTANCE & SELECTION DATA SORTED BY SPECIES

Species	% Total Browsing	% Free B.Bottles	Free Pref.Indx.
Acacia caffra	4.17	1.48	2.81
Acacia gerrardii	3.75	1.54	2.44
Acacia karroo	6.25	5.47	1.14
Acacia nilotica	3.33	.69	4.82
Acacia robusta	0.00	.02	0.00
Acacia schweinfurthii/ataxacantha	0.00	.00	0.00
Acacia spp.	0.00	.11	0.00
Acalypha sonderiana	1.67	.10	15.91
Acalypha glabrata	12.29	3.98	3.08
Adenopodia spicata	0.00	.07	0.00
Berchemia zeyheri	0.00	.56	0.00
Capparis sepiaria	0.00	.02	0.00
Cassine aethiopica	0.00	.82	0.00
Celtis africana	.42	.34	1.24
Clausena anisata	0.00	.02	0.00
Clutia pulchella	0.00	.05	0.00
Coddia rudis	1.67	.49	3.44
Cola natalensis	0.00	.01	0.00
Combretum apiculatum	0.00	.04	0.00
Combretum molle	0.00	.07	0.00
Cordia caffra	0.00	2.64	0.00
Croton sylvaticus	0.00	.07	0.00
Dalbergia armata	0.00	.07	0.00
Dalbergia obovata	0.00	.00	0.00
Dichrostachys cinerea	13.54	10.45	1.30
Diospyros lycioides	6.46	6.90	.94
Dombeya burgessiae	6.46	.15	44.32
Dombeya rotundifolia	0.00	2.53	0.00
Dovyalis zeyheri	0.00	.02	0.00
Ehretia amoena	0.00	.58	0.00
Ehretia rigida	0.00	.07	0.00
Erythroxylum emarginatum	0.00	.01	0.00
Euclea crispa	0.00	2.87	0.00
Euclea divinorum	0.00	9.37	0.00
Euclea racemosa	0.00	6.34	0.00
Eugenia natalitia	0.00	.02	0.00
Galpinia transvaalica	1.25	.26	4.83
Grewia caffra	0.00	.07	0.00
Grewia flavescens	0.00	.20	0.00
Grewia occidentalis	0.00	.03	0.00
Grewia subspathulata	0.00	.13	0.00
Hippobromus pauciflorus	.21	.08	3.27
Indigofera natalensis/cylindrica	.83	.07	11.44
Justicia suffruticosa	1.67	.10	16.64
Kraussia floribunda	0.00	2.11	0.00
Lantana camara	0.00	.11	0.00
Lippia javanica	0.00	.96	0.00
Maytenus heterophylla	0.00	.12	0.00
Maytenus nemorosa	6.88	1.86	6.46
Maytenus senegalensis	.83	1.60	.52
Ozoroa engleri	.42	.87	.48
Pancovia golungensis	1.04	.55	1.90
Pappia capensis	1.25	.04	34.32
Peltophorum africanum	0.00	.70	0.00
Phyllanthus reticulatus	.83	.57	1.47
Plectroniella armata	0.00	2.13	0.00
Rhoicissus tridentata	0.00	1.73	0.00
Rhus chirindensis	0.00	.11	0.00
Rhus dentata	0.00	.28	0.00
Rhus gueinzii	0.00	.09	0.00
Rhus pentheri	1.25	7.84	.16
Rhus pyroides	0.00	.26	0.00
Rhus spp.	0.00	7.79	0.00
Rothmannia globosa	0.00	.02	0.00
Schotia brachypetala	.83	.53	1.58
Schrebera trichoclada	0.00	.02	0.00
Sclerocarya birrea	0.00	.18	0.00
Scolopia mundii	.21	.02	11.44
Scutia myrtina	1.04	1.31	.80
Sideroxylon inerme	1.88	.28	6.71
Solanum giganteum	17.92	9.10	1.97
Spirostachys africana	0.00	.04	0.00
Unknown 12	0.00	.01	0.00
Unknown 13	0.00	.87	0.00
Unknown 15	0.00	.81	0.00
Unknown 16	.83	.08	10.64
Zanthoxylum capense	0.00	.09	0.00
Ziziphus mucronata	.83	.47	1.79

TABLE 6.1b HLUHLUWE PILOT SURVEY - POOLED SPECIES AVAILABILITY, IMPORTANCE & SELECTION
DATA SORTED BY % TOTAL BROWSING

Species	% Total Browsing	% Free B.Bottles	Free Pref.Indx.
Solanum giganteum	17.92	9.10	1.97
Dichrostachys cinerea	13.54	10.45	1.30
Acalypha glabrata	12.29	3.98	3.08
Maytenus nemorosa	6.88	1.06	6.46
Diospyros lyciodes	6.46	6.90	.94
Dombeya burgessiae	6.46	.15	44.32
Acacia karroo	6.25	5.47	1.14
Acacia caffra	4.17	1.48	2.81
Acacia gerrardii	3.75	1.54	2.44
Acacia nilotica	3.33	.69	4.82
Sideroxylon inerme	1.88	.28	6.71
Acalypha sonderiana	1.67	.10	15.91
Coddia rudis	1.67	.48	3.44
Justicia sufritescens	1.67	.10	16.64
Galpinia transvaalica	1.25	.26	4.83
Pappea capensis	1.25	.04	34.32
Rhus pentheri	1.25	7.84	.16
Pancovia golungensis	1.04	.55	1.90
Scutia myrtina	1.04	1.31	.80
Indigofera natalensis/cylindrica	.83	.07	11.44
Maytenus senegalensis	.83	1.60	.52
Phyllanthus reticulatus	.83	.57	1.47
Schotia brachypetala	.83	.53	1.58
Unknown 16	.83	.08	10.64
Zizyphus mucronata	.83	.47	1.79
Celtis africana	.42	.34	1.24
Ozoroa engleri	.42	.87	.48
Hippobromus pauciflorus	.21	.06	3.27
Scolopia mundii	.21	.02	11.44
Acacia robusta	0.00	.02	0.00
Acacia schweinfurthii/ataxacantha	0.00	.00	0.00
Acacia spp.	0.00	.11	0.00
Adenopodia spicata	0.00	.87	0.00
Berchemia zeyheri	0.00	.56	0.00
Capparis sepiaria	0.00	.02	0.00
Cassine aethiopica	0.00	.82	0.00
Clausena anisata	0.00	.02	0.00
Clutia pulchella	0.00	.05	0.00
Cola natalensis	0.00	.01	0.00
Combretum apiculatum	0.00	.04	0.00
Combretum molle	0.00	.07	0.00
Cordia caffra	0.00	2.64	0.00
Croton sylvaticus	0.00	.07	0.00
Dalbergia armata	0.00	.07	0.00
Dalbergia obovata	0.00	.00	0.00
Dombeya rotundifolia	0.00	2.53	0.00
Dovyalis zeyheri	0.00	.02	0.00
Ehretia amoena	0.00	.58	0.00
Ehretia rigida	0.00	.07	0.00
Erythroxylum emarginatum	0.00	.01	0.00
Euclea crispa	0.00	2.87	0.00
Euclea divinorum	0.00	9.37	0.00
Euclea racemosa	0.00	6.34	0.00
Eugenia natalitia	0.00	.02	0.00
Grewia caffra	0.00	.07	0.00
Grewia flavescens	0.00	.28	0.00
Grewia occidentalis	0.00	.03	0.00
Grewia subspathulata	0.00	.13	0.00
Kraussia floribunda	0.00	2.11	0.00
Lantana camara	0.00	.11	0.00
Lippia javanica	0.00	.96	0.00
Maytenus heterophylla	0.00	.12	0.00
Peltophorum africanum	0.00	.70	0.00
Plectroniella armata	0.00	2.13	0.00
Rhoicissus tridentata	0.00	1.73	0.00
Rhus chirindensis	0.00	.11	0.00
Rhus dentata	0.00	.28	0.00
Rhus gueinzii	0.00	.09	0.00
Rhus pyroides	0.00	.26	0.00
Rhus spp.	0.00	7.79	0.00
Rothmannia globosa	0.00	.02	0.00
Schrebera trichoclada	0.00	.02	0.00
Sclerocarya birrea	0.00	.18	0.00
Spirostachys africana	0.00	.04	0.00
Unknown 12	0.00	.81	0.00
Unknown 13	0.00	.07	0.00
Unknown 15	0.00	.01	0.00
Zanthoxylum capense	0.00	.09	0.00

TABLE 6.2a UMFOLOZI PILOT SURVEY - POOLED SPECIES AVAILABILITY, IMPORTANCE & SELECTION
DATA SORTED BY SPECIES

Species	% Total Browsing	% Free B.Bottles	Free Pref.Indx.
Acacia borleae	2.48	.97	2.55
Acacia burkei	1.51	1.71	.88
Acacia caffra	0.80	.85	0.80
Acacia gerrardii	11.17	3.54	3.16
Acacia grandicornuta	1.62	3.18	.52
Acacia karroo	4.08	18.08	.44
Acacia luederitzii	1.35	4.97	.27
Acacia nigrescens	.76	1.96	.39
Acacia nilotica	3.78	2.24	1.68
Acacia seberiana	.65	.87	9.12
Acacia tortilis	10.15	4.33	2.34
Asclepias fruticosa	0.08	.40	0.80
Asparagus spp.	.27	1.71	.16
Azima tetracantha	0.00	.02	0.00
Berchemia zeyheri	.97	.14	7.10
Boscia albitrunca	.38	.32	1.17
Brachylaena ilicifolia	3.79	3.59	1.06
Capparis sepiaria	0.08	.04	0.00
Capparis tomentosa	.38	.78	.48
Carissa bispinosa	0.00	.17	0.00
Cassine transvaalensis	0.00	.13	0.08
Clutia pulchella	0.08	.03	0.08
Coddia rudis	.11	1.60	.07
Commiphora neglecta	1.19	.38	3.10
Croton menyhartii	1.13	1.49	.76
Dichrostachys cinerea	2.27	2.52	.90
Diospyros lycioides	0.00	.01	0.00
Dombeya tiliacea	.54	.87	7.81
Ehretia amoena	.22	1.38	.16
Euclea divinorum	0.80	9.54	0.00
Euclea racemosa	.05	1.35	.04
Euclea undulata	1.30	4.19	.31
Gardenia cornuta	0.00	.98	0.00
Grewia flava	1.57	1.75	.89
Grewia monticola	.32	.31	1.04
Grewia occidentalis	.86	.28	4.40
Indigofera natalensis/cylindrica	.78	.34	2.84
Lycium acutifolium	0.88	.14	0.98
Maerua angolensis	3.35	.17	19.78
Maytenus heterophylla	2.75	2.59	1.06
Maytenus mossambicensis	.05	.06	.88
Maytenus nemorosa	5.07	4.79	1.06
Maytenus senegalensis	0.00	.16	0.08
Melanthus didyma	.05	.10	.54
Olea europaea	0.00	.25	0.00
Ormocarpum trichocarpum	.11	.33	.33
Pappea capensis	.11	.19	.57
Plectroniella armata	0.00	.02	0.00
Pyrostria hystrix	1.78	1.40	1.27
Rhoicissus rhomboidea	.86	.25	3.41
Rhus dentata	0.00	.00	0.00
Rhus gueinzii	0.00	.38	0.00
Rhus pentheri	.43	.97	.44
Schotia capitata	2.27	4.96	.46
Sclerocarya birrea	0.00	.03	0.00
Scolopia zeyheri	0.08	.09	0.00
Sida cordifolia/rhombifolia	.11	.18	.59
Sideroxylon inerme	0.08	.05	0.00
Solanum giganteum	.22	.25	.87
Spirostachys africana	26.58	12.25	2.16
Strychnos spp.	0.08	.10	0.80
Tarchonanthus camphoratus	1.88	1.91	.57
Unknown 10	0.08	.81	0.80
Unknown 11	0.08	.74	0.80
Unknown 16	0.00	.06	0.09
Unknown 9	0.88	.42	0.00
Zizyphus mucronata	.97	.93	1.85

TABLE 6.2b UMFOLOZI PILOT SURVEY - POOLED SPECIES AVAILABILITY, IMPORTANCE & SELECTION
DATA SORTED BY % TOTAL BROWSING

Species	% Total Browsing	% Free B.Bottles	Free Pref.Indx.
Spirostachys africana	26.50	12.25	2.16
Acacia gerrardii	11.17	3.54	3.16
Acacia tortilis	10.15	4.33	2.34
Maytenus nemorosa	5.07	4.79	1.06
Acacia karroo	4.80	10.80	.44
Acacia nilotica	3.78	2.24	1.68
Brachylaena ilicifolia	3.78	3.58	1.06
Maerua angolensis	3.35	.17	19.78
Maytenus heterophylla	2.75	2.59	1.06
Acacia borleae	2.48	.97	2.55
Dichrostachys cinerea	2.27	2.52	.90
Schotia capitata	2.27	4.96	.46
Pyrostria hystrix	1.78	1.40	1.27
Acacia grandicornuta	1.62	3.10	.52
Grewia flava	1.57	1.75	.89
Acacia burkei	1.51	1.71	.80
Acacia luederitzii	1.35	4.97	.27
Euclea undulata	1.30	4.19	.31
Commiphora neglecta	1.19	.38	3.10
Croton menyhartii	1.13	1.49	.76
Tarchonanthus camphoratus	1.08	1.91	.57
Berchemia zeyheri	.97	.14	7.10
Zizyphus mucronata	.97	.93	1.05
Grewia occidentalis	.86	.20	4.40
Rhoicissus rhomboidea	.86	.25	3.41
Acacia nigrescens	.76	1.96	.39
Indigofera natalensis/cylingorica	.70	.34	2.04
Acacia seberiana	.65	.07	9.12
Dombeya tiliacea	.54	.07	7.81
Rhus pentheri	.43	.97	.44
Boscia albitrunca	.38	.32	1.17
Capparis tomentosa	.38	.78	.48
Grewia monticola	.32	.31	1.04
Asparagus spp.	.27	1.71	.16
Ehretia amoena	.22	1.38	.16
Solanum giganteum	.22	.25	.87
Coddia rudis	.11	1.60	.07
Ormacarpum trichocarpum	.11	.33	.33
Pappea capensis	.11	.19	.57
Sida cordifolia/rhombifolia	.11	.18	.59
Euclea racemosa	.05	1.35	.04
Maytenus mossambicensis	.05	.06	.88
Melanthus didyma	.05	.10	.54
Acacia caffra	0.00	.05	0.00
Asclepias fruticosa	0.00	.40	0.00
Azima tetracantha	0.00	.02	0.00
Capparis sepiaria	0.00	.04	0.00
Carissa bispinosa	0.00	.17	0.00
Cassine transvaalensis	0.00	.15	0.00
Clutia pulchella	0.00	.03	0.00
Diospyros lycioides	0.00	.01	0.00
Euclea divinorum	0.00	9.54	0.00
Gardenia cornuta	0.00	.00	0.00
Lycium acutifolium	0.00	.14	0.00
Maytenus senegalensis	0.00	.16	0.00
Olea europaea	0.00	.25	0.00
Plectroniella armata	0.00	.02	0.00
Rhus dentata	0.00	.00	0.00
Rhus gueinzii	0.00	.38	0.00
Sclerocarya birrea	0.00	.03	0.00
Scolopia zeyheri	0.00	.09	0.00
Sideroxylon inerme	0.00	.05	0.00
Strychnos spp.	0.00	.10	0.00
Unknown 10	0.00	.01	0.00
Unknown 11	0.00	.74	0.00
Unknown 16	0.00	.06	0.00
Unknown 9	0.00	.42	0.00

o *Rhus* species were strongly rejected, making up 16.36% of available Free bottles but only 1.25% of total browsing.

UMFOLOZI GAME RESERVE

o *Spirostachys africana, A.gerrardii, Acacia tortilis, M.nemorosa, A.karroo, A.nilotica, Brachylaena ilicifolia, Maerua angolensis, Maytenus heterophylla, D.cinerea* and *Schotia capitata* were the most important contributors to the Umfolozi diet in the Pilot survey.

o Of those species in the Umfolozi Pilot survey that contributed at least 3% of all recorded Free bottles, *S.africana, A.gerrardii, A.nilotica,* and *A.tortilis* were preferred, while *B.ilicifolia,* and *D.cinerea,* were rated as intermediate in acceptance.

o Of the rarer species in Umfolozi, *Acacia borleae, Acacia senegal, Berchemia zeyheri, Commiphora neglecta, Grewia occidentalis, Indigofera* species, *Pyrostria hystrix* and *Rhoicissus rhomboidea* appeared to be preferred. Once again the limited data suggest that the "hard" forb *Indigofera natalensis/cylingorica* may be a preferred dietary item. More data are required to substantiate these results.

o *Grewia* species are regularly eaten in Umfolozi (2.75% of total Umfolozi Pilot Browsing), although they are probably not among the most preferred species (Mean Free Preference Index 1.22). More data are required to substantiate these conclusions.

o Species rejection patterns were similar to those of Hluhluwe. *Euclea's* contributed 1.35% of the diet but 15.08% of the habitat. *Rhus* species were just over three times more abundant in the habitat than in the diet.

COMPARISON BETWEEN STUDY AREAS

o "*Acacias*" contributed 40.5% of all browsing in the Umfolozi and 31.0% in the Hluhluwe Pilot plots. The increased contribution of "Acacias" to the Umfolozi diet may well reflect their higher proportional contribution to Free Bottles in the Umfolozi Pilot Plots (UGR-36.3% HGR-19.8%).

Although as a group "Acacias" were generally preferred, palatability appears to vary between species. The Pilot data suggest that *A.gerrardii, A.borleae, A.nilotica, A.caffra* and possibly *A.senegal* are the most preferred species. The more ubiquitous *D.cinerea* and *A.karroo* were less preferred, but very important dietary items; while *A.luderitzii, A.grandicornuta* and *A.nigrescens* appear to be rejected. The latter three species have amongst the most formidable physical defence among the "Acacias" listed above. This may account for their apparent lower feeding preferences.

o *S.africana* was the most important browse species in the Umfolozi Pilot plots, contributing 26.5% of total browsing. Although young *S.africana* thicket was not selected for study in the Hluhluwe Pilot survey, visual observations indicated that *S.africana* was also a key food species in Hluhluwe in 1988. *Acalypha* species which are also members of the family Euphorbiaceae (along with *S.africana*) were both important and preferred species in Hluhluwe.

o *Maytenus* was indicated as a genus where feeding preferences varied markedly between species. *M.nemorosa* was an important dietary species, contributing 6.88% and 5.07% to total Hluhluwe and Umfolozi Pilot survey offtake respectively. *M.heterophylla* appears to be an intermediate food species in Umfolozi, while *M.senegalensis* was rejected in Hluhluwe.

o *Ziziphus mucronata* is generally held to be a preferred browse species. However, in both Hluhluwe and Umfolozi Pilot plots, this species contributed less than 1% of the total recorded browse offtake.

RIDGE REGRESSION ANALYSIS OF FEEDING LEVELS

INFLUENCE OF BUSH PHYSIOGNOMY ON FEEDING

o Total offtake in the Pilot survey was greater in communities with higher densities of trees less than 2.5m, and higher Total browse bottle availabilities (Figure 6.1). Conversely, increased densities of taller tress (>2.5m) with higher percentage canopy cover was negatively related to total feeding. Although Figure 6.1 showed that smaller tree density was positively related to feeding levels, black rhino feeding levels declined as soon as bush density made it difficult to walk inside the plots (High Impenetrability Index).

SIZE CLASS PREFERENCES

"*Acacia*" size selection

o The ridge trace obtained after regressing the total amount of "*Acacia*" browsing against "*Acacia*" densities by size class, revealed that dietary importance varied with size (Figure 6.2). Tall (≥ 4m) "*Acacia*"s were least important, while smaller "Acacias" (≤ 1.75m) were indicated as the most important size. Intermediate sizes (1.75-4m) were intermediate in importance. (Figure 6.2 clearly vindicates the use of ridge regression as the standardised regression coefficients obtained from traditional multiple regression [Theta = 0] were clearly unstable and unreliable as a result of multicollinearity.)

o In Umfolozi, clear size class selections were indicated for the following food "Acacias" (*A.nilotica, A.tortilis, A.gerrardii, A.nigrescens, A.borleae, A.karroo, A.senegal* and *D.cinerea* - Figure 6.3). Offtake from "Acacias"

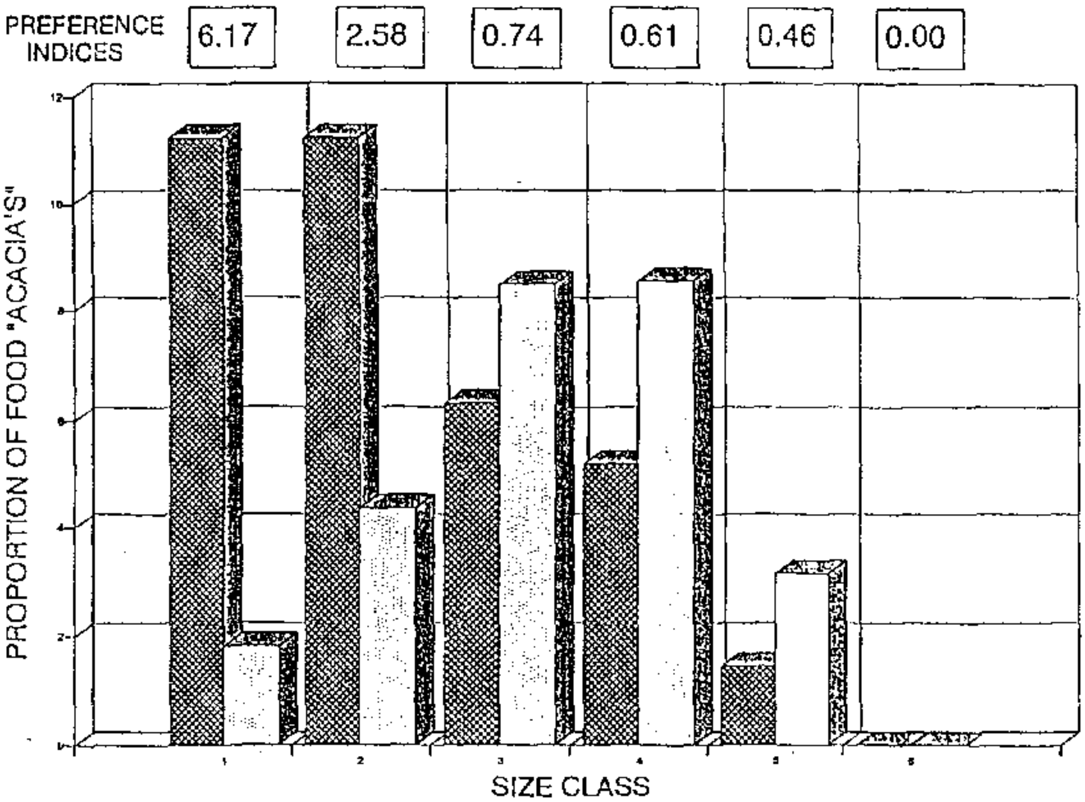


FIGURE 6.3

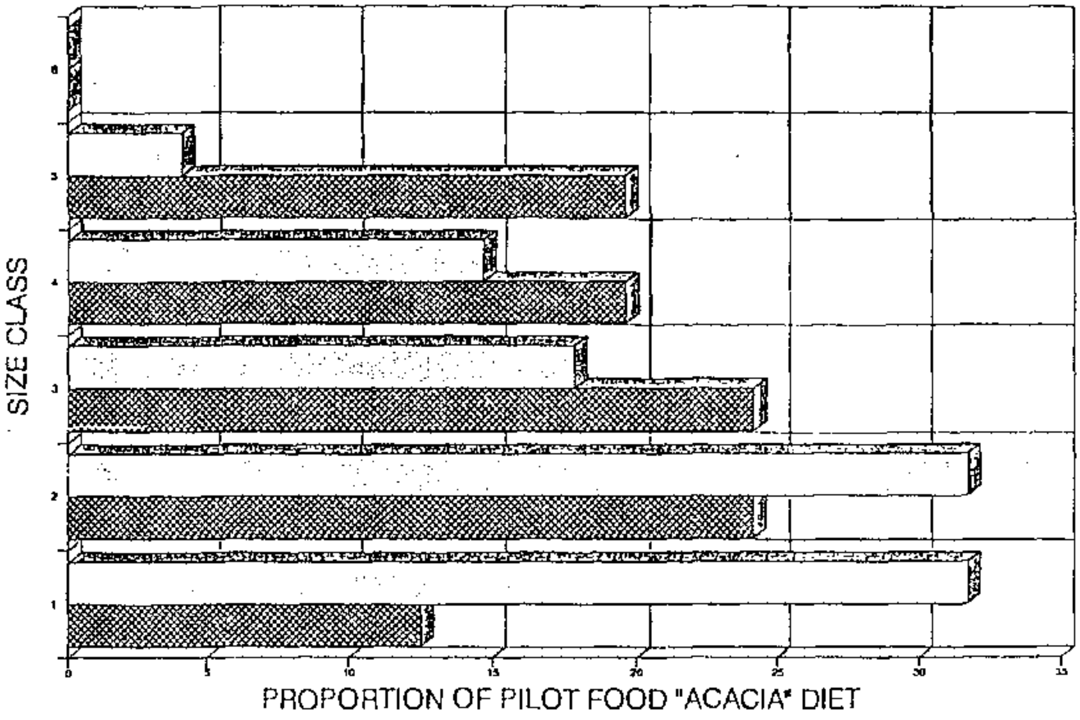


FIGURE 6.4

less than 0.75m in Umfolozi was equivalent to 53.0% of the total browse availability (standing crop) on these trees. On "Acacias" between 0.75m and 1.25 metres, offtake represented 23.7% of standing crop, dropping to 7.2% and 2.5% of "Acacias" 1.25-2.49m and 2.5-3.99m respectively. Only 1.3% of Umfolozi "Acacia" available standing crop was browsed on trees greater than 4m.

o The pattern was less clear in Hluhluwe where feeding on "Acacias" was more equitably distributed among the size classes than in Umfolozi (Figure 6.4). "*Acacia*" size class selection clearly differed between Umfolozi and Hluhluwe. A total of 95.8 % of the feeding on preferred food "*Acacia*" species occurred on trees <2.5m in Umfolozi but only 80.4% in Hluhluwe. Most feeding (63.4%) on food "Acacias" in Umfolozi occurred on small trees <1.25m; yet in Hluhluwe the small food "Acacias" accounted for only 36.6% of "*Acacia*" offtake.

o In Umfolozi, this size selection pattern was shown for most species of "Acacias". Trees under 1.25m were the most preferred for eight out of the ten "*Acacia*" species fed on in Umfolozi. This contrasted with Hluhluwe, where the most preferred "*Acacia*" size was generally 1.25-4m (4/6 "*Acacia*" species fed on). While size class 1 (<0.75m) "Acacias" were generally the most preferred size in Umfolozi, only "*D.cinerea*" size 1's were the most preferred in Hluhluwe.

o Small *A.nilotica*'s were highly preferred in the Umfolozi Pilot plots, with 60% of all *A.nilotica* browsing occurring on trees less than 0.75m (Free Preference Index or FPI : 5.26 ***). A further 34% of *A.nilotica* browsing occurred on trees from 0.75-1.25m (FPI : 2.14 **). Taller *A.nilotica*'s (≥ 1.25m) were highly rejected in Umfolozi (FPI 0.18 ---). As will become apparent later, this finding is important when assessing the likely impact of habitat changes over much of Hluhluwe on black rhino.

Spirostachys africana size selection

o Height selection for *S.africana* in Umfolozi differed from that shown for "Acacias". Size 4 trees (1.75-2.49m) were both the most important (48.2% of *S.africana* browsing) and most preferred *S.africana* size class.

o One-way ANOVA's showed there were significant differences between strata in both Hluhluwe (F=3.887 df 8,18 p=0.0000) and Umfolozi (F=2.463 df 9,10 p=0.0447) in levels of black rhino browsing. However, high coefficients in variation, and low levels of pseudoreplication meant that Tukey Multiple Comparison testing did not allow significant differences to be shown between most of the different strata from each other (Table 6.3). Caution should therefore be exercised in the interpretation of the strata preferences recorded in the Pilot survey. Table 6.3 gives mean summary data for the different Pilot strata. Lowland forest margin and riverine forest were the most important habitat patches surveyed in Hluhluwe.

o Young *S.africana* thicket was both the most important and most preferred strata sampled in Umfolozi. Although this strata was not measured in the Hluhluwe Pilot survey, visual observations during 1988 indicated it was also a major black rhino habitat in Hluhluwe.

o *A.nilotica* closed woodland and the later successional *Euclea racemosa/B.zeyheri* Lowland Forest have increased in extent in Hluhluwe since 1940 to cover extensive areas (see Chapters 16 and 20). Patches of these habitats were neither important or preferred in the Pilot survey (Table 6.3).

o Heavily grazed open savanna in Umfolozi was the second most preferred habitat patch surveyed, although offtake levels were lower than most other strata. "Acacias" contributed 62.6% of all Free Browse available in these patches and comprised 75.6% of the diet in this strata. Grass interference was only 10.9% on the highly preferred Size 1 "Acacias" (<0.75m). "Acacias" <1.25m made up 61.1% of the diet and 27.4% of the available browse in this strata.

TABLE 6.3 Mean Summary Data for Pilot Study Strata

	OFFTAKE Importance Index (Mean=100)	90%Tukey Multiple Range Test	FREE BB Pref. Index	HIDDEN BB (%Total BB)	BB OFFTAKE (%Total BB)	RANK IMPORTANCE: PREFERENCE
HLUHLUWE PILOT STRATA						
Oncobeni Lowland Forest Margins	354	*	2.20	11.00	8.56	1:2
Maphumulo Riverine Forest	167	**	2.85	35.94	7.99	2:1
Depression Grasslands near Pan	101	*	1.43	43.87	3.50	3:3
Combretum molle Woodland	66	*	0.52	23.43	1.75	4:6
Acacia karoo/Euclea crispa/Rhus rehmanniana	53	*	0.37	14.69	1.38	5:8
Acacia nilotica Closed Woodland	51	*	0.67	21.93	2.29	6:4
Dichrostachys cinerea/Acacia karroo Grasslands	47	*	0.41	39.73	1.09	7:7
Euclea racemosa/Berchemia zeyheri Lowland Forest	41	*	0.64	8.59	2.55	8:5
Mature Euclea divinorum Woodland	21	*	0.23	26.74	0.74	9:9
UMFOLOZI PILOT STRATA						
Young Spirostachys africana Thicket	318	*	1.84	21.19	15.45	1:1
Mixed Gqoyini Plateau Grasslands	131	**	0.84	9.24	8.18	2:6
Drainage Line Mature Spirostachys africana Woodland	127	**	0.88	30.00	6.60	3:5
Acacia karoo Thicket	113	**	1.13	22.84	9.34	4:3
Donga Dissected Euclea undulata Dense Hillslope Bush	62	*	0.59	34.36	4.10	5:9
Mid-Slope Acacia Savanna	60	*	1.03	28.10	7.94	6:4
Acacia borleae/Euclea divinorum Woodland	58	*	0.50	34.45	3.49	7:10
Mixed Gqoyini Grassland/Savanna	51	*	0.83	20.68	7.04	8:7
Heavily Grazed Open Acacia Savanna	49	*	1.25	22.83	10.27	9:2
Acacia nigrescens Open Woodland	32	*	0.65	21.95	5.40	10:8

EFFECTS OF BROWSE INTERFERENCE ON FEEDING

○ Grass height and biomass was found to be negatively related to black rhino feeding levels in the Pilot Survey (Figure 6.1). Grass biomass had a particularly marked influence on feeding levels in the Pilot surveys (Figure 6.1).

○ Exploratory plotting of the Pilot survey data revealed a mirroring in Hluhluwe of Log transformed available "*Acacia*"browse bottle density and Grass biomass. The Umfolozi Pilot plots did not show the same clear relationship. In Umfolozi, some of the highest plot preference values occurred when high densities of available "*Acacia*" bottles were associated with low grass biomass.

○ The mean percentage of Total "*Acacia*" browse bottles hidden by grass was 32.8% in the Hluhluwe Pilot plots, but only 12.6% in the Umfolozi plots. Comparable mean forb interference levels on "*Acacia*" were low in both areas (HGR 1.8% and UGR 0.3%). Mean levels of thicket interference of "*Acacia*" bottles were 3.3% in Hluhluwe and 6.1% in Umfolozi. In Umfolozi thicket interference was highest on "Acacias" from 1.25-2.5m at just under 10%. Grass interference was therefore the major form of browse interference of "*Acacias*" in both reserves.

○ Figure 6.5 shows that high levels of grass interference were recorded for Hluhluwe "Acacias" up to 2.5m - but only on "Acacias" less than 1.25m in Umfolozi.

○ The Pilot data suggested that although the small "Acacias" were the most preferred size in Umfolozi, the next tallest size classes were preferred as grass interference increased.

The Pilot survey results therefore imply that the increased levels of grass interference in Hluhluwe (following from the wet period during the mid-late 1980s; and exacerbated by heavy-culling during the early 1980s dry period) have forced Hluhluwe black rhinos to eat more of the less preferred taller size classes of "Acacias".

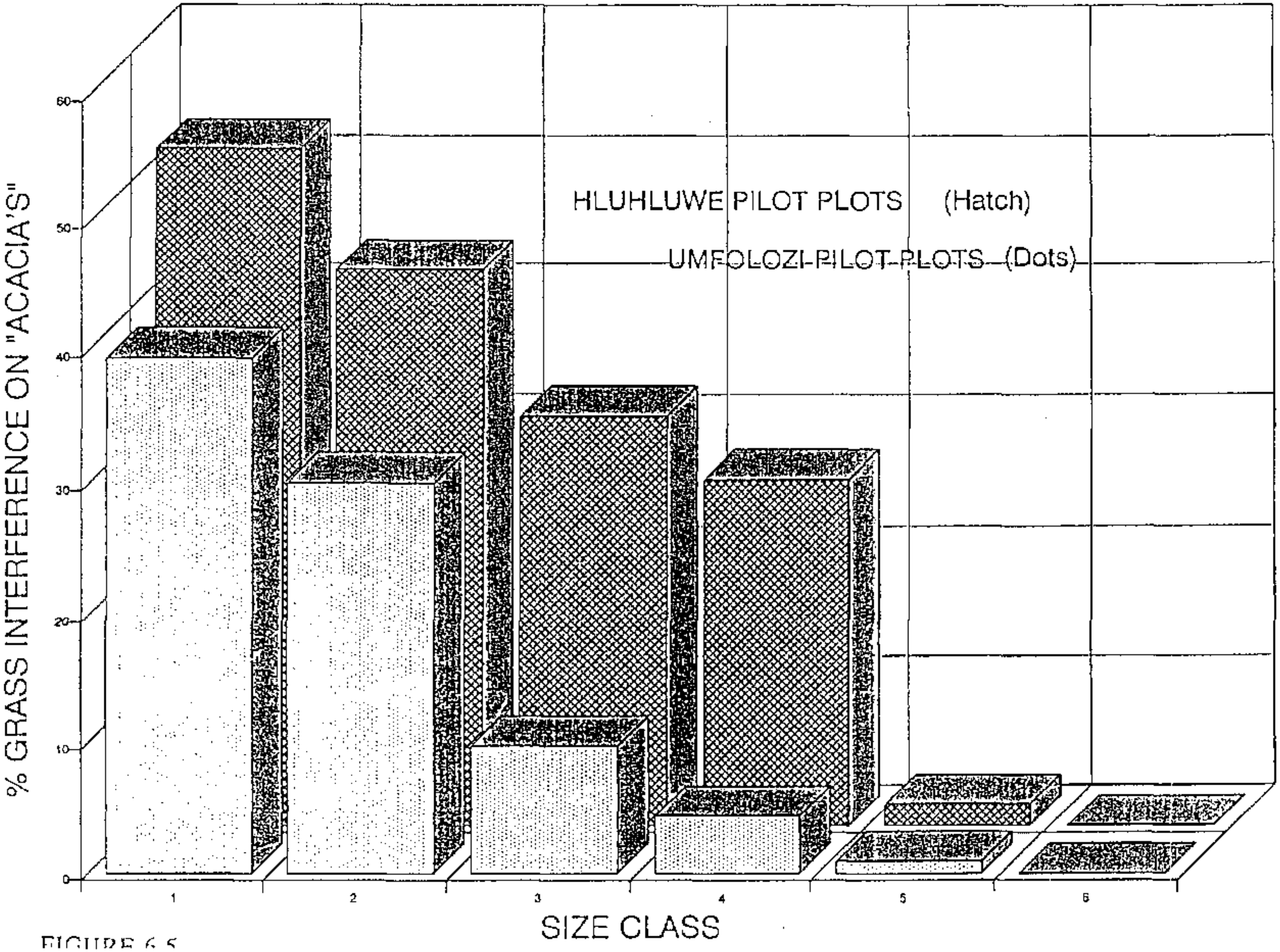

% GRASS INTERFERENCE ON "ACACIA'S"
0
10
20
30
40
50
60
HLUHLUWE PILOT PLOTS (Hatch)
UMFOLOZI PILOT PLOTS (Dots)
1
2
3
4
5
6
SIZE CLASS

FIGURE 6.5

CHAPTER 7

BLACK RHINO FEEDING PATTERNS II: GRID SURVEY RESULTS - IMPORTANT, PREFERRED AND REJECTED COMMUNITIES, SPECIES & SPIZES

INTRODUCTION

o **This chapter is the first of two chapters that details the feeding patterns recorded during the extensive Grid surveys carried out in both Hluhluwe and Umfolozi study areas in 1989**. For details of methods, sampling strategies and analytical approaches, interested readers are referred to Chapters 3, 4 and 5.

o The importance of the sampling design and large sample sizes used in the Grid surveys are discussed.

o Woody browse abundance in each study area is compared with recorded feeding patterns to quantify the dietary importance and degrees of preference/rejection for all the commoner species and spizes. Selection patterns in the two study areas are also contrasted. Finally, food selection is examined at a hierarchy of scales from a community/patch level down to an individual spize level.

o The following chapter (8) continues the analysis of Grid survey selection patterns, by examining the influence of grass interference and grass height on black rhino feeding in some detail.

o Throughout this chapter the terms *Hluhluwe* and *Umfolozi* have been used as a shorthand way to refer to the two Grid study areas. For maps of the Grid study areas (and transect locations) readers are referred to Figures 1.2, 4.2 and 4.3. For example, for "*feeding levels in Hluhluwe*" read "*feeding levels in the Hluhluwe Grid Survey Study Area*". If reference is intended to the whole Game Reserve the text will make this clear (eg "*feeding levels throughout Hluhluwe Game Reserve*").

IMPORTANCE OF SAMPLING DESIGN USED IN THE GRID SURVEYS

A systematic sampling design (with randomised grid origin) was used in the Grid surveys to enable statistical inferences about the whole population of trees in each of the two study areas to be made[#1]. If we had simply measured selected transects near roads (as in most vegetation surveys) - we would not have been justified in making inferences about vegetation and black rhino feeding throughout whole study areas. In addition serious biases would have been introduced into our results. This is because road traffic causes disturbance that can influence black rhino movement and feeding patterns; and vegetation adjacent to roads is not representative of vegetation throughout the study area, as roads favour valleys, ecotones and easily accessed areas. Trees growing next to roads also benefit from increased run off and reduced below ground competition; although their leaves may be covered with a thick layer of dust thrown up by passing vehicles.

GRID SURVEY SAMPLE SIZES

In most cases the results of database queries have been presented without corresponding standard errors and confidence levels, or tests of statistical significance. The sheer number of queries, and time constraints precluded such calculations. This was especially the case where data distributions were non- normal, and it would have been preferable to non-parametrically estimate error terms using bootstrapping (Effron 1979,1981,1982,1987; Effron & Gong 1983; Effron & Tibshirani 1986)[#2].

Fortunately in most cases, the large data sets used in the queries minimised this problem. The Grid survey results which follow were based on a sample of 25,623 trees (242 transects) in the 4,900 Ha North-East/Central Hluhluwe Study area and 7,098 trees (187 transects) in the 4,675 Ha North-West Umfolozi Study Area.

In many cases findings were clear-cut and common sense dictated that statistical tests were clearly not needed. For example, one doesn't need a statistical test to know that the observed difference in contribution of small "*Acacias*" (<1m) to the Umfolozi black rhino woody diet (23.22%) and available Free bottles (3.49%) is highly significant. Theoretically with large sample sizes, it may be possible to show some small differences as statistically significant. However, practically we are really only interested in gross and clear-cut differences and patterns, rather than very small scale minor ones. Therefore if the large sample Grid surveys could not clearly reveal patterns or differences, then those patterns or differences were unlikely to be of much practical importance.

However, should it ever prove necessary, specific tests or error estimates could always be undertaken at a later date.

Dietary composition, Importance, and Preference/Rejection values were derived from samples of 1,458.5 (Hluhluwe) and 1,875.5 (Umfolozi) browse bottles removed from the transects. Total Grid offtake levels only represented a very small proportion of the Total available browse bottles in the habitat - 3.62% in Umfolozi and 1.11% in Hluhluwe. The intensive Grid sampling was therefore vindicated.

BASELINE WOODY BROWSE ABUNDANCE IN EACH GRID STUDY AREA IN 1989

Readers may wonder what relevance measurements of browse abundance have in a chapter on black rhino feeding patterns. The answer is simple. Measurements of abundance in the habitat are needed to calculate Preference/Rejection indices. Without corresponding measures of browse abundance to go with feeding data; only dietary importance of different resources can be quantified.

BASELINE WOODY VEGETATION DATASETS - AN IMPORTANT BY-PRODUCT OF BLACK RHINO PROJECT 2000

During the design of the Grid survey, we thought about the kind of information about habitat structure and composition that we would have really liked to have had for different times in the past. If possible, we wanted to be able to use the Grid surveys to generate such information as a by-product. Detailed 1989 baseline datasets on the densities, canopy cover and abundances of species and spizes throughout the two study areas are the result of this concern. Unfortunately, similar data for 1939, 1949, 1959, 1969, and 1979 were not available for comparison with 1989 data. However, researchers now have large baseline datasets against which they can monitor future woody spize population and community changes.

GROSS DIFFERENCES BETWEEN STUDY AREAS

Mean tree densities (excluding small seedlings) in 1989 were substantially higher in Hluhluwe (7,070/Ha) than in Umfolozi (2,531/Ha). The 1989 Hluhluwe tree density was higher than the 1,777/Ha and 4,152/Ha recorded in two N Hluhluwe black rhino home ranges by Hitchins twenty years previously (Hitchins 1969). However not too much should be made of these differences as the 1969 estimates were based on very small sample sizes, and for multi-stemmed species it was not clear what was counted as an individual plant.

Mean Total available browse bottle densities in Hluhluwe were double those in Umfolozi (Hluhluwe: 36,319/Ha Umfolozi: 18,455/Ha).

Mean Canopy Cover was three times greater in Hluhluwe. The total canopy cover of trees over four metres tall was almost six times greater in Hluhluwe (44.15% vs. 7.42%).

SPECIES ABUNDANCE LEVELS

CONTRIBUTION OF SPECIES TO TOTAL AVAILABLE BROWSE BOTTLES

Tables 7.1 and 7.2 list the species in order of their percentage contribution to Total available browse bottles in the Hluhluwe and Umfolozi Grid Study areas respectively. There was a more equitable distribution of available browse in Hluhluwe than in Umfolozi. In Hluhluwe no species accounted for more than 7.73% of Total available bottles. By way of contrast two species made up 25.42% of Total available bottles in Umfolozi.

Hluhluwe

Using RESOURCE (Emslie 1991d) analysis of the Total bottle data (Chapter 5), the key species in Hluhluwe were identified. Species were classified according to the downweights derived for each species using Emslie's combination weight (which takes frequency of occurrence, overall abundance levels, and the degree of equatability of abundance between plots into account)[#3].

In the Hluhluwe Study Area:

> Species with the most available browse were *A.caffra, A.karroo, A.nilotica, A.robusta, B.zeyheri, C.caffra, D.cinerea, D.lycioides, D.simii, D.rotundifolia, E.crispa, E.divinorum, E.racemosa, K.floribunda, L.javanica, M.heterophylla, M.nemorosa, M.senegalensis, R.pentheri, R.tridentata, S.myrtina, S.inerme, Solanum* species, and *Z.mucronata* (not downweighted).
>
> A further 24 species were still important contributors to available browse: *A.glabrata, Canthium inerme, Celtis africana, Combretum molle, Coddia rudis, Dalbergia obovata, Dovyalis caffra,*

TABLE 7.1

PERCENTAGE CONTRIBUTION OF EACH SPECIES TO TOTAL BROWSE BOTTLES
HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	%Total Bottles
Dichrostachys cinerea	7.73
Spirostachys africana	5.78
Acacia caffra	5.78
Diospyros lycioides	5.53
Acacia karroo	5.44
Lippia javanica	5.22
Rhus pentheri	4.62
Acalypha glabrata	4.41
Kraussia floribunda	3.80
Euclea crispa	3.71
Euclea racemosa	3.60
Maytenus senegalensis	3.02
Berchemia zeyheri	2.94
Euclea divinorum	2.86
Rhoicissus tridentata	2.63
Scutia myrtina	2.08
Vernonia subuligera	2.03
Solanum	1.76
Diospyros simii	1.70
Abutilon/Hibiscus spp.	1.63
Acacia nilotica	1.56
Maytenus nemorosa	1.41
Ziziphus mucronata	1.24
Plectroniella armata	1.21
Dombeya rotundifolia	1.09
Rhus rehmanniana	.93
Acacia gerrardii	.82
Coddia rudis	.81
Acalypha sonderiana	.80
Dombeya burgessiae	.78
Cordia caffra	.71
Hippobromus pauciflorus	.56
Azima tetracantha	.54
Maytenus heterophylla	.52
Heteropyxis natalensis	.51
Sideroxylon inerme	.50
Galpinia transvaalica	.49
Ehretia rigida/amoena	.43
Clutia pulchella	.43
Dalbergia obovata	.41
Dovyalis caffra	.38
Phyllanthus reticulatus	.38
Canthium inerme	.38
Sclerocarya birrea	.37
Euclea natalensis	.35
Acacia robusta	.34
Scolopia zeyheri	.31
Combretum molle	.31
Tarchonanthus camphoratus	.30
Chromolaena odorata	.27
Geranium spp.	.27
Adenopodia spicata	.26
Monanthotaxis caffra	.26
Schotia brachypetala	.25
Unknown 15	.25
Rhus spp.	.22
Cassine aethiopica	.21
Zanthoxylum capense	.18
Rhus chirindensis	.18
Chaetachme aristata	.16
Diospyros spp.	.16
Peltophorum africanum	.16
Forb spp.	.15
Ximenia caffra	.14
Celtis africana	.12
Pancovia golungensis	.12
Bersama lucens	.10
Manilkara discolor	.10
Croton sylvaticus	.10
Grewia occidentalis	.09
Acacia grandicornuta	.07
Grewia flavescens	.07
Ficus sur	.06
Cola greenwayi	.06
Asparagus spp.	.05
Dalbergia armata	.05
Sesbania sesban	.05
Clausena anisata	.04
Ficus spp.	.04
Capparis tomentosa	.04
Cunonia capensis	.04
Trema orientalis	.04
Grewia caffra	.03
Ficus sycomorus	.03
Thespesia acutiloba	.03
Psychotria capensis	.03
Eugenia natalitia	.03
Bequaertiodendron natalense	.03
Crotolaria capensis	.02
Ozoroa engleri	.02
Melanthus didyma	.02
Rhoicissus tomentosa	.02
Lycium acutifolium	.02
Ficus glumosa	.02
Unknown 8	.02
Ochna natalitia	.02
Indigofera natalensis/cylindrica	.02
Strychnos innocua	.02
Manilkara concolor	.01
Acacia schweinfurthii/ataxacantha	.01
Strychnos madagascariensis	.01
Cassine transvaalensis	.01
Rhoicissus rhomboidea	.01
Capparis sepiaria	.01
Commiphora harveyi	.01
Acacia burkei	.01
Ormocarpum trichocarpum	.01
Oricia bachmannii	.01
Erythroxylum emarginatum	.00
Asclepias fruticosa	.00
Trichocladus grandiflorus	.00
Diospyros whyteana	.00
Vitellariopsis marginata	.00
Canthium spp.	.00
Rhus gueinzii	.00
Turraea floribunda	.00
Vitex harveyana	.00
Teclea gerrardii	.00
Pappea capensis	.00
Aloe marlothii	0.00
Cussonia spp.	0.00
Harpephyllum caffrum	0.00
Teclea natalensis	0.00

TABLE 7.2

PERCENTAGE CONTRIBUTION OF EACH SPECIES TO TOTAL BROWSE BOTTLES
UMFOLOZI GAME RESERVE 1989 GRID STUDY AREA

Species	%Total Bottles
Croton menyhartii	13.96
Spirostachys africana	11.46
Euclea divinorum	5.85
Euclea undulata	4.91
Asparagus spp.	4.40
Dichrostachys cinerea	4.02
Tarchonanthus camphoratus	3.84
Brachylaena ilicifolia	3.82
Acacia grandicornuta	3.34
Ehretia rigida/amoena	3.31
Maytenus nemorosa	2.95
Schotia capitata	2.89
Schotia brachypetala	2.67
Acacia karroo	2.43
Acacia borleae	1.96
Euclea racemosa	1.91
Plectroniella armata	1.79
Acacia tortilis	1.76
Rhus pentheri	1.56
Acacia nilotica	1.30
Acacia gerrardii	1.20
Maytenus heterophylla	1.15
Grewia flavescens	1.05
Acacia nigrescens	1.04
Capparis tomentosa	.93
Olea europaea	.89
Rhus gueinzii	.84
Grewia flava	.74
Maytenus senegalensis	.73
Acacia luederitzii	.69
Acacia robusta	.64
Carissa bispinosa	.63
Pyrostria hystrix	.62
Coddia rudis	.61
Zizyphus mucronata	.60
Grewia occidentalis	.57
Commiphora neglecta	.57
Acacia caffra	.52
Pappea capensis	.44
Sideroxylon inerme	.44
Azima tetracantha	.37
Rhoicissus rhomboidea	.36
Grewia villosa	.27
Ormocarpum trichocarpum	.26
Euclea natalensis	.23
Unknown 15	.23
Boscia albitrunca	.19
Sida cordifolia/rhombifolia	.19
Acacia senegal	.18
Solanum	.16
Capparis sepiaria	.16
Cassine tetragona	.15
Cassine aethiopica	.15
Helanthus didyma	.15
Cassine transvaalensis	.15
Grewia bicolor	.14
Ozoroa engleri	.12
Dombeya tiliacea	.10
Combretum apiculatum	.10
Diospyros lycioides	.10
Berchemia zeyheri	.09
Grewia monticola	.09
Gardenia volkensii	.08
Sesbania sesban	.08
Strychnos madagascariensis	.07
Diospyros whyteana	.06
Gardenia cornuta	.06
Dombeya rotundifolia	.06
Lycium acutifolium	.05
Scolopia zeyheri	.05
Sclerocarya birrea	.04
Strychnos spp.	.04
Aloe marlothii	.04
Unknown 4	.03
Hippobromus pauciflorus	.03
Erythrina lysistemon	.03
Grewia spp.	.03
Rhus rehmanniana	.03
Cussonia zuluensis	.02
Acacia burkei	.02
Cadaba natalensis	.02
Monanthotaxis caffra	.02
Sesbania punicea	.02
Maerua angolensis	.02
Clutia pulchella	.02
Diospyros spp.	.02
Melia azedarach	.02
Zanthoxylum capense	.01
Unknown 1	.01
Lippia javanica	.01
Canthium spp.	.01
Commiphora harveyi	.01
Crotalaria capensis	.01
Galpinia transvaalica	.01
Unknown 6	.01
Unknown 2	.00
Unknown 3	.00
Unknown 5	.00

E.rigida/amoena, Euclea natalensis, Galpinia transvaalica, G.occidentalis, Heteropyxis natalensis, H.pauciflorus, Phyllanthus reticulatus, Plectroniella armata, Rhus chirindensis, R.rehmanniana, Sclerocarya birrea, Schotia brachypetala, Scolopia zeyheri, S.africana, Vernonia subilgera, Ximenia caffra and *Zanthoxylum capensis* (Downweighted by > 0.4, the critical passive weight).

Six species were less abundant (*Cassine aethiopica, Chaetachme aristata, Clutia pulchella, Chromolaena odorata*[*4], *D.burgessiae*, and *Monanthotaxis caffra*).

Over half (56.5%) of the 124 species sampled in the Hluhluwe Grid Survey were rare and contributed little to Total browse availability.

D.cinerea, A.caffra and *A.karroo* accounted for 18.95% of Total available bottles.

Six other *Acacia* species contributed a further 2.81%.

Five common species in lowland grassland in N.E.Hluhluwe (*Diospyros lycioides, Lippia javanica, Euclea crispa, Rhoicissus tridentata* and *Maytenus senegalensis*) accounted for a further 20.11%.

Umfolozi

In the Umfolozi Study Area:

Croton menyhartii and *S.africana* together accounted for just over a quarter of all available browse bottles. The proportion of available *S.africana* bottles in Umfolozi was also twice that in the Hluhluwe Study Area.

Euclea divinorum was the third biggest contributing species in Umfolozi (5.85% Total BB).

Thirteen different "*Acacia*" species accounted for about a fifth (19.1%) of the Total available bottles in Umfolozi.

Eight of the common species in dense Umfolozi bush (*Euclea undulata, Brachylaena ilicifolia, Maytenus nemorosa, Schotia capitata, Olea europaea, Pyrostria hystrix, Rhoicissus rhomboidea,* and *Carissa bispinosa*) contributed a further 17.07% of Total available bottles.

CONTRIBUTION OF SPECIES TO TOTAL CANOPY COVER

Tables 7.3 and 7.4 list the species in order of their proportional contribution to total canopy cover in the Hluhluwe and Umfolozi Grid Study areas. Total canopy cover was obtained by summing the percentage Canopy Cover scores (= Braun-Blanquet percentage Canopy Cover Class Midpoints) for all species.

Hluhluwe

In the Hluhluwe Study Area:

Almost one third of total canopy cover (31.22%) was made up by four key canopy dominants (*E.racemosa, B.zeyheri, R.pentheri and A.nilotica*) in the succession from *A.nilotica* closed woodland to *E.racemosa\B.zeyheri* Lowland forest (see Chapter 20).

E.racemosa was the major canopy dominant accounting for almost an eighth of total canopy cover, but only 3.6% of available bottles. The reason for this discrepancy was that most foliage was out of reach of black rhino. Similarly *A.nilotica* accounted for 5.45% of total canopy cover,

TABLE 7.3

CONTRIBUTION OF EACH SPECIES TO TOTAL CUMMULATIVE CANOPY COVER % SCORES
HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	% Canopy Cover
Euclea racemosa	12.12
Berchemia zeyheri	7.07
Rhus pentheri	6.58
Dichrostachys cinerea	6.22
Acacia nilotica	5.45
Euclea divinorum	4.42
Acacia karroo	4.30
Spirostachys africana	3.47
Diospyros lycioides	3.21
Scutia myrtina	2.77
Acacia caffra	2.60
Kraussia floribunda	2.47
Lippia javanica	2.29
Maytenus nemorosa	2.19
Acalypha glabrata	2.14
Maytenus senegalensis	1.67
Rhoicissus tridentata	1.64
Diospyros simii	1.63
Euclea crispa	1.41
Solanum	1.33
Cordia caffra	1.27
Acacia robusta	1.22
Sclerocarya birrea	1.20
Ziziphus mucronata	1.12
Plectroniella armata	1.08
Vernonia subuligera	1.07
Sideroxylon inerme	.88
Schotia brachypetala	.85
Adenopodia spicata	.79
Combretum molle	.77
Clutia pulchella	.74
Dalbergia obovata	.70
Heteropyxis natalensis	.69
Hippobromus pauciflorus	.68
Cassine aethiopica	.63
Dombeya rotundifolia	.59
Acalypha sonderiana	.57
Dombeya burgessiae	.55
Galpinia transvaalica	.51
Celtis africana	.50
Abutilon/Hibiscus spp.	.41
Maytenus heterophylla	.39
Scolopia zeyheri	.39
Dovyalis caffra	.38
Euclea natalensis	.36
Phyllanthus reticulatus	.36
Ehretia rigida/amoena	.31
Chromolaena odorata	.30
Rhus rehmanniana	.30
Peltophorum africanum	.29
Zanthoxylum capense	.27
Tarchonanthus camphoratus	.26
Canthium inerme	.25
Coddia rudis	.22
Chaetachme aristata	.21
Rhus chirindensis	.20
Manilkara discolor	.18
Acacia burkei	.18
Grewia occidentalis	.17
Acacia gerrardii	.16
Pappea capensis	.16
Unknown 15	.16
Teclea gerrardii	.15
Trema orientalis	.13
Diospyros spp.	.13
Bersama lucens	.12
Monanthotaxis caffra	.10
Geranium spp.	.10
Trichocladus grandiflorus	.10
Croton sylvaticus	.09
Cussonia spp.	.09
Harpephyllum caffrum	.09
Dalbergia armata	.09
Rhus spp.	.09
Ximenia caffra	.09
Azima tetracantha	.08
Pancovia golungensis	.08
Capparis tomentosa	.07
Forb spp.	.07
Asparagus spp.	.07
Clausena anisata	.07
Cola greenwayi	.05
Rhoicissus tomentosa	.05
Ficus sur	.04
Manilkara concolor	.04
Acacia grandicornuta	.04
Eugenia natalitia	.04
Helanthus didyma	.04
Teclea natalensis	.04
Vitex harveyana	.04
Grewia caffra	.03
Indigofera natalensis/cylindrica	.03
Ochna natalitia	.03
Sesbania sesban	.03
Thespesia acutiloba	.03
Acacia schweinfurthii/ataxacantha	.02
Berquaertiodendron natalense	.02
Capparis sepiaria	.02
Commiphora harveyi	.02
Cunonia capensis	.02
Ficus spp.	.02
Unknown 8	.02
Erythroxylum emarginatum	.01
Grewia flavescens	.01
Lycium acutifolium	.01
Oricia bachmannii	.01
Ormocarpum trichocarpum	.01
Rhus gueinzii	.01
Strychnos madagascarensis	.01
Aloe marlothii	.01
Asclepias fruticosa	.01
Canthium spp.	.01
Cassine transvaalensis	.01
Crotalaria capensis	.01
Diospyros whyteana	.01
Ficus glumosa	.01
Ficus sycomorus	.01
Ozoroa engleri	.01
Psychotria capensis	.01
Rhoicissus rhomboidea	.01
Strychnos innocua	.01
Turraea floribunda	.01
Vitellariopsis marginata	.01

TABLE 7.4

CONTRIBUTION OF EACH SPECIES TO TOTAL CUMMULATIVE CANOPY COVER % SCORES
UMFOLOZI GAME RESERVE 1989 GRID STUDY AREA

Species	% Canopy Cover
Spirostachys africana	8.93
Croton menyhartii	8.11
Acacia nigrescens	5.28
Dichrostachys cinerea	4.74
Acacia grandicornuta	4.48
Asparagus spp.	4.19
Euclea undulata	3.61
Ehretia rigida/amoena	3.35
Tarchonanthus camphoratus	3.30
Euclea divinorum	3.28
Maytenus nemorosa	3.25
Schotia capitata	2.97
Acacia karroo	2.66
Acacia nilotica	2.26
Brachylaena ilicifolia	2.14
Acacia luederitzii	2.05
Pappia capensis	1.98
Acacia gerrardii	1.89
Acacia tortilis	1.89
Euclea racemosa	1.81
Plectroniella armata	1.77
Maytenus heterophylla	1.63
Acacia robusta	1.25
Capparis tomentosa	1.18
Sida cordifolia/rhombifolia	1.08
Grewia occidentalis	.94
Olea europaea	.94
Acacia borleae	.87
Grewia flava	.87
Commiphora neglecta	.85
Zizyphus mucronata	.78
Azima tetracantha	.75
Rhus pentheri	.75
Grewia flavescens	.73
Pyrostria hystrix	.68
Schotia brachypetala	.68
Solanum	.66
Grewia villosa	.64
Ormocarpum trichocarpum	.61
Rhoicissus rhomboidea	.61
Hemanthus didyma	.59
Rhus gueinzii	.59
Boscia albitrunca	.57
Sideroxylon inerme	.54
Coddia rudis	.52
Combretum apiculatum	.47
Gardenia cornuta	.47
Maytenus senegalensis	.47
Acacia caffra	.42
Cassine transvaalensis	.42
Acacia sengal	.38
Unknown 15	.38
Sclerocarya birrea	.33
Cassine aethiopica	.24
Gardenia volkensii	.24
Carissa bispinosa	.21
Grewia bicolor	.19
Maerua angolensis	.19
Berchemia zeyheri	.16
Cussonia zuluensis	.16
Grewia monticola	.16
Lycium acutifolium	.14
Dombeya rotundifolia	.12
Hippobromus pauciflorus	.12
Capparis sepiaria	.09
Euclea natalensis	.09
Strychnos spp.	.09
Diospyros spp.	.07
Dombeya tiliacea	.07
Ozoroa engleri	.07
Scolopia zeyheri	.07
Canthium spp.	.05
Casine tetragona	.05
Commiphora harveyi	.05
Crotolaria capensis	.05
Diospyros lycioides	.05
Diospyros whyteana	.05
Erythrina lysistemon	.05
Lippia javanica	.05
Monanthotaxis caffra	.05
Rhus rehmanniana	.05
Unknown 6	.05
Zanthoxylum capense	.05
Acacia burkei	.02
Aloe marlothii	.02
Cadaba natalensis	.02
Clutia pulchella	.02
Galpinia transvaalica	.02
Grewia spp.	.02
Melia azedarach	.02
Sesbania punicea	.02
Sesbania sesban	.02
Strychnos madagascarensis	.02
Unknown 1	.02
Unknown 2	.02
Unknown 3	.02
Unknown 4	.02
Unknown 5	.02

but only 1.56% of available bottles. The canopy dominant *B.zeyheri* showed a similar pattern. Three other species associated with this forest succession (*K.floribunda, C.caffra* and *S.inerme*) made up a further 4.62% of total canopy cover. These seven species together accounted for 35.84% of canopy cover but only 17.73% of Total available bottles.

D.cinerea was an important canopy cover species (6.22%). Taller mature individuals of this species were often associated with transitional *A.nilotica* closed woodland-*E.racemosa**B.zeyheri* Lowland forest communities.

Umfolozi

In the Umfolozi Study Area:

In contrast to Hluhluwe, the two major contributors to Total available bottles (*Croton menyhartii* and *S.africana)* were also the two most important contributors to total canopy cover.

The tall-growing *A.nigrescens* was the third most important contributor to canopy cover (5.28%). It contributed only 1.04% of Total available bottles.

SPIZE ABUNDANCE LEVELS

CONTRIBUTION OF SPIZES TO TOTAL AVAILABLE BROWSE BOTTLES

Tables 7.15 through to 7.18 give more detailed summary abundance data broken down at a spize level. The spize data again reveal a more equitable distribution of available browse in Hluhluwe than in Umfolozi. In Hluhluwe, no spize accounted for more than 3.23% of total Free bottles. By way of contrast, in Umfolozi, 3 spizes (*C.menyhartii3, C.menyhartii2* and *S.africana3*) accounted for 21.66% of all available Free bottles in Umfolozi.

IMPORTANT AND UNIMPORTANT BROWSE SPECIES

Tables 7.5 and 7.6 list the woody species in order of their dietary importance (in terms of all bottles eaten) in the Hluhluwe and Umfolozi Grid Study areas .

o "*Acacia*" species made up a large part of the total diet in both study areas, but more in Umfolozi (Hluhluwe 33.8% and Umfolozi 46.0%).

o *Euphorbiaceae* species were key dietary items. In both study areas *S.africana* was the most important species in the diet; while in Hluhluwe *Acalypha glabrata* was the second most important. Together these two species accounted for 37.37% of the Hlubluwe diet. *Croton sylvaticus* made up 2.5% the Hluhluwe diet while *C.menyhartii* made up 2.27% of the Umfolozi diet.

o A comparison between Tables 7.5 and 7.6 reveals very similar contributions to the diet by the six species which occurred in both study areas' "top 10" most important species lists (% All Bottles Browsed - Hluhluwe|Umfolozi : *S.africana* 22.9|24.63 ; *D.cinerea* 10.63|9.97 ; *A.karroo* 8.16|10.58 ; *A.nilotica* 3.81|4.80 ; *A.gerrardii* 3.57|5.28 ; *Maytenus nemorosa* 3.22|3.23). Proportional differences in their contribution to available browse in the habitat were less similar (percentage Free Bottles Available - Hluhluwe|Umfolozi : *S.africana* 7.28|12.11 ; *D.cinerea* 6.11|3.03 ; *A.karroo* 4.46|1.45 ; *A.nilotica* 1.30|0.93 ; *A.gerrardii* 1.01|1.00; *Maytenus nemorosa* 1.72|3.24).

TABLE 7.5

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL BROWSE BOTTLES EATEN (NEW+OLD)
HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (New&Old)
Spirostachys africana	22.90
Acalypha glabrata	14.47
Dichrostachys cinerea	10.63
Acacia karroo	8.16
Berchemia zeyheri	6.14
Acacia caffra	5.21
Acacia nilotica	3.81
Acacia gerrardii	3.57
Abutilon/Hibiscus spp.	3.43
Maytenus nemorosa	3.22
Croton sylvaticus	2.50
Acacia robusta	2.30
Hippobromus pauciflorus	1.44
Zizyphus mucronata	1.23
Diospyros simii	1.17
Dovyalis caffra	1.13
Dombeya burgessiae	1.10
Rhus pentheri	.96
Diospyros lycioides	.86
Euclea racemosa	.55
Galpinia transvaalica	.45
Lippia javanica	.45
Scutia myrtina	.41
Coddia rudis	.34
Dombeya rotundifolia	.34
Ficus sur	.27
Geranium spp.	.27
Adenopodia spicata	.24
Ehretia rigida/amoena	.24
Indigofera natalensis/cylindrica	.24
Plectroniella armata	.24
Celtis africana	.17
Scolopia zeyheri	.17
Combretum molle	.14
Ficus sycomorus	.14
Forb spp.	.14
Maytenus senegalensis	.14
Sideroxylon inerme	.14
Solanum	.14
Unknown 8	.10
Acacia grandicornuta	.07
Cassine aethiopica	.07
Euclea crispa	.07
Rhus rehmanniana	.07
Acacia burkei	.03
Asparagus spp.	.03
Canthium spp.	.03
Monanthotaxis caffra	.03
Phyllanthus reticulatus	.03
Zanthoxylum capense	.03
Acacia schweinfurthii/ataxacantha	0.00
Acalaypha sonderiana	0.00
Aloe marlothii	0.00
Asclepias fruticosa	0.00
Azima tetracantha	0.00
Berquaertiodendron natalense	0.00
Bersama lucens	0.00
Canthium inerme	0.00
Capparis sepiaria	0.00
Capparis tormentosa	0.00
Cassine transvaalensis	0.00
Chaetachme aristata	0.00
Chromolaena odorata	0.00
Clausena anisata	0.00
Clutia pulchella	0.00
Cola greenwayi	0.00
Commiphora harveyi	0.00
Cordia caffra	0.00
Crotalaria capensis	0.00
Cunonia capensis	0.00
Cussonia spp.	0.00
Dalbergia armata	0.00
Dalbergia obovata	0.00
Diospyros spp.	0.00
Diospyros whyteana	0.00
Erythroxylum emarginatum	0.00
Euclea divinarum	0.00
Euclea natalensis	0.00
Eugenia nataltia	0.00
Ficus glumosa	0.00
Ficus spp.	0.00
Grewia caffra	0.00
Grewia flavescens	0.00
Grewia occidentalis	0.00
Harpephyllum caffrum	0.00
Heteropyxis natalensis	0.00
Kraussia floribunda	0.00
Lycium acutifolium	0.00
Manilkara concolor	0.00
Manilkara discolor	0.00
Maytenus heterophyla	0.00
Melanthus didyma	0.00
Ochna nataltia	0.00
Oricia bachmannii	0.00
Ormocarpum trichocarpum	0.00
Ozoroa engleri	0.00
Pancovia galungensis	0.00
Pappia capensis	0.00
Peltopharum africanum	0.00
Psychotria capensis	0.00
Rhoicissus rhombidea	0.00
Rhoicissus tomentosa	0.00
Rhoicissus tridentata	0.00
Rhus chirindensis	0.00
Rhus gueinzii	0.00
Rhus spp.	0.00
Schotia brachypetala	0.00
Sclerocarya birrea	0.00
Sesbania sesban	0.00
Strychnos innocua	0.00
Strychnos madagascarensis	0.00
Tarchonanthus camphoratus	0.00
Teclea gerrardii	0.00
Teclea natalensis	0.00
Thespesia acutiloba	0.00
Trema orientalis	0.00
Trichocladus grandiflorus	0.00
Turraea floribunda	0.00
Unknown 15	0.00
Vernonia subuligera	0.00
Vitellariopsis marginata	0.00
Vitex harveyana	0.00
Ximenia caffra	0.00

TABLE 7.6

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL BROWSE BOTTLES EATEN (NEW+OLD)
UMFOLOZI GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (New&Old)
Spirostachys africana	24.63
Acacia karroo	10.58
Dichrostachys cinerea	9.97
Acacia borleae	5.52
Ehretia rigida/amoena	5.39
Acacia gerrardii	5.28
Acacia nilotica	4.80
Acacia tortilis	4.37
Maytenus nemorosa	3.23
Schotia capitata	3.01
Acacia senegal	2.35
Croton menyhartii	2.27
Grewia flava	1.23
Acacia caffra	1.17
Asparagus spp.	1.17
Commiphora neglecta	1.01
Brachylaena ilicifolia	1.01
Capparis tomentosa	.99
Grewia occidentalis	.80
Acacia robusta	.75
Ormocarpum trichocarpum	.72
Tarchonanthus camphoratus	.67
Acacia nigrescens	.61
Grewia bicolor	.56
Pappea capensis	.56
Plectroniella armata	.56
Azima tetracantha	.53
Cassine transvaalensis	.45
Ziziphus mucronata	.45
Boscia albitrunca	.43
Sida cordifolia/rhombifolia	.43
Gardenia cornuta	.35
Acacia grandicornuta	.32
Rhus gueinzii	.32
Acacia luederitzii	.29
Grewia villosa	.27
Rhus pentheri	.27
Grewia flavescens	.24
Unknown 15	.24
Rhoicissus rhomboidea	.24
Coddia rudis	.19
Solanum	.19
Euclea divinorum	.16
Euclea racemosa	.16
Scolopia zeyheri	.16
Melia azedarach	.13
Cadaba natalensis	.11
Lycium acutifolium	.11
Unknown 6	.11
Erythrina lysistemon	.08
Maytenus heterophylla	.08
Pyrostria hystrix	.08
Berchemia zeyheri	.05
Crotalaria capensis	.05
Diospyros lycioides	.05
Euclea undulata	.05
Ozoroa engleri	.05
Strychnos spp.	.05
Unknown 5	.05
Maerua angolensis	.03
Melanthus didyma	.03
Acacia burkei	0.00
Aloe marlothii	0.00
Canthium spp.	0.00
Capparis sepiaria	0.00
Carissa bispinosa	0.00
Cassine tetragona	0.00
Cassine aethiopica	0.00
Clutia pulchella	0.00
Combretum apiculatum	0.00
Commiphora harveyi	0.00
Cussonia zuluensis	0.00
Diospyros spp.	0.00
Diospyros whyteana	0.00
Dombeya rotundifolia	0.00
Dombeya tiliacea	0.00
Euclea natalensis	0.00
Galpinia transvaalica	0.00
Gardenia volkensii	0.00
Grewia monticola	0.00
Grewia spp.	0.00
Hippobromus pauciflorus	0.00
Lippia javanica	0.00
Maytenus senegalensis	0.00
Monanthotaxis caffra	0.00
Olea europaea	0.00
Rhus rehmanniana	0.00
Schotia brachypetala	0.00
Sclerocarya birrea	0.00
Sesbania punicea	0.00
Sesbania sesban	0.00
Sideroxylon inerme	0.00
Strychnos madagascariensis	0.00
Unknown 1	0.00
Unknown 2	0.00
Unknown 3	0.00
Unknown 4	0.00
Zanthoxylum capense	0.00

FIGURE 7.1 Relative contributions to the diet and habitat of the six species which occurred in both study areas' lists of "top 10 ,most important species" in the black rhino woody plant diet. Relative percentages were calculated using the total % score for the six species as the denominator. Indices of Dissimilarity calculated as per Hammond & McCullagh (1974). The Index of Dissimilarity is also known as Florence's (1948) Coefficient of Localisation and Smith's (1969) Index of Change.

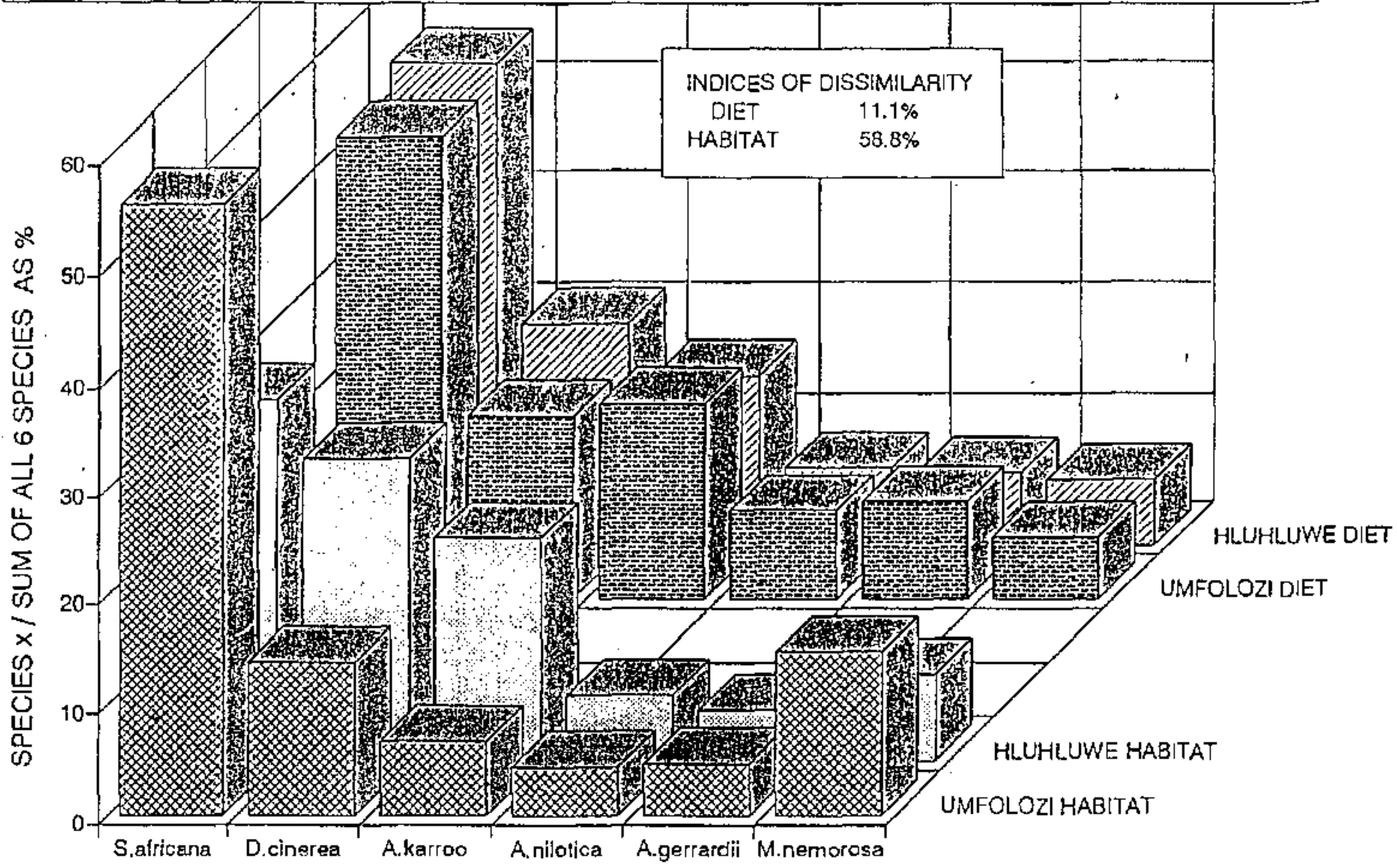


Figure 7.1 illustrates this quite clearly. In Figure 7.1 the above percentages for the six species were scaled to add up to 100%. Indices of Dissimilarity (also known as Florence's (1948) Coefficient of Localisation and Smith's (1969) Index of Change) were then calculated as per Hammond & McCullagh (1974). While the Index of Dissimilarity between Hluhluwe and Umfolozi for the six species in the diet was only 11.1%, the comparable figure for the six species in the habitat was 58.8%. This finding suggests that there may be a limit to the amount of a certain species a black rhino may choose to eat irrespective of its abundance in the habitat (e.g. *S.africana*). If this is true there are important implications for habitat assessments and the feeding of cut browse to boma'ed black rhino. This behaviour could be due to the need to obtain different micro and macro nutrients or specific fatty acids (Bruce Davidson pers.comm..) from different species; and/or a direct result of the build up of defensive secondary plant chemicals. Extensive analysis of browse chemistry is needed if selection patterns are to be fully understood.

o *B.zeyheri* and *Abutilon/Hibiscus* species were other important dietary components in Hluhluwe (6.14% and 3.43% respectively).

o In Umfolozi, other important dietary species were *Ehretia rigida/amoena* (5.39%), *Schotia capitata* (3.01%) and five *Grewia* species which together made up 3.1 % of the diet.

o With the exception of *M.nemorosa*, *Maytenus* species were relatively unimportant dietary items - *M.heterophylla* and *M.senegalensis* together contributing only 0.14% and 0.08% to Hluhluwe and Umfolozi diets.

o The Grid survey indicates that the dietary importance of *Solanum* species and *D.lycioides* was overestimated by the Pilot survey. These species only accounted for 1.00% of browse offtake in the Hluhluwe Grid survey.

o As a group, *Eucleas* only accounted for 0.62% of total offtake in Hluhluwe and 0.37% in Umfolozi. This contrasts with their major contribution to Total available bottles (Hluhluwe: 10.52% Umfolozi: 12.90%).

o *Rhus* species were also unimportant, contributing only 1.03% and 0.59% to the Hluhluwe and Umfolozi diets.

TABLE 7.7

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL NEW BROWSE BOTTLES EATEN
HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (New)
Dichrostachys cinerea	22.77
Acalypha glabrata	21.49
Acacia caffra	13.04
Acacia karroo	7.35
Spirostachys africana	6.24
Acacia robusta	3.21
Acacia nilotica	3.21
Hippobromus pauciflorus	3.12
Berchemia zeyheri	2.75
Acacia gerrardii	1.84
Diospyros simii	1.74
Maytenus nemorosa	1.56
Zizyphus mucronata	1.38
Croton sylvaticus	1.19
Lippia javanica	1.10
Dombeya burgessiae	.92
Ficus sur	.73
Adenopodia spicata	.64
Indigofera natalensis/cylindrica	.64
Coddia rudis	.55
Scutia myrtina	.55
Galpinia transvaalica	.46
Diospyros lycioides	.37
Ficus sycomorus	.37
Forb spp.	.37
Celtis africana	.28
Dovyalis caffra	.28
Solanum	.28
Unknown 8	.28
Acacia grandicornuta	.18
Ehretia rigida/amoena	.18
Plectroniella armata	.18
Rhus rehmanniana	.18
Scolopia zeyheri	.18
Acacia burkei	.09
Asparagus spp.	.09
Monanthotaxis caffra	.09
Phyllanthus reticulatus	.09
Abutilon/Hibiscus spp.	0.00
Acacia schweinfurthii/ataxacantha	0.00
Acalypha sonderiana	0.00
Aloe marlothii	0.00
Asclepias fruticosa	0.00
Azima tetracantha	0.00
Bequaertiodendron natalense	0.00
Bersama lucens	0.00
Canthium inerme	0.00
Canthium spp.	0.00
Capparis sepiaria	0.00
Capparis tomentosa	0.00
Cassine aethiopica	0.00
Cassine transvaalensis	0.00
Chaetachme aristata	0.00
Chromolaena odorata	0.00
Clausena anisata	0.00

HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (New)
Clutia pulchella	0.00
Cola greenwayi	0.00
Combretum molle	0.00
Commiphora harveyi	0.00
Cordia caffra	0.00
Crotalaria capensis	0.00
Cussonia zuluensis	0.00
Cussonia spp.	0.00
Dalbergia armata	0.00
Dalbergia obovata	0.00
Diospyros spp.	0.00
Diospyros whyteana	0.00
Dombeya rotundifolia	0.00
Erythroxylum emarginatum	0.00
Euclea crispa	0.00
Euclea divinorum	0.00
Euclea natalensis	0.00
Euclea racemosa	0.00
Eugenia natalitia	0.00
Ficus glumosa	0.00
Ficus spp.	0.00
Geranium spp.	0.00
Grewia caffra	0.00
Grewia flavescens	0.00
Grewia occidentalis	0.00
Harpephyllum caffrum	0.00
Heteropyxis natalensis	0.00
Kraussia floribunda	0.00
Lycium acutifolium	0.00
Manilkara concolor	0.00
Manilkara discolor	0.00
Maytenus heterophylla	0.00
Maytenus senegalensis	0.00
[illegible] didyma	0.00
Ochna natalitia	0.00
Oricia bachmannii	0.00
Ormocarpum trichocarpum	0.00
Ozoroa engleri	0.00
Pancovia golungensis	0.00
Pappea capensis	0.00
Peltophorum africanum	0.00
Psychotria capensis	0.00
Rhoicissus rhomboidea	0.00
Rhoicissus tomentosa	0.00
Rhoicissus tridentata	0.00
Rhus chirindensis	0.00
Rhus gueinzii	0.00
Rhus pentheri	0.00
Rhus spp.	0.00
Schotia brachypetala	0.00
Sclerocarya birrea	0.00
Sesbania sesban	0.00
Sideroxylon inerme	0.00
Strychnos innocua	0.00
Strychnos madagascariensis	0.00
Tarchonanthus camphoratus	0.00

Table 7.7

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL NEW BROWSE BOTTLES EATEN
HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (New)
Teclea gerrardii	0.00
Teclea natalensis	0.00
Thespesia acutiloba	0.00
Trema orientalis	0.00
Trichocladus grandiflorus	0.00
Turraea floribunda	0.00
Unknown 15	0.00
Vernonia subuligera	0.00
Vitellariopsis marginata	0.00
Vitex harveyana	0.00
Ximenia caffra	0.00
Zanthoxylum capense	0.00

TABLE 7.8

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL OLD BROWSE BOTTLES EATEN
HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (Old)
Spirostachys africana	32.82
Acalypha glabrata	10.28
Acacia karroo	8.64
Berchemia zeyheri	8.15
Abutilon/Hibiscus spp.	5.47
Acacia gerrardii	4.60
Maytenus nemorosa	4.21
Acacia nilotica	4.16
Dichrostachys cinerea	3.39
Croton sylvaticus	3.28
Acacia robusta	1.75
Dovyalis caffra	1.64
Rhus pentheri	1.53
Dombeya burgessiae	1.20
Diospyros lycioides	1.15
Zizyphus mucronata	1.15
Euclea racemosa	.88
Diospyros simii	.82
Acacia caffra	.55
Dombeya rotundifolia	.55
Galpinia transvaalica	.44
Geranium spp.	.44
Hippobromus pauciflorus	.44
Scutia myrtina	.33
Ehretia rigida/amoena	.27
Plectroniella armata	.27
Coddia rudis	.22
Combretum molle	.22
Maytenus senegalensis	.22
Sideroxylon inerme	.22
Scolopia zeyheri	.16
Cassine aethiopica	.11
Celtis africana	.11
Euclea crispa	.11
Canthium spp.	.05
Lippia javanica	.05
Solanum	.05
Zanthoxylum capense	.05
Acacia burkei	0.00
Acacia grandicornuta	0.00
Acacia schweinfurthii/ataxacantha	0.00
Acalypha sonderiana	0.00
Adenopodia spicata	0.00
Aloe marlothii	0.00
Asclepias fruticosa	0.00
Asparagus spp.	0.00
Azima tetracantha	0.00
Bequaertiodendron natalense	0.00
Bersama lucens	0.00
Canthium inerme	0.00
Capparis sepiaria	0.00
Capparis tomentosa	0.00
Cassine transvaalensis	0.00
Chaetachme aristata	0.00
Chromolaena odorata	0.00

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL OLD BROWSE BOTTLES EATEN
HLUHLUWE GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (Old)
Clausena anisata	0.00
Clutia pulchella	0.00
Cola greenwayi	0.00
Commiphora harveyi	0.00
Cordia caffra	0.00
Crotalaria capensis	0.00
Cunonia capensis	0.00
Cussonia spp.	0.00
Dalbergia armata	0.00
Dalbergia obovata	0.00
Diospyros spp.	0.00
Diospyros whyteana	0.00
Erythroxylum emarginatum	0.00
Euclea divinorum	0.00
Euclea natalensis	0.00
Eugenia natalitia	0.00
Ficus glumosa	0.00
Ficus spp.	0.00
Ficus sur	0.00
Ficus sycomorus	0.00
Forb spp.	0.00
Grewia caffra	0.00
Grewia flavescens	0.00
Grewia occidentalis	0.00
Harpephyllum caffrum	0.00
Heteropyxis natalensis	0.00
Indigofera natalensis/cylindrica	0.00
Kraussia floribunda	0.00
Lycium acutifolium	0.00
Manilkara concolor	0.00
Manilkara discolor	0.00
Maytenus heterophyla	0.00
Melanthus didyma	0.00
Monanthotaxis caffra	0.00
Ochna natalitia	0.00
Oricia bachmannii	0.00
Ormocarpum trichocarpum	0.00
Ozoroa engleri	0.00
Pancovia golungensis	0.00
Pappea capensis	0.00
Peltophorum africanum	0.00
Phyllanthus reticulatus	0.00
Psychotria capensis	0.00
Rhoicissus rhomboidea	0.00
Rhoicissus tomentosa	0.00
Rhoicissus tridentata	0.00
Rhus chirindensis	0.00
Rhus gueinzii	0.00
Rhus rehmanniana	0.00
Rhus spp.	0.00
Schotia brachypetala	0.00
Sclerocarya birrea	0.00
Sesbania sesban	0.00
Strychnos innocua	0.00
Strychnos madagascariensis	0.00
Tarchonanthus camphoratus	0.00

TABLE 7.9

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL NEW BROWSE BOTTLES EATEN
UMFOLOZI GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (New)
Spirostachys africana	17.09
Dichrostachys cinerea	11.11
Acacia gerrardii	9.26
Acacia karroo	8.97
Acacia borleae	8.26
Maytenus nemorosa	5.27
Acacia nilotica	3.70
Capparis tomentosa	3.56
Acacia tortilis	2.85
Acacia caffra	2.71
Croton menyhartii	2.14
Ehretia rigida/amoena	2.14
Schotia capitata	1.99
Pappia capensis	1.42
Plectroniella armata	1.42
Tarchonanthus camphoratus	1.42
Cassine transvaalensis	1.28
Asparagus spp.	1.14
Sida cordifolia/rhombifolia	1.14
Acacia nigrescens	1.00
Boscia albitrunca	1.00
Grewia flavescens	1.00
Grewia occidentalis	1.00
Acacia robusta	.85
Scolopia zeyheri	.85
Acacia grandicornuta	.71
Grewia villosa	.71
Melia azedarach	.71
Azima tetracantha	.57
Commiphora neglecta	.57
Grewia flava	.57
Rhus gueinzii	.57
Erythrina lysistemon	.43
Maytenus heterophylla	.43
Brachylaena ilicifolia	.28
Crotolaria capensis	.28
Unknown 6	.28
Acacia luederitzii	.14
Acacia senegal	.14
Berchemia zeyheri	.14
Diospyros lycioides	.14
Gardenia cornuta	.14
Maerua angolensis	.14
Ormocarpum trichocarpum	.14
Rhoicissus rhomboidea	.14
Unknown 15	.14
Acacia burkei	0.00
Aloe marlothii	0.00
Cadaba natalensis	0.00
Canthium spp.	0.00
Capparis sepiaria	0.00
Carissa bispinosa	0.00
Cazine tetragona	0.00
Cassine aethiopica	0.00
Clutia pulchella	0.00
Coddia rudis	0.00
Combretum apiculatum	0.00
Commiphora harveyi	0.00
Cussonia zuluensis	0.00
Diospyros spp.	0.00
Diospyros whyteana	0.00
Dombeya rotundifolia	0.00
Dombeya tiliacea	0.00
Euclea divinorum	0.00
Euclea natalensis	0.00
Euclea racemosa	0.00
Euclea undulata	0.00
Galpinia transvaalica	0.00
Gardenia volkensii	0.00
Grewia bicolor	0.00
Grewia monticola	0.00
Grewia spp.	0.00
Hippobromus pauciflorus	0.00
Lippia javanica	0.00
Lycium acutifolium	0.00
Maytenus senegalensis	0.00
Melanthus didyma	0.00
Monanthotaxis caffra	0.00
Olea europaea	0.00
Ozoroa engleri	0.00
Pyrostria hystrix	0.00
Rhus pentheri	0.00
Rhus rehmanniana	0.00
Schotia brachypetala	0.00
Sclerocarya birrea	0.00
Sesbania punicea	0.00
Sesbania sesban	0.00
Sideroxylon inerme	0.00
Solanum	0.00
Strychnos madagascarensis	0.00
Strychnos spp.	0.00
Unknown 1	0.00
Unknown 2	0.00
Unknown 3	0.00
Unknown 4	0.00
Unknown 5	0.00
Zanthoxylum capense	0.00
Zizyphus mucronata	0.00

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL NEW BROWSE BOTTLES EATEN
UMFOLOZI GAME RESERVE 1989 GRID STUDY AREA

TABLE 7.10

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL OLD BROWSE BOTTLES EATEN
UMFOLOZI GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (Old)
Spirostachys africana	26.37
Acacia karroo	10.95
Dichrostachys cinerea	9.71
Ehretia rigida/amoena	6.33
Acacia nilotica	5.85
Acacia borleae	4.89
Acacia tortilis	4.72
Acacia gerrardii	4.36
Schotia capitata	3.25
Acacia sengal	2.85
Maytenus nemorosa	2.76
Croton menyhartii	2.30
Grewia flava	1.38
Asparagus spp.	1.18
Brachylaena ilicifolia	1.18
Commiphora neglecta	1.12
Ormocarpum trichocarpum	.85
Acacia caffra	.82
Grewia occidentalis	.75
Acacia robusta	.72
Grewia bicolor	.69
Zizyphus mucronata	.56
Acacia nigrescens	.52
Azima tetracantha	.52
Tarchonanthus camphoratus	.49
Capparis tomentosa	.39
Gardenia cornuta	.39
Pappia capensis	.36
Plectroniella armata	.36
Acacia luederitzii	.33
Rhus pentheri	.33
Boscia albitrunca	.30
Cassine transvaalensis	.26
Rhoicissus rhombidea	.26
Rhus gueinzii	.26
Sida cordifolia/rhombifolia	.26
Unknown 15	.26
Acacia grandicornuta	.23
Coddia rudis	.23
Salanum	.23
Euclea divinorum	.20
Euclea racemosa	.20
Grewia villosa	.16
Cadaba natalensis	.13
Lycium acutifolium	.13
Pyrostria hystrix	.10
Euclea undulata	.07
Grewia flavescens	.07
Ozoroa engleri	.07
Strychnos spp.	.07
Unknown 5	.07
Unknown 6	.07
Berchemia zeyheri	.03

CONTRIBUTION TO DIET OF EACH SPECIES : % TOTAL OLD BROWSE BOTTLES EATEN
UMFOLOZI GAME RESERVE 1989 GRID STUDY AREA

Species	% Bottles (Old)
Acacia burkei	0.00
Aloe marlothii	0.00
Canthium spp.	0.00
Capparis sepiaria	0.00
Carissa bispinosa	0.00
Casine tetragona	0.00
Cassine aethiopica	0.00
Clutia pulchella	0.00
Combretum apiculatum	0.00
Commiphora harveyi	0.00
Crotalaria capensis	0.00
Cussonia zuluensis	0.00
Diospyros spp.	0.00
Diospyros whyteana	0.00
Dombeya rotundifolia	0.00
Dombeya tiliacea	0.00
Erythrina lysistemon	0.00
Euclea natalensis	0.00
Galpinia transvaalica	0.00
Gardenia volkensii	0.00
Grewia monticola	0.00
Grewia spp.	0.00
Hippobromus pauciflorus	0.00
Lippia javanica	0.00
Maerua angolensis	0.00
Maytenus heterophylla	0.00
Maytenus senegalensis	0.00
Melia azedarach	0.00
Monanthotaxis caffra	0.00
Olea europaea	0.00
Rhus rehmanniana	0.00
Schotia brachypetala	0.00
Sclerocarya birrea	0.00
Scolopia zeyheri	0.00
Sesbania punicea	0.00
Sesbania sesban	0.00
Sideroxylon inerme	0.00
Strychnos madagascarensis	0.00
Unknown 1	0.00
Unknown 2	0.00
Unknown 3	0.00
Unknown 4	0.00
Zanthazylum capense	0.00

DIFFERENCES BETWEEN LATE SUMMER (NEW) AND OLDER (OLD) BROWSING

Tables 7.7, 7.8 (Hluhluwe) and 7.9 and 7.10 (Umfolozi) list the woody species in order of their dietary importance broken down into late summer diet (new bottles browsed) and the diet during the rest of the year (old bottles). When comparing directly between Umfolozi and Hluhluwe it should be remembered that Umfolozi plots were measured on average about 1 month later than the Hluhluwe plots.

o *S.africana* and *A.karroo* appear to be less important dietary items in late summer (%NewDiet|%OldDiet Hluhluwe 13.59|41.46 Umfolozi 26.06|37.32).

o *D.cinerea, A.glabrata* and *A.caffra* appear to contribute more to late summer browsing (%NewDiet|%OldDiet Hluhluwe 57.30|14.22 Umfolozi 13.82|10.53).

o The differential contribution of "*Acacia*" species to the diet in the two study areas was most marked in late summer (Hluhluwe 23.1% and Umfolozi 49.7%).

PREFERRED AND REJECTED BROWSE SPECIES

PREFERENCE AND REJECTION INDICES BASED ON BROWSE BOTTLE DATA

Tables 7.11 and 7.12 present Species Preference indices based on browse bottle data, together with supporting dietary importance and availability data. The Free Preference index was used as the primary preference ratio as Free Bottles (that is browse bottles within black rhino reach, but not hidden by grass) better describes available browse as seen through the eyes of a black rhino (compared to Total Bottles).

The ratio of Free:Total bottles indicates the relative degree of grass interference on each species. Species with values lower than 1 have higher levels of grass interference than average.

High ratios of percentage Canopy Cover: Total bottles (CC:TB ratios) indicate taller species where most foliage is not available to black rhino.

PREFERRED SPECIES

A comparison of Tables 7.11 and 7.12 reveals that:

o Many of the most important species in the diet were also the most preferred species.

o In Umfolozi the 7 most highly preferred species were all "Acacias". (*A.senegal* also appears to have been highly preferred in Umfolozi, but this species does not appear on Table 7.11 as it contributed less than 0.25% of all Free bottles in the habitat.)

o In Hluhluwe, 3 of the 4 most highly preferred species were Acacias. The ubiquitous *D.cinerea* and *A.karroo* were also preferred species in Hluhluwe.

o *S.africana*, *A.karroo*, *A.gerrardii* and *A.nilotica* were preferred species in both study areas.

o In Hluhluwe, *A.glabrata*, *B.zeyheri*, *Abutilon/Hibiscus*, *H.pauciflorus*, *D.caffra*, and *D.burgessiae* were also preferred species. These species were rare in Umfolozi only contributing 0.09% of Total available browse bottles.

o In Umfolozi *A.borleae*, *A.tortilis*, *E.rigida/amoena*, *Grewia flava*, *Commiphora neglecta*, *Capparis tomentosa*, *G.occidentalis* and *Azima tetracantha* were preferred species. These species were rare in Hluhluwe only contributing 1.10% of Total available browse bottles.

TABLE 7.11

HLUHLUWE 1989 GRID SURVEY
SPECIES PREFERENCE RATIOS (For Species with %FreeBottles >= 0.25%)
DATA SORTED BY % CONTRIBUTION TO TOTAL WOODY DIET (Old & New Bottles)

Key to Free Preference Index Symbols : *** Highly Prefered (>=2.75); ** Prefered (2-2.74);
* Slight preference (1.25-1.99); - Slight rejection (0.5-0.79); -- Rejected (0.36-0.49);
and --- Highly rejected (<0.36)

Species	Free Pref Index		Total Pref Index	Cover Pref Index	%Total Bottles	%Free Bottles	%Canopy Cover	%AllBotEaten	Free:Total Bot.	Ccover:Total Bot.
Spirostachys africana	***	3.14	3.96	6.59	5.79	7.28	3.47	22.90	1.26	.60
Acalypha glabrata	**	2.53	3.28	6.75	4.41	5.72	2.14	14.47	1.30	.49
Dichrostachys cinerea	*	1.74	1.37	1.71	7.73	6.11	6.22	10.63	.79	.80
Acacia karroo	*	1.83	1.50	1.90	5.44	4.46	4.30	6.16	.82	.79
Berchemia zeyheri	*	1.69	2.09	.87	2.94	3.25	7.07	6.14	1.11	2.40
Acacia caffra		.92	.90	2.01	5.78	5.64	2.60	5.21	.98	.45
Acacia nilotica	***	2.92	2.43	.70	1.36	1.30	5.45	3.81	.83	3.49
Acacia gerrardii	***	3.55	4.36	22.26	.82	1.01	.16	3.57	1.23	.20
Abutilon/Hibiscus spp.	*	1.72	2.10	8.33	1.63	1.99	.41	3.43	1.22	.25
Maytenus nemorosa	*	1.88	2.29	1.47	1.41	1.72	2.19	3.22	1.22	1.56
Acacia robusta	***	6.87	6.75	1.88	.34	.33	1.22	2.30	.98	3.59
Hippobromus pauciflorus	***	3.12	2.57	2.12	.56	.46	.68	1.44	.82	1.21
Zizyphus mucronata		1.05	1.00	1.10	1.24	1.17	1.12	1.23	.95	.91
Diospyros simii	-	.59	.69	.71	1.70	1.96	1.63	1.17	1.16	.96
Dovyalis caffra	**	2.51	2.97	2.96	.38	.45	.38	1.13	1.19	1.00
Dombeya burgessiae	*	1.43	1.40	1.99	.78	.77	.55	1.10	.98	.70
Rhus pentheri	---	.18	.21	.15	4.62	5.24	6.58	.96	1.14	1.42
Diospyros lycioides	---	.19	.16	.27	5.53	4.62	3.21	.86	.84	.58
Euclea racemosa	---	.13	.15	.05	3.60	4.29	12.12	.55	1.19	3.37
Galpinia transvaalica		.88	.91	.87	.49	.51	.51	.45	1.04	1.04
Lippia javanica	---	.11	.09	.20	5.22	3.95	2.29	.45	.76	.44
Scutia myrtina	---	.16	.20	.15	2.08	2.51	2.77	.41	1.21	1.33
Coddia rudis	--	.36	.42	1.57	.81	.95	.22	.34	1.16	.27
Dombeya rotundifolia	--	.39	.31	.58	1.09	.88	.59	.34	.81	.54
Adenopodia spicata	-	.72	.92	.30	.26	.33	.79	.24	1.27	3.02
Ehretia rigida/amoena	--	.49	.56	.78	.43	.49	.31	.24	1.13	.72
Plectroniella armata	---	.16	.20	.22	1.21	1.47	1.08	.24	1.21	.90
Scolopia zeyheri	--	.45	.56	.44	.31	.38	.39	.17	1.24	1.26
Combretum molle	--	.44	.45	.18	.31	.31	.77	.14	1.02	2.53
Maytenus senegalensis	---	.04	.05	.08	3.02	3.07	1.67	.14	1.02	.55
Sideroxylon inerme	---	.24	.27	.15	.50	.58	.88	.14	1.16	1.77
Solanum	---	.10	.09	.10	1.76	1.44	1.33	.14	.82	.76
Cassine aethiopica	---	.27	.33	.11	.21	.26	.63	.07	1.24	3.07
Euclea crispa	---	.03	.02	.05	3.71	2.27	1.41	.07	.61	.38
Rhus rehmanniana	---	.12	.07	.23	.93	.57	.30	.07	.62	.32
Monanthotaxis caffra	---	.16	.13	.34	.26	.25	.10	.03	.96	.40
Phyllanthus reticulatus	---	.10	.09	.10	.38	.33	.36	.03	.88	.94
Acalypha sonderiana	---	0.00	0.00	0.00	.80	1.04	.57	0.00	1.30	.71
Azima tetracantha	---	0.00	0.00	0.00	.54	.70	.08	0.00	1.30	.15
Canthium inerme	---	0.00	0.00	0.00	.38	.38	.25	0.00	1.01	.66
Chromolaena odorata	---	0.00	0.00	0.00	.27	.33	.30	0.00	1.23	1.13
Clutia pulchella	---	0.00	0.00	0.00	.43	.46	.74	0.00	1.08	1.72
Cordia caffra	---	0.00	0.00	0.00	.71	.76	1.27	0.00	1.07	1.78
Dalbergia obovata	---	0.00	0.00	0.00	.41	.46	.70	0.00	1.13	1.73
Euclea divinorum	---	0.00	0.00	0.00	2.86	3.34	4.42	0.00	1.17	1.54
Euclea natalensis	---	0.00	0.00	0.00	.35	.45	.36	0.00	1.28	1.02
Heteropyxis natalensis	---	0.00	0.00	0.00	.51	.43	.69	0.00	.84	1.35
Kraussia floribunda	---	0.00	0.00	0.00	3.80	4.56	2.47	0.00	1.20	.65
Maytenus heterophylla	---	0.00	0.00	0.00	.52	.50	.39	0.00	.97	.75
Rhoicissus tridentata	---	0.00	0.00	0.00	2.63	1.62	1.64	0.00	.62	.62
Schotia brachypetala	---	0.00	0.00	0.00	.25	.25	.85	0.00	1.01	3.41
Sclerocarya birrea	---	0.00	0.00	0.00	.37	.28	1.20	0.00	.76	3.24
Tarchonanthus camphoratus	---	0.00	0.00	0.00	.30	.38	.26	0.00	1.28	.09
Vernonia subuligera	---	0.00	0.00	0.00	2.03	2.22	1.07	0.00	1.09	.53

TABLE 7.12

UMFOLOZI 1989 GRID SURVEY
SPECIES PREFERENCE RATIOS (For Species with %FreeBottles >= 0.25%)
DATA SORTED BY % CONTIBUTION TO TOTAL WOODY DIET (Old & New Bottles)

Key to Free Preference Index Symbols : *** Highly Prefered (>=2.75); ** Prefered (2-2.74);
* Slight preference (1.25-1.99); - Slight rejection (0.5-0.79); -- Rejected (0.36-0.49);
and --- Highly rejected (<0.36)

Species	Free Pref Index		Total Pref Index	Cover Pref Index	%Total Bottles	%Free Bottles	%Canopy Cover	%AtlBotEaten	Free:Total Bot.	CCover:Total Bot.
Spirostachys africana	**	2.03	2.15	2.76	11.46	12.11	8.93	24.63	1.06	.78
Acacia karroo	***	7.31	4.35	3.98	2.43	1.45	2.66	10.58	.59	1.09
Dichrostachys cinerea	***	3.29	2.48	2.11	4.02	3.03	4.74	9.97	.75	1.18
Acacia borleae	**	2.58	2.82	6.33	1.96	2.14	.87	5.52	1.09	.45
Ehretia rigida/amoena	*	1.59	1.62	1.61	3.31	3.39	3.35	5.39	1.02	1.01
Acacia gerrardii	***	5.29	4.41	2.80	1.20	1.00	1.89	5.28	.83	1.58
Acacia nilotica	***	5.18	3.70	2.12	1.30	.93	2.26	4.80	.71	1.74
Acacia tortilis	**	2.57	2.49	2.32	1.76	1.78	1.89	4.37	.97	1.07
Maytenus nemorosa		.99	1.09	.99	2.95	3.24	3.25	3.23	1.10	1.10
Schotia capitata		.93	1.04	1.01	2.89	3.25	2.97	3.01	1.13	1.03
Croton menyhartii	---	.15	.16	.28	13.96	15.50	8.11	2.27	1.11	.58
Grewia flava	*	1.87	1.65	1.41	.74	.65	.87	1.23	.88	1.17
Acacia caffra	***	2.95	2.27	2.77	.52	.40	.42	1.17	.77	.82
ASparagus spp.	---	.28	.27	.28	4.40	4.23	4.19	1.17	.96	.95
Commiphora neglecta	**	2.31	1.77	1.19	.57	.44	.85	1.01	.77	1.48
Brachylaena ilicifolia	---	.25	.27	.47	3.82	4.05	2.14	1.01	1.06	.56
Capparis tomentosa	*	1.39	1.06	.84	.93	.71	1.18	.99	.76	1.26
Grewia occidentalis	*	1.56	1.40	.85	.57	.51	.94	.80	.98	1.65
Acacia robusta		1.07	1.17	.60	.64	.70	1.25	.75	1.10	1.95
Tarchonanthus camphoratus	---	.20	.17	.20	3.84	3.39	3.30	.67	.88	.86
Acacia nigrescens	-	.68	.59	.12	1.04	.90	5.28	.61	.86	5.06
Pappia capensis		1.16	1.26	.28	.44	.48	1.98	.56	1.09	4.45
Plectroniella armata	---	.29	.31	.32	1.79	1.93	1.77	.56	1.08	.99
Azima tetracantha	*	1.59	1.43	.71	.37	.33	.75	.53	.90	2.03
Zizyphus mucronata	-	.75	.76	.58	.60	.61	.78	.45	1.01	1.30
Acacia grandicornuta	---	.09	.10	.07	3.34	3.48	4.48	.32	1.02	1.34
Rhus gueinzii	--	.37	.38	.54	.84	.85	.59	.32	1.02	.70
Acacia luederitzii	--	.39	.43	.14	.69	.75	2.05	.29	1.09	2.98
Rhus pentheri	---	.19	.17	.35	1.56	1.39	.75	.27	.89	.48
Grewia flavescens	---	.21	.23	.33	1.05	1.16	.73	.24	1.10	.69
Rhoicissus rhomboidea	-	.64	.66	.39	.36	.37	.61	.24	1.03	1.69
Coddia rudis	---	.33	.31	.36	.61	.57	.52	.19	.93	.85
Euclea divinorum	---	.03	.03	.05	5.85	5.96	3.28	.16	1.02	.56
Euclea racemosa	---	.08	.08	.09	1.91	2.00	1.81	.16	1.85	.95
Maytenus heterophylla	---	.11	.07	.05	1.15	.75	1.63	.08	.66	1.42
Pyrostria hystrix	---	.12	.13	.12	.62	.67	.68	.08	1.10	1.11
Euclea undulata	---	.01	.01	.01	4.91	5.49	3.61	.05	1.12	.73
Carissa bispinosa	---	0.00	0.00	0.00	.63	.70	.21	0.00	1.11	.34
Maytenus senegalensis	---	0.00	0.00	0.00	.73	.54	.47	0.00	.74	.65
Olea europaea	---	0.00	0.00	0.00	.89	1.00	.94	0.00	1.13	1.06
Schotia brachypetala	---	0.00	0.00	0.00	2.67	3.01	.68	0.00	1.13	.26
Sideroxylon inerme	---	0.00	0.00	0.00	.44	.48	.54	0.00	1.09	1.24

Key to Free Preference Index Symbols : *** Highly Prefered (>=2.75); ** Prefered (2-2.74);
* Slight preference (1.25-1.99); - Slight rejection (0.5-0.79); -- Rejected (0.36-0.49);
and --- Highly rejected (<0.36)

o *A.caffra* was highly preferred in Umfolozi, but only intermediate in preference in Hluhluwe. Again rhino preference for a spize increased as its abundance decreased. *A.caffra* was the third most abundant species in Hluhluwe in terms of available bottles, but only accounted for 0.52% of available bottles in Umfolozi.

o *S.africana*, *A.robusta* and *M.nemorosa* were also less preferred in the study area where they were more abundant.

o *A.nilotica* was less preferred in Hluhluwe where a much higher proportion of *A.nilotica* foliage was out of rhino reach (CC:TB ratios Hluhluwe:3.49 Umfolozi:1.74).

INTERMEDIATE/REJECTED SPECIES

o *Ziziphus mucronata* was intermediate in acceptance in Hluhluwe and slightly rejected in Umfolozi where it formed a greater proportion of the available browse bottles.

o *Rhus* (except *R.guenzii*) and *Euclea* species were strongly rejected in both study areas as they had been in the Pilot study. *Tarchonathus camphoratus*, *S.inerme* and *P.armata* were also rejected in both study areas.

o The physically defended *A.grandicornuta* and *A.luderitzii* were rejected in Umfolozi (as found in the Pilot survey).

o In Hluhluwe, *C.caffra* and *K.floribunda* were rejected, corroborating the Pilot study findings.

o The abundant *L.javanica* and *D.lycioides* were also rejected in Hluhluwe.

o The three species with the greatest mean grass interference in Hluhluwe (*E. crispa*, *R.tridentata* and *R.rehmanniana*) were all highly rejected.

o Fifty-four species in Hluhluwe contributed at least 0.25% of all Free browse bottles in Hluhluwe. Much of the foliage was out of reach for black rhino on ten of these species (CC:TB Ratios> 2). The majority of these ten species were rejected (*E.racemosa, S.birrea, C.aethiopica, S.brachypetala, Adenopodia spicata*, and *C.molle*). Of the ten species only *B.zeyheri, A.nilotica* and *A.robusta* were preferred.

o *S.inerme* and *A.nigrescens* were the two tall species in Umfolozi with the highest proportion of their foliage unavailable to black rhino. Both species were rejected.

o Although *C.menyhartii* was the eleventh most important species in the diet it was highly rejected.

o Of eight common species in dense bush clump vegetation in Umfolozi, *M.nemorosa,* and *S.capitata* were intermediate in preference. *Rhoicissus rhomboidea* was rejected, and *E.undulata, B.ilicifolia, Olea europaea, Pyrostria hystrix,* and *Carissa bispinosa* were all highly rejected. This corroborates the finding of low preference for this community in the Pilot study.

PREFERENCE AND REJECTION INDICES BASED ON COUNT DATA

For comparative purposes, Tables 7.13 and 7.14 present species preference and abundance data calculated using count data. Different selection patterns were revealed when using the cruder count rather than browse bottle data. (The count based preference indices seemed to bear a closer resemblance to the psychological impressions about species selection gained during fieldwork. It therefore appears that human perception is most influenced by the proportion of available individual plants eaten, rather than the density of plants eaten, the fraction of the available browse eaten, or mean offtake levels per browsed plant. The latter variables contribute more to Free browse bottle derived preference indices.)

TABLE 7.13

HLUHLUWE 1989 UNIQ SURVEY
SPECIES IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES BASED ON COUNT DATA
(FOR SPECIES WITH DENSITIES OF >= 5/ha)

Species	Number	Preference Index	% Total n Eaten	% Total n Present	Tree n Eaten/Ha	Tree n Present/Ha
Abutilon/Hibiscus spp.	--	.40	.20	.50	.28	35.54
Acacia caffra	*	1.80	3.66	2.03	4.96	143.66
Acacia gerrardii	***	7.76	1.83	.24	2.48	16.67
Acacia karroo	*	1.34	6.10	4.56	8.26	322.11
Acacia nilotica	*	1.50	3.66	2.45	4.96	172.87
Acacia robusta	***	2.99	2.24	.75	3.03	52.89
Acalypha sonderiana	---	0.00	0.00	.51	0.00	35.81
Acalypha glabrata	***	4.29	10.98	2.56	14.88	180.99
Adenopodia spicata	*	1.97	.20	.10	.29	7.30
Asparagus spp.	**	2.67	.20	.08	.28	5.37
Azima tetracantha	---	0.00	0.00	.09	0.00	6.47
Berchemia zeyheri	*	1.55	5.69	3.67	7.71	259.37
Canthium inerme	---	0.00	0.00	.31	0.00	21.90
Capparis tomentosa	---	0.00	0.00	.11	0.00	7.85
Cassine aethiopica		1.23	.20	.17	.28	11.71
Celtis africana	**	2.06	1.02	.49	1.38	34.85
Chaetachme aristata	---	0.00	0.00	.15	0.00	10.74
Chromolaena odorata	---	0.00	0.00	.10	0.00	6.89
Clausena anisata	---	0.00	0.00	.11	0.00	7.71
Clutia pulchella	---	0.00	0.00	.58	0.00	41.05
Coddia rudis	**	2.01	1.02	.50	1.38	35.67
Combretum molle	-	.55	.20	.37	.28	26.31
Cordia caffra	---	0.00	0.00	1.08	0.00	76.45
Croton sylvaticus	***	10.18	.81	.08	1.10	5.65
Cunonia capensis	---	0.00	0.00	.09	0.00	6.06
Dalbergia armata	---	0.00	0.00	.11	0.00	7.71
Dalbergia obovata	---	0.00	0.00	.83	0.00	58.40
Dichrostachys cinerea	*	1.68	15.85	9.42	21.49	665.98
Diospyros lycioides	---	.20	1.02	4.99	1.38	352.69
Diospyros simii	-	.53	1.42	2.69	1.93	190.43
Diospyros spp.	---	0.00	0.00	.25	0.00	17.77
Dombeya burgessiae	***	4.11	1.63	.40	2.20	27.96
Dombeya rotundifolia	---	.17	.20	1.18	.28	83.20
Dovyalis caffra	***	3.20	1.02	.32	1.38	22.45
Ehretia rigida/amoena	*	1.68	.81	.49	1.10	34.30
Euclea crispa	---	.05	.20	4.09	.28	289.39
Euclea divinorum	---	0.00	0.00	2.95	0.00	208.33
Euclea natalensis	---	0.00	0.00	.42	0.00	30.03
Euclea racemosa	---	.09	.61	6.86	.83	484.71
Forb spp.	-	.61	.20	.33	.28	23.42
Galpinia transvaalica	**	2.39	1.02	.42	1.38	30.03
Grewia occidentalis	---	0.00	0.00	.14	0.00	9.64
Heteropyxis natalensis	---	0.00	0.00	.47	0.00	33.20
Hippobromus pauciflorus	**	2.34	2.24	.96	3.03	67.56
Kraussia floribunda	---	0.00	0.00	4.37	0.00	308.95
Lippia javanica	---	.08	.41	4.97	.55	351.03
Maytenus heterophylla	---	0.00	0.00	.48	0.00	33.75
Maytenus nemorosa	**	2.36	2.85	1.21	3.86	85.26
Maytenus senegalensis	---	.09	.20	2.22	.28	157.16
Melanthus didyma	---	0.00	0.00	.08	0.00	5.51
Monanthotaxis caffra	-	.67	.20	.30	.28	21.35
Pancovia golungensis	---	0.00	0.00	.17	0.00	11.98
Peltophorum africanum	---	0.00	0.00	.15	0.00	10.88
Phyllanthus reticulatus	---	.34	.20	.60	.28	42.56
Plectroniella armata	--	.46	.61	1.34	.83	94.45
Rhoicissus tridentata	---	0.00	0.00	3.88	0.00	274.04
Rhus chirindensis	---	0.00	0.00	.20	0.00	14.33
Rhus pentheri	---	.12	.41	3.41	.55	241.05
Rhus rehmanniana	-	.51	.20	.40	.28	28.37
Rhus spp.	---	0.00	0.00	.10	0.00	7.02
Schotia brachypetala	---	0.00	0.00	.27	0.00	19.15
Sclerocarya birrea	---	0.00	0.00	.21	0.00	14.88
Scolopia zeyheri		.88	.61	.69	.83	48.90
Scutia myrtina	-	.58	1.02	1.76	1.38	124.72
Sesbania sesban	---	0.00	0.00	.19	0.00	13.09
Sideroxylon inerme	--	.39	.20	.52	.28	36.64
Solanum	---	.32	1.63	5.09	2.20	359.92
Spirostachys africana	***	5.37	23.37	4.35	31.68	307.79
Tarchonanthus camphoratus	---	0.00	0.00	.22	0.00	15.70
Unknown 15	---	0.00	0.00	.14	0.00	10.19
Vernonia subuligera	---	0.00	0.00	1.33	0.00	93.80
Ximenia caffra	---	0.00	0.00	.09	0.00	6.47
Zanthoxylum capense	-	.57	.20	.35	.28	25.07
Zizyphus mucronata	**	2.17	1.63	.75	2.20	52.89

Key to Free Preference Index Symbols : *** Highly Prefered (>=2.75); ** Prefered (2-2.74);
* Slight preference (1.25-1.99); - Slight rejection (0.5-0.79); -- Rejected (0.36-0.49);
and --- Highly rejected (<0.36)

TABLE 7.14

UMFOLOZI 1989 GRID SURVEY
SPECIES IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES BASED ON COUNT DATA
(FOR SPECIES WITH DENSITIES OF >= 5/ha)

Species	Number	PreferenceIndex	% Total n Eaten	% Total n Present	Tree n Eaten/Ha	Tree n Present/Ha
Acacia borleae	***	2.88	3.45	1.20	8.91	30.30
Acacia caffra	***	3.16	2.21	.70	5.70	17.65
Acacia gerrardii	*	1.42	4.00	2.82	10.34	71.48
Acacia grandicornuta	---	.14	.69	4.78	1.78	120.86
Acacia karroo	*	1.99	7.03	3.54	18.18	89.66
Acacia luederitzii	--	.46	.41	.89	1.07	22.64
Acacia nigrescens	-	.52	1.52	2.90	3.92	73.44
Acacia nilotica	*	1.35	4.14	3.06	10.70	77.36
Acacia robusta		.88	.83	.94	2.14	23.71
Acacia sengal	***	3.46	1.66	.48	4.28	12.12
Acacia tortilis	**	2.27	4.28	1.88	11.05	47.59
Asparagus spp.	--	.42	2.48	5.89	6.42	149.16
Azima tetracantha		1.19	.83	.70	2.14	17.65
Boscia albitrunca	*	1.33	.55	.42	1.43	10.52
Brachylaena ilicifolia	---	.35	1.24	3.50	3.21	88.59
Capparis sepiaria	---	0.00	0.00	.23	0.00	5.70
Capparis tomentosa		1.04	1.24	1.20	3.21	30.30
Carissa bispinosa	---	0.00	0.00	.53	0.00	13.37
Cassine transvaalensis	***	2.80	.83	.30	2.14	7.49
Coddia rudis	-	.62	.41	.67	1.07	16.93
Combretum apiculatum	---	0.00	0.00	.32	0.00	8.16
Commiphora neglecta	-	.62	.55	.89	1.43	22.64
Croton menyhartii	---	.22	1.38	6.34	3.57	160.43
Dichrostachys cinerea	*	1.96	16.41	8.36	42.42	211.55
Ehretia rigida/amoena		.83	4.55	5.50	11.76	139.22
Euclea divinorum	---	.14	.41	2.99	1.07	75.58
Euclea racemosa	---	.07	.14	1.94	.36	49.20
Euclea undulata	---	.09	.14	1.58	.36	39.93
Grewia flava	*	1.37	1.38	1.01	3.57	25.49
Grewia flavescens	--	.38	.14	.36	.36	9.09
Grewia occidentalis		1.00	1.24	1.24	3.21	31.37
Grewia villosa	-	.75	.41	.55	1.07	13.90
Maytenus heterophylla	---	.12	.28	2.28	.71	57.75
Maytenus nemorosa	*	1.56	2.34	1.51	6.06	38.15
Maytenus senegalensis	---	0.00	0.00	.92	0.00	23.35
Nelanthus didyma	---	.08	.14	1.75	.36	44.17
Olea europaea	---	0.00	0.00	.32	0.00	8.02
Ornocarpum trichocarpum		1.19	1.38	1.16	3.57	29.23
Pappea capensis	*	1.56	1.24	.80	3.21	20.14
Plectroniella armata	-	.67	1.10	1.66	2.85	41.89
Pyrostria hystrix	---	.22	.14	.64	.36	16.22
Rhoicissus rhomboidea	--	.38	.28	.72	.71	18.18
Rhus gueinzii	-	.62	.41	.67	1.07	16.93
Rhus pentheri	---	.17	.14	.80	.36	20.32
Schotia brachypetala	---	0.00	0.00	.25	0.00	6.42
Schotia capitata	*	1.77	1.66	.94	4.28	23.71
Sida cordifolia/rhombifolia	-	.66	1.10	1.66	2.85	42.07
Sideroxylon inerme	---	0.00	0.00	.35	0.00	8.73
Solanum	-	.76	.69	.91	1.78	22.99
Spirostachys africana	**	2.15	18.90	8.78	48.84	222.28
Tarchonanthus camphoratus	--	.48	1.10	2.28	2.85	57.75
Unknown 15	**	2.12	.55	.26	1.43	6.60
Zizyphus mucronata		1.02	.55	.54	1.43	13.73

The main differences were that:

1] *Z.mucronata* was listed a preferred species in both reserves using binomial data while it was only listed as intermediate in acceptance in Hluhluwe and slightly rejected in Umfolozi using Free bottle data; and

2] A number of the commoner *Acacia* species received lower preference ratings.

HLUHLUWE

In the Hluhluwe Study Area:

A.gerrardii, A.robusta, A.glabrata, C.sylvaticus, D.burgessiae, D.caffra and *S.africana* were listed as highly preferred using the binomial data.

Protoasparagus species, Celtis africana, C.rudis, Galpinia transvaalica, H.pauciflorus, M.nemorosa, and *Z.mucronata* were listed as preferred species.

A.caffra, A.karroo, A.nilotica, Adenopodia spicata, B.zeyheri, D.cinerea, and *E.rigida/amoena* were listed as slightly preferred.

UMFOLOZI

In the Umfolozi Study Area:

A.borleae, A.caffra, A.senegal and *Cassine transvaalensis* were listed as highly preferred using the binomial data.

A.tortilis and *Z.mucronata* were listed as preferred species.

A.gerrardii, A.karroo, A.nilotica, Boscia albitrunca, D.cinerea, G.flava, M.nemorosa, Pappea capensis and *S.capitata* were listed as slightly preferred.

IMPORTANT, PREFERRED AND REJECTED SPIZES

Tables 7.15 and 7.16 present Species Preference Indices based on browse bottle data, together with supporting dietary importance and availability data.

IMPORTANCE, PREFERENCE AND REJECTION INDICES BASED ON BROWSE BOTTLE DATA

S.africana size 3 and 2 were the two most important spizes in the diet in both study areas. Again higher preferences were recorded in the Hluhluwe study area where this species was less common.

UMFOLOZI

In the Umfolozi Study Area:

"Acacias" less than 1m (Size 1) were also both very important and highly preferred. Six of the ten most important spizes were "Acacias" less than 1m (*D.cinerea1, A.karroo1, A.nilotica1, A.gerrardii1, A.tortilis1* and *A.borleae1*). All six of these spizes were rated as highly preferred. These six spizes made up only 3.49% of available Free bottles, yet contributed almost a quarter of total offtake (23.22%).

TABLE 7.15 (i) HLUHLUWE 1989 GRID SURVEY

SPIZE DIETARY IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES (For Spizes with %Free Bottles >=0.25%)
DATA SORTED BY % CONTRIBUTION TO TOTAL WOODY DIET

Species	Size	Free Preference Index		Total Pref Index	Cover Pref Index	%Total Bottles	%Free Bottles	%Total C. Cover	%Browsing-New+Old	FB:TB Ratio	CC:TB Ratio
Spirostachys africana	3	***	3.87	5.83	8.98	2.86	2.67	1.45	18.35	1.30	.56
Spirostachys africana	2	***	4.87	6.29	17.33	1.40	1.81	.51	8.81	1.29	.36
Acalypha glabrata	2	***	3.85	3.97	10.79	1.93	2.50	.71	7.64	1.30	.37
Acalypha glabrata	3	**	2.32	3.07	5.53	2.04	2.65	1.11	6.14	1.38	.54
Dichrostachys cinerea	1	**	2.36	1.43	2.18	3.82	2.31	2.50	5.45	.60	.66
Dichrostachys cinerea	2	*	1.67	1.52	3.95	3.29	3.01	1.27	5.01	.91	.38
Acacia caffra	3		1.17	1.52	2.61	2.48	3.23	1.45	3.77	1.38	.58
Acacia karroo	3	**	2.46	3.20	2.95	1.12	1.46	1.22	3.68	1.30	1.89
Acacia gerrardii	2	***	3.91	4.94	80.03	.71	.89	.04	3.50	1.26	.06
Spirostachys africana	1	**	2.34	2.64	4.65	1.31	1.48	.74	3.46	1.13	.57
Abutilon/Hibiscus spp.	2	**	2.11	2.64	11.77	1.38	1.62	.29	3.43	1.25	.22
Acacia karroo	2	*	1.36	1.05	2.95	3.87	2.37	1.09	3.22	.77	.36
Berchemia zeyheri	2	**	2.36	2.76	5.22	1.81	1.17	.53	2.78	1.17	.53
Maytenus nemorosa	3	**	2.57	3.34	1.95	.62	.80	1.85	2.86	1.30	1.71
Acacia nilotica	2	***	4.14	3.94	7.38	.50	.48	.27	1.99	.95	.53
Berchemia zeyheri	3	*	1.80	2.35	.67	.76	.99	2.67	1.78	1.30	3.52
Berchemia zeyheri	1	*	1.71	1.51	2.23	1.85	.92	.71	1.58	.88	.68
Acacia karroo	1	***	2.98	1.20	1.59	1.11	.45	.84	1.34	.40	.76
Acacia caffra	2	-	.54	.41	1.32	2.81	2.17	.88	1.17	.77	.31
Acacia nilotica	1	**	2.17	1.28	1.74	.78	.46	.57	.99	.59	.73
Acacia nilotica	3	**	2.60	3.37	.36	.24	.32	2.31	.82	1.30	9.49
Diospyros simii	2	-	.80	.99	1.15	.79	.99	.69	.79	1.26	.87
Maytenus nemorosa	2	*	1.28	1.60	2.38	.47	.59	.32	.75	1.25	.67
Acalypha glabrata	1		1.18	1.41	1.95	.44	.56	.32	.62	1.28	.72
Bombeya burgessiae	2		1.12	1.89	1.47	.57	.55	.42	.62	.97	.74
Diospyros lyciodes	2	---	.19	.17	.39	3.41	3.03	1.50	.58	.89	.44
Rhus pentheri	3	---	.26	.34	.16	1.63	2.11	3.40	.55	1.30	2.09
Zizyphus mucronata	2		.84	.80	2.94	.64	.61	.17	.51	.96	.27
Hippobromus pauciflorus	2	*	1.84	1.79	1.42	.27	.26	.34	.48	.97	1.26
Lippia javanica	2	---	.15	.11	.32	4.88	2.99	1.41	.45	.75	.35
Maytenus nemorosa	1	*	1.59	1.55	1.49	.27	.26	.28	.41	.98	1.04
Rhus pentheri	2	---	.16	.17	.38	2.41	2.58	1.08	.41	1.07	.45
Scutia myrtina	1	-	.62	.66	1.26	.62	.66	.33	.41	1.06	.53
Diospyros simii	1	-	.54	.54	.82	.70	.78	.46	.38	1.01	.66
Coddia rudis	1	--	.36	.42	1.62	.81	.94	.21	.34	1.36	.26
Euclea racemosa	3	---	.29	.38	.08	.90	1.17	4.38	.34	1.38	4.85
Diospyros lyciodes	3	--	.49	.64	.31	.43	.56	.89	.27	1.30	2.89
Spirostachys africana	4	---	.21	.27	.26	1.81	1.32	1.07	.27	1.30	1.06
Euclea racemosa	2	---	.10	.12	.16	1.75	2.12	1.28	.21	1.21	.73
Dichrostachys cinerea	3	---	.21	.28	.07	.62	.88	2.37	.17	1.30	3.85
Maytenus senegalensis	1	---	.28	.18	.29	.75	.49	.48	.14	.66	.64
Plectranella armata	3	---	.25	.33	.31	.41	.54	.44	.14	1.30	1.07
Sideroxylon inerme	2	-	.52	.62	1.18	.22	.26	.12	.14	1.19	.53
Solanum	1	---	.29	.18	.20	.58	.36	.51	.18	.62	.88
Euclea crispa	1	---	.13	.05	.18	1.41	.55	.71	.07	.39	.50
Plectranella armata	2	---	.14	.17	.47	.48	.50	.15	.07	1.27	.37
Rhus rehmanniana	2	---	.16	.09	.38	.78	.42	.18	.07	.54	.23
Plectronella armata	1	---	.09	.09	.10	.37	.40	.35	.03	1.06	.92
Solanum	2	---	.03	.03	.04	1.17	1.07	.81	.83	.92	.69
Abutilon/Hibiscus spp.	1	---	0.00	0.08	0.00	.26	.28	.01	0.08	1.06	.06
Acalaypha sonderiana	2	---	0.00	0.00	0.00	.65	.84	.25	0.00	1.30	.39
Azima tetracantha	2	---	0.00	0.00	0.80	.40	.52	.04	0.00	1.30	.09
Clutia pulchella	2	---	0.00	0.00	0.00	.27	.27	.38	8.00	.99	1.37
Cordia caffra	2	---	0.00	0.00	0.00	.34	.37	.36	0.08	1.09	1.07
Diospyros lyciodes	1	---	0.00	0.00	0.80	1.69	1.03	.71	0.00	.61	.42

TABLE 7.15jj HLUHLUWE 1989 GRID SURVEY

SPIZE DIETARY IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES (For Spizes with %Free Bottles >=0.25%)
DATA SORTED BY % CONTRIBUTION TO TOTAL WOODY DIET

Species	Size	Free Preference Index		Total Pref Index	Cover Pref Index	%Total Bottles	%Free Bottles	%Total C. Cover	%Browsing-New+Old	FB:TB Ratio	CC:TB Ratio
Diospyros simii	3	---	0.00	0.00	0.00	.20	.27	.45	0.00	1.30	2.20
Dombeya rotundifolia	1	---	0.00	0.00	0.00	.47	.26	.27	0.00	.56	.57
Dombeya rotundifolia	2	---	0.00	0.00	0.00	.53	.49	.20	0.00	.93	.38
Euclea crispa	2	---	0.00	0.00	0.00	2.27	1.70	.68	0.00	.75	.30
Euclea divinorum	1	---	0.00	0.00	0.00	.41	.34	.45	0.00	.81	1.09
Euclea divinorum	2	---	0.00	0.00	0.00	1.62	1.93	.98	0.00	1.19	.60
Euclea divinorum	3	---	0.00	0.00	0.00	.78	1.01	2.01	0.00	1.30	2.59
Euclea natalensis	2	---	0.00	0.00	0.00	.23	.29	.08	0.00	1.29	.35
Euclea racemosa	1	---	0.00	0.00	0.00	.76	.76	1.10	0.00	.99	1.44
Kraussia floribunda	1	---	0.00	0.00	0.00	1.24	1.40	.89	0.00	1.13	.72
Kraussia floribunda	2	---	0.00	0.00	0.00	1.88	2.27	.78	0.00	1.21	.41
Kraussia floribunda	3	---	0.00	0.00	0.00	.67	.87	.77	0.00	1.30	1.16
Lippia javanica	1	---	0.00	0.00	0.00	.77	.36	.42	0.00	.47	.54
Lippia javanica	3	---	0.00	0.00	0.00	.46	.59	.46	0.00	1.30	1.00
Maytenus senegalensis	2	---	0.00	0.00	0.00	1.63	1.76	.57	0.00	1.08	.35
Maytenus senegalensis	3	---	0.00	0.00	0.00	.63	.82	.62	0.00	1.30	.98
Rhoicissus tridentata	1	---	0.00	0.00	0.00	.92	.43	.58	0.00	.46	.63
Rhoicissus tridentata	2	---	0.00	0.00	0.00	1.70	1.18	1.01	0.00	.70	.59
Rhus pentheri	1	---	0.00	0.00	0.00	.43	.35	.44	0.00	.80	1.03
Scutia myrtina	2	---	0.00	0.00	0.00	.68	.85	.36	0.00	1.24	.53
Scutia myrtina	3	---	0.00	0.00	0.00	.43	.56	.85	0.00	1.30	2.00
Scutia myrtina	4	---	0.00	0.00	0.00	.35	.45	1.23	0.00	1.30	3.56
Vernonia subuligera	2	---	0.00	0.00	0.00	1.92	2.09	.91	0.00	1.08	.47

TABLE 7.16(i) UMFOLOZI 1989 GRID SURVEY

SPIZE DIETARY IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES (for Spizes with %Free Bottles >=0.25%)
DATA SORTED BY % CONTRIBUTION TO TOTAL WOODY DIET

Species	Size	Free Preference Index		Total Pref Index	Cover Pref Index	%Total Bottles	%Free Bottles	%Total C. Cover	%Browsing-New+Old	FB:TB Ratio	CC:TB Ratio
Spirostachys africana	3	*	1.82	2.05	4.07	5.98	6.75	3.02	12.26	1.13	.50
Spirostachys africana	2	**	2.44	2.61	3.66	3.11	3.33	2.21	8.18	1.07	.71
Dichrostachys cinerea	1	***	5.87	2.96	2.09	2.19	1.28	3.11	6.48	.58	1.42
Acacia karroo	2	***	7.53	5.25	5.76	.88	.61	.80	4.61	.70	.91
Spirostachys africana	1	**	2.22	1.88	2.04	2.00	1.62	1.77	3.60	.81	.88
Acacia karroo	1	***	9.82	3.12	2.69	1.14	.36	1.32	3.55	.32	1.16
Acacia nilotica	1	***	10.89	4.79	2.51	.73	.32	1.39	3.49	.44	1.91
Acacia gerrardii	1	***	7.78	4.95	2.84	.69	.44	1.20	3.41	.64	1.74
Acacia tortilis	1	***	5.57	4.72	3.45	.69	.58	.94	3.25	.85	1.37
Acacia borleae	1	***	5.94	5.98	8.06	.51	.51	.38	3.04	.99	.73
Dichrostachys cinerea	2	**	2.27	2.05	2.31	1.41	1.27	1.25	2.83	.90	.89
Acacia borleae	2	*	1.52	1.72	5.81	1.44	1.63	.49	2.48	1.13	.34
Ehretia rigida	3	***	5.46	6.16	6.12	.40	.45	.40	2.45	1.13	1.81
Acacia karroo	3	***	5.13	5.79	4.68	.42	.47	.54	2.43	1.13	1.29
Maytenus nemorosa	3	*	1.34	1.51	1.14	1.50	1.69	1.98	2.27	1.13	1.32
Schotia capitata	3		1.04	1.15	1.22	1.83	2.87	1.77	2.16	1.13	.97
Ehretia rigida	1		1.23	1.11	.71	1.45	1.30	2.24	1.60	.90	1.55
Ehretia rigida	2		.82	.91	1.89	1.47	1.63	.71	1.33	1.11	.48
Acacia tortilis	2	*	1.48	1.58	2.64	.75	.76	.42	1.12	1.81	.57
Asparagus spp.	1	**	.46	.40	.37	2.29	1.97	2.43	.91	.86	1.06
Acacia nilotica	2	***	3.38	3.35	3.73	.26	.26	.24	.88	.99	.98
Croton menyhartii	2	---	.13	.14	.22	5.74	6.32	3.61	.80	1.10	.63
Schotia capitata	4		.94	1.06	.81	.76	.85	.99	.80	1.13	1.31
Croton menyhartii	3	---	.09	.10	.20	7.61	8.59	3.68	.75	1.13	.48
Croton menyhartii	1		1.23	1.17	.87	.62	.58	.82	.72	.95	1.34
Spirostachys africana	4	*	1.60	1.81	.34	.37	.42	1.93	.67	1.13	5.24
Acacia gerrardii	3	*	1.81	2.04	1.24	.30	.34	.49	.61	1.13	1.65
Dichrostachys cinerea	3	*	1.26	1.43	1.63	.43	.49	.38	.61	1.13	.88
Acacia nigrescens	1	*	1.89	1.11	.44	.51	.30	1.27	.56	.59	2.52
Brachylaena ilicifolia	3		.83	.93	1.03	.57	.65	.52	.53	1.13	.91
Capparis tomentosa	2	*	1.38	1.31	1.95	.39	.37	.26	.51	.95	.67
Tarchonanthus camphoratus	2	---	.33	.31	.32	1.47	1.39	1.44	.45	.94	.98
Acacia nilotica	3	*	1.27	1.43	.95	.30	.34	.45	.43	1.13	1.50
Acacia grandicornuta	1	---	.24	.22	.23	1.47	1.34	1.37	.32	.91	.93
Brachylaena ilicifolia	2	---	.13	.15	.33	2.21	2.44	.97	.32	1.10	.44
Acacia luederitzii	3	-	.65	.71	.21	.41	.46	1.41	.29	1.13	3.44
Maytenus nemorosa	4	---	.32	.36	.67	.74	.84	.48	.27	1.13	.54
Rhus pentheri	2	--	.39	.31	.75	.87	.68	.35	.27	.79	.41
Asparagus spp.	2	---	.16	.17	.21	1.40	1.46	1.15	.24	1.84	.83
Tarchonanthus camphoratus	1	--	.47	.21	.32	.90	.45	.66	.21	.45	.66
Coddia rudis	1	--	.38	.35	.44	.53	.49	.42	.19	.93	.88
Grewia flava	2	-	.52	.47	.47	.48	.36	.40	.19	.90	1.00
Brachylaena ilicifolia	1	---	.16	.15	.24	1.85	.97	.66	.16	.93	.63
Euclea divinorum	1	---	.32	.22	.21	.72	.50	.75	.16	.69	1.05
Euclea racemosa	2	---	.13	.14	.31	1.11	1.19	.52	.16	1.07	.47
Pappia capensis	4	-	.55	.62	.16	.26	.29	1.01	.16	1.13	3.94
Rhus gueinzii	3	--	.46	.52	.94	.26	.29	.14	.13	1.13	.55
Plectronella armata	3	---	.08	.89	.12	1.24	1.40	.87	.11	1.13	.70
Maytenus heterophyla	1	---	.27	.12	.86	.67	.29	1.25	.08	.43	1.86
Rhus gueinzii	2	---	.23	.23	.48	.34	.35	.16	.03	1.84	.48
Acacia nigrescens	4	---	.19	.21	.02	.25	.29	3.51	.05	1.13	13.87
Euclea undulata	3	---	.02	.02	.02	3.04	3.43	2.57	.05	1.13	.84
Plectronella armata	2	---	.18	.19	.11	.28	.30	.49	.05	1.09	1.79
Asparagus spp.	3	---	.03	.04	.05	.69	.78	.59	.03	1.13	.86
Maytenus nemorosa	2	---	.05	.05	.07	.53	.57	.40	.03	1.09	.76

TABLE 7.16(ii) UMFOLOZI 1989 GRID SURVEY

SPIZE DIETARY IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES (For Spizes with %Free Bottles >=0.25%)
DATA SORTED BY % CONTRIBUTION TO TOTAL WOODY DIET

Species	Size	Free Preference Index	Total Pref Index	Cover Pref Index	%Total Bottles	%Free Bottles	%Total C. Cover	%Browsing-New+Old	FB:TB Ratio	CC:TB Ratio
Acacia grandicornuta	2	--- 0.00	0.00	0.00	.78	.82	.78	0.00	1.06	1.00
Acacia grandicornuta	3	--- 0.00	0.00	0.00	.98	1.11	1.32	0.00	1.13	1.34
Acacia tortilis	3	--- 0.00	0.00	0.00	.32	.36	.52	0.00	1.13	1.61
Carissa bispinosa	1	--- 0.00	0.00	0.00	.43	.48	.74	0.00	1.10	.33
Euclea divinorum	2	--- 0.00	0.00	0.00	3.14	3.22	1.34	0.00	1.02	.43
Euclea divinorum	3	--- 0.00	0.00	0.00	1.87	2.11	1.15	0.00	1.13	.62
Euclea racemosa	1	--- 0.00	0.00	0.00	.34	.29	.61	0.00	.87	1.82
Euclea racemosa	3	--- 0.00	0.00	0.00	.40	.45	.57	0.00	1.13	1.43
Euclea undulata	1	--- 0.00	0.00	0.00	.33	.33	.31	0.00	1.01	.94
Euclea undulata	2	--- 0.00	0.00	0.00	1.19	1.34	.35	0.00	1.12	.30
Euclea undulata	4	--- 0.00	0.00	0.00	.35	.40	.38	0.00	1.13	1.07
Grewia flavescens	3	--- 0.00	0.00	0.00	.85	.96	.42	0.00	1.13	.50
Maytenus senegalensis	1	--- 0.00	0.00	0.00	.41	.31	.35	0.00	.75	.87
Olea europaea	3	--- 0.00	0.00	0.00	.48	.54	.33	0.00	1.13	.69
Olea europaea	4	--- 0.00	0.00	0.00	.33	.37	.57	0.00	1.13	1.72
Pyrostria hystrix	3	--- 0.00	0.00	0.00	.32	.37	.40	0.00	1.13	1.23
Rhus pentheri	3	--- 0.00	0.00	0.00	.52	.58	.16	0.00	1.13	.32
Schotia brachypetala	2	--- 0.00	0.00	0.00	2.63	2.96	.05	0.00	1.13	.02
Tarchonanthus camphoratus	3	--- 0.00	0.00	0.00	1.37	1.55	1.18	0.00	1.13	.86
Zizyphus mucronata	3	--- 0.00	0.00	0.00	.32	.36	.33	0.00	1.13	1.03

16 of the 23 preferred spizes were "Acacias" less than 4m.

The most highly preferred spize in Umfolozi was *A.nilotica*-Size 1 (<1m). Size 2 *A.nilotica's* were preferred and Size 3 *A.nilotica's* were slightly preferred. This corroborates the finding of the Pilot study. As was mentioned earlier, this finding is particularly important when one comes to assess the likely effects of past habitat changes in Hluhluwe on black rhino.

Similarly, as *D.cinerea*, *A.karroo*, *A.borleae* and *A.tortilis* got larger in Umfolozi they became less preferred food resources.

The only size of *A.nigrescens* to be classed as preferred was size 1.

Size class 1 (<1m) was also the most preferred size for four of the rarer "*Acacia*" species'- *A.caffra*, *A.grandicornuta*, *A.robusta* and *A.senegal*.

The most preferred size for all but one of the twelve "*Acacia*" species in Umfolozi on which feeding was recorded was size class 1 (<1m). In the case of the odd man out (*A.luderitzii*), this species was both rare and rejected, and the little amount of feeding recorded on it came from only three size class 3 (2-4m) individuals in one plot.

Size 1 "Acacias" made up 25.83% of all black rhino woody plant browsing in Umfolozi. The comparable percentages for size classes 2,3 and 4 were 14.74%, 5.39% and 0.05% respectively. The pooled Free Preference Ratios for "*Acacia*" species were Size1:4.68 (***), Size2:2.30 (**), Size3:1.35 (*), and Size 4:0.08 (---). The differences in size class preferences were even more pronounced if one only looked at the important palatable "*Acacia*" species (Free Preference Indices: Size1:6.58 (***), Size2:2.84 (***), Size3:2.21 (**), and Size4:0.00 (---)).

Both the Pilot survey and the Grid survey showed that the heavily defended *A.grandicornuta, A.luderitzii* and *A.nigrescens* trees were rejected (with the exception of small *A.nigrescens* trees <1m).

Size class 3 (2-4m) was the most preferred *M.nemorosa* spize.

Although *C.menyhartii* was highly rejected as a species in Umfolozi, a slight preference was shown for *C.menyhartii* size 1 trees.

HLUHLUWE

In the Hluhluwe Study Area:

Although "*Acacia*" spizes were still preferred in Hluhluwe (accounting for 9 of the 22 common preferred spizes), different patterns of "*Acacia*" spize selection were recorded in Hluhluwe compared to Umfolozi:

○ After pooling the data for all "Acacias", Hluhluwe showed a similar size preference ordering, although preference indices were generally lower than in Umfolozi (Size1:2.48 ** Size2:1.73 * Size3:1.52 * Size4:0.00 ---).

○ In contrast to Umfolozi, size 1 trees (<1m) were the most preferred size for only *A.karroo, A.robusta, D.cinerea* and *A.caffra* out of the common "Acacias". Only one size 1 "*Acacia*" in Hluhluwe (*A.karroo1*) was rated as highly preferred and contributed more than 0.25% of Free bottles (compared to 6 in Umfolozi).

○ Size class 2 trees (1-2m) of *A.nilotica* and *A.gerrardii* were the most preferred size in Hluhluwe.

○ Size 3 (2-4m) trees were the second most preferred size class for *A.caffra, A.nilotica* and *A.karroo*. In Hluhluwe, these three species are commonly associated with tall grass, and it is suggested that the high levels of grass interference prevailing in Hluhluwe at the time may have forced the black rhinos to browse more on these taller and generally less preferred *Acacia* spizes (see Chapter 8).

○ The pooled "*Acacia*" data showed that in Hluhluwe, "Acacias" between 1 and 2m (size2) were the most important (15.70% of all browsing). Taller size 3 "Acacias" (2-4m) contributed about the same proportion of total browsing (9.12%) as size 1's (8.95%). Thus in Hluhluwe, size 1 "Acacias" made up only about a third as much of the total woody diet as in Umfolozi, but size class 3 "Acacias" made up about 70% more. Given the evidence presented in Chapter 8, we feel that these differences between study areas were primarily related to the increased grass interference recorded in Hluhluwe.

○ Many of the size 4 (>4m) spizes that were major contributors to total canopy cover in Hluhluwe were not listed in Table 7.15, as they contributed less than 0.25% of available Free bottles. The biggest single contributor to total canopy cover in Hluhluwe was *E.racemosa4*, yet this spize contributed only 0.24% of Free available bottles. Similarly *B.zeyheri4, A.nilotica4* and *R.pentheri4* were also excluded from Table 7.15, yet they were the 4th, 9th and 11th most important contributors to total canopy cover respectively.

TABLE 7.17(i)

HLUHLUWE 1989 GRID SURVEY
SPIZE IMPORTANCE, AVAILABILITY AND PREFRENCE INDICES BASED ON COUNT DATA Page 1
(FOR SPIZES WITH DENSITIES OF >= 5/Ha)

Species	Size	Number	PreferenceIndex	% Total n Eaten	% Total n Present	Tree n Eaten/Ha	Tree n Present/Ha
Abutilon/Hibiscus spp.	2	--	.50	.20	.41	.28	18.93
Acacia caffra	1		1.13	.61	.54	.83	38.22
Acacia caffra	2	*	1.33	1.22	.92	1.65	64.94
Acacia caffra	3	***	3.33	1.83	.55	2.48	38.84
Acacia gerrardii	1	**	2.09	.20	.10	.28	6.89
Acacia gerrardii	2	***	14.64	1.63	.11	2.20	7.85
Acacia karroo	1		.88	1.83	2.08	2.48	147.31
Acacia karroo	2	*	1.26	2.24	1.77	3.03	125.21
Acacia karroo	3	***	4.50	2.03	.45	2.75	31.96
Acacia karroo	4	---	0.00	0.00	.25	0.00	17.63
Acacia nilotica	1	*	1.25	1.63	1.30	2.20	91.74
Acacia nilotica	2	***	4.07	1.63	.40	2.20	28.24
Acacia nilotica	3		.93	.41	.44	.55	30.85
Acacia nilotica	4	---	0.00	0.00	.31	0.00	22.04
Acacia robusta	1	***	3.07	1.42	.46	1.93	32.78
Acacia robusta	2	***	4.35	.61	.14	.83	9.92
Acacia robusta	4	---	0.00	0.00	.11	0.00	7.44
Acalypha sonderiana	2	---	0.00	0.00	.37	0.00	26.03
Acalypha sonderiana	3	---	0.00	0.00	.11	0.00	7.71
Acalypha glabrata	1	*	1.54	1.02	.66	1.38	46.69
Acalypha glabrata	2	***	5.16	6.10	1.18	8.26	83.61
Acalypha glabrata	3	***	5.13	3.66	.71	4.96	50.41
Berchemia zeyheri	1	*	1.29	2.24	1.73	3.03	122.45
Berchemia zeyheri	2	**	2.72	2.44	.90	3.31	63.36
Berchemia zeyheri	3	*	1.53	1.02	.67	1.38	47.11
Berchemia zeyheri	4	---	0.00	0.00	.37	0.00	26.45
Canthium inerme	1	---	0.00	0.00	.13	0.00	9.50
Canthium inerme	2	---	0.00	0.00	.14	0.00	9.92
Capparis tomentosa	1	---	0.00	0.00	.09	0.00	6.06
Cassine aethiopica	1	---	0.00	0.00	.08	0.00	5.79
Celtis africana	1	**	2.28	.81	.36	1.10	25.21
Celtis africana	2	---	0.00	0.00	.18	0.00	9.16
Chaetachme aristata	1	---	0.00	0.00	.09	0.00	6.20
Clausena anisata	1	---	0.00	0.00	.09	0.00	6.47
Clutia pulchella	1	---	0.00	0.00	.08	0.00	5.51
Clutia pulchella	2	---	0.00	0.00	.41	0.00	28.93
Clutia pulchella	3	---	0.00	0.00	.09	0.00	5.61
Coddia rudis	1	**	2.03	1.02	.50	1.38	35.40
Combretum molle	1		.92	.20	.22	.28	13.70
Combretum molle	2	---	0.00	0.00	.07	0.00	5.10
Cordia caffra	1	---	0.00	0.00	.43	0.00	30.30
Cordia caffra	2	---	0.00	0.00	.44	0.00	30.99
Cordia caffra	3	---	0.00	0.00	.16	0.00	11.02
Cunonia capensis	1	---	0.00	0.00	.09	0.00	6.06
Dalbergia armata	2	---	0.00	0.00	.09	0.00	6.20
Dalbergia obovata	1	---	0.00	0.00	.42	0.00	29.75
Dalbergia obovata	2	---	0.00	0.00	.24	0.00	17.08
Dalbergia obovata	3	---	0.00	0.00	.11	0.00	7.71
Dichrostachys cinerea	1	*	1.78	11.79	6.62	15.98	463.18
Dichrostachys cinerea	2	*	1.68	3.66	2.18	4.96	154.27
Dichrostachys cinerea	3	-	.68	.41	.63	.55	42.42
Diospyros lycioides	1	---	0.00	0.00	2.32	0.00	164.12
Diospyros lycioides	2	---	.36	.81	2.26	1.10	161.29
Diospyros lycioides	3	-	.55	.20	.37	.28	26.17
Diospyros simii	1	--	.38	.61	1.60	.83	112.88

TABLE 7.17 (ii)

HLUHLUWE 1989 GRID SURVEY
SPIZE IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES BASED ON COUNT DATA   Page 2
(FOR SPIZES WITH DENSITIES OF >= 5/Ha)

Species	Size	Number	PreferenceIndex	% Total n Eaten	% Total n Present	Tree n Eaten/Ha	Tree n Present/Ha
Diospyros simil	2		.90	.81	.91	1.10	64.05
Diospyros simil	3	---	0.00	0.00	.18	0.00	12.95
Diospyros spp.	1	---	0.00	0.00	.20	0.00	14.46
Dombeya burgessiae	1	***	4.81	.61	.13	.83	8.95
Dombeya burgessiae	2	***	3.37	.81	.24	1.10	17.08
Dombeya rotundifolia	1	---	0.00	0.00	.77	0.00	54.68
Dombeya rotundifolia	2	---	0.00	0.00	.33	0.00	23.55
Dovyalis caffra	1	---	0.00	0.00	.17	0.00	11.98
Dovyalis caffra	2	***	4.35	.41	.09	.55	6.61
Ehretia rigida/amoena	1		1.19	.41	.34	.55	24.10
Ehretia rigida/amoena	2	***	3.16	.41	.13	.55	9.09
Euclea crispa	1	---	.08	.20	2.64	.28	186.36
Euclea crispa	2	---	0.00	0.00	1.43	0.00	101.38
Euclea divinorum	1	---	0.00	0.00	1.11	0.00	78.58
Euclea divinorum	2	---	0.00	0.00	1.20	0.00	84.85
Euclea divinorum	3	---	0.00	0.00	.48	0.00	33.61
Euclea divinorum	4	---	0.00	0.00	.16	0.00	11.29
Euclea natalensis	1	---	0.00	0.00	.15	0.00	10.33
Euclea natalensis	2	---	0.00	0.00	.21	0.00	14.74
Euclea racemosa	1	---	0.00	0.00	2.72	0.00	192.42
Euclea racemosa	2	---	.19	.43	2.13	.55	150.69
Euclea racemosa	3	---	.16	.20	1.24	.28	87.88
Euclea racemosa	4	---	0.00	0.00	.76	0.00	53.72
Forb spp.	1		.83	.20	.24	.28	17.22
Forb spp.	2	---	0.00	0.00	.09	0.00	6.20
Galpinia transvaalica	1	***	2.88	.41	.28	1.10	19.97
Galpinia transvaalica	2	**	2.13	.20	.10	.28	6.75
Grewia occidentalis	1	---	0.00	0.00	.09	0.00	6.34
Heteropyxis natalensis	1	---	0.00	0.00	.22	0.00	15.84
Heteropyxis natalensis	2	---	0.00	0.00	.17	0.00	12.12
Hippobromus pauciflorus	1	*	1.78	1.02	.57	1.38	40.29
Hippobromus pauciflorus	2	***	3.68	1.22	.33	1.65	23.42
Kraussia floribunda	1	---	0.06	0.00	2.35	0.00	165.84
Kraussia floribunda	2	---	0.00	0.00	1.62	0.00	114.74
Kraussia floribunda	3	---	0.00	0.00	.38	0.00	26.72
Lippia javanica	1	---	0.00	0.00	1.45	0.00	102.75
Lippia javanica	2	---	.12	.41	3.31	.55	234.23
Lippia javanica	3	---	0.00	0.00	.20	0.00	14.05
Maytenus heterophylla	1	---	0.00	0.00	.29	0.00	20.25
Maytenus heterophylla	2	---	0.00	0.00	.15	0.00	10.74
Maytenus nemorosa	1	*	1.40	.61	.58	1.10	41.05
Maytenus nemorosa	2	***	3.38	1.22	.36	1.65	25.46
Maytenus nemorosa	3	***	3.66	.61	.22	1.10	15.70
Maytenus senegalensis	1	---	.18	.20	1.16	.28	81.82
Maytenus senegalensis	2	---	0.00	0.00	.83	0.00	58.54
Maytenus senegalensis	3	---	0.00	0.00	.23	0.00	16.53
Melanthus didyma	1	---	0.00	0.00	.08	0.00	5.51
Monanthotaxis caffra	1		.98	.20	.21	.28	14.60
Monanthotaxis caffra	2	---	0.00	0.00	.09	0.00	6.47
Pancovia golungensis	1	---	0.00	0.00	.08	0.00	5.51
Pancovia golungensis	2	---	0.00	0.00	.09	0.00	6.20
Phyllanthus reticulatus	1	-	.55	.20	.37	.28	26.03
Phyllanthus reticulatus	2	---	0.00	0.00	.20	0.00	14.05
Plectroniella armata	1	---	.27	.20	.75	.28	52.86
Plectroniella armata	2	-	.55	.20	.37	.28	26.17
Plectroniella armata	3		1.04	.20	.19	.28	13.77

TABLE 7.17 (iii)

HLUHLUWE 1989 GRID SURVEY
SPIZE IMPORTANCE, AVAILABILITY AND PREFRENCE INDICES BASED ON COUNT DATA Page 3
(FOR SPIZES WITH DENSITIES OF >= 5/Ha)

Species	Size	Number	PreferenceIndex	% Total n Eaten	% Total n Present	Tree n Eaten/Ha	Tree n Present/Ha
Rhoicissus tridentata	1	---	0.00	0.00	1.91	0.00	135.19
Rhoicissus tridentata	2	---	0.00	0.00	1.95	0.00	137.74
Rhus chirindensis	2	---	0.00	0.00	.15	0.00	10.47
Rhus pentheri	1	---	0.00	0.00	.93	0.00	65.84
Rhus pentheri	2	---	.14	.20	1.44	.28	101.65
Rhus pentheri	3	---	.25	.20	.82	.28	58.13
Rhus pentheri	4	---	0.00	0.00	.22	0.00	15.43
Rhus rehmanniana	1	---	0.00	0.00	.08	0.00	5.51
Rhus rehmanniana	2	-	.70	.20	.29	.28	20.66
Schotia brachypetala	1	---	0.00	0.00	.12	0.00	8.54
Schotia brachypetala	2	---	0.00	0.00	.08	0.00	5.37
Sclerocarya birrea	2	---	0.00	0.00	.09	0.00	6.20
Scolopia zeyheri	1	-	.73	.41	.55	.55	39.12
Scolopia zeyheri	2	*	1.71	.20	.12	.28	8.48
Scutia myrtina	1		1.00	1.02	1.02	1.38	71.97
Scutia myrtina	2	---	0.00	0.00	.52	0.00	36.50
Scutia myrtina	3	---	0.00	0.00	.13	0.00	9.89
Scutia myrtina	4	---	0.00	0.00	.10	0.00	7.16
Sesbania sesban	1	---	0.00	0.00	.10	0.00	6.89
Sesbania sesban	2	---	0.00	0.00	.09	0.00	6.20
Sideroxylon inerme	1	---	0.00	0.00	.24	0.00	16.67
Sideroxylon inerme	2	*	1.29	.20	.16	.28	11.16
Solanum	1	---	.23	.61	2.60	.83	183.75
Solanum	2	--	.41	1.02	2.49	1.38	175.90
Spirostachys africana	1	***	2.84	5.69	2.00	7.71	141.53
Spirostachys africana	2	***	8.57	10.77	1.26	14.60	88.84
Spirostachys africana	3	***	9.35	6.71	.72	9.09	50.69
Spirostachys africana	4	-	.54	.20	.38	.28	26.72
Tarchonanthus camphoratus	1	---	0.00	0.00	.09	0.00	6.20
Tarchonanthus camphoratus	3	---	0.00	0.00	.08	0.00	5.51
Unknown 15	2	---	0.00	0.00	.12	0.00	8.26
Vernonia subuligera	2	---	0.00	0.00	1.26	0.00	89.39
Zanthoxylum capense	1	---	0.00	0.00	.19	0.00	13.77
Zanthoxylum capense	2	*	1.58	.20	.13	.28	9.09
Zizyphus mucronata	1		1.12	.41	.36	.55	25.62
Zizyphus mucronata	2	***	3.11	.81	.26	1.10	18.46
Zizyphus mucronata	3	**	2.27	.20	.09	.28	6.34

TABLE 7.18 (i)

UMFOLOZI 1989 GRID SURVEY
SPIZE IMPORTANCE, AVAILABILITY AND PREFERENCE INDICES BASED ON COUNT DATA   Page 1
(FOR SPIZES WITH DENSITIES OF >= 5/Ha)

Species	Size	Number	PreferenceIndex	% Total n Eaten	% Total n Present	Tree n Eaten/Ha	Tree n Present/Ha
Acacia borleae	1	**	2.67	2.07	.77	5.35	19.61
Acacia borleae	2	***	3.26	1.38	.42	3.57	10.70
Acacia caffra	1		1.07	.41	.39	1.07	9.80
Acacia caffra	2	***	5.67	1.52	.27	3.92	6.77
Acacia gerrardii	1		.98	2.21	2.26	5.78	57.22
Acacia gerrardii	3	**	2.13	.69	.32	1.78	8.20
Acacia grandicornuta	1	---	.22	.69	3.18	1.78	80.39
Acacia grandicornuta	2	---	0.00	0.00	.74	0.00	18.72
Acacia grandicornuta	3	---	0.00	0.00	.56	0.00	14.26
Acacia grandicornuta	4	---	0.00	0.00	.30	0.00	7.49
Acacia karroo	1		1.21	2.90	2.40	7.49	60.61
Acacia karroo	2	***	2.99	2.76	.92	7.13	23.35
Acacia karroo	3	***	6.12	1.38	.23	3.57	5.70
Acacia luederitzii	1	---	0.00	0.00	.39	0.00	9.80
Acacia luederitzii	3	*	1.40	.41	.30	1.07	7.49
Acacia nigrescens	1	-	.68	1.24	1.83	3.21	46.35
Acacia nigrescens	4	---	.34	.28	.82	.71	20.68
Acacia nilotica	1		1.14	2.90	2.54	7.49	64.35
Acacia nilotica	3	**	2.06	.55	.27	1.43	6.77
Acacia robusta	1	*	1.27	.69	.54	1.78	13.73
Acacia sengel	1	***	3.15	1.24	.39	3.21	9.98
Acacia tortilis	1	**	2.57	3.31	1.29	8.56	32.62
Acacia tortilis	2	**	2.74	.97	.35	2.50	8.91
Acacia tortilis	3	---	0.00	0.00	.24	0.00	6.06
Asparagus spp.	1	-	.51	2.07	4.06	5.35	102.67
Asparagus spp.	2	---	.22	.28	1.23	.71	31.16
Asparagus spp.	3	---	.23	.14	.59	.36	14.97
Azima tetracantha	1		.82	.41	.51	1.07	12.83
Boscia albitrunca	1		.91	.28	.30	.71	7.66
Brachylaena ilicifolia	1	---	.32	.55	1.76	1.43	44.83
Brachylaena ilicifolia	2	--	.36	.55	1.52	1.43	38.50
Brachylaena ilicifolia	3	-	.58	.14	.24	.36	6.06
Capparis tomentosa	1	-	.80	.69	.87	1.78	21.93
Capparis tomentosa	2	*	1.68	.41	.25	1.07	6.24
Carissa bispinosa	1	---	0.00	0.00	.44	0.00	11.23
Cassine transvaalensis	1	***	3.16	.69	.22	1.78	5.53
Coddia rudis	1	-	.70	.41	.59	1.07	14.97
Combretum apiculatum	1	---	0.00	0.00	.23	0.00	5.88
Commiphora neglecta	1	--	.41	.28	.67	.71	16.93
Croton menyhartii	1	--	.37	.55	1.48	1.43	37.43
Croton menyhartii	2	---	.09	.28	3.23	.71	81.64
Croton menyhartii	3	---	.34	.55	1.63	1.43	41.35
Dichrostachys cinerea	1	*	1.79	11.59	6.48	29.95	163.99
Dichrostachys cinerea	2	**	2.70	4.28	1.58	11.05	40.07
Dichrostachys cinerea	3	*	1.86	.55	.30	1.43	7.49
Ehretia rigida/amoena	1	-	.54	2.48	4.59	6.42	116.04
Ehretia rigida/amoena	2	*	1.45	1.10	.76	2.85	19.25
Euclea divinorum	1	---	.34	.41	1.23	1.07	31.19
Euclea divinorum	2	---	0.00	0.00	1.27	0.00	32.26
Euclea divinorum	3	---	0.00	0.00	.46	0.00	11.76
Euclea racemosa	1	---	0.00	0.00	.97	0.00	24.42
Euclea racemosa	2	---	.19	.14	.74	.36	18.72
Euclea undulata	1	---	0.00	0.00	.51	0.00	13.01
Euclea undulata	2	---	0.00	0.00	.50	0.00	12.66
Euclea undulata	3	---	.29	.14	.48	.36	12.12

TABLE 7.18 (ii)

UMFOLOZI 1989 GRID SURVEY
SPIZE IMPORTANCE, AVAILABILITY AND PREFRENCE INDICES BASED ON COUNT DATA   Page 2
(FOR SPIZES WITH DENSITIES OF >= 5/Ha)

Species	Size	Number	PreferenceIndex	% Total n Eaten	% Total n Present	Tree n Eaten/Ha	Tree n Present/Ha
Grewia flava	1	++	2.41	1.10	.46	2.85	11.59
Grewia flava	2	-	.65	.28	.42	.71	10.70
Grewia occidentalis	1	-	.78	.69	.88	1.78	22.28
Grewia occidentalis	2	+	1.51	.41	.27	1.07	6.95
Grewia villosa	1		.92	.41	.45	1.07	11.41
Maytenus heterophylla	1	---	.15	.28	1.90	.71	48.13
Maytenus heterophylla	2	---	0.00	0.00	.27	0.00	6.77
Maytenus nemorosa	1		.84	.41	.49	1.07	12.48
Maytenus nemorosa	2	--	.41	.14	.34	.36	8.56
Maytenus nemorosa	3	+++	2.76	1.52	.55	3.92	13.90
Maytenus senegalensis	1	---	0.00	0.00	.70	0.00	17.83
Maytenus senegalensis	2	---	0.00	0.00	.22	0.00	5.53
Melanthus didyma	1	---	.08	.14	1.75	.36	44.17
Ormocarpum trichocarpum	1		1.02	1.10	1.08	2.85	27.45
Pappia capensis	1	+	1.60	.55	.35	1.43	8.73
Pappia capensis	4		1.22	.28	.23	.71	5.70
Plectroniella armata	1	+	1.38	.83	.60	2.14	15.15
Plectroniella armata	2	--	.47	.14	.30	.36	7.49
Plectroniella armata	3	---	.19	.14	.73	.36	18.54
Pyrostria hystrix	1	---	0.00	0.00	.25	0.00	6.24
Pyrostria hystrix	2	-	.61	.14	.23	.36	5.70
Rhoicissus rhomboidea	1	---	.25	.14	.54	.36	13.73
Rhus gueinzii	1	--	.48	.14	.29	.36	7.31
Rhus gueinzii	2	-	.52	.14	.27	.36	6.77
Rhus pentheri	1	---	0.00	0.00	.28	0.00	7.15
Rhus pentheri	2	---	.34	.14	.41	.36	10.34
Schotia capitata	3	++	2.21	.97	.44	2.58	11.05
Sida cordifolia/rhombifolia	1	-	.66	1.10	1.66	2.85	42.07
Solanum	1	-	.64	.55	.87	1.43	21.93
Spirostachys africana	1		1.24	5.10	4.12	15.19	104.28
Spirostachys africana	2	+++	3.09	7.17	2.32	18.54	58.82
Spirostachys africana	3	+++	3.40	5.93	1.75	15.33	44.21
Spirostachys africana	4		1.17	.69	.59	1.78	14.97
Tarchonanthus camphoratus	1	--	.38	.41	1.08	1.07	27.45
Tarchonanthus camphoratus	2		.91	.69	.76	1.78	19.25
Tarchonanthus camphoratus	3	---	0.00	0.00	.42	0.00	10.70
Zityphus mucronata	1	-	.68	.14	.20	.36	5.17

IMPORTANCE, PREFERENCE AND REJECTION INDICES BASED ON COUNT DATA

Tables 7.17 and 7.18 present species preference and abundance data calculated using count data. Spize preference indices calculated using the binomial count data again produced indices than differed markedly from those calculated using browse bottle offtake and available Free bottles.

The main deficiencies in the use of count data were:

1) that in terms of availability, all the trees were considered equally important, irrespective of tree size or the volume of browse available to black rhino; and

2) that the amount removed per browsed tree was ignored and effectively treated as equal for all species and all sizes.

For these reasons, the results based on browse bottle data are preferred over those obtained using simpler count data. However, count data are cheaper and easier to collect, and a number of researchers have used count data in the past to study feeding. It was therefore worth undertaking a comparison of the results obtained using both bottle and count data.

Small size 1 "*Acacias*" were rarely listed as preferred using the binomial data. The six key size 1 "*Acacias*" which contributed 23.22% of the woody diet but only 3.49% of the available Free bottles were all rated as highly preferred using the bottle data. None of these six were rated as highly preferred using the count data. Three of these spizes (*A.karroo1*, *A.nilotica1* and *A.gerrardii1*) were not even rated as slightly preferred using the count data, despite being the three most preferred common spizes in Umfolozi based on bottle data. These three spizes contributed 10.45% of the total woody browse offtake in Umfolozi but only 1.12% of the Free available bottles. The same spizes made up 8.01% of the total number of trees eaten and 7.20% of all the trees in the study area.

Taller size 2 and 3 spizes were often rated as more preferred using binomial data as a higher proportion of these less common trees were browsed.

These differences between indices can be understood by summarising the data on the top 10 most important "*Acacia*" species in Umfolozi:

> Size 1 trees were 4.44 times commoner than size 2's in the habitat. However, only 2.18 times more size 1's were eaten than size 2's. Therefore a higher proportion of the size2 top 10 "Acacias" were browsed than size1's (15.4% of size1's, 31.4% of size2's). In addition offtake levels were slightly higher per browsed tree on size 2 "*Acacias*" (2.3 bottles per tree on size 1's and 2.9 bottles per tree on size2's).
>
> Size1's contributed almost 73% more to the diet than size class 2's. This was largely a function of the greater density of browsed size 1's. When size 1 "Acacias" were eaten, the average offtake per tree represented a larger proportion of the standing crop of available browse.

Interestingly, the data indicated that more bottles were removed per tree on the more preferred "*Acacia*" size 1 and 2 spizes, than the less preferred ones. Thus habitat selection occurred at a hierarchy of scales.

> Browse offtake from the favoured *A.borleae, A.senegal, A.gerrardii, A.nilotica* and *A.tortilis* averaged 2.58 (size1) and 3.63 (size2) bottles per browsed tree.
>
> Mean offtake levels on the less preferred *A.karroo, D.cinerea* and *A.caffra* were lower (Size 1: 1.60 and Size 2: 2.78 bottles/browsed tree).
>
> Mean offtake levels were even less on the usually rejected *A.luderitzii, A.grandicornuta* and *A.schweinfurthii*, averaging only 1.17 bottles per browsed tree less than two metres.

Subtle differences in spize selection like this cannot be detected using the cruder count data. The above, emphasises the need not just to consider "*Acacia*" densities when assessing black rhino habitat, but also the size and species of "*Acacias*".

PATCH SELECTION: DIFFERENCES BETWEEN PLOTS WITH (YES) AND WITHOUT FEEDING (NO)

Tables 7.19 through to 7.22 contrast the differences between spizes in plots with and without feeding. Plots with feeding have been termed YES plots and those without feeding NO plots. Tables 7.19 (Hluhluwe) and 7.20 (Umfolozi) highlight differences in canopy cover while Tables 7.21 (Hluhluwe) and 7.22 (Umfolozi) present data on spize availability (bottles and densities), structure (%Canopy Cover : %Total Bottle Ratio's) and grass interference levels. Twice as many plots in Hluhluwe had no black rhino feeding in them than in Umfolozi (40.2% v 20.9%).

In both reserves availability of preferred spizes was generally higher in YES plots, with correspondingly higher densities of rejected spizes normally occurring in NO plots. This finding was reflected in the lower Free Preference Indices for many spizes when calculated using only YES plot data. This indicates that black rhinos are selecting for patches at a broad scale, choosing to concentrate their feeding in better quality patches. This was particularly marked in Hluhluwe.

Of the six common spizes in Hluhluwe that were rated as highly preferred (***) using data for ALL plots (Table 7.15) none were rated as highly preferred (***), one as preferred (**), three as slightly preferred (*) and two as intermediate ( ) using only YES plot data.

TABLE 7.19 p1

HLUHLUWE GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC:TBYES	CC:TBNO
Abutilon/Hibiscus spp.	1		.03		2.72		.05
Abutilon/Hibiscus spp.	2	.73	.25	38.32	26.53	.85	.12
Abutilon/Hibiscus spp.	3	.48	.01	25.23	1.36	2.45	.83
Acacia burkei	1	.07		3.74		3.05	
Acacia burkei	3	.04		1.87		0.00	
Acacia burkei	4	.74	.01	38.94	1.36	0.00	0.00
Acacia caffra	1	.60	.17	31.78	17.69	.95	.33
Acacia caffra	2	1.97	.85	103.74	89.12	.70	.22
Acacia caffra	3	4.08	1.89	214.64	114.06	.86	.56
Acacia caffra	4		.09		9.52		1.82
Acacia gerrardii	1	.28	.01	14.95	1.36	1.57	.56
Acacia gerrardii	2	.18	.01	9.35	1.36	.08	.24
Acacia gerrardii	3	.14		7.48		1.22	
Acacia gerrardii	4	.07	.01	3.74	1.36	10.17	0.00
Acacia grandicornuta	1	.04		1.87		1.22	
Acacia grandicornuta	2	.07	.01	3.74	1.36	.64	.67
Acacia grandicornuta	3	.04		1.87		.64	
Acacia karroo	1	1.60	.92	84.11	95.92	1.47	.59
Acacia karroo	2	2.46	1.05	129.60	109.52	.70	.26
Acacia karroo	3	3.23	1.00	170.09	104.54	1.44	1.26
Acacia karroo	4	1.53	1.48	80.37	154.65	11.82	7.76
Acacia nilotica	1	1.72	.39	90.65	40.82	1.14	.66
Acacia nilotica	2	.68	.23	35.51	24.49	.72	.57
Acacia nilotica	3	3.24	2.95	170.40	388.39	8.53	11.91
Acacia nilotica	4	2.51	3.19	132.09	332.65	37.17	101.80
Acacia robusta	1	.64	.14	33.64	14.97	2.45	1.49
Acacia robusta	2	.28	.04	14.95	4.08	1.07	.67
Acacia robusta	3	.18	.04	9.35	4.08	.99	.69
Acacia robusta	4	2.27	.73	119.63	75.96	244.08	77.49
Acacia schweinfurthii/ataxacantha	1	.04	.01	1.87	1.36	1.22	8.33
Acacia schweinfurthii/ataxacantha	2	.04		1.87		3.05	
Acalypha sonderiana	1	.07		3.74		1.11	
Acalypha sonderiana	2	.78	.16	40.81	17.01	.41	2.89
Acalypha sonderiana	3	.25	.45	13.08	46.71	.83	7.24
Acalypha glabrata	1	.68	.32	35.51	33.33	.84	.88
Acalypha glabrata	2	1.85	.59	97.20	61.68	.43	.56
Acalypha glabrata	3	3.53	.69	185.67	72.11	.84	.50
Acalypha glabrata	4	.04		1.87		3.81	
Adenopodia spicata	1	.04	.03	1.87	2.72	6.10	.45
Adenopodia spicata	2		.01		1.36		.21
Adenopodia spicata	3	.04	.19	1.87	19.73	0.00	1.04
Adenopodia spicata	4	2.43	.27	128.04	28.34	6.97	0.00
Aloe marlothii	3		.01		1.36		0.80
Asclepias fruticosa	2	.04		1.87		2.46	
Asparagus spp.	1	.04	.07	1.87	6.80	6.10	1.19
Asparagus spp.	2		.01		1.36		.33
Asparagus spp.	3	.04	.01	1.87	1.36	3.85	2.08
Azima tetracantha	1	.18		9.35		.51	
Azima tetracantha	2	.18		9.35		.15	
Azima tetracantha	3	.04		1.87		.38	
Berchemia zeyheri	1	1.56	.69	82.24	72.11	1.07	.59
Berchemia zeyheri	2	.99	.59	52.34	61.22	.75	.50
Berchemia zeyheri	3	4.46	3.15	234.58	329.02	4.21	3.68
Berchemia zeyheri	4	4.19	4.12	220.25	430.39	28.53	24.17
Bequaertiodendron natalense	1	.04	.01	1.87	1.36	6.10	3.33

TABLE 7.19 p2

HLUHLUWE GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH
FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC;TBYES	CC;TBNO
Berquaertiodendron natalense	3	.04		1.87		.51	
Bersama lucens	1	.04		1.87		1.02	
Bersama lucens	2		.07		6.80		1.16
Bersama lucens	3	.18	.08	9.35	8.16	1.53	1.35
Canthium inerme	1	.21	.12	11.21	12.24	1.26	1.16
Canthium inerme	2	.21	.09	11.21	9.52	.81	.50
Canthium inerme	3	.04	.05	1.87	5.44	2.54	.28
Canthium inerme	4	.04		1.87		30.51	
Canthium spp.	1	.04		1.87		6.10	
Capparis sepiaria	1		.03		2.72		2.64
Capparis sepiaria	2		.01		1.36		1.39
Capparis tomentosa	1	.18	.03	9.35	2.72	4.01	1.67
Capparis tomentosa	2	.04	.01	1.87	1.36	3.05	.69
Capparis tomentosa	4		.01		1.36		1.39
Cassine aethiopica	1	.04	.07	1.87	6.80	1.22	1.10
Cassine aethiopica	2	.04	.07	1.87	6.80	.51	.52
Cassine aethiopica	3	.04	.16	1.87	17.01	.31	5.78
Cassine aethiopica	4	.74	.53	38.94	55.10	35.31	9.92
Cassine transvaalensis	3	.04		1.87		.95	
Celtis africana	1	.43	.16	22.43	16.33	4.19	2.37
Celtis africana	2	.11	.05	5.61	5.44	2.29	.71
Celtis africana	3	.25		13.08		11.86	
Celtis africana	4	.04	.39	1.87	41.04	0.00	0.00
Chaetachme aristata	1	.07	.09	3.74	9.52	2.03	1.10
Chaetachme aristata	2	.04	.04	1.87	4.08	.24	.42
Chaetachme aristata	3	.04	.01	1.87	1.36	1.91	.83
Chaetachme aristata	4		.18		18.37		12.49
Chromolaena odorata	1	.04		1.87		12.71	
Chromolaena odorata	2	.07	.03	3.74	2.72	.58	.28
Chromolaena odorata	3	1.22	.01	64.17	1.36	2.85	.17
Chromolaena odorata	4	.04		1.87		3.05	
Clausena anisata	1		.08		8.16		1.35
Clausena anisata	2	.04	.01	1.87	1.36	1.02	4.16
Clausena anisata	3		.01		1.36		1.67
Clutia pulchella	1	.04	.01	1.87	1.36	.81	.33
Clutia pulchella	2	.48	.50	25.23	51.70	5.15	.99
Clutia pulchella	3	.21	.54	11.21	56.69	6.54	2.38
Coddia rudis	1	.43	.22	22.43	23.13	.28	.34
Coddia rudis	2		.01		1.36		4.16
Cola greenwayi	1		.01		1.36		.83
Cola greenwayi	3	.04	.07	1.87	6.80	.38	1.49
Combretum molle	1	.25	.04	13.08	4.08	1.01	.62
Combretum molle	2	.14	.04	7.48	4.08	1.16	.56
Combretum molle	3	.62	.03	32.71	2.72	2.62	5.55
Combretum molle	4	2.26	.08	118.69	8.16	23.63	3.57
Commiphora harveyi	1		.04		4.08		2.27
Cordia caffra	1	.39	.44	28.56	45.58	2.94	1.58
Cordia caffra	2	.50	.46	26.17	48.30	1.44	1.00
Cordia caffra	3	.57	.35	29.91	36.73	2.05	1.71
Cordia caffra	4	.28	.38	14.95	40.14	122.04	20.47
Crotolaria capensis	2		.01		1.36		.28
Croton sylvaticus	1	.07	.01	3.74	1.36	4.69	1.67
Croton sylvaticus	2	.11		5.61		1.45	
Croton sylvaticus	3	.07	.07	3.74	6.80	1.27	.69
Cunonia capensis	1	.07	.01	3.74	1.36	.61	4.16
Cussonia spp.	4		.16		17.01		0.00

TABLE 7.19 p3

HLUHLUWE GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC:TBYES	CC:TBNO
Dalbergia armata	1	.04		1.87		6.10	
Dalbergia armata	2	.07	.03	3.74	2.72	.87	.95
Dalbergia armata	3		.01		1.36		.59
Dalbergia armata	4		.08		8.16		0.80
Dalbergia obovata	1	.25	.13	13.08	13.61	1.31	1.12
Dalbergia obovata	2	.62	.08	32.71	8.16	1.96	.83
Dalbergia obovata	3	.07	.31	3.74	32.43	2.03	1.96
Dalbergia obovata	4		.39		41.04		3.69
Dichrostachys cinerea	1	5.95	2.30	313.08	240.14	.98	.60
Dichrostachys cinerea	2	3.54	.97	185.98	101.36	.70	.29
Dichrostachys cinerea	3	4.48	2.60	235.51	271.43	4.43	4.40
Dichrostachys cinerea	4	.18	.08	9.35	8.16	0.00	0.00
Diospyros lycioides	1	1.47	.72	77.57	75.51	.52	.45
Diospyros lycioides	2	2.88	1.63	151.40	170.52	.51	.50
Diospyros lycioides	3	2.06	.84	108.10	87.98	2.31	2.96
Diospyros lycioides	4	.11	.16	5.61	17.81	0.00	0.00
Diospyros simii	1	1.28	.35	67.29	36.73	.99	.62
Diospyros simii	2	1.85	.55	97.20	57.82	1.60	.64
Diospyros simii	3	1.01	.44	53.27	45.58	3.34	1.99
Diospyros simii	4	.18		9.35		12.71	
Diospyros spp.	1	.07	.14	3.74	14.97	2.03	.69
Diospyros spp.	2	.07	.01	3.74	1.36	1.74	.56
Diospyros spp.	3	.04		1.87		1.53	
Diospyros spp.	4	.04		1.87		.76	
Diospyros whyteana	1	.04		1.87		3.05	
Dombeya burgessiae	1	.11	.04	5.61	4.08	.75	.24
Dombeya burgessiae	2	1.03	.38	54.21	39.23	1.10	.69
Dombeya burgessiae	3	.25	.07	13.08	6.80	1.87	.65
Dombeya rotundifolia	1	.53	.29	28.04	29.93	1.02	.47
Dombeya rotundifolia	2	.36	.23	18.69	24.49	.53	.36
Dombeya rotundifolia	3	.18	.13	9.35	13.61	2.93	.92
Dombeya rotundifolia	4		.01		1.36		1.67
Dovyalis caffra	1	.14	.13	7.48	13.61	.94	1.16
Dovyalis caffra	2	.11	.08	5.61	8.16	.56	.54
Dovyalis caffra	3	.28	.12	14.95	12.24	2.00	.61
Dovyalis caffra	4	.44		25.36		23.84	
Ehretia rigida/amoena	1	.36	.10	18.69	10.88	1.21	.77
Ehretia rigida/amoena	2	.14	.08	7.48	8.16	.60	.26
Ehretia rigida/amoena	3	.04	.18	1.87	18.37	.95	2.34
Erythroxylum emarginatum	1		.01		1.36		3.33
Erythroxylum emarginatum	3		.01		1.36		2.08
Euclea crispa	1	1.35	.77	71.03	80.27	.88	.41
Euclea crispa	2	1.05	.84	55.14	87.76	.61	.24
Euclea crispa	3	.04	.01	1.87	1.36	30.51	.28
Euclea divinorum	1	1.07	.42	56.07	43.54	1.29	1.39
Euclea divinorum	2	2.91	.69	152.96	72.11	.87	.62
Euclea divinorum	3	4.10	2.10	215.58	219.50	2.54	4.05
Euclea divinorum	4	2.39	.86	125.86	89.80	51.36	12.49
Euclea natalensis	1	.11	.08	5.61	8.16	3.66	.95
Euclea natalensis	2	.21	.07	11.21	6.80	1.02	.28
Euclea natalensis	3	.48	.20	25.23	21.09	7.92	1.77
Euclea racemosa	1	2.81	1.23	105.61	127.89	2.07	1.33
Euclea racemosa	2	2.82	1.26	148.29	131.29	1.23	.61
Euclea racemosa	3	6.72	5.38	353.27	561.22	5.98	4.85
Euclea racemosa	4	8.69	6.41	457.32	669.16	28.49	35.61
Eugenia natalitia	1	.07	.03	3.74	2.72	1.16	2.22

TABLE 7.19 p4

HLUHLUWE GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC:T%YES	CC:T%NO
Eugenia nataltia	2	.04		1.87		3.81	
Ficus glumosa	2		.01		1.36		.33
Ficus spp.	2	.04	.03	1.87	2.72	.76	.49
Ficus sur	2	.21		11.21		1.14	
Ficus sycomorus	2	.04		1.87		.34	
Forb spp.	1	.18		9.35		.61	
Forb spp.	2	.18		9.35		1.13	
Galpinia transvealica	1	.50	.07	26.17	6.80	1.11	1.19
Galpinia transvaalica	2	.32	.03	16.82	2.72	.57	.93
Galpinia transvealica	3	.07	.10	3.74	10.88	.64	.94
Galpinia transvaalica	4	.44	.23	23.36	23.81	11.92	5.60
Geranium spp.	2	.48		25.23		.59	
Grewia caffra	1		.03		2.72		.67
Grewia caffra	2	.07		3.74		1.45	
Grewia flavescens	1	.07		3.74		.34	
Grewia occidentalis	1	.07	.07	3.74	6.80	2.44	.95
Grewia occidentalis	2	.07	.03	3.74	2.72	1.11	.64
Grewia accidentalis	3	.44		23.36		23.84	
Harpephyllum caffrum	4		.16		17.01		0.00
Heteropyxis natalensis	1	.21	.05	11.21	5.44	.51	.35
Heteropyxis natalensis	2	.18	.28	9.35	29.25	.69	1.18
Heteropyxis natalensis	3	.07	.34	3.74	35.37	2.18	2.04
Heteropyxis natalensis	4	1.04	.01	54.52	1.36	74.16	1.04
Hippobromus pauciflorus	1	.60	.22	31.78	23.13	.94	1.86
Hippobromus pauciflorus	2	.69	.35	36.45	36.51	1.21	2.06
Hippobromus pauciflorus	3		.08		8.16		1.61
Hippobromus pauciflorus	4	.04	.08	1.87	8.16	0.00	16.65
Indigofera natalensis/cylingorica	1	.04	.01	1.87	1.36	12.71	2.19
Indigofera natalensis/cylingorica	2	.07		3.74		1.74	
Kraussia floribunda	1	1.74	.96	91.59	100.00	1.09	.64
Kraussia floribunda	2	1.81	.72	95.33	75.51	.55	.44
Kraussia floribunda	3	1.58	.80	83.18	83.67	1.29	1.45
Kraussia floribunda	4	.11	.01	5.61	1.36	1.91	4.16
Lippia javanica	1	.64	.51	33.64	53.74	.33	.66
Lippia javanica	2	3.27	1.32	171.96	138.10	.68	.26
Lippia javanica	3	1.70	.20	89.41	20.41	1.76	.67
Lycium acutifolium	1	.04	.01	1.87	1.36	6.10	.33
Manilkara concolor	1		.04		4.08		2.00
Manilkara concolor	3		.04		4.08		3.57
Manilkara discolor	3	.44		23.36		1.49	
Manilkara discolor	4		.16		17.01		0.00
Maytenus heterophylla	1	.32	.12	16.82	12.24	.81	.71
Maytenus heterophylla	2	.39	.07	20.56	6.80	.95	.40
Maytenus heterophylla	3	.11	.04	5.61	4.08	.69	.42
Maytenus heterophylla	4		.18		18.37		56.21
Maytenus nemorosa	1	.71	.23	37.38	24.49	1.43	1.09
Maytenus nemorosa	2	1.01	.20	53.27	20.41	1.04	.62
Maytenus nemorosa	3	2.59	.93	136.45	97.28	2.42	1.69
Maytenus nemorosa	4	1.22	.52	64.17	54.42	65.47	5.46
Maytenus senegalensis	1	1.08	.46	57.01	47.62	1.16	.50
Maytenus senegalensis	2	1.84	.34	96.88	35.37	.75	.20
Maytenus senegalensis	3	1.60	.51	84.11	53.74	1.44	.94
Maytenus senegalensis	4	.04		1.87		3.05	
Melanthus didyma	1	.11	.03	5.61	2.72	7.38	.70
Monanthotaxis caffra	1	.07	.08	3.74	8.16	2.03	.32
Monanthotaxis caffra	2	.04	.05	1.87	5.44	.10	.46

TABLE 7.19 p5

HLUHLUWE GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC:TBYES	CC:TBNO
Monanthotaxis caffra	3		.01		1.36		1.39
Ochna natalitia	1	.04	.01	1.87	1.36	12.71	1.39
Ochna natalitia	2	.07		3.74		1.74	
Oricia bachmannii	1		.01		1.36		2.78
Oricia bachmannii	2		.01		1.36		2.08
Ormocarpum trichocarpum	1	.04	.01	1.87	1.36	3.05	3.33
Ozoroa engleri	1		.01		1.36		.28
Pancovia golungensis	1	.07	.04	3.74	4.08	3.05	1.67
Pancovia golungensis	2	.11	.03	5.61	2.72	.92	.24
Pancovia golungensis	3		.01		1.36		.83
Pappia capensis	1	.04		1.87		12.71	
Pappia capensis	4	.74		38.94		0.00	
Peltophorum africanum	1	.11	.01	5.61	1.36	.87	3.33
Peltophorum africanum	2	.07	.01	3.74	1.36	.37	.42
Peltophorum africanum	3		.27		28.34		3.61
Peltophorum africanum	4	.44		23.36		63.56	
Phyllanthus reticulatus	1	.39	.16	20.56	16.33	1.89	1.00
Phyllanthus reticulatus	2	.04	.21	1.87	21.77	.58	.58
Phyllanthus reticulatus	3	.21	.04	11.21	4.08	2.77	1.09
Plectroniella armata	1	.78	.33	41.12	34.69	1.55	.77
Plectroniella armata	2	.32	.14	16.82	14.97	.46	.41
Plectroniella armata	3	1.10	.39	57.63	40.82	2.78	.66
Plectroniella armata	4	.52	.08	27.10	8.16	13.41	3.84
Psychotria capensis	3	.04		1.87		.38	
Rhoicissus rhombidea	1	.04		1.87		1.02	
Rhoicissus tomentosa	3	.04		1.87		2.54	
Rhoicissus tomentosa	4	.21		11.21		3.98	
Rhoicissus tridentata	1	1.21	.60	63.55	62.59	.87	.62
Rhoicissus tridentata	2	2.77	.79	145.48	82.31	.95	.31
Rhoicissus tridentata	3	.21	.01	11.21	1.36	7.04	2.08
Rhus chirindensis	1	.07	.07	3.74	6.80	2.44	6.94
Rhus chirindensis	2	.21	.10	11.21	10.88	.96	.81
Rhus chirindensis	3	.11	.03	5.61	2.72	6.54	3.33
Rhus chirindensis	4	.07		3.74		.95	
Rhus gueinzii	1		.01		1.36		3.33
Rhus gueinzii	4	.04		1.87		0.00	
Rhus pentheri	1	.99	.43	52.34	44.90	1.96	.79
Rhus pentheri	2	2.72	.93	142.99	97.28	.70	.40
Rhus pentheri	3	7.05	3.50	370.72	364.85	2.59	2.29
Rhus pentheri	4	1.96	2.25	103.12	234.69	11.53	10.97
Rhus rehmanniana	1	.11	.03	5.61	2.72	1.14	.67
Rhus rehmanniana	2	.28	.22	14.95	23.13	.60	.17
Rhus rehmanniana	3	.36	.01	18.69	1.36	1.34	.59
Rhus spp.	1	.14		7.48		1.60	
Rhus spp.	2	.07	.08	3.74	8.16	.23	.41
Schotia brachypetala	1	.11	.09	5.61	9.52	2.03	.63
Schotia brachypetala	2	.14	.03	7.48	2.72	.51	.57
Schotia brachypetala	3	.04	.01	1.87	1.36	2.54	.42
Schotia brachypetala	4	.69	1.03	36.45	107.03	0.00	18.20
Sclerocarya birrea	1	.04	.05	1.87	5.44	1.22	.31
Sclerocarya birrea	2	.04	.09	1.87	9.52	.34	.21
Sclerocarya birrea	3	.04	.14	1.87	14.97	5.08	4.95
Sclerocarya birrea	4	4.21	.28	221.50	29.71	90.38	25.97
Scolopia zeyheri	1	.36	.37	18.69	38.78	2.01	1.96
Scolopia zeyheri	2	.21	.05	11.21	5.44	1.11	.47
Scolopia zeyheri	3	.04	.05	1.87	5.44	1.39	.74

TABLE 7.19 p6

HLUHLUWE GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC:TOYES	CC:TBNO
Scutia myrtina	1	.71	.33	37.38	34.81	.70	.54
Scutia myrtina	2	.53	.46	28.04	47.62	.67	.52
Scucia myrtina	3	1.78	.87	93.46	91.16	4.54	1.41
Scucia myrtina	4	2.11	1.43	110.90	149.21	8.54	2.61
Sesbania sesban	1	.84	.81	1.87	1.36	.68	2.19
Sesbania sesban	2	.07		3.74		.74	
Sideroxylon inerme	1	.43	.12	22.43	12.24	2.87	.99
Sideroxylon inerme	2	.36	.08	18.69	8.16	1.14	.32
Sideroxylon inerme	3	.25	.18	13.08	19.85	2.81	1.91
Sideroxylon inerme	4	.32	.71	16.82	74.15	7.85	5.13
Solanum	1	1.55	.35	81.31	36.73	1.51	.68
Solanum	2	2.45	.55	128.66	57.14	1.74	.37
Solanum	3		.01		1.36		2.08
Spirostachys africana	1	2.83	.29	148.91	30.61	.85	.61
Spirostachys africana	2	2.37	.04	124.92	4.08	.58	.25
Spirostachys africana	3	4.46	.43	234.58	44.67	.80	.83
Spirostachys africana	4	2.66	.94	139.88	97.73	1.16	1.73
Strychnos innocua	1		.01		1.36		.37
Strychnos madagascarensis	1		.01		1.36		1.11
Strychnos madagascarensis	2		.01		1.36		.83
Tarchonanthus camphoratus	1	.04		1.87		.17	
Tarchonanthus camphoratus	2	.04		1.87		.15	
Tarchonanthus camphoratus	3	1.04		54.52		2.22	
Tarchonanthus camphoratus	4	.18		9.35		0.00	
Teclea gerrardii	4		.27		28.34		115.65
Teclea natalensis	4		.07		6.80		0.00
Thespesia acutiloba	1		.01		1.36		.83
Thespesia acutiloba	2		.03		2.72		.48
Thespesia acutiloba	4		.01		1.36		0.00
Trema orientalis	2	.04	.01	1.87	1.36	1.53	.42
Trema orientalis	3		.04		4.88		1.92
Trema orientalis	4	.48		25.23		25.74	
Trichoctadus grandiflorus	2		.01		1.36		4.16
Trichoctadus grandiflorus	4		.16		17.01		26.02
Turraea floribunda	1		.01		1.36		3.33
Unknown 15	1		.03		2.72		.39
Unknown 15	2	.11	.05	5.61	5.44	.80	.15
Unknown 15	4		.16		17.01		104.09
Unknown 8	1	.04		1.87		3.05	
Unknown 8	2	.04		1.87		.76	
Unknown 8	3		.01		1.36		0.80
Vernonia subuligera	1	.04	.01	1.87	1.36	6.10	.83
Vernonia subuligera	2	1.94	.92	101.07	96.15	1.37	.30
Vernonia subuligera	3	.48	.08	25.23	8.16	5.15	.57
Vitellariopsis marginata	2		.01		1.36		2.19
Vitex harveyana	4	.18		9.35		38.14	
Ximenia caffra	1	.11	.01	5.61	1.36	.70	.83
Ximenia caffra	2	.04	.03	1.87	2.72	.95	.26
Ximenia caffra	3	.07	.04	3.74	4.08	2.18	2.50
Zanthoxylum capense	1	.28	.16	14.95	16.33	3.39	1.32
Zanthoxylum capense	2	.14	.09	7.48	9.52	1.36	1.00
Zanthoxylum capense	3	.07	.04	3.74	4.08	3.05	1.47
Zanthoxylum capense	4		.01		1.36		0.00
Zizyphus mucronata	1	.57	.22	29.91	23.13	1.01	.67
Zizyphus mucronata	2	.53	.12	28.04	12.24	.43	.25
Zizyphus mucronata	3	.46	.27	24.30	27.89	1.36	1.62
Zizyphus mucronata	4	.99	.47	52.02	48.98	12.87	5.76

TABLE 7.20 p1

UMFOLOZI GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 79.1% OF PLOTS WITH
FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC:TBYES	CC:TBNO
Acacia borleae	1	.47		18.02		.76	
Acacia borleae	2	.62		23.65		.36	
Acacia burkei	1	.03		1.13		1.27	
Acacia caffra	1	.27		10.14		2.24	
Acacia caffra	2	.18		6.76		.47	
Acacia caffra	3	.09		3.38		.69	
Acacia gerrardii	1	1.33	.69	50.68	25.64	1.73	.57
Acacia gerrardii	2	.12		4.50		.48	
Acacia gerrardii	3	.59	.11	22.52	4.27	1.92	.11
Acacia gerrardii	4	.12		4.50		0.00	
Acacia grandicornuta	1	1.60	.46	60.31	17.09	.93	.45
Acacia grandicornuta	2	.95	.11	36.84	4.27	1.06	.16
Acacia grandicornuta	3	1.42	.91	54.05	34.19	1.25	1.00
Acacia grandicornuta	4	.77	1.94	29.28	72.65	7.11	3.04
Acacia karroo	1	1.57	.34	59.68	12.82	1.24	.16
Acacia karroo	2	1.01		38.29		.95	
Acacia karroo	3	.59	.34	22.52	12.82	1.47	.17
Acacia luederitzii	1	.15		5.63		1.23	
Acacia luederitzii	2	.18		6.76		.85	
Acacia luederitzii	3	1.78		67.57		3.58	
Acacia luederitzii	4	.47		18.02		101.70	
Acacia nigrescens	1	1.27	1.26	48.42	47.81	2.50	.65
Acacia nigrescens	2	.24	.11	9.01	4.27	1.06	.50
Acacia nigrescens	3	.12	.91	4.50	34.19	2.31	.82
Acacia nigrescens	4	3.11	5.03	118.24	188.03	11.26	8.80
Acacia nilotica	1	1.42	1.26	54.05	47.01	2.11	.31
Acacia nilotica	2	.30		11.26		.93	
Acacia nilotica	3	.50	.23	19.14	8.55	1.47	.67
Acacia nilotica	4	.03	.80	1.13	29.91	0.00	4.38
Acacia robusta	1	.71		27.03		2.87	
Acacia robusta	2	.24		9.01		1.37	
Acacia robusta	3	.09		3.38		.76	
Acacia robusta	4	.30	.91	11.26	34.19	8.20	.24
Acacia sengal	1	.33		12.39		3.73	
Acacia sengal	2	.12		4.50		2.31	
Acacia sengal	3	.03		1.13		.36	
Acacia tortilis	1	1.01	.69	38.29	25.64	1.35	.42
Acacia tortilis	2	.47	.23	18.02	8.55	.55	.29
Acacia tortilis	3	.24	1.60	9.01	59.83	.66	2.92
Aloe marlothii	3	.03		1.13		.64	
Asparagus spp.	1	2.43	2.40	92.34	89.74	.98	.44
Asparagus spp.	2	1.07	1.49	40.54	55.56	.86	.17
Asparagus spp.	3	.56	.69	21.40	25.64	1.06	.12
Asparagus spp.	4	.03		1.13		1.27	
Azima tetracantha	1	.68		25.90		3.25	
Azima tetracantha	2	.24	.11	9.01	4.27	1.07	.35
Berchemia zeyheri	1	.18		6.76		1.67	
Berchemia zeyheri	4	.03		1.13		12.71	
Boscia albitrunca	1	.41	.23	15.77	8.55	4.75	.33
Boscia albitrunca	2	.09		3.38		1.66	
Boscia albitrunca	3	.12	.11	4.50	4.27	2.42	5.00
Brachylaena ilicifolia	1	.71	.46	27.03	17.09	.62	.19
Brachylaena ilicifolia	2	1.13	.34	42.79	12.82	.46	.09
Brachylaena ilicifolia	3	.65		24.77		.94	
Cadaba natalensis	1	.03		1.13		1.27	
Canthium spp.	1	.03		1.13		6.36	
Canthium spp.	2	.03		1.13		6.36	
Capparis sepiaria	1	.03		1.13		1.69	
Capparis sepiaria	2	.06		2.25		.64	
Capparis sepiaria	3		.11		4.27		.07
Capparis tomentosa	1	.80	.69	30.41	25.64	1.62	1.02
Capparis tomentosa	2	.33		12.39		.70	
Capparis tomentosa	3	.15	.11	5.63	4.27	1.25	.50
Carissa bispinosa	1	.12	.23	4.50	8.55	.36	.06
Carissa bispinosa	2	.06	.11	2.25	4.27	.31	.13
Casine tetragona	1	.03		1.13		4.24	
Casine tetragona	3	.03		1.13		.17	
Cassine aethiopica	2	.06		2.25		1.45	
Cassine aethiopica	3	.03		1.13		.64	
Cassine aethiopica	4	.21		7.88		2.17	
Cassine transvaalensis	1	.27		10.14		3.81	
Cassine transvaalensis	2	.06		2.25		1.41	
Cassine transvaalensis	3	.03		1.13		1.27	
Cassine transvaalensis	4	.18		6.76		7.63	
Clutia pulchella	3	.03		1.13		1.59	
Coddia rudis	1	.44	.34	16.89	12.82	.87	.14
Coddia rudis	2	.12		4.50		1.18	
Combretum apiculatum	1	.15	.46	5.63	17.09	7.95	.45
Combretum apiculatum	2	.03	.11	1.13	4.27	2.54	3.13
Combretum apiculatum	3	.21		7.88		6.85	
Combretum apiculatum	4	.06		2.25		8.47	
Commiphora harveyi	3	.06		2.25		6.47	
Commiphora neglecta	1	.59	.57	22.52	21.37	1.86	1.61
Commiphora neglecta	2	.15	.11	5.63	4.27	.86	.50
Commiphora neglecta	3	.15		5.63		.88	

TABLE 7.20 p2

UMFOLOZI GRID STUDY AREA : SPSIZE CANOPY COVER COMPARISONS BETWEEN THE 79.1% OF PLOTS WITH FEEDING (YES) AND THE 28.9% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPta/HaYES	TotCPta/HaNO	CC:TBYES	CC:TBNO
Crotalaria capensis	1	.03	.11	1.13	4.27	6.36	2.58
Croton menyhartii	1	.71	1.26	27.83	47.81	1.19	.44
Croton menyhartii	2	2.55	7.66	96.85	286.32	.59	.15
Croton menyhartii	3	1.63	11.54	61.94	431.62	.34	.13
Cussonia zuluensis	1	.06	.11	2.25	4.27	7.26	.83
Cussonia zuluensis	2	.03		1.13		3.39	
Cussonia zuluensis	3	.06	.11	2.25	4.27	8.80	1.67
Dichrostachys cinerea	1	3.55	1.37	135.14	51.28	1.44	.40
Dichrostachys cinerea	2	1.48	.34	56.31	12.82	.89	.59
Dichrostachys cinerea	3	.41	.23	15.77	8.55	.85	.40
Diospyros lycioides	1	.06		2.25		.50	
Diospyros spp.	1	.03		1.13		2.12	
Diospyros spp.	2	.03		1.13		12.71	
Diospyros spp.	3	.03		1.13		12.71	
Diospyros whyteana	1	.06		2.25		.79	
Dombeya rotundifolia	1	.09		3.38		1.82	
Dombeya rotundifolia	3	.06		2.25		3.18	
Dombeya tiliacea	1	.03		1.13		2.12	
Dombeya tiliacea	2	.03		1.13		.79	
Dombeya tiliacea	3	.03		1.13		.42	
Ehretia rigida/amoena	1	2.22	2.29	84.46	85.47	1.44	.59
Ehretia rigida/amoena	2	.74	.57	28.15	21.37	.46	.19
Ehretia rigida/amoena	3	.47	.11	18.02	4.27	1.88	.15
Erythrina lysistemon	1	.03		1.13		1.59	
Erythrina lysistemon	2	.03		1.13		1.59	
Euclea divinorum	1	.74	.80	28.15	29.91	1.86	.25
Euclea divinorum	2	1.54	.57	58.56	21.37	.43	.13
Euclea divinorum	3	1.27	.69	48.42	25.64	.58	.56
Euclea divinorum	4	.03		1.13		.21	
Euclea natalensis	1	.03		1.13		6.36	
Euclea natalensis	2	.06		2.25		.34	
Euclea natalensis	3	.03		1.13		.28	
Euclea racemosa	1	.68	.34	25.90	12.82	1.88	.39
Euclea racemosa	2	.59	.23	22.52	8.55	.50	.07
Euclea racemosa	3	.53	.69	28.27	25.64	1.13	5.00
Euclea racemosa	4	.15		5.63		1.96	
Euclea undulata	1	.30	.34	11.26	12.82	.95	.21
Euclea undulata	2	.36	.34	13.51	12.82	.33	.05
Euclea undulata	3	3.02	.80	114.86	29.91	.84	.56
Euclea undulata	4	.47		18.02		1.11	
Galpinia transvaalica	1		.11		4.27		.83
Gardenia cornuta	1	.12		4.50		3.70	
Gardenia cornuta	3	.03		1.13		3.18	
Gardenia cornuta	4	.44		16.89		15.89	
Gardenia volkensii	1	.18	.23	6.76	8.55	5.45	.71
Gardenia volkensii	3	.03		1.13		.67	
Gardenia volkensii	4	.03		1.13		3.18	
Grewia bicolor	1		.23		8.55		1.25
Grewia bicolor	2	.15		3.63		1.32	
Grewia bicolor	3	.03		1.13		.55	
Grewia flava	1	.27	.34	10.14	12.82	2.25	.25
Grewia flava	2	.24	1.03	9.01	38.46	.98	.24
Grewia flava	3		.91		34.19		.23
Grewia flavescens	1	.27		10.14		2.97	
Grewia flavescens	2	.09		3.38		.72	
Grewia flavescens	3	.50	.11	19.14	4.27	.50	.42
Grewia flavescens	4		.11		4.27		.21
Grewia monticola	1	.09	.23	3.38	8.55	2.31	.51
Grewia monticola	2	.03		1.13		1.21	
Grewia monticola	3	.03		1.13		1.59	
Grewia occidentalis	1	.65	.46	24.77	17.89	2.54	.25
Grewia occidentalis	2	.21	.11	7.88	4.27	1.12	.89
Grewia occidentalis	3	.18		6.76		1.96	
Grewia spp.	3	.03		1.13		.91	
Grewia villosa	1	.47	.69	18.02	25.64	2.81	.55
Grewia villosa	2	.09	.23	3.38	8.55	1.19	.91
Hippobromus pauciflorus	1	.09		3.38		8.47	
Hippobromus pauciflorus	2	.03		1.13		1.82	
Hippobromus pauciflorus	3	.03		1.13		2.54	
Lippia javanica	1	.03		1.13		5.08	
Lippia javanica	2	.03		1.13		6.36	
Lycium acutifolium	1	.09	.23	3.38	8.55	5.88	1.11
Lycium acutifolium	2	.03		1.13		.85	
Maerua angolensis	1	.03		1.13		5.08	
Maerua angolensis	2	.21		7.88		12.71	
Maytenus heterophylla	1	1.21	1.37	46.17	51.28	2.15	.29
Maytenus heterophylla	2	.21	.11	7.88	4.27	.67	.83
Maytenus heterophylla	3	.18	.11	6.76	4.27	1.01	0.08
Maytenus heterophylla	4	.03		1.13		.36	
Maytenus nemorosa	1	.41	.69	15.77	25.64	2.33	.88
Maytenus nemorosa	2	.47	.11	18.02	4.27	.77	.31
Maytenus nemorosa	3	1.45	4.00	55.18	149.57	1.10	.42

TABLE 7.20 p3

UMFOLOZI GRID STUDY AREA : SPIZE CANOPY COVER COMPARISONS BETWEEN THE 79.1% OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	Cover%YES	Cover%NO	TotCPts/HaYES	TotCPts/HaNO	CC:%BYES	CC:%BNO
Maytenus nemorosa	4	.30	.80	11.26	29.91	.59	.10
Maytenus senegalensis	1	.33	.46	12.39	17.09	.83	.23
Maytenus senegalensis	2	.09	.23	3.38	8.55	.25	.45
Melanthus didyma	1	.59	.57	22.52	21.37	3.62	1.62
Melia azedarach	2	.03		1.13		1.59	
Monanthotaxis caffra	1	.06		2.25		2.54	
Olea europaea	2	.06		2.25		.62	
Olea europaea	3	.24	.69	9.01	25.64	.64	.17
Olea europaea	4	.65	.23	24.77	8.55	5.04	.04
Ormocarpum trichocarpum	1	.53	.46	20.27	17.09	2.22	.98
Ormocarpum trichocarpum	2	.09		3.38		2.82	
Ormocarpum trichocarpum	3	.03		1.13		1.27	
Ozoroa engleri	1	.03	.11	1.13	4.27	6.36	2.30
Ozoroa engleri	3	.03		1.13		.21	
Pappia capensis	1	.38	.11	14.64	4.27	5.75	.67
Pappia capensis	2	.06		2.25		3.39	
Pappia capensis	3	.24	1.94	9.01	72.65	3.51	1.52
Pappia capensis	4	1.24	.11	47.30	4.27	4.01	0.00
Plectroniella armata	1	.41	.11	15.77	4.27	1.50	1.25
Plectroniella armata	2	.56	.23	21.40	8.55	1.83	.45
Plectroniella armata	3	1.10		41.67		.73	
Plectroniella armata	4	.06		2.25		1.27	
Pyrostria hystrix	1	.18	.11	6.76	4.27	2.15	.17
Pyrostria hystrix	2	.12	.11	4.50	4.27	.85	.86
Pyrostria hystrix	3	.30	.80	11.26	29.91	1.65	.19
Rhoicissus rhombidea	1	.41	.57	15.77	21.37	2.24	.29
Rhoicissus rhombidea	2	.12	.34	4.50	12.82	1.03	.48
Rhus gueinzii	1	.24	.23	9.01	8.55	1.56	.19
Rhus gueinzii	2	.15	.23	5.63	8.55	.41	.22
Rhus gueinzii	3	.12	.23	4.50	8.55	.52	.14
Rhus gueinzii	4	.06		2.25		.77	
Rhus pentheri	1	.24	.23	9.01	8.55	1.82	.14
Rhus pentheri	2	.33	.46	12.39	17.09	.44	.07
Rhus pentheri	3	.15	.23	5.63	8.55	.30	.09
Rhus rehmanniana	1	.03		1.13		2.54	
Rhus rehmanniana	2	.03		1.13		1.45	
Schotia brachypetala	1	.12		4.50		4.84	
Schotia brachypetala	2	.06		2.25		.02	
Schotia brachypetala	4	.65	.11	24.77	4.27	21.51	0.00
Schotia capitata	1	.09	.11	3.38	4.27	1.34	.11
Schotia capitata	2	.09	.23	3.38	8.55	1.66	.06
Schotia capitata	3	1.48	2.86	56.31	106.84	.98	.21
Schotia capitata	4	.74	1.94	28.15	72.65	1.16	.36
Sclerocarya birrea	1	.06		2.25		1.21	
Sclerocarya birrea	3	.03	.11	1.13	4.27	0.00	0.00
Sclerocarya birrea	4	.24	.23	9.01	8.55	0.00	0.00
Scolopia zeyheri	1	.09		3.38		1.57	
Sesbania punicea	3	.03		1.13		1.27	
Sesbania sesban	2	.03		1.13		.32	
Sida cordifolia/rhombifolia	1	1.04	1.26	39.41	47.01	5.91	1.31
Sideroxylon inerme	1	.12	.23	4.50	8.55	1.88	.71
Sideroxylon inerme	2	.12		4.50		.97	
Sideroxylon inerme	3	.27		10.14		1.47	
Sideroxylon inerme	4	.09	.11	3.38	4.27	.93	.13
Solanum	1	.65	.46	24.77	17.09	3.88	1.67
Solanum	2	.06		2.25		3.63	
Spirostachys africana	1	1.92	1.14	73.20	42.74	.87	.30
Spirostachys africana	2	2.67	.46	101.35	17.09	.76	.09
Spirostachys africana	3	3.32	1.83	126.13	68.38	.52	.11
Spirostachys africana	4	1.42	3.89	54.05	145.30	3.79	2.83
Strychnos madagascarensis	4	.03		1.13		.33	
Strycnos spp.	1	.06		2.25		8.47	
Strycnos spp.	2		.11		4.27		.17
Strycnos spp.	3	.03		1.13		4.24	
Tarchonanthus camphoratus	1	.71	.46	27.03	17.09	.72	.11
Tarchonanthus camphoratus	2	1.21	2.29	46.17	85.47	1.08	.18
Tarchonanthus camphoratus	3	.80	2.63	30.41	98.29	.75	.23
Tarchonanthus camphoratus	4		.11		4.27		.50
Unknown 1	1		.11		4.27		.50
Unknown 15	1	.24		9.01		2.75	
Unknown 15	3	.06		2.25		.73	
Unknown 15	4	.18		6.76		1.59	
Unknown 2	1		.11		4.27		2.50
Unknown 3	1	.03		1.13		12.71	
Unknown 4	2	.03		1.13		.71	
Unknown 5	1	.03		1.13		12.71	
Unknown 6	1	.06		2.25		8.47	
Zanthozylum capense	1	.03		1.13		25.42	
Zanthozylum capense	2		.11		4.27		.36
Zizyphus mucronata	1	.18	.46	6.76	17.09	2.03	.95
Zizyphus mucronata	2	.09	.34	3.38	12.82	.73	.18
Zizyphus mucronata	3	.38	.11	14.64	4.27	1.05	.31
Zizyphus mucronata	4	.09		3.38		12.71	

TABLE 7.21 p1(i)

HLUHLUWE CRIB STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8%
OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO) Page 1

SppName	Size	FreePrefIndex	TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Abutilon/Hibiscus spp.	1	---			.61		.54		126.98		155.33		.82
Abutilon/Hibiscus spp.	2	*** 3.05	3.09	.87	2.65	.86	2.11	205.14	597.28	230.53	609.98	1.01	.98
Abutilon/Hibiscus spp.	3	--- 0.00	0.00	.22	.02	.20	.02	52.34	4.54	52.34	4.54	1.14	1.00
Acacia burkei	1	* 1.92	1.14	.01		.02		3.27		6.23		.60	
Acacia burkei	3	--- 0.00	0.00	0.00		0.00		0.00		0.00		0.00	
Acacia burkei	4	--- 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Acacia caffra	1	.95	.34	.22	.28	.64	.52	52.55	58.21	170.16	149.98	.35	.39
Acacia caffra	2	-- .44	.32	2.05	3.08	2.81	3.92	482.32	646.56	751.71	1,135.37	.73	.57
Acacia caffra	3	- .55	.62	5.37	2.69	4.72	1.95	1,262.93	565.53	1,262.93	565.53	1.14	1.00
Acacia caffra	4	---			.07		.05		14.51		14.51		1.00
Acacia gerrardii	1	-- .41	.30	.13	.03	.18	.02	30.22	5.44	48.29	6.80	.71	.80
Acacia gerrardii	2	1.18	1.30	2.31	.08	2.09	.05	542.98	15.87	559.19	15.87	1.10	1.00
Acacia gerrardii	3	--- 0.00	0.00	.13		.12		31.15		31.15		1.14	
Acacia gerrardii	4	--- 0.00	0.00	.01	0.00	.01	0.00	1.87	0.00	1.87	0.00	1.14	0.00
Acacia grandicornuta	1	--- 0.00	0.00	.00		.03		1.17		7.79		.17	
Acacia grandicornuta	2	* .50	.48	.11	.03	.11	.02	25.02	5.67	29.91	5.67	.95	1.00
Acacia grandicornuta	3	--- 0.00	0.00	.06		.06		14.95		14.95		1.14	
Acacia karroo	1	** 2.06	.96	.51	.57	1.08	1.56	118.74	119.90	290.03	453.15	.47	.26
Acacia karroo	2	.94	.72	2.67	3.02	3.50	3.98	627.96	634.72	937.20	1,152.38	.76	.55
Acacia karroo	3	1.10	1.25	2.56	1.12	2.25	.81	600.62	234.69	600.62	234.69	1.14	1.00
Acacia karroo	4	--- 0.00	0.00	.15	.26	.13	.19	34.58	55.33	34.58	55.33	1.14	1.00
Acacia nilotica	1	.92	.51	.84	.32	1.51	.59	198.31	66.65	403.68	171.20	.56	.39
Acacia nilotica	2	* 1.80	1.65	.86	.35	.94	.41	201.57	74.10	250.47	119.37	.92	.62
Acacia nilotica	3	* 1.48	1.69	.43	.34	.38	.25	101.56	71.88	101.56	71.88	1.14	1.00
Acacia nilotica	4	--- 0.00	0.00	.08	.04	.07	.03	18.07	9.07	18.07	9.87	1.14	1.00
Acacia robusta	1	*** 3.62	2.35	.17	.10	.26	.10	39.81	20.43	69.91	27.80	.65	.73
Acacia robusta	2	** 2.70	2.20	.22	.86	.27	.06	50.98	11.56	71.34	17.01	.81	.68
Acacia robusta	3	*** 2.87	3.27	.20	.08	.18	.06	47.98	16.33	47.98	16.33	1.14	1.00
Acacia robusta	4	--- 0.00	0.00	.01	.01	.01	.01	2.49	2.72	2.49	2.72	1.14	1.00
Acacia schweinfurthii/ataxacantha	1	--- 0.00	0.00	.03	.00	.03	.00	7.79	.45	7.79	.45	1.14	1.00
Acacia schweinfurthii/ataxacantha	2	--- 0.00	0.00	.01		.01		3.12		3.12		1.14	
Acalaypha sonderiana	1	--- 0.00	0.00	.07		.06		17.13		17.13		1.14	
Acalaypha sonderiana	2	--- 0.00	0.00	2.17	.08	1.91	.06	510.90	16.33	510.90	16.33	1.14	1.00
Acalaypha sonderiana	3	--- 0.00	0.00	.34	.09	.30	.06	79.75	17.91	79.75	17.91	1.14	1.00
Acalypha glabrata	1	- .53	.60	.91	.48	.80	.36	214.45	101.22	214.64	185.67	1.14	.96
Acalypha glabrata	2	1.20	1.37	4.94	1.46	4.34	1.05	1,161.92	305.44	1,161.99	305.44	1.14	1.00
Acalypha glabrata	3	1.00	1.14	4.77	1.92	4.19	1.39	1,120.25	403.63	1,120.25	403.63	1.14	1.00
Acalypha glabrata	4	*** 5.03	5.72	.01		.01		2.49		2.49		1.14	
Adenopodia spicata	1	--- 0.00	0.00	.01	.07	.01	.06	1.56	14.88	1.56	16.78	1.14	.89
Aderopodia spicata	2	---			.08		.06		16.33		16.14		.90
Adenopodia spicata	3	--- 0.00	0.00	0.00	.25	0.00	.18	0.00	52.61	0.00	52.61	0.00	1.00
Adenopodia spicata	4	-- .47	.53	.40	0.00	.35	0.00	93.46	0.00	93.46	0.00	1.14	0.00
Aloe marlothii	3	---			0.00		0.00		0.00		0.00		0.00
Asclepias fruticosa	2	--- 0.00	0.00	.01		.01		2.51		3.86		.74	
Asparagus spp.	1	*** 4.02	4.58	.01	.05	.01	.05	1.56	11.22	1.56	15.87	1.14	.71
Asparagus spp.	2	---			.02		.04		3.40		11.34		.30
Asparagus spp.	3	--- 0.00	0.00	.01	.01	.01	.01	3.12	1.81	3.12	1.81	1.14	1.00
Azima tetracantha	1	--- 0.00	0.00	.40		.35		93.46		93.46		1.14	
Azima tetracantha	2	--- 0.00	0.00	1.39		1.22		327.10		327.10		1.14	
Azima tetracantha	3	--- 0.00	0.00	.11		.09		24.92		24.92		1.14	
Berchemia zeyheri	1	1.07	.84	1.15	1.08	1.46	1.17	269.52	227.18	391.71	340.23	.78	.67
Berchemia zeyheri	2	* 1.61	1.62	1.34	1.48	1.33	1.18	315.44	310.75	355.45	342.86	1.01	.91
Berchemia zeyheri	3	1.15	1.31	1.21	1.18	1.06	.86	283.49	248.07	283.49	248.07	1.14	1.00
Berchemia zeyheri	4	--- 0.00	0.00	.17	.24	.15	.17	39.25	49.43	39.25	49.43	1.14	1.00
Berquaertiodendron natalense	1	--- 0.00	0.00	.01	.01	.81	.00	1.46	1.13	1.56	1.13	1.08	1.00

TABLE 7.21 p1(ii)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO) Page 1

SppName	Size	FreePrefIndex		H/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassIntXYES	MeanGrassIntXNO
Abutilon/Hibiscus spp.	1	---			6.80				18.25
Abutilon/Hibiscus spp.	2	***	3.05	32.71	23.81	2.67	31.15	11.01	2.08
Abutilon/Hibiscus spp.	3	---	0.00	4.98	.45	0.00	0.00	0.00	0.00
Acacia burkei	1	*	1.92	3.12		.03	.31	47.50	
Acacia burkei	3	--	0.00	.62		0.00	0.00	0.00	
Acacia burkei	4	---	0.00	.62	.45	0.00	0.00	0.00	0.00
Acacia caffra	1		.95	42.68	31.86	.21	2.49	69.11	61.19
Acacia caffra	2	--	.44	70.09	55.90	.91	10.59	35.84	43.05
Acacia caffra	3	-	.55	51.71	26.30	2.93	34.27	0.00	0.00
Acacia caffra	4	---			2.72				0.00
Acacia gerrardii	1	--	.41	12.46	2.27	.05	.62	37.42	20.00
Acacia gerrardii	2		1.18	16.20	1.13	2.72	31.78	2.90	0.00
Acacia gerrardii	3	---	0.00	2.49		0.00	0.00	0.00	
Acacia gerrardii	4	---	0.00	1.25	.45	0.00	0.00	0.00	0.00
Acacia grandicornuta	1	---	0.00	1.56		8.00	0.00	85.00	
Acacia grandicornuta	2	-	.50	5.61	1.13	.05	.62	16.33	0.00
Acacia grandicornuta	3	---	0.00	1.25		0.00	0.00	0.00	
Acacia karroo	1	**	2.06	133.64	145.24	1.04	12.15	59.06	73.54
Acacia karroo	2		.94	114.64	122.68	2.51	29.28	33.00	44.92
Acacia karroo	3		1.19	41.12	22.68	2.80	32.71	0.00	0.00
Acacia karroo	4	---	0.00	13.71	19.05	0.08	0.00	0.00	0.00
Acacia nilotica	1		.92	138.94	49.89	.77	9.03	50.87	61.07
Acacia nilotica	2	*	1.80	38.94	18.14	1.55	18.07	19.52	37.92
Acacia nilotica	3	*	1.48	21.81	34.92	.64	7.48	0.00	0.00
Acacia nilotica	4	---	0.00	16.20	24.49	0.00	0.00	0.00	0.00
Acacia robusta	1	***	3.62	49.22	18.14	.61	7.17	43.05	26.53
Acacia robusta	2	**	2.70	14.64	5.67	.59	6.85	28.54	32.00
Acacia robusta	3	***	2.87	3.74	1.81	.59	6.85	0.00	0.00
Acacia robusta	4	---	0.00	10.59	4.54	0.00	0.00	0.00	0.00
Acacia schweinfurthii/ataxacantha	1	---	0.00	1.56	.45	0.00	0.00	0.00	0.00
Acacia schweinfurthii/ataxacantha	2	---	0.00	1.56		0.00	0.00	8.00	
Acalypha sonderiana	1	---	0.00	4.67		0.00	0.00	0.00	
Acalypha sonderiana	2	---	0.00	51.40	5.44	0.00	0.00	0.00	0.00
Acalypha sonderiana	3	---	0.00	6.23	8.16	0.00	0.00	0.00	0.00
Acalypha glabrata	1	-	.53	56.70	35.60	.48	5.61	.09	4.21
Acalypha glabrata	2		1.20	126.79	45.35	5.95	69.47	.01	0.00
Acalypha glabrata	3		1.00	72.90	29.93	4.77	55.76	0.00	0.00
Acalypha glabrata	4	***	5.03	.62		.05	.62	0.00	
Adenopodia spicata	1	---	0.00	1.56	3.17	0.00	0.00	0.00	11.35
Adenopodia spicata	2	---			.91				10.00
Adenopodia spicata	3	---	0.00	.62	1.81	0.00	0.00	0.00	0.00
Adenopodia spicata	4	--	.47	4.98	.91	.19	2.18	0.00	0.00
Aloe marlothii	3	---			.45				0.00
Asclepias fruticosa	2	---	0.00	1.56		0.00	0.00	35.00	
Asparagus spp.	1	***	4.02	1.56	5.67	.03	.31	0.00	29.29
Asparagus spp.	2	---			1.13				70.00
Asparagus spp.	3	---	0.00	.62	.45	0.00	0.00	0.00	0.00
Azima tetracantha	1	---	0.00	4.67		0.00	0.00	0.00	
Azima tetracantha	2	---	0.00	9.35		0.00	0.00	0.00	
Azima tetracantha	3	---	0.00	.62		0.00	0.00	0.00	
Berchemia zeyheri	1		1.07	127.10	109.07	1.23	14.33	31.19	33.23
Berchemia zeyheri	2	*	1.61	58.57	61.68	2.16	25.23	11.26	9.37
Berchemia zeyheri	3		1.15	42.99	46.26	1.39	16.20	0.00	0.00
Berchemia zeyheri	4	---	0.00	11.21	35.37	0.00	0.00	0.00	0.00
							0.00	5.00	0.00

TABLE 7.21 p2(i)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	FreePrefIndex	TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Berquaertiodendron natalense	3	--- 0.00	8.00	.08		.07		18.69		18.69		1.14	
Bersama lucens	1	--- 0.00	0.00	.04		.03		9.35		9.35		1.14	
Bersama lucens	2	---			.06		.06		13.06		16.33		.80
Bersama lucens	3	--- 0.00	0.00	.13	.08	.12	.06	31.15	16.78	31.15	16.78	1.14	1.00
Canthium inerme	1	--- 0.00	0.00	.07	.09	.17	.10	17.29	18.80	45.17	29.25	.44	.64
Canthium inerme	2	--- 0.00	0.00	.24	.21	.26	.18	56.54	43.03	70.09	53.29	.92	.81
Canthium inerme	3	--- 0.00	0.00	.02	.26	.01	.19	3.74	54.88	3.74	54.88	1.14	1.00
Canthium inerme	4	--- 0.00	0.00	.00		.00		.31		.31		1.14	
Canthium spp.	1	*** 4.23	4.58	.01		.01		1.48		1.56		1.09	
Capparis sepiaria	1	---			.01		.01		2.46		2.86		.86
Capparis sepiaria	2	---			.01		.01		2.72		2.72		1.00
Capparis tomentosa	1	--- 0.00	0.00	.05	.02	.04	.02	10.70	4.31	11.84	4.54	1.03	.95
Capparis tomentosa	2	--- 0.00	0.00	.01	.02	.01	.02	3.12	4.90	3.12	5.44	1.14	.90
Capparis tomentosa	4	---			.01		.01		2.72		2.72		1.00
Cassine aethiopica	1	--- 0.00	0.00	.03	.08	.03	.06	7.01	16.62	7.79	17.23	1.02	.96
Cassine aethiopica	2	.96	.76	.06	.17	.07	.13	13.08	36.28	18.69	36.28	.80	1.00
Cassine aethiopica	3	--- 0.00	0.00	.13	.04	.12	.03	31.15	8.16	31.15	8.16	1.14	1.80
Cassine aethiopica	4	--- 0.00	0.00	.02	.07	.02	.05	5.61	15.42	5.61	15.42	1.14	1.00
Cassine transvaalensis	3	--- 0.00	0.00	.04		.04		9.97		9.97		1.14	
Celtis africana	1	1.02	1.05	.10	.08	.10	.07	24.52	17.78	27.23	19.14	1.02	.93
Celtis africana	2	--- 0.00	0.00	.05	.10	.05	.07	11.06	21.13	12.46	21.32	1.01	.99
Celtis africana	3	1.12	1.27	.02		.02		5.61		5.61		1.14	
Celtis africana	4	--- 0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chaetachme aristata	1	--- 0.00	0.00	.02	.11	.03	.08	4.77	23.08	9.35	24.04	.58	.96
Chaetachme aristata	2	--- 0.00	0.00	.14	.13	.15	.09	33.10	27.21	38.94	27.21	.97	1.00
Chaetachme aristata	3	--- 0.00	0.00	.02	.02	.02	.02	4.98	4.54	4.98	4.54	1.14	1.00
Chaetachme aristata	4	---			.02		.01		4.08		4.08		1.00
Chromolaena odorata	1	--- 0.00	0.00	.00		.00		.75		.75		1.14	
Chromolaena odorata	2	--- 0.00	0.00	.09	.13	.12	.09	20.25	27.21	32.71	27.21	.70	1.00
Chromolaena odorata	3	--- 0.00	0.00	.49	.11	.43	.08	114.64	22.68	114.64	22.68	1.14	1.00
Chromolaena odorata	4	--- 0.00	0.00	.01		.01		3.12		3.12		1.14	
Clausena anisata	1	---			.07		.06		14.63		16.78		.87
Clausena anisata	2	--- 0.00	0.00	.04	.80	.03	.00	8.88	.91	9.35	.91	1.08	1.00
Clausena anisata	3	---			.01		.01		2.27		2.77		1.00
Clutia pulchella	1	--- 0.00	0.00	.05	.03	.04	.04	11.71	6.80	11.71	11.34	1.14	.60
Clutia pulchella	2	--- 0.00	0.00	.10	.51	.09	.50	24.30	107.69	24.92	145.67	1.11	.74
Clutia pulchella	3	--- 0.80	0.00	.04	.32	.03	.23	8.72	66.21	8.72	66.21	1.14	1.00
Coddia rudis	1	--- .17	.17	1.60	.76	1.53	.65	376.25	160.44	408.10	188.89	1.05	.85
Coddia rudis	2	---			.00		.00		.91		.91		1.00
Cola greenwayi	1	---			.02		.02		4.54		4.54		1.00
Cola greenwayi	3	--- 0.00	0.00	.11	.06	.09	.04	24.92	12.70	24.92	12.70	1.14	1.00
Combretum molle	1	* .68	.43	.16	.05	.25	.06	36.76	9.75	65.73	18.14	.64	.54
Combretum molle	2	--- 0.00	0.00	.11	.08	.12	.07	25.23	16.55	32.71	20.41	.88	.81
Combretum molle	3	--- 0.00	0.00	.27	.01	.24	.00	63.55	1.36	63.55	1.36	1.14	1.00
Combretum molle	4	--- 0.00	0.00	.11	.03	.10	.02	25.55	6.35	25.55	6.35	1.14	1.00
Commiphora harveyi	1	---			.02		.02		4.81		4.99		.96
Cordia caffra	1	--- 0.00	0.00	.12	.20	.13	.28	27.79	42.39	35.51	79.95	.89	.53
Cordia caffra	2	--- 0.00	0.00	.35	.52	.35	.46	82.46	108.56	92.52	134.47	1.01	.81
Cordia caffra	3	--- 0.00	0.00	.32	.28	.28	.21	74.14	59.64	74.14	59.64	1.14	1.00
Cordia caffra	4	--- 0.00	0.00	.00	.03	.00	.02	.62	5.44	.62	5.44	1.14	1.00
Crotalaria capensis	2	---			.06		.05		13.61		13.61		1.00
Croton sylvaticus	1	--- 0.00	0.00	.02	.01	.02	.01	3.68	2.27	4.05	2.27	1.03	1.00
Croton sylvaticus	2	*** 20.97	17.80	.06		.07		14.64		19.63		.85	
Croton sylvaticus	3	*** 10.86	11.44	.06	.13	.06	.09	14.95	27.21	14.95	27.21	1.14	1.00
Cunonia capensis	1	--- 0.00	0.00	.02	.00	.12	.00	3.68	.54	31.15	.91	.13	.60
Cussonia spp.	4	---			0.00		0.00		0.00		0.00		0.00

TABLE 7.21 p2(ii)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8%
OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO) Page 2

SppName	Size	FreePrefIndex		N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassInt%YES	MeanGrassInt%NO
Berquaertiodendron natalense	3	---	0.00	.62		0.00	0.00	0.00	
Bersama lucens	1	---	0.00	3.12		0.00	0.00	0.00	
Bersama lucens	2	---			1.36				20.00
Bersama lucens	3	---	0.00	3.12	1.81	0.00	0.00	0.00	0.00
Canthium inerme	1	---	0.00	9.35	8.84	0.00	0.00	61.72	35.74
Canthium inerme	2	---	0.00	11.53	7.94	0.00	0.00	19.33	19.26
Canthium inerme	3	---	0.00	.62	3.17	0.00	0.00	0.00	0.00
Canthium inerme	4	---	0.00	.62		0.00	0.00	0.00	
Canthium spp.	1	***	4.23	1.56		.03	.31	5.00	
Capparis sepiaria	1	---			2.27				13.89
Capparis sepiaria	2	---			.45				0.00
Capparis tomentosa	1	---	0.00	10.59	2.27	0.00	0.00	9.61	5.00
Capparis tomentosa	2	---	0.00	1.56	.91	0.00	0.00	0.00	10.00
Capparis tomentosa	4	---			.91				0.00
Cassine aethiopica	1	---	0.00	1.56	8.39	0.00	0.00	10.00	3.55
Cassine aethiopica	2		.96	1.56	2.27	.05	.62	30.00	0.00
Cassine aethiopica	3	---	0.00	.62	1.36	0.00	0.00	0.00	0.00
Cassine aethiopica	4	---	0.00	1.87	3.17	0.00	0.00	0.00	0.00
Cassine transvaalensis	3	---	0.00	.62		0.00	0.00	0.00	
Celtis africana	1		1.02	30.84	19.05	.11	1.25	9.95	7.11
Celtis africana	2	---	0.00	4.67	8.39	0.00	0.00	11.25	.85
Celtis africana	3		1.12	1.87		.03	.31	0.00	
Celtis africana	4	---	0.00	.62	2.27	0.00	0.00	0.00	0.00
Chaetachme aristata	1	---	0.00	3.72	7.94	0.00	0.00	49.00	3.96
Chaetachme aristata	2	---	0.00	1.56	4.54	0.00	0.00	15.00	0.00
Chaetachme aristata	3	---	0.00	.62	.45	0.00	0.00	0.00	0.00
Chaetachme aristata	4	---			.91				0.00
Chromolaena odorata	1	---	0.00	1.56		0.00	0.00	0.00	
Chromolaena odorata	2	---	0.00	4.67	2.27	0.00	0.00	38.10	0.00
Chromolaena odorata	3	---	0.00	4.98	.45	0.00	0.00	0.00	0.00
Chromolaena odorata	4	---	0.00	.62		0.00	0.00	0.00	
Clausena anisata	1	---			10.66				12.84
Clausena anisata	2	---	0.00	1.56	.45	0.00	0.00	5.00	0.00
Clausena anisata	3	---			.45				0.00
Clutia pulchella	1	---	0.00	4.67	5.67	0.00	0.00	0.00	40.00
Clutia pulchella	2	---	0.00	7.79	41.95	0.00	0.00	2.50	26.07
Clutia pulchella	3	---	0.00	1.87	9.52	0.00	0.00	0.00	0.00
Coddia rudis	1	---	.17	40.50	28.80	.27	3.12	7.81	15.06
Coddia rudis	2	---			.45				0.00
Cola greenwayi	1	---			1.13				0.00
Cola greenwayi	3	---	0.00	.62	.91	0.00	0.00	0.00	0.00
Combretum molle	1	—	.68	26.17	6.80	.11	1.25	44.08	46.25
Combretum molle	2	---	0.00	6.85	3.40	0.00	0.00	22.86	18.89
Combretum molle	3	---	0.00	3.74	.91	0.00	0.00	0.00	0.00
Combretum molle	4	---	0.00	5.61	1.36	0.00	0.00	0.00	0.00
Commiphora harveyi	1	---			4.99				3.64
Cordia caffra	1	---	0.00	17.45	37.39	0.00	0.00	21.75	46.98
Cordia caffra	2	---	0.00	23.05	34.24	0.00	0.00	10.88	19.27
Cordia caffra	3	---	0.00	13.08	8.62	0.00	0.00	0.00	0.00
Cordia caffra	4	---	0.00	2.49	4.99	8.00	0.00	0.00	0.00
Crotalaria capensis	2	---			1.13				0.00
Croton sylvaticus	1	---	0.00	2.18	2.27	0.00	0.00	9.23	0.00
Croton sylvaticus	2	***	20.97	4.98		1.31	15.26	25.38	
Croton sylvaticus	3	***	10.06	1.25	.91	.64	7.48	0.00	0.00
[illegible]	[illegible]			[illegible]	.91	0.00	0.00	88.20	40.00

TABLE 7.21 p3(i)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size		FreePrefIndex	TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Dalbergia armata	1	---	8.00	0.80	.01		.01		1.56		1.56		1.14	
Dalbergia armata	2	---	0.00	0.00	.09	.84	.08	.03	21.81	7.94	21.81	7.94	1.14	1.80
Dalbergia armata	3	---				.03		.02		6.35		6.35		1.80
Dalbergia armata	4	---				0.00		0.00		0.00		0.00		0.00
Dalbergia obovata	1	---	0.08	0.00	.11	.13	.19	.12	25.09	27.66	30.72	33.79	.56	.82
Dalbergia obovata	2	---	0.00	0.00	.35	.10	.32	.09	82.94	21.77	84.74	27.21	1.11	.80
Dalbergia obovata	3	---	0.00	0.00	.04	.22	.03	.16	9.35	45.80	9.35	45.80	1.14	1.00
Dalbergia obovata	4	---				.15		.11		30.84		30.84		1.00
Dichrostachys cinerea	1	*	1.34	.70	3.17	2.48	6.05	3.82	744.29	520.77	1,618.57	1,107.57	.52	.47
Dichrostachys cinerea	2		.85	.77	4.59	2.84	5.05	3.40	1,078.94	595.88	1,351.40	985.62	.91	.61
Dichrostachys cinerea	3	---	.12	.13	1.15	.82	1.01	.59	278.09	171.20	270.09	171.20	1.14	1.00
Dichrostachys cinerea	4	---	0.00	0.08	0.08	0.00	0.00	0.00	8.08	0.00	0.00	0.00	0.00	0.00
Diospyros lycioides	1	---	0.00	0.00	1.52	1.03	2.81	1.59	357.10	215.85	752.77	461.72	.54	.47
Diospyros lycioides	2	---	.09	.08	5.11	2.47	5.61	3.27	1,200.39	518.65	1,501.25	947.39	.91	.55
Diospyros lycioides	3	---	.21	.24	1.01	.39	.89	.28	238.01	82.54	238.01	82.54	1.14	1.00
Diospyros lycioides	4	---	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Diospyros simii	1	---	.27	.23	1.10	.65	1.29	.57	258.18	135.50	344.24	165.03	.85	.82
Diospyros simii	2	--	.49	.53	1.24	1.15	1.15	.86	292.06	241.84	308.41	250.57	1.08	.97
Diospyros simii	3	---	0.00	0.00	.34	.30	.30	.22	81.00	63.49	81.00	63.49	1.14	1.00
Diospyros simii	4	---	0.00	0.00	.02		.01		3.74		3.74		1.14	
Diospyros spp.	1	---	0.00	0.00	.03	.21	.03	.21	7.01	43.65	9.35	60.09	.85	.73
Diospyros spp.	2	---	0.00	0.00	.04	.03	.04	.02	10.20	6.80	10.90	6.80	1.06	1.00
Diospyros spp.	3	---	0.00	0.00	.03		.02		6.23		6.23		1.14	
Diospyros spp.	4	---	0.00	0.00	.05		.05		12.46		12.46		1.14	
Diospyros whyteana	1	---	0.00	0.00	.01		.01		2.80		3.12		1.02	
Dombeya burgessiae	1	***	3.59	1.12	.04	.17	.14	.16	10.47	35.96	38.13	46.53	.31	.77
Dombeya burgessiae	2	-	.73	.51	.66	.68	.93	.55	154.70	141.90	250.03	158.05	.70	.90
Dombeya burgessiae	3	*	1.41	1.61	.15	.14	.13	.10	35.51	29.02	35.51	29.02	1.14	1.00
Dombeya rotundifolia	1	---	0.00	0.00	.20	.41	.52	.62	47.82	86.99	139.81	178.46	.39	.49
Dombeya rotundifolia	2	---	8.00	0.00	.46	.71	.67	.64	107.79	148.75	179.13	186.39	.68	.80
Dombeya rotundifolia	3	***	3.67	4.40	.07	.20	.06	.14	16.20	41.27	16.20	41.27	1.14	1.00
Dombeya rotundifolia	4	---				.01		.81		2.27		2.27		1.00
Dovyalis caffra	1	---	0.00	0.00	.07	.14	.15	.11	17.13	30.16	40.50	32.65	.48	.92
Dovyalis caffra	2		1.12	1.26	.21	.20	.19	.14	50.24	41.72	51.09	41.72	1.12	1.00
Dovyalis caffra	3	***	3.96	4.50	.16	.26	.14	.19	38.01	55.33	38.01	55.33	1.14	1.00
Dovyalis caffra	4	---	0.00	0.00	.02		.02		4.98		4.98		1.14	
Ehretia rigida/amoena	1	---	.25	.27	.32	.15	.29	.13	75.38	30.76	78.69	39.00	1.09	.79
Ehretia rigida/amoena	2	--	.39	.45	.27	.30	.24	.30	63.86	62.59	63.86	85.71	1.14	.73
Ehretia rigida/amoena	3	---	0.00	0.00	.04	.10	.04	.08	9.97	21.77	9.97	21.77	1.14	1.00
Erythroxylum emarginatum	1	---				.01		.00		1.13		1.13		1.00
Erythroxylum emarginatum	3	---				.01		.01		1.81		1.81		1.00
Euclea crispa	1	---	.08	.03	.64	.67	1.54	1.88	150.49	141.28	410.72	543.99	.42	.26
Euclea crispa	2	---	0.00	0.00	1.35	2.61	1.72	3.54	318.35	548.16	459.19	1,024.26	.79	.54
Euclea crispa	3	---	0.00	0.00	.00	.06	.00	.05	.31	13.61	.31	13.61	1.14	1.00
Euclea divinorum	1	---	0.00	0.00	.52	.31	.83	.30	123.12	64.90	220.81	86.85	.63	.75
Euclea divinorum	2	---	0.00	0.00	3.41	1.46	3.34	1.11	801.25	306.12	893.46	320.86	1.02	.95
Euclea divinorum	3	---	0.00	0.00	1.83	.72	1.61	.52	431.15	158.57	431.15	150.57	1.14	1.00
Euclea divinorum	4	---	0.00	0.00	.05	.10	.05	.07	12.46	19.95	12.46	19.95	1.14	1.00
Euclea natalensis	1	---	0.00	0.00	.02	.11	.03	.08	4.74	22.79	7.79	23.81	.69	.96
Euclea natalensis	2	---	0.00	0.00	.24	.45	.21	.32	55.28	94.10	56.07	94.10	1.12	1.00
Euclea natalensis	3	---	0.00	0.00	.07	.16	.06	.11	16.20	33.11	16.20	33.11	1.14	1.00
Euclea racemosa	1	---	0.00	0.00	.80	1.01	.97	.92	188.19	211.34	259.50	266.58	.83	.79
Euclea racemosa	2	---	.06	.07	2.49	2.61	2.28	2.07	585.19	547.95	610.90	598.87	1.09	.91
Euclea racemosa	3	---	.21	.24	1.28	1.53	1.12	1.11	300.31	321.32	300.31	321.32	1.14	1.00
Euclea racemosa	4	---	0.00	0.00	.35	.25	.31	.18	81.62	52.15	81.62	52.15	1.14	1.00
Eugenia natalitia	1	---	0.00	0.80	.07	.01	.06	.01	15.80	3.00	16.32	3.40	1.10	.88

TABLE 7.21 p3(ii)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8%
OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	FreePrefIndex		N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassInt%YES	MeanGrassInt%NO
Dalbergia armata	1	---	0.00	1.56		0.00	0.00	0.00	
Dalbergia armata	2	---	0.00	6.23	5.67	0.00	0.00	0.00	0.00
Dalbergia armata	3	---			.45				0.00
Dalbergia armata	4	---			.91				0.00
Dalbergia obovata	1	---	0.00	34.89	23.58	0.00	0.00	50.52	18.12
Dalbergia obovata	2	---	0.00	19.94	13.61	0.00	0.00	2.12	20.00
Dalbergia obovata	3	---	0.00	1.87	11.34	0.00	0.00	0.00	0.00
Dalbergia obovata	4	---			6.35				0.00
Dichrostachys cinerea	1	*	1.34	526.79	387.30	4.24	49.53	54.02	52.98
Dichrostachys cinerea	2		.85	170.40	129.93	3.89	45.48	20.16	39.44
Dichrostachys cinerea	3	---	.12	49.84	33.56	.13	1.56	0.00	0.00
Dichrostachys cinerea	4	---	0.00	.62	1.36	0.08	0.00	0.00	0.00
Diospyros lycioides	1	---	0.00	178.82	140.02	0.00	0.00	52.56	53.25
Diospyros lycioides	2	---	.09	181.00	133.79	.45	5.30	20.04	45.25
Diospyros lycioides	3	---	.21	28.66	22.22	.21	2.49	0.00	0.00
Diospyros lycioides	4	---	0.00	1.87	.45	0.00	0.00	0.00	0.00
Diospyros simii	1	---	.27	147.98	78.12	.29	3.43	25.00	17.90
Diospyros simii	2	--	.49	68.54	55.56	.61	7.17	5.30	3.48
Diospyros simii	3	---	0.00	13.08	11.79	0.00	0.00	0.00	0.00
Diospyros simii	4	---	0.00	1.25		0.00	0.00	0.00	
Diospyros spp.	1	---	0.00	4.67	20.41	0.00	0.00	25.00	27.36
Diospyros spp.	2	---	0.00	4.67	1.13	0.00	0.00	6.43	0.00
Diospyros spp.	3	---	0.00	.62		0.00	0.00	0.00	
Diospyros spp.	4	---	0.00	.62		0.00	0.00	0.00	
Diospyros whyteana	1	---	0.00	1.56		0.00	0.00	10.00	
Dombeya burgessiae	1	***	3.59	9.35	7.94	.16	1.87	72.55	22.71
Dombeya burgessiae	2	*	.73	23.36	11.11	.48	5.61	38.13	10.22
Dombeya burgessiae	3	*	1.41	3.12	.91	.21	2.49	0.00	0.00
Dombeya rotundifolia	1	---	0.00	31.46	67.12	0.00	0.00	65.80	51.25
Dombeya rotundifolia	2	---	0.00	18.38	25.40	0.00	0.00	39.83	20.19
Dombeya rotundifolia	3	***	3.87	4.36	4.54	.27	3.12	0.00	0.00
Dombeya rotundifolia	4	---			.45				0.00
Dovyalis caffra	1	---	0.00	7.79	14.06	0.00	0.00	57.69	7.64
Dovyalis caffra	2		1.12	5.30	7.03	.24	2.80	1.66	0.00
Dovyalis caffra	3	***	3.96	3.74	3.17	.64	7.48	0.00	0.00
Dovyalis caffra	4	---	0.00	.62		0.00	0.00	0.00	
Ehretia rigida/amoena	1	---	.25	31.15	17.01	.08	.93	4.21	21.31
Ehretia rigida/amoena	2	--	.39	7.79	9.30	.11	1.25	0.00	26.98
Ehretia rigida/amoena	3	---	0.00	.62	1.36	0.00	0.00	0.00	0.00
Erythroxylum emarginatum	1	---			1.13				0.00
Erythroxylum emarginatum	3	---			.45				0.00
Euclea crispa	1	---	.08	167.13	185.15	.05	.62	63.36	74.03
Euclea crispa	2	---	0.00	62.93	121.09	0.00	0.00	30.67	46.48
Euclea crispa	3	---	0.00	.62	2.27	0.00	0.00	0.00	0.00
Euclea divinorum	1	---	0.00	91.74	62.59	0.00	0.00	44.24	25.27
Euclea divinorum	2	---	0.00	118.69	53.29	0.00	0.00	10.32	4.59
Euclea divinorum	3	---	0.00	38.01	27.66	0.00	0.00	0.00	0.00
Euclea divinorum	4	---	0.00	15.58	7.26	0.00	0.00	0.00	0.00
Euclea natalensis	1	---	0.00	6.23	12.47	0.00	0.00	39.20	4.29
Euclea natalensis	2	---	0.00	14.64	13.61	0.00	0.00	1.42	0.00
Euclea natalensis	3	---	0.00	4.98	4.54	0.00	0.00	0.00	0.00
Euclea racemosa	1	---	0.00	159.81	200.45	0.00	0.00	27.48	20.72
Euclea racemosa	2	---	.06	129.28	153.97	.16	1.87	4.21	8.50
Euclea racemosa	3	---	.21	81.62	85.26	.27	3.12	0.00	0.00
Euclea racemosa	4		0.00	47.35	53.97	0.00	0.00	0.00	0.00

TABLE 7.21 p4(i)

HLUHLUWE GRIB STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8%
OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	FreePrefIndex		TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Eugenia natalitia	2	---	0.00	0.08	.01		.01		1.99		2.49		.91	
Ficus glumosa	2	---				.04		.04		9.07		11.34		.80
Ficus spp.	2	---	0.00	0.00	.03	.04	.05	.05	7.48	9.30	12.46	15.42	.68	.60
Ficus sur	2	**	2.01	1.14	.11		.19		24.92		49.84		.57	
Ficus sycomorus	2		.89	1.02	.12		.10		28.04		28.04		1.14	
Forb spp.	1	*	1.61	.37	.07		.29		15.58		77.88		.23	
Forb spp.	2	---	0.00	0.00	.06		.16		14.72		42.06		.40	
Galpinia transvaalica	1	-	.57	.42	.33	.04	.45	.05	77.26	8.73	119.94	15.87	.73	.55
Galpinia transvaalica	2	---	.31	.29	.51	.04	.56	.03	120.02	8.16	149.53	8.16	.91	1.00
Galpinia transvaalica	3	---	0.00	0.00	.13	.15	.11	.11	29.91	31.97	29.91	31.97	1.14	1.00
Galpinia transvaalica	4	---	0.00	0.00	.04	.06	.04	.04	9.97	11.79	9.97	11.79	1.14	1.00
Geranium spp.	2	-	.61	.26	.35		.82		82.55		218.07		.43	
Grewia caffra	1	---				.05		.04		10.77		11.34		.95
Grewia caffra	2	---	0.00	0.00	.06		.05		13.08		13.08		1.14	
Grewia flavescens	1	---	0.00	0.00	.23		.21		54.21		56.07		1.10	
Grewia occidentalis	1	---	0.00	0.00	.03	.08	.03	.07	5.92	17.76	7.79	19.95	.86	.89
Grewia occidentalis	2	---	0.00	0.00	.07	.06	.06	.04	16.20	11.79	17.13	11.79	1.08	1.00
Grewia occidentalis	3	---	0.00	0.00	.02		.02		4.98		4.98		1.14	
Harpephyllum caffrum	4	---				0.00		0.00		0.00		0.00		0.00
Heteropyxis natalensis	1	---	0.00	0.00	.12	.11	.42	.15	27.73	22.45	112.15	43.08	.28	.52
Heteropyxis natalensis	2	---	0.00	0.00	.20	.28	.26	.24	47.04	59.68	68.54	69.02	.78	.86
Heteropyxis natalensis	3	---	0.00	0.00	.04	.23	.03	.17	8.72	48.07	8.72	48.07	1.14	1.00
Heteropyxis natalensis	4	---	0.00	0.00	.02	.02	.01	.01	3.74	3.63	3.74	3.63	1.14	1.00
Hippobromus pauciflorus	1	**	2.12	1.17	.35	.08	.64	.12	82.94	16.50	171.34	34.60	.55	.48
Hippobromus pauciflorus	2	-	.69	.65	.54	.13	.57	.17	126.32	28.32	152.65	49.30	.94	.57
Hippobromus pauciflorus	3	---				.07		.05		14.06		14.06		1.00
Hippobromus pauciflorus	4	---	0.00	0.00	0.00	.01	0.00	.00	0.00	1.36	0.00	1.36	0.00	1.00
Indigofera natalensis/cylingorica	1	---	0.00	0.00	.00	.00	.08	.01	.07	.03	.75	1.72	.11	.02
Indigofera natalensis/cylingorica	2	***	6.26	4.58	.03		.04		7.01		10.98		.73	
Kraussia floribunda	1	---	0.00	0.00	1.47	1.87	1.59	1.49	345.08	391.42	425.42	431.16	.92	.91
Kraussia floribunda	2	---	0.00	0.00	3.55	2.08	3.30	1.66	834.24	435.94	883.49	479.82	1.07	.91
Kraussia floribunda	3	---	0.00	0.00	1.40	.76	1.23	.55	328.35	159.64	328.35	159.64	1.14	1.00
Kraussia floribunda	4	---	0.08	0.00	.06	.00	.06	.00	14.95	.91	14.95	.91	1.14	1.00
Lippia javanica	1	---	0.00	0.00	.47	.41	1.21	.78	109.45	86.34	322.74	225.69	.39	.38
Lippia javanica	2	---	.09	.07	3.91	3.38	4.79	5.03	917.85	789.24	1,281.31	1,657.82	.82	.49
Lippia javanica	3	---	0.00	0.00	1.10	.40	.96	.29	257.94	84.81	257.94	84.81	1.14	1.00
Lycium acutifolium	1	---	0.00	0.00	.00	.06	.01	.04	1.09	7.94	1.56	11.34	.80	.70
Manilkara concolor	1	---				.02		.02		4.76		5.67		.84
Manilkara concolor	3	---				.02		.01		3.17		3.17		1.00
Manilkara discolor	3	---	0.00	0.00	.34		.30		79.75		79.75		1.14	
Manilkara discolor	4	---				0.00		0.00		0.00		0.00		0.00
Maytenus heterophylla	1	---	0.00	0.00	.18	.16	.39	.17	41.15	33.63	104.98	48.07	.45	.70
Maytenus heterophylla	2	---	0.00	0.00	.39	.21	.41	.16	91.84	43.03	109.66	46.94	.95	.92
Maytenus heterophylla	3	---	0.00	0.00	.17	.13	.15	.09	41.12	27.21	41.12	27.21	1.14	1.00
Maytenus heterophylla	4	---				.00		.00		.91		.91		1.00
Maytenus nemorosa	1	-	.78	.65	.41	.24	.50	.22	95.95	49.53	132.52	62.59	.82	.79
Maytenus nemorosa	2	-	.56	.60	1.04	.44	.97	.32	245.48	91.84	260.12	91.84	1.07	1.00
Maytenus nemorosa	3	*	1.31	1.49	1.22	.76	1.07	.55	286.60	160.09	286.60	160.09	1.14	1.00
Maytenus nemorosa	4	---	0.00	0.00	.02	.13	.02	.10	4.98	27.66	4.98	27.66	1.14	1.00
Maytenus senegalensis	1	---	.13	.11	.81	.42	.93	.92	191.09	88.27	249.84	266.21	.87	.33
Maytenus senegalensis	2	---	0.00	0.00	2.58	1.75	2.47	1.71	605.51	367.40	660.64	496.15	1.04	.74
Maytenus senegalensis	3	---	0.00	0.00	1.27	.76	1.11	.55	297.82	158.73	297.82	158.73	1.14	1.00
Maytenus senegalensis	4	---	0.00	0.00	.01		.01		3.12		3.12		1.14	
Melanthus didyma	1	---	0.00	0.00	.01	.00	.01	.04	1.68	.26	3.86	10.75	.50	.02
Monanthotaxis caffra	1		.94	.76	.03	.18	.03	.15	6.70	36.83	9.35	43.76	.82	.84
Monanthotaxis caffra	2	---	0.00	0.08	.26	.12	.35	.11	60.75	25.17	93.46	32.65	.74	.77

TABLE 7.21 p4(ii)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8%
OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO) Page 4

SppName	Size	FreePrefIndex	x/HaYES	x/HaNO	%Diet	Browsing/Ha	MeanGrassInt%YES	MeanGrassInt%NO
Eugenia natalitia	2	--- 0.00	.62		0.00	0.00	20.00	
Ficus glumosa	2	---		1.13				20.00
Ficus spp.	2	--- 0.00	1.56	1.59	0.00	0.00	40.00	38.71
Ficus sur	2	** 2.01	6.23		.21	2.49	50.00	
Ficus sycomorus	2	.69	1.56		.11	1.25	0.00	
Forb spp.	1	* 1.61	38.94		.11	1.25	80.00	
Forb spp.	2	--- 0.00	14.02		0.00	0.00	65.00	
Galpinia transvaalica	1	- .57	34.27	7.94	.19	2.18	35.58	45.00
Galpinia transvaalica	2	--- .31	12.46	2.04	.16	1.87	19.74	0.00
Galpinia transvaalica	3	--- 0.00	1.87	2.27	0.00	0.00	0.00	0.00
Galpinia transvaalica	4	--- 0.00	.62	1.36	0.00	0.00	0.00	0.00
Geranium spp.	2	- .81	7.79		.21	2.49	62.14	
Grewia caffra	1	---		2.27				5.00
Grewia caffra	2	--- 0.00	3.74		0.00	0.00	0.00	
Grewia flavescens	1	--- 0.00	9.35		0.00	0.00	3.33	
Grewia occidentalis	1	--- 0.00	3.12	8.16	0.00	0.00	24.00	11.02
Grewia occidentalis	2	--- 0.00	4.67	1.59	0.00	0.00	5.45	0.00
Grewia occidentalis	3	--- 0.00	.62		0.00	0.00	0.00	
Harpephyllum caffrum	4	---		.45				0.00
Heteropyxis natalensis	1	--- 0.00	21.81	10.20	0.00	0.00	75.28	47.89
Heteropyxis natalensis	2	--- 0.00	10.90	12.02	0.00	0.00	31.36	13.53
Heteropyxis natalensis	3	--- 0.00	1.25	4.54	0.00	0.00	0.00	0.00
Heteropyxis natalensis	4	--- 0.00	3.74	.45	0.00	0.00	0.00	0.00
Hippobromus pauciflorus	1	** 2.12	54.52	26.84	.75	8.72	51.59	52.31
Hippobromus pauciflorus	2	* .69	21.81	22.68	.37	4.36	17.24	42.55
Hippobromus pauciflorus	3	---		3.17				0.00
Hippobromus pauciflorus	4	--- 0.00	.62	2.72	0.00	0.00	0.00	0.00
Indigofera natalensis/cylingorica	1	--- 0.00	1.56	1.13	0.00	0.00	90.00	98.00
Indigofera natalensis/cylingorica	2	*** 6.26	4.67		.19	2.18	35.71	
Kraussia floribunda	1	--- 0.00	156.39	159.15	0.00	0.00	18.88	9.22
Kraussia floribunda	2	--- 0.00	131.15	93.42	0.00	0.00	5.57	9.14
Kraussia floribunda	3	--- 0.00	31.78	20.86	0.00	0.00	0.00	0.00
Kraussia floribunda	4	--- 0.00	3.12	.45	0.00	0.00	0.00	0.00
Lippia javanica	1	--- 0.00	117.45	83.67	0.00	0.00	66.09	61.71
Lippia javanica	2	--- .09	266.67	191.50	.35	4.05	28.37	51.35
Lippia javanica	3	--- 0.00	24.92	4.99	0.00	0.00	0.00	0.00
Lycium acutifolium	1	--- 0.00	1.56	2.27	0.00	0.00	30.00	30.00
Manilkara concolor	1	---		5.67				16.00
Manilkara concolor	3	---		1.36				0.00
Manilkara discolor	3	--- 0.00	1.25		0.00	0.00	0.00	
Manilkara discolor	4	---		.91				0.00
Maytenus heterophylla	1	--- 0.00	23.36	16.33	0.00	0.00	60.80	29.62
Maytenus heterophylla	2	--- 0.00	13.08	8.16	0.00	0.00	16.25	8.33
Maytenus heterophylla	3	--- 0.00	2.49	1.81	0.00	0.00	0.00	0.00
Maytenus heterophylla	4	---		.91				0.00
Maytenus nemorosa	1	* .78	55.14	27.44	.32	3.74	27.60	20.87
Maytenus nemorosa	2	- .56	32.71	18.14	.59	6.85	5.63	0.00
Maytenus nemorosa	3	* 1.31	17.45	13.15	1.60	13.69	0.00	0.00
Maytenus nemorosa	4	--- 0.00	3.12	2.72	0.00	0.00	0.00	0.00
Maytenus senegalensis	1	--- .13	81.00	75.74	.11	1.25	23.52	66.84
Maytenus senegalensis	2	--- 0.00	77.26	40.14	0.00	0.00	8.32	25.95
Maytenus senegalensis	3	--- 0.00	21.81	11.34	0.00	0.00	0.00	0.00
Maytenus senegalensis	4	--- 0.00	.62		0.00	0.00	0.00	
Melanthus didyma	1	--- 0.00	6.23	4.54	0.00	0.00	56.45	97.59
			[illegible]	[illegible]	.07	.31	28.33	15.85

TABLE 7.21 p5(i)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8%
OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO) Page 5

SppName	Size		FreePrefIndex	TotalPrefIndex	FreeBBXYES	FreeBBXNO	TotalBBXYES	TotalBBXNO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Monanthotaxis caffra	3	---				.07		.81		2.72		2.72		1.00
Ochna natalitia	1	---	0.00	0.00	.00	.01	.08	.01	.71	1.63	.75	2.72	1.88	.60
Ochna natalitia	2	---	0.00	0.00	.05		.04		10.98		10.98		1.14	
Oricia bachmannii	1	---				.01		.08		1.36		1.36		1.00
Oricia bachmannii	2	---				.01		.01		1.81		1.81		1.00
Ormocarpum trichocarpum	1	---	0.00	0.00	.00	.00	.01	.00	.93	.40	3.12	1.13	.34	.35
Ozoroa engleri	1	---			.	.05		.05		10.88		13.61		.80
Pancovia golungensis	1	---	0.00	0.00	.03	.03	.02	.02	6.23	6.80	6.23	6.80	1.14	1.00
Pancovia golungensis	2	---	0.00	0.00	.13	.15	.12	.11	31.15	31.75	31.15	31.75	1.14	1.00
Pancovia golungensis	3	---				.02		.02		4.54		4.54		1.00
Pappea capensis	1	---	0.00	0.00	.00		.00		.75		.75		1.14	
Pappea capensis	4	---	0.00	0.00	0.00		0.00		0.00		0.00		0.00	
Peltophorum africanum	1	---	0.00	0.00	.07	.01	.12	.08	16.51	1.13	32.71	1.13	.57	1.00
Peltophorum africanum	2	---	0.00	0.00	.18	.04	.19	.03	41.43	9.07	51.40	9.07	.92	1.00
Peltophorum africanum	3	---				.10		.88		21.77		21.77		1.08
Peltophorum africanum	4	---	0.00	0.00	.01		.81		1.87		1.87		1.14	
Phyllanthus reticulatus	1	---	.14	.13	.18	.16	.21	.16	43.36	32.79	55.45	45.35	.89	.72
Phyllanthus reticulatus	2	---	0.00	0.00	.06	.26	.06	.36	13.86	54.25	16.32	103.85	.91	.52
Phyllanthus reticulatus	3	---	0.00	0.00	.09	.05	.08	.04	20.56	10.88	20.56	10.88	1.14	1.00
Plectroniella armata	1	---	.06	.05	.44	.51	.50	.43	102.63	107.49	134.70	125.58	.87	.86
Plectroniella armata	2	---	.07	.08	.76	.48	.69	.35	177.73	101.17	185.36	101.45	1.09	1.00
Plectroniella armata	3	---	.24	.27	.45	.82	.39	.59	105.30	171.43	105.30	171.43	1.14	1.00
Plectroniella armata	4	---	0.00	0.00	.04	.03	.04	.02	10.28	5.90	10.28	5.90	1.14	1.00
Psychotria capensis	3	---	0.00	0.00	.11		.09		24.92		24.92		1.14	
Rhoicissus rhomboidea	1	---	0.00	0.00	.01		.03		2.34		9.35		.28	
Rhoicissus tomentosa	3	---	0.00	0.00	.02		.01		3.74		3.74		1.14	
Rhoicissus tomentosa	4	---	0.00	0.00	.06		.05		14.33		14.33		1.14	
Rhoicissus tridentata	1	---	0.00	0.00	.66	.39	1.39	.96	155.31	82.44	372.27	279.50	.47	.29
Rhoicissus tridentata	2	---	0.00	0.00	1.78	1.14	2.92	1.55	418.17	239.59	780.87	448.39	.61	.53
Rhoicissus tridentata	3	---	0.00	0.00	.03	.01	.03	.01	8.10	1.81	8.10	1.81	1.14	1.00
Rhus chirindensis	1	---	0.00	0.00	.02	.01	.03	.01	4.74	2.72	7.79	2.72	.69	1.00
Rhus chirindensis	2	---	0.00	0.00	.24	.17	.22	.13	56.54	35.51	59.19	37.19	1.09	.95
Rhus chirindensis	3	---	0.00	0.00	.02	.01	.02	.01	4.36	2.27	4.36	2.27	1.14	1.00
Rhus chirindensis	4	---	0.00	0.00	.08		.07		19.94		19.94		1.14	
Rhus gueinzii	1	---				.01		.00		1.13		1.13		1.00
Rhus gueinzii	4	---	0.00	0.00	0.00		0.00		0.00		0.00		0.00	
Rhus pentheri	1	---	0.00	0.00	.35	.47	.51	.55	81.87	99.21	135.76	158.50	.69	.63
Rhus pentheri	2	---	.09	.08	3.58	2.75	3.89	2.35	840.42	576.16	1,041.74	681.18	.92	.85
Rhus pentheri	3	---	.14	.16	3.09	2.11	2.72	1.53	727.10	442.40	727.10	442.40	1.14	1.00
Rhus pentheri	4	---	0.00	0.00	.19	.28	.17	.21	45.48	59.41	45.48	59.41	1.14	1.00
Rhus rehmanniana	1	---	0.00	0.00	.03	.03	.09	.04	6.62	6.69	24.92	11.34	.30	.59
Rhus rehmanniana	2	---	.14	.11	.37	.62	.47	1.38	86.66	130.84	126.98	376.42	.78	.35
Rhus rehmanniana	3	---	0.00	0.00	.30	.03	.27	.02	71.03	6.35	71.03	6.35	1.14	1.00
Rhus spp.	1	---	0.00	0.00	.02		.09		5.37		23.80		.26	
Rhus spp.	2	---	0.00	0.00	.14	.13	.30	.19	32.09	28.12	81.00	55.33	.45	.51
Schotia brachypetala	1	---	0.00	0.00	.04	.12	.05	.15	9.66	26.16	14.02	42.18	.78	.62
Schotia brachypetala	2	---	0.00	0.00	.25	.05	.28	.05	59.81	10.84	74.77	13.24	.91	.82
Schotia brachypetala	3	---	0.00	0.00	.02	.04	.01	.83	3.74	9.07	3.74	9.07	1.14	1.00
Schotia brachypetala	4	---	0.00	0.00	0.00	.08	0.00	.06	0.00	16.33	0.00	16.33	0.00	1.00
Sclerocarya birrea	1	---	0.00	0.00	.02	.09	.03	.17	4.67	19.05	7.79	48.75	.68	.39
Sclerocarya birrea	2	---	0.00	0.00	.06	.36	.10	.43	14.02	74.57	28.04	125.26	.57	.60
Sclerocarya birrea	3	---	0.00	0.00	.01	.04	.01	.03	1.87	8.39	1.87	8.39	1.14	1.00
Sclerocarya birrea	4	---	0.00	0.00	.05	.02	.05	.01	12.46	3.17	12.46	3.17	1.14	1.00
Scolopia zeyheri	1	-	.58	.60	.19	.24	.18	.19	42.93	49.95	47.35	54.78	1.03	.91
Scolopia zeyheri	2	---	.12	.14	.22	.15	.19	.11	50.78	31.88	51.40	32.43	1.12	.98
Scolopia zeyheri	3	---	0.00	0.00	.03	.10	.03	.07	6.85	20.41	6.85	20.41	1.14	1.00

TABLE 7.21 p5(ii)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	FreePrefIndex	N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassInt%YES	MeanGrassInt%NO
Monanthotaxis caffra	3	---		.45				0.00
Ochna natalitia	1	--- 0.80	1.56	1.36	0.00	0.00	5.00	48.00
Ochna natalitia	2	--- 0.00	3.12		0.00	0.90	0.08	
Oricia bachmannii	1	---		.45				0.00
Oricia bachmannii	2	---		.45				0.00
Ormocarpum trichocarpum	1	--- 0.00	3.12	1.13	0.00	0.00	70.00	65.00
Ozoroa engleri	3	---		1.13				20.00
Pancovia golungensis	1	--- 0.00	3.12	6.88	0.00	0.00	0.08	0.00
Pancovia golungensis	2	--- 8.00	4.67	6.80	0.00	0.00	0.00	8.00
Pancovia golungensis	3	---		.45				0.00
Pappia capensis	1	--- 0.00	1.56		0.00	0.00	0.00	
Pappia capensis	4	--- 0.80	.62		0.80	0.00	0.00	
Peltophorum africanum	1	--- 0.00	7.79	1.13	0.00	0.00	49.52	0.00
Peltophorum africanum	2	--- 0.00	7.79	2.27	0.08	0.00	19.39	0.00
Peltophorum africanum	3	---		2.72				0.00
Peltophorum africanum	4	--- 0.00	.62		0.00	0.08	0.80	
Phyllanthus reticulatus	1	--- .14	29.28	21.54	.03	.31	21.81	27.70
Phyllanthus reticulatus	2	--- 0.00	4.67	19.73	0.00	0.00	20.00	47.76
Phyllanthus reticulatus	3	--- 0.00	3.74	1.36	0.00	0.00	0.00	0.00
Plectroniella armata	1	--- .06	61.53	42.23	.03	.31	23.81	14.40
Plectroniella armata	2	--- .07	32.71	19.27	.05	.62	4.12	.28
Plectroniella armata	3	--- .24	11.21	14.51	.11	1.25	0.00	0.00
Plectroniella armata	4	--- 0.00	2.49	.91	0.00	0.00	0.00	0.00
Psychatria capensis	3	--- 0.00	.62		0.00	0.08	0.00	
Rhoicissus rhomboidea	1	--- 0.00	4.67		0.00	0.00	75.00	
Rhoicissus tomentosa	3	--- 0.80	.62		0.00	0.00	0.00	
Rhoicissus tomentosa	4	--- 0.00*	1.25		0.00	0.00	0.00	
Rhoicissus tridentata	1	--- 0.00	133.96	125.06	0.00	0.00	58.28	70.50
Rhoicissus tridentata	2	--- 0.00	170.40	102.72	0.00	0.00	46.45	46.57
Rhoicissus tridentata	3	--- 0.00	1.87	.45	0.00	0.00	0.00	0.00
Rhus chirindensis	1	--- 0.00	3.12	.45	0.00	0.00	39.20	0.00
Rhus chirindensis	2	--- 0.00	10.90	9.30	0.00	0.00	4.47	4.51
Rhus chirindensis	3	--- 0.00	1.87	.91	0.00	0.00	0.00	0.00
Rhus chirindensis	4	--- 0.00	1.87		0.00	0.00	8.08	
Rhus gueinzii	1	---		1.13				0.00
Rhus gueinzii	4	--- 0.00	2.49		0.00	0.00	0.00	
Rhus pentheri	1	--- 0.00	59.81	64.85	0.00	0.00	39.69	37.41
Rhus pentheri	2	--- .09	100.31	94.33	.32	3.74	19.33	15.42
Rhus pentheri	3	--- .14	64.80	48.53	.43	4.98	8.00	0.00
Rhus pentheri	4	--- 0.00	10.59	17.69	0.00	0.00	0.00	0.00
Rhus rehmanniana	1	--- 0.00	7.79	3.40	0.00	0.00	73.44	41.00
Rhus rehmanniana	2	--- .14	15.58	22.68	.05	.62	31.75	65.24
Rhus rehmanniana	3	--- 0.00	4.36	.45	0.00	0.00	0.80	0.00
Rhus spp.	1	--- 0.00	7.48		0.00	0.00	77.43	
Rhus spp.	2	--- 0.00	3.12	3.85	0.00	0.00	60.38	49.18
Schotia brachypetala	1	--- 0.00	6.23	9.52	0.00	0.00	31.11	37.97
Schotia brachypetala	2	--- 0.00	9.35	2.04	8.00	0.00	20.00	18.15
Schotia brachypetala	3	--- 0.00	.62	.45	0.00	0.00	0.00	0.00
Schotia brachypetala	4	--- 0.00	4.98	4.08	0.00	0.00	0.00	0.00
Sclerocarya birrea	1	--- 0.00	1.56	4.54	0.00	0.00	40.00	60.93
Sclerocarya birrea	2	--- 0.00	1.56	9.07	0.00	0.00	50.00	40.47
Sclerocarya birrea	3	--- 0.00	.62	1.81	0.00	0.00	0.00	0.00
Sclerocarya birrea	4	--- 0.80	7.48	.91	0.00	0.00	0.00	0.00
Scolopia zeyheri	1	- .58	33.33	40.14	.11	1.25	9.41	8.82
Scolopia zeyheri	2	--- .12	10.90	5.90	.03	.31	1.21	1.68

TABLE 7.21 p6(i)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8% OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO) Page 6

SppName	Size	FreqPrefIndex	TotalPrefIndex	FreeBBXYES	FreeBBXNO	TotalBBXYES	TotalBBXNO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Scutia myrtina	1	--- .34	.31	.95	.67	1.02	.60	224.39	141.27	272.09	174.60	.94	.81
Scutia myrtina	2	--- 0.00	0.00	.90	1.12	.80	.97	212.31	234.81	213.71	252.38	1.13	.93
Scutia myrtina	3	--- 0.00	0.80	.45	.85	.39	.62	104.67	179.14	104.67	179.14	1.14	1.00
Scutia myrtina	4	--- 0.00	0.00	.28	.76	.25	.55	66.04	158.73	66.04	158.73	1.14	1.00
Sesbania sesban	1	--- 0.00	0.80	.01	.00	.05	.01	2.80	.17	14.02	1.72	.23	.10
Sesbania sesban	2	--- 0.00	0.80	.04		.10		9.32		25.67		.41	
Sideroxylon inerme	1	--- 0.00	0.00	.17	.11	.21	.12	41.12	22.69	55.14	34.38	.85	.66
Sideroxylon inerme	2	--- .33	.34	.32	.32	.31	.25	75.23	66.16	83.18	71.43	1.03	.93
Sideroxylon inerme	3	--- 0.00	0.00	.10	.13	.09	.10	23.68	27.66	23.68	27.66	1.14	1.00
Sideroxylon inerme	4	--- 0.00	0.00	.05	.19	.04	.14	10.90	40.14	10.90	40.14	1.14	1.00
Solanum mauritianum/giganteum	1	--- .12	.08	.65	.26	1.02	.52	152.39	54.69	273.33	150.75	.63	.36
Solanum mauritianum/giganteum	2	--- .02	.02	1.32	1.27	1.41	1.47	311.17	266.16	376.82	425.17	.94	.63
Solanum mauritianum/giganteum	3	---			.01		.01		1.81		1.81		1.00
Spirostachys africana	1	.83	.81	3.26	.59	3.32	.48	765.19	124.44	887.85	138.32	.98	.90
Spirostachys africana	2	* 1.49	1.68	4.60	.22	4.07	.36	1,081.62	45.35	1,098.79	45.35	1.13	1.00
Spirostachys africana	3	* 1.27	1.45	6.32	.71	5.55	.51	1,485.36	148.98	1,485.36	148.98	1.14	1.00
Spirostachys africana	4	--- .08	.09	2.62	.75	2.30	.54	615.58	156.92	615.58	156.92	1.14	1.00
Strychnos innocua	1	---			.03		.04		6.63		10.20		.65
Strychnos madagascarensis	1	---			.01		.01		2.21		3.40		.65
Strychnos madagascarensis	2	---			.02		.02		4.08		4.54		.90
Tarchonanthus camphoratus	1	--- 0.00	0.00	.23		.21		53.27		56.07		1.08	
Tarchonanthus camphoratus	2	--- 0.00	0.00	.27		.23		62.31		62.31		1.14	
Tarchonanthus camphoratus	3	--- 0.00	0.00	.53		.47		124.61		124.61		1.14	
Tarchonanthus camphoratus	4	--- 0.00	0.00	0.00		0.00		0.00		0.00		0.00	
Teclea gerrardii	4	---			.00		.00		.68		.68		1.00
Teclea natalensis	4	---			0.00		0.00		0.00		0.00		0.00
Thespesia acutiloba	1	---			.01		.02		2.27		4.54		.50
Thespesia acutiloba	2	---			.07		.05		15.65		15.87		.99
Thespesia acutiloba	4	---			0.00		0.00		0.00		0.00		0.00
Trema orientalis	2	--- 0.00	0.00	.03	.04	.02	.03	6.23	9.07	6.23	9.07	1.14	1.00
Trema orientalis	3	---			.03		.02		5.90		5.90		1.00
Trema orientalis	4	--- 0.00	0.00	.02		.02		4.98		4.98		1.14	
Trichocladus grandiflorus	2	---			.00		.00		.91		.91		1.00
Trichocladus grandiflorus	4	---			.01		.01		1.81		1.81		1.00
Turraea floribunda	1	---			.01		.00		1.13		1.13		1.00
Unknown 15	1	---			.09		.07		19.30		19.50		.99
Unknown 15	2	--- 0.00	0.00	.11	.31	.13	.35	26.17	65.08	35.83	100.91	.53	.64
Unknown 15	4	---			.00		.00		.45		.45		1.08
Unknown 8	1	--- 0.00	0.00	.00		.01		.31		3.12		.11	
Unknown 8	2	*** 4.31	1.72	.02		.05		4.36		12.46		.40	
Unknown 8	3	---			0.00		0.00		0.00		0.00		0.00
Vernonia subuligera	1	--- 0.00	0.00	.00	.02	.01	.02	.16	3.17	1.56	4.54	.11	.70
Vernonia subuligera	2	--- 0.00	0.00	1.13	3.66	1.42	3.02	264.53	767.79	378.50	875.28	.80	.88
Vernonia subuligera	3	--- 0.00	0.00	.11	.19	.09	.14	24.92	39.91	24.92	39.91	1.14	1.00
Vitellariopsis marginata	2	---			.01		.01		1.72		1.72		1.00
Vitex harveyana	4	--- 0.00	0.00	.01		.00		1.25		1.25		1.14	
Ximenia caffra	1	--- 0.00	0.00	.07	.01	.15	.02	16.82	1.59	40.50	4.54	.47	.35
Ximenia caffra	2	--- 0.80	0.00	.03	.10	.04	.10	7.48	20.63	9.97	29.48	.85	.70
Ximenia caffra	3	--- 0.00	0.00	.04	.02	.03	.02	8.72	4.54	8.72	4.54	1.14	1.00
Zanthoxylum capense	1	--- 0.00	0.00	.08	.08	.08	.12	19.22	15.91	22.43	34.33	.98	.46
Zanthoxylum capense	2	--- .22	.25	.12	.10	.10	.09	28.04	21.09	28.04	26.53	1.14	.79
Zanthoxylum capense	3	--- 0.00	0.00	.03	.04	.02	.03	6.23	7.71	6.23	7.71	1.14	1.00
Zanthoxylum capense	4	---			0.00		0.00		0.00		0.00		0.00
Ziziphus mucronata	1	--- .27	.14	.30	.26	.56	.33	70.48	54.17	151.09	95.92	.53	.56
Ziziphus mucronata	2	-- .37	.32	1.07	.47	1.25	.48	251.99	98.07	334.89	138.32	.86	.71
Ziziphus mucronata	3	.83	.94	.39	.23	.34	.17	90.97	47.85	90.97	47.85	1.14	1.00
Ziziphus mucronata	4	* 1.83	2.08	.09	.11	.08	.08	20.56	23.58	20.56	23.58	1.14	1.00

TABLE 7.21 p6(ii)

HLUHLUWE GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 55.8%
OF PLOTS WITH FEEDING (YES) AND THE 44.2% OF PLOTS WITH NO FEEDING (NO) Page 6

SppName	Size	FreePrefIndex	N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassIntXYES	MeanGrassInt%NO
Scutia myrtina	1	--- .34	69.47	67.91	.32	3.74	17.53	19.89
Scutia myrtina	2	--- 0.00	25.23	41.72	0.00	0.00	.66	6.96
Scutia myrtina	3	--- 0.00	7.48	9.52	0.00	0.00	0.00	0.00
Scutia myrtina	4	--- 0.00	4.36	8.62	0.00	0.00	0.00	0.00
Sesbania sesban	1	--- 0.00	14.02	1.13	0.00	0.00	80.00	90.00
Sesbania sesban	2	--- 0.00	14.02		0.00	0.00	63.69	
Sideroxylon inerme	1	--- 0.00	18.38	14.06	0.00	0.00	25.42	33.98
Sideroxylon inerme	2	--- .33	13.71	8.39	.11	1.25	9.55	7.38
Sideroxylon inerme	3	--- 0.00	2.49	5.44	0.00	0.00	0.00	0.00
Sideroxylon inerme	4	--- 0.00	4.36	4.08	0.00	0.00	0.00	0.00
Solanum mauritianum/giganteum	1	--- .12	241.12	126.98	.08	.93	44.25	63.72
Solanum mauritianum/giganteum	2	--- .02	173.52	163.27	.03	.31	17.42	37.40
Solanum mauritianum/giganteum	3	---		.45				0.00
Spirostachys africana	1	.83	260.12	43.65	2.69	31.46	13.82	10.04
Spirostachys africana	2	* 1.49	186.92	18.20	6.85	80.06	.66	0.00
Spirostachys africana	3	* 1.27	95.33	14.07	8.05	94.08	0.00	0.00
Spirostachys africana	4	--- .08	32.40	28.41	.21	2.49	0.00	0.00
Strychnos innocua	1	---		3.40				35.00
Strychnos madagascarensis	1	---		1.13				35.00
Strychnos madagascarensis	2	---		1.13				10.00
Tarchonanthus camphoratus	1	--- 0.00	14.02		0.00	0.00	5.00	
Tarchonanthus camphoratus	2	--- 0.00	7.79		0.00	0.00	0.00	
Tarchonanthus camphoratus	3	--- 0.00	12.46		0.00	0.00	0.00	
Tarchonanthus camphoratus	4	--- 0.00	1.25		0.00	0.00	0.00	
Teclea gerrardii	4	---		1.36				0.00
Teclea natalensis	4	---		.45				0.00
Thespesia acutiloba	1	---		1.13				50.00
Thespesia acutiloba	2	---		3.40				1.43
Thespesia acutiloba	4	---		.45				0.00
Trema orientalis	2	--- 0.00	1.56	1.13	0.00	0.00	0.00	0.00
Trema orientalis	3	---		1.36				0.00
Trema orientalis	4	--- 0.00	1.25		0.00	0.00	0.00	
Trichocladus grandiflorus	2	---		.45				0.00
Trichocladus grandiflorus	4	---		.45				0.00
Turraea floribunda	1	---		1.13				0.00
Unknown 15	1	---		2.72				1.05
Unknown 15	2	--- 0.00	9.35	6.80	0.00	0.00	26.96	39.51
Unknown 15	4	---		.45				0.00
Unknown 8	1	--- 0.00	3.12		0.00	0.00	90.00	
Unknown 8	2	*** 4.31	1.56		.08	.93	65.00	
Unknown 8	3	---		.45				0.00
Vernonia subuligera	1	--- 0.00	1.56	1.13	0.00	0.00	90.00	30.00
Vernonia subuligera	2	--- 0.00	82.55	87.07	0.00	0.00	30.11	12.28
Vernonia subuligera	3	--- 0.00	3.12	2.72	0.00	0.00	0.00	0.00
Vitellariopsis marginata	2	---		1.13				0.00
Vitex harveyana	4	--- 0.00	.62		0.00	0.00	0.00	
Ximenia caffra	1	--- 0.00	6.23	1.13	0.00	0.00	58.46	65.00
Ximenia caffra	2	--- 0.00	.62	2.27	0.00	0.00	25.00	30.00
Ximenia caffra	3	--- 0.00	1.25	1.36	0.00	0.00	0.00	0.00
Zanthoxylum capense	1	--- 0.00	11.53	14.29	0.00	0.00	14.31	53.66
Zanthoxylum capense	2	--- .22	10.90	7.03	.03	.31	0.00	20.51
Zanthoxylum capense	3	--- 0.00	1.25	2.27	0.00	0.00	0.00	0.00
Zanthoxylum capense	4	---		.45				0.00
Zizyphus mucronata	1	--- .27	26.48	22.90	.08	.93	53.35	43.52
Zizyphus mucronata	2	-- .37	27.73	10.20	.40	4.67	24.75	29.10
Zizyphus mucronata	3	[illegible]	7.48	4.99	.32	3.74	0.00	0.00

TABLE 7.22 p1(i)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1%
OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO) Page 1

SppName	Size	FreePrefIndex		TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Acacia borleae	1	***	4.88	4.90	.62		.62		105.73		120.05		1.00	
Acacia borleae	2	*	1.25	1.43	1.98		1.74		336.26		336.26		1.14	
Acacia burkei	1	---	0.00	0.00	.00		.02		.09		4.50		.02	
Acacia caffra	1	***	3.29	1.12	.04		.12		6.89		22.97		.34	
Acacia caffra	2	**	2.60	2.06	.30		.38		50.59		72.52		.79	
Acacia caffra	3	*	1.83	2.08	.15		.13		24.77		24.77		1.14	
Acacia gerrardii	1	***	6.58	4.44	.52	.09	.77	.30	88.19	12.91	148.76	45.30	.67	.28
Acacia gerrardii	2	***	4.77	5.03	.26		.25		44.67		48.20		1.05	
Acacia gerrardii	3	*	1.75	1.99	.35	.28	.31	.26	59.68	39.32	59.68	39.32	1.16	1.00
Acacia gerrardii	4	---	0.00	0.00	0.00		0.08		0.00		0.00		0.00	
Acacia grandicornuta	1	---	.20	.19	1.60	.12	1.72	.25	271.57	17.14	332.88	37.61	.93	.46
Acacia grandicornuta	2	---	0.00	0.00	.96	.20	.90	.18	163.04	27.35	173.65	27.35	1.07	1.00
Acacia grandicornuta	3	---	0.00	0.00	1.29	.25	1.74	.23	220.05	34.19	220.85	34.19	1.14	1.00
Acacia grandicornuta	4	---	0.00	0.00	.12	.17	.11	.16	20.95	23.93	20.95	23.93	1.16	1.00
Acacia karroo	1	***	8.82	2.81	.40	.17	1.26	.53	68.30	23.93	243.92	79.49	.32	.30
Acacia karroo	2	***	6.19	4.36	.75		1.06		126.63		204.73		.70	
Acacia karroo	3	***	5.29	6.02	.46	.54	.40	.50	77.93	75.21	77.93	75.21	1.14	1.00
Acacia luederitzii	1	---	0.00	0.00	.12		.12		19.75		23.20		.97	
Acacia luederitzii	2	---	0.00	0.00	.23		.21		38.51		40.54		1.08	
Acacia luederitzii	3	-	.52	.59	.56		.50		95.95		95.95		1.14	
Acacia luederitzii	4	---	0.00	0.00	.01		.00		.90		.90		1.14	
Acacia nigrescens	1	**	2.05	1.10	.27	.40	.51	.48	46.51	56.15	98.65	72.65	.54	.77
Acacia nigrescens	2	---	0.00	0.00	.25	.04	.22	.06	42.97	5.98	43.24	8.55	1.13	.70
Acacia nigrescens	3	---	0.00	0.00	.06	.30	.05	.28	9.91	41.88	9.91	41.88	1.14	1.00
Acacia nigrescens	4	---	.17	.19	.31	.15	.28	.14	53.38	21.37	53.38	21.37	1.14	1.00
Acacia nilotica	1	***	11.15	5.17	.31	.35	.67	.99	53.23	49.36	138.52	150.00	.46	.33
Acacia nilotica	2	***	2.78	2.78	.32		.32		53.74		61.26		1.00	
Acacia nilotica	3		1.09	1.25	.39	.09	.34	.08	66.22	12.82	66.22	12.82	1.14	1.00
Acacia nilotica	4	---	0.00	0.00	0.00	.05	0.00	.05	0.00	6.84	0.00	6.84	0.00	1.00
Acacia robusta	1	**	2.50	2.59	.26		.25		43.45		47.86		1.03	
Acacia robusta	2	-	.54	.62	.20		.17		33.33		33.33		1.14	
Acacia robusta	3	---	0.00	0.00	.13		.12		22.52		22.52		1.14	
Acacia robusta	4	---	0.00	0.00	.04	1.04	.04	.96	6.98	145.30	6.98	145.30	1.14	1.00
Acacia sengal	1	***	14.72	10.99	.07		.09		11.08		16.89		.75	
Acacia sengal	2	***	13.12	12.49	.05		.05		8.29		9.91		.95	
Acacia sengal	3	***	8.05	9.16	.09		.08		15.77		15.77		1.14	
Acacia tortilis	1	***	5.21	4.35	.62	.40	.75	.41	106.05	55.15	144.59	61.54	.83	.90
Acacia tortilis	2	*	1.28	1.30	.88	.21	.86	.19	148.82	28.70	166.67	29.06	1.02	.99
Acacia tortilis	3	---	0.00	0.00	.41	.15	.36	.14	69.59	20.51	69.59	20.51	1.14	1.00
Aloe marlothii	3	---	0.00	0.00	.05		.05		9.01		9.01		1.14	
Asparagus spp.	1	--	.42	.37	2.16	1.12	2.48	1.35	366.32	155.79	480.18	234.27	.87	.76
Asparagus spp.	2	---	.19	.19	1.28	2.29	1.24	2.18	217.47	318.82	239.41	329.23	1.03	.97
Asparagus spp.	3	---	.04	.05	.60	1.58	.53	1.46	102.48	220.51	102.48	220.51	1.14	1.00
Asparagus spp.	4	---	0.00	0.00	.03		.02		4.50		4.50		1.14	
Azima tetracantha	1	*	1.41	1.02	.15		.21		25.65		40.54		.72	
Azima tetracantha	2	*	1.36	1.45	.24	.09	.22	.08	40.09	12.82	42.79	12.82	1.07	1.00
Berchemia zeyheri	1	-	.56	.50	.10		.11		16.15		20.61		.89	
Berchemia zeyheri	4	---	0.00	0.00	.00		.00		.45		.45		1.14	
Boscia albitrunca	1	***	3.96	2.14	.05	.01	.09	.17	8.00	1.28	16.89	25.64	.54	.05
Boscia albitrunca	2	---	0.00	0.00	.04		.05		7.57		10.36		.83	
Boscia albitrunca	3	***	4.31	4.90	.06	.01	.05	.01	9.46	.85	9.46	.85	1.14	1.00
Brachylaena ilicifolia	1	---	.15	.14	1.05	.62	1.14	.58	177.82	86.32	220.72	88.03	.92	.98
Brachylaena ilicifolia	2	---	.12	.13	2.74	1.01	2.47	.93	466.30	140.17	477.25	140.17	1.11	1.00
Brachylaena ilicifolia	3	-	.68	.77	.73		.69		133.33		133.33		1.14	
Cadaba natalensis	1	***	4.23	4.58	.03		.02		4.28		4.50		1.08	

TABLE 7.22 pl(ii)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1%
OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO) Page 1

SppName	Size	FreePrefIndex	TotalPrefIndex	FreeBBXYES	FreeBBXNO	N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassIntXYES	MeanGrassIntXNO
Acacia borleae	1	*** 4.88	4.90	.62		24.77		3.04	25.68	11.92	
Acacia borleae	2	* 1.25	1.43	1.98		13.51		2.48	20.95	0.00	
Acacia burkei	1	--- 0.00	0.00	.00		1.13		0.00	0.00	98.00	
Acacia caffra	1	*** 3.29	1.12	.04		12.39		.13	1.13	70.02	
Acacia caffra	2	** 2.60	2.86	.30		8.56		.77	6.53	30.25	
Acacia caffra	3	* 1.83	2.08	.15		1.35		.27	2.25	0.00	
Acacia gerrardii	1	*** 6.58	4.44	.52	.09	60.81	43.59	3.41	28.83	40.72	71.51
Acacia gerrardii	2	*** 4.77	5.03	.26		5.41		1.25	10.59	7.31	
Acacia gerrardii	3	* 1.75	1.99	.35	.28	9.91	1.71	.61	5.18	0.00	0.00
Acacia gerrardii	4	--- 0.00	0.00	0.00		2.25		0.00	0.00	0.00	
Acacia grandicornuta	1	--- .20	.19	1.60	.12	89.19	47.01	.32	2.70	18.42	54.43
Acacia grandicornuta	2	--- 0.00	0.00	.96	.20	23.20	1.71	0.00	0.00	6.11	0.00
Acacia grandicornuta	3	--- 0.00	0.00	1.29	.25	14.86	11.97	0.00	0.00	0.00	0.00
Acacia grandicornuta	4	--- 0.00	0.00	.12	.17	5.86	13.68	0.00	0.00	0.00	0.00
Acacia karroo	1	*** 8.82	2.81	.40	.17	69.37	27.35	3.55	29.95	72.00	69.89
Acacia karroo	2	*** 6.19	4.36	.75		29.50		4.61	38.96	38.15	
Acacia karroo	3	*** 5.29	6.02	.46	.54	5.86	5.13	2.43	20.50	0.00	0.00
Acacia luederitzii	1	--- 0.00	0.00	.12		12.39		0.00	0.00	14.85	
Acacia luederitzii	2	--- 0.00	0.00	.23		4.50		0.00	0.00	5.00	
Acacia luederitzii	3	- .52	.59	.56		9.46		.29	2.48	0.00	
Acacia luederitzii	4	--- 0.00	0.00	.81		2.25		0.00	0.00	0.00	
Acacia nigrescens	1	** 2.05	1.18	.27	.40	49.77	33.33	.56	4.73	52.86	22.71
Acacia nigrescens	2	--- 0.00	0.00	.25	.04	4.05	1.71	0.00	0.00	.62	30.00
Acacia nigrescens	3	--- 0.00	0.00	.06	.30	1.80	6.84	0.00	0.00	0.00	0.00
Acacia nigrescens	4	--- .17	.19	.31	.15	19.82	23.93	.05	.45	0.00	0.00
Acacia nilotica	1	*** 11.15	5.17	.31	.35	62.84	70.09	3.49	29.50	59.22	67.09
Acacia nilotica	2	*** 2.78	2.78	.32		6.08		.88	7.43	12.28	
Acacia nilotica	3	1.09	1.25	.39	.09	7.66	3.42	.43	3.60	0.00	0.00
Acacia nilotica	4	--- 0.00	0.00	0.00	.05	.45	5.13	0.00	0.00	0.00	0.00
Acacia robusta	1	** 2.50	2.59	.26		17.34		.64	5.41	9.21	
Acacia robusta	2	- .54	.62	.20		4.50		.11	.90	0.00	
Acacia robusta	3	--- 0.00	0.00	.13		2.25		0.00	0.00	0.00	
Acac'a robusta	4	--- 0.00	0.00	.04	1.04	3.15	10.26	0.00	0.00	0.00	0.00
Acacia sengal	1	*** 14.72	10.99	.07		12.61		.96	6.11	34.40	
Acacia sengal	2	*** 13.12	12.49	.05		2.25		.64	5.41	16.36	
Acacia sengal	3	*** 8.05	9.16	.09		.45		.75	6.31	0.00	
Acacia tortilis	1	*** 5.21	4.35	.62	.40	36.26	18.80	3.25	27.48	26.66	10.39
Acacia tortilis	2	* 1.28	1.30	.88	.21	10.36	3.42	1.12	9.46	10.71	1.24
Acacia tortilis	3	--- 0.00	0.00	.41	.15	4.95	10.26	0.00	0.00	0.00	0.00
Aloe marlothii	3	--- 0.00	0.00	.05		.45		0.00	0.00	0.00	
Asparagus spp.	1	-- .42	.37	2.16	1.12	109.23	77.78	.91	7.66	23.71	23.73
Asparagus spp.	2	--- .19	.19	1.28	2.29	27.48	45.13	.24	2.03	9.17	3.16
Asparagus spp.	3	--- .04	.05	.60	1.58	10.81	30.77	.03	.23	0.00	0.00
Asparagus spp.	4	--- 0.00	0.00	.03		.45		0.00	0.00	0.00	
Azima tetracantha	1	* 1.41	1.02	.15		16.22		.21	1.80	36.72	
Azima tetracantha	2	* 1.36	1.45	.24	.09	4.95	4.27	.32	2.70	6.32	0.00
Berchemia zeyheri	1	- .56	.50	.10		5.86		.05	.45	21.64	
Berchemia zeyheri	4	--- 0.00	0.00	.00		.45		0.00	0.00	0.00	
Boscia albitrunca	1	*** 3.96	2.14	.05	.01	7.21	9.40	.19	1.58	52.61	95.00
Boscia albitrunca	2	--- 0.00	0.00	.04		1.35		0.00	0.00	26.96	
Boscia albitrunca	3	*** 4.31	4.90	.06	.01	1.80	1.71	.24	2.03	0.00	0.00
Brachylaena ilicifolia	1	--- .15	.14	1.05	.62	50.23	20.51	.16	1.35	19.44	1.94
Brachylaena ilicifolia	2	--- .12	.13	2.74	1.01	46.85	6.84	.32	2.70	2.30	0.00
[illegible]	3	[illegible]	[illegible]	[illegible]		7.66	[illegible]	.53	4.50	0.00	

TABLE 7.22 p2(i)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1% OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	FreePrefIndex		TotalPrefIndex	FreeBBXYES	FreeBBXNO	TotalBBXYES	TotalBBXNO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Canthium spp.	1	---	0.00	0.00	.00		.00		.81		.90		1.02	
Canthium spp.	2	---	0.00	0.00	.01		.00		.86		.90		1.08	
Capparis sepiaria	1	---	0.00	0.00	.02		.02		3.38		3.38		1.14	
Capparis sepiaria	2	---	0.00	0.00	.11		.09		18.02		18.02		1.14	
Capparis sepiaria	3	---				.42		.38		58.12		58.12		1.00
Capparis tomentosa	1	*	1.60	.75	.23	.16	.49	.17	39.57	22.86	95.72	25.21	.47	.91
Capparis tomentosa	2		1.14	1.09	.45		.47		75.74		90.09		.96	
Capparis tomentosa	3	-	.79	.90	.14	.06	.12	.06	22.97	8.55	22.97	8.55	1.14	1.00
Carissa bispinosa	1	---	0.00	0.00	.37	.95	.33	.93	63.63	132.05	63.96	141.03	1.13	.94
Carissa bispinosa	2	---	0.00	0.00	.21	.25	.19	.23	36.35	34.19	36.49	34.19	1.13	1.00
Casine tetragona	1	---	0.00	0.00	.01		.01		1.35		1.35		1.14	
Casine tetragona	3	---	0.00	0.00	.20		.18		34.23		34.23		1.14	
Cassine aethiopica	2	---	0.00	0.00	.05		.04		7.77		7.88		1.12	
Cassine aethiopica	3	---	0.00	0.00	.05		.05		9.01		9.01		1.14	
Cassine aethiopica	4	---	0.00	0.00	.11		.10		18.47		18.47		1.14	
Cassine transvaalensis	1	***	5.58	4.22	.07		.09		11.37		17.12		.76	
Cassine transvaalensis	2	*	1.91	1.91	.04		.04		7.12		8.11		1.00	
Cassine transvaalensis	3	---	0.00	0.00	.03		.02		4.50		4.50		1.14	
Cassine transvaalensis	4	---	0.00	0.00	.03		.02		4.50		4.50		1.14	
Clutia pulchella	3	---	0.00	0.00	.02		.02		3.60		3.60		1.14	
Coddia rudis	1	--	.39	.37	.48	.52	.51	.62	81.97	72.14	98.20	94.02	.95	.77
Coddia rudis	2	---	0.00	0.00	.10		.10		16.51		19.37		.97	
Combretum apiculatum	1	---	0.00	0.00	.01	.05	.02	.25	1.11	6.58	3.60	37.61	.35	.18
Combretum apiculatum	2	---	0.00	0.00	.01	.01	.01	.01	2.14	1.30	2.25	1.37	1.08	.95
Combretum apiculatum	3	---	0.00	0.00	.03		.03		5.86		5.86		1.14	
Combretum apiculatum	4	---	0.00	0.00	.01		.01		1.35		1.35		1.14	
Commiphora harveyi	3	---	0.00	0.00	.01		.01		1.35		1.35		1.14	
Commiphora neglecta	1	--	.36	.17	.15	.07	.32	.09	24.97	9.81	61.49	13.25	.46	.74
Commiphora neglecta	2	*	1.28	1.24	.17	.06	.17	.06	28.29	8.12	33.33	8.55	.97	.95
Commiphora neglecta	3	***	3.88	4.42	.19		.17		32.66		32.66		1.14	
Crotalaria capensis	1	***	40.23	11.44	.00	.01	.00	.01	.23	1.71	.90	1.71	.28	1.00
Croton menyhartii	1	*	1.29	1.20	.56	.71	.60	.70	94.47	98.97	115.54	105.98	.93	.93
Croton menyhartii	2	---	.17	.18	4.78	13.46	4.35	12.46	812.68	1,874.70	841.44	1,882.91	1.10	1.00
Croton menyhartii	3	---	.14	.16	5.42	23.27	4.76	21.45	920.72	3,241.03	920.72	3,241.03	1.14	1.00
Cussonia zuluensis	1	---	0.00	0.00	.00	.04	.01	.03	.45	5.13	1.58	5.13	.33	1.00
Cussonia zuluensis	2	---	0.00	0.00	.01		.01		1.69		1.69		1.14	
Cussonia zuluensis	3	---	0.00	0.00	0.00	.02	0.00	.02	0.00	2.56	0.00	2.56	0.00	1.00
Dichrostachys cinerea	1	***	4.39	2.63	1.48	.35	2.46	.85	250.98	48.69	476.35	128.21	.60	.38
Dichrostachys cinerea	2	*	1.90	1.73	1.52	.12	1.67	.14	257.91	16.74	322.30	21.71	.91	.77
Dichrostachys cinerea	3		1.10	1.25	.56	.15	.49	.14	94.59	21.37	94.59	21.37	1.14	1.00
Diospyros lycioides	1	-	.54	.45	.10		.12		16.89		22.97		.84	
Diospyros spp.	1	---	0.00	0.00	.02		.01		2.70		2.20		1.14	
Diospyros spp.	2	---	0.00	0.00	.00		.00		.45		.45		1.14	
Diospyros spp.	3	---	0.00	0.00	.00		.00		.45		.45		1.14	
Diospyros whyteana	1	---	0.00	0.00	.05		.07		8.33		14.41		.66	
Dombeya rotundifolia	1	---	0.00	0.00	.04		.05		6.23		9.46		.75	
Dombeya rotundifolia	3	---	0.00	0.00	.02		.02		3.60		3.60		1.14	
Dombeya tiliacea	1	---	0.00	0.00	.02		.01		2.70		2.70		1.14	
Dombeya tiliacea	2	---	0.00	0.00	.04		.04		6.85		7.21		1.08	
Dombeya tiliacea	3	---	0.00	0.00	.08		.07		13.51		13.51		1.14	
Ehretia rigida/amoena	1		1.11	1.04	1.44	.65	1.54	.96	245.36	90.06	298.76	145.73	.93	.62
Ehretia rigida/amoena	2	-	.73	.82	1.82	.79	1.62	.74	308.94	109.40	313.51	111.97	1.12	.98
Ehretia rigida/amoena	3	***	4.90	5.57	.50	.21	.44	.19	85.14	29.06	85.14	29.06	1.14	1.00
Erythrina lysistemon	1	---	0.00	0.00	.02		.02		3.60		3.60		1.14	
Erythrina lysistemon	2	***	3.77	4.29	.02		.02		3.60		3.60		1.14	
Euclea divinorum	1	--	.37	.23	.44	.77	.70	.81	74.11	107.01	135.14	121.79	.62	.88

TABLE 7.22 p2(ii)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1%
OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO) Page 2

SppName	Size	FreePrefIndex		N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassInt%YES	MeanGrassInt%NO
Canthium spp.	1	---	0.00	.45		0.00	0.00	10.00	
Canthium spp.	2	---	0.00	.45		0.00	0.00	5.00	
Capparis sepiaria	1	---	0.00	2.25		0.00	0.00	0.00	
Capparis sepiaria	2	---	0.00	4.50		0.00	0.00	0.00	
Capparis sepiaria	3	---			1.71				0.00
Capparis tomentosa	1	*	1.60	24.32	12.82	.37	3.15	58.66	9.32
Capparis tomentosa	2		1.14	7.88		.51	4.28	15.92	
Capparis tomentosa	3	-	.79	2.25	1.71	.11	.90	0.00	0.00
Carissa bispinosa	1	---	0.00	4.05	38.46	0.00	0.00	.53	6.36
Carissa bispinosa	2	---	0.00	1.58	4.27	0.00	0.00	.37	0.00
Casine tetragona	1	---	0.00	.45		0.00	0.00	0.00	
Casine tetragona	3	---	0.00	.45		0.00	0.00	0.00	
Cassine aethiopica	2	---	0.00	1.58		0.00	0.00	1.43	
Cassine aethiopica	3	---	0.00	.45		0.00	0.00	0.00	
Cassine aethiopica	4	---	0.00	.90		0.00	0.00	0.00	
Cassine transvaalensis	1	***	5.58	6.98		.37	3.15	33.55	
Cassine transvaalensis	2	*	1.91	1.58		.08	.68	12.22	
Cassine transvaalensis	3	---	0.00	.45		0.00	0.00	0.00	
Cassine transvaalensis	4	---	0.00	.45		0.00	0.00	0.00	
Clutia pulchella	3	---	0.00	.45		0.00	0.00	0.00	
Coddia rudis	1	--	.39	14.41	17.09	.19	1.58	16.52	23.27
Coddia rudis	2	---	0.00	2.48		0.00	0.00	14.77	
Combretum apiculatum	1	---	0.00	2.25	19.66	0.00	0.00	69.13	82.50
Combretum apiculatum	2	---	0.00	.45	.68	0.00	0.00	5.00	5.00
Combretum apiculatum	3	---	0.00	1.35		0.00	0.00	0.00	
Combretum apiculatum	4	---	0.00	.90		0.00	0.00	0.00	
Commiphora harveyi	3	---	0.00	.90		0.00	0.00	0.00	
Commiphora neglecta	1	--	.36	17.12	16.24	.05	.45	59.40	25.97
Commiphora neglecta	2	*	1.28	3.60	1.71	.21	1.80	15.14	5.00
Commiphora neglecta	3	***	3.88	3.15		.75	6.31	0.00	
Crotolaria capensis	1	***	40.23	.90	1.71	.05	.45	75.00	0.00
Croton menyhartii	1	*	1.29	35.14	46.15	.72	6.08	18.24	6.61
Croton menyhartii	2	---	.17	66.67	138.46	.80	6.76	3.42	.44
Croton menyhartii	3	---	.14	27.93	92.31	.75	6.31	0.00	0.00
Cussonia zuluensis	1	---	0.00	1.58	1.71	0.00	0.00	71.43	0.00
Cussonia zuluensis	2	---	0.00	1.13		0.00	0.00	0.00	
Cussonia zuluensis	3	---	0.00	.90	1.71	0.00	0.00	0.00	0.00
Dichrostachys cinerea	1	***	4.39	193.24	52.99	6.48	54.73	47.31	62.02
Dichrostachys cinerea	2	*	1.90	48.65	7.52	2.88	24.32	19.98	22.91
Dichrostachys cinerea	3		1.10	7.66	6.84	.61	5.10	0.00	0.00
Diospyros lycioides	1	-	.54	4.50		.05	.45	26.47	
Diospyros spp.	1	---	0.00	1.80		0.00	0.00	0.00	
Diospyros spp.	2	---	0.00	.45		0.00	0.00	0.00	
Diospyros spp.	3	---	0.00	.45		0.00	0.00	0.00	
Diospyros whyteana	1	---	0.00	5.86		0.00	0.00	42.19	
Dombeya rotundifolia	1	---	0.00	1.80		0.00	0.00	34.19	
Dombeya rotundifolia	3	---	0.00	.90		0.00	0.00	0.00	
Dombeya tiliacea	1	---	0.00	.45		0.00	0.00	0.00	
Dombeya tiliacea	2	---	0.00	.90		0.00	0.00	5.00	
Dombeya tiliacea	3	---	0.00	.45		0.00	0.00	0.00	
Ehretia rigida/amoena	1		1.11	123.20	88.89	1.60	13.51	17.87	38.20
Ehretia rigida/amoena	2	-	.73	21.40	11.11	1.33	11.26	1.46	2.29
Ehretia rigida/amoena	3	***	4.90	4.50	1.71	2.45	20.72	0.00	0.00
Erythrina lysistemon	1	---	0.00	1.80		0.00	0.00	0.00	
Erythrina lysistemon	2	***	3.77	.90		.08	.68	0.00	
Euclea divinorum	1	--	.37	28.38	41.88	.16	1.35	45.16	12.14

TABLE 7.22 p3(i)

UMFOLOZI GRID STUDY AREA ; SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1% OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	FreePrefIndex		TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Euclea divinorum	2	---	0.00	0.00	3.68	1.06	3.56	1.10	625.52	148.25	688.74	166.67	1.03	.89
Euclea divinorum	3	---	0.00	0.00	2.49	.33	2.19	.31	423.87	46.15	423.87	46.15	1.14	1.00
Euclea divinorum	4	---	0.00	0.00	.16		.14		27.93		27.93		1.14	
Euclea natalensis	1	---	0.00	0.00	.00		.00		.27		.90		.34	
Euclea natalensis	2	---	0.00	0.00	.16		.17		37.75		33.33		.95	
Euclea natalensis	3	---	0.00	0.00	.12		.10		20.27		20.27		1.14	
Euclea racemosa	1	---	0.00	0.00	.31	.23	.36	.21	52.11	31.45	69.93	32.48	.85	.97
Euclea racemosa	2	---	.13	.14	1.26	.83	1.18	.76	214.59	115.38	229.05	115.38	1.07	1.00
Euclea racemosa	3	---	0.00	0.00	.54	.04	.47	.03	90.99	5.13	90.99	5.13	1.14	1.00
Euclea racemosa	4	---	0.00	0.00	.09		.08		14.64		14.64		1.14	
Euclea undulata	1	---	0.00	0.00	.31	.43	.31	.40	51.99	60.09	60.02	60.68	.99	.99
Euclea undulata	2	---	0.00	0.00	1.21	1.91	1.08	1.76	205.81	265.81	208.56	265.81	1.12	1.00
Euclea undulata	3	---	.01	.01	4.09	.38	3.59	.35	695.05	52.99	695.05	52.99	1.14	1.00
Euclea undulata	4	---	0.00	0.00	.49		.43		82.43		82.43		1.14	
Galpinia transvaalica	1	---				.04		.03		5.13		5.13		1.00
Gardenia cornuta	1	***	9.47	4.16	.01		.03		2.39		6.19		.44	
Gardenia cornuta	3	---	0.00	0.00	.01		.01		1.80		1.80		1.14	
Gardenia cornuta	4	***	6.70	7.63	.03		.03		5.41		5.41		1.14	
Gardenia volkensii	1	---	0.00	0.00	.02	.08	.03	.08	3.31	11.45	6.31	11.97	.60	.96
Gardenia volkensii	3	---	0.00	0.00	.05		.04		8.56		8.56		1.14	
Gardenia volkensii	4	---	0.00	0.00	.01		.01		1.80		1.80		1.14	
Grewia bicolor	1	---				.00		.05		.17		6.84		.02
Grewia bicolor	2	***	4.62	5.81	.12		.11		20.59		21.62		1.08	
Grewia bicolor	3	---	0.00	0.00	.06		.05		10.36		10.36		1.14	
Grewia flava	1	***	15.75	8.80	.07	.18	.12	.35	11.22	25.47	22.86	52.14	.56	.49
Grewia flava	2	*	.74	.71	.25	.85	.26	1.06	42.75	118.89	50.90	160.68	.96	.74
Grewia flava	3	---				1.18		1.09		164.10		164.10		1.00
Grewia flavescens	1	***	3.21	2.68	.07		.09		12.70		17.34		.83	
Grewia flavescens	2	---	0.00	0.00	.13		.12		22.23		23.87		1.06	
Grewia flavescens	3	---	0.00	0.00	1.15	.07	1.01	.07	195.95	10.26	195.95	10.26	1.14	1.00
Grewia flavescens	4	---				.15		.14		20.51		20.51		1.00
Grewia monticola	1	---	0.00	0.00	.02	.00	.04	.11	3.29	.27	7.43	16.67	.50	.02
Grewia monticola	2	---	0.00	0.00	.02		.02		3.31		4.73		.80	
Grewia monticola	3	---	0.00	0.00	.02		.02		3.60		3.60		1.14	
Grewia occidentalis	1	**	2.69	2.08	.20	.26	.26	.46	33.64	36.58	49.55	69.23	.77	.53
Grewia occidentalis	2		.82	.86	.20	.33	.19	.31	33.23	46.15	35.81	46.15	1.06	1.00
Grewia occidentalis	3		1.03	1.17	.10		.09		17.57		17.57		1.14	
Grewia spp.	3	---	0.00	0.00	.04		.03		6.31		6.31		1.14	
Grewia villosa	1	**	2.16	1.58	.12	.23	.17	.31	20.97	32.05	32.66	47.01	.73	.68
Grewia villosa	2	---	0.00	0.00	.08	.06	.07	.06	14.03	7.86	14.41	9.40	1.11	.84
Hippobromus pauciflorus	1	---	0.00	0.00	.01		.01		1.13		2.03		.63	
Hippobromus pauciflorus	2	---	0.00	0.00	.01		.02		1.26		3.15		.46	
Hippobromus pauciflorus	3	---	0.00	0.00	.01		.01		2.25		2.25		1.14	
Lippia javanica	1	---	0.00	0.00	.00		.01		.56		1.13		.57	
Lippia javanica	2	---	0.00	0.00	.01		.00		.90		.90		1.14	
Lycium acutifolium	1	***	8.60	6.10	.01	.05	.02	.05	2.11	7.26	3.38	7.69	.71	.94
Lycium acutifolium	2	---	0.00	0.00	.04		.03		6.76		6.76		1.14	
Maerua angolensis	1	***	5.03	4.58	.01		.01		.90		1.13		.91	
Maerua angolensis	2	---	0.00	0.00	.02		.02		3.01		3.15		1.09	
Maytenus heterophylla	1	---	.35	.14	.23	.57	.57	1.18	39.08	79.90	109.35	178.63	.41	.45
Maytenus heterophylla	2	---	0.00	0.00	.26	.04	.31	.03	44.49	5.13	59.68	5.13	.85	1.00
Maytenus heterophylla	3	---	0.00	0.00	.20	0.00	.18	0.00	34.01	0.00	34.01	0.00	1.14	0.00
Maytenus heterophylla	4	---	0.00	0.00	.09		.08		15.77		15.77		1.14	
Maytenus nemorosa	1	***	5.25	3.74	.13	.18	.18	.19	21.58	24.87	34.46	29.06	.71	.86
Maytenus nemorosa	2	---	.04	.04	.68	.10	.62	.09	114.99	13.68	119.59	13.68	1.09	1.00
Maytenus nemorosa	3	*	1.50	1.71	1.51	2.55	1.32	2.35	256.08	355.56	256.08	355.56	1.14	1.00

TABLE 7.22 p3(ii)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1% OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO) Page 3

SppName	Size	FreePrefIndex		N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassIntXYES	MeanGrassIntXNO
Euclea divinorum	2	---	0.00	36.04	17.95	0.00	0.00	9.18	11.05
Euclea divinorum	3	---	0.00	13.51	5.13	0.00	0.00	0.00	0.00
Euclea divinorum	4	---	0.00	.45		0.00	0.00	0.00	
Euclea natalensis	1	---	0.00	.45		0.00	0.00	70.00	
Euclea natalensis	2	---	0.00	.90		0.00	0.00	16.76	
Euclea natalensis	3	---	0.00	.45		0.00	0.00	0.00	
Euclea racemosa	1	---	0.00	27.48	12.82	0.00	0.00	25.49	3.16
Euclea racemosa	2	---	.13	21.17	9.40	.16	1.35	6.31	0.00
Euclea racemosa	3	---	0.00	4.50	3.42	0.00	0.00	0.00	0.00
Euclea racemosa	4	---	0.00	2.25		0.00	0.00	0.00	
Euclea undulata	1	---	0.00	12.84	13.68	0.00	0.00	13.38	.99
Euclea undulata	2	---	0.00	13.29	10.26	0.00	0.00	1.32	0.00
Euclea undulata	3	---	.01	13.96	5.13	.05	.45	0.00	0.00
Euclea undulata	4	---	0.08	2.70		0.00	0.00	0.00	
Galpinia transvaalica	1	---			1.71				0.00
Gardenia cornuta	1	***	9.47	2.48		.13	1.13	61.36	
Gardenia cornuta	3	---	0.00	.45		0.00	0.00	0.00	
Gardenia cornuta	4	***	6.70	1.35		.21	1.80	0.00	
Gardenia volkensii	1	---	0.00	2.70	3.42	0.00	0.00	47.50	4.29
Gardenia volkensii	3	---	0.00	.45		0.00	0.00	0.00	
Gardenia volkensii	4	---	0.00	.45		0.00	0.00	0.00	
Grewia bicolor	1	---			6.84				97.50
Grewia bicolor	2	***	4.62	2.70		.56	4.73	4.79	
Grewia bicolor	3	---	0.00	.45		0.00	0.00	0.00	
Grewia flava	1	***	15.75	11.04	13.68	1.04	8.78	50.94	51.15
Grewia flava	2	-	.74	5.86	29.06	.19	1.58	16.02	26.01
Grewia flava	3	---			15.38				0.00
Grewia flavescens	1	***	3.21	5.18		.24	2.03	26.75	
Grewia flavescens	2	---	0.00	1.35		0.00	0.00	6.89	
Grewia flavescens	3	---	0.00	4.05	1.71	0.00	0.00	0.00	0.00
Grewia flavescens	4	---			1.71				0.00
Grewia monticola	1	---	0.00	3.38	5.98	0.00	0.00	55.76	98.38
Grewia monticola	2	---	0.00	.45		0.00	0.00	30.00	
Grewia monticola	3	---	0.00	.45		0.00	0.00	0.00	
Grewia occidentalis	1	**	2.69	22.75	20.51	.53	4.50	32.12	47.16
Grewia occidentalis	2		.82	7.43	5.13	.16	1.35	7.20	0.00
Grewia occidentalis	3		1.03	2.70		.11	.90	0.00	
Grewia spp.	3	---	0.00	.45		0.00	0.00	0.00	
Grewia villosa	1	**	2.16	10.36	15.38	.27	2.25	35.79	31.82
Grewia villosa	2	---	0.00	2.25	3.42	0.00	0.00	2.69	16.36
Hippobromus pauciflorus	1	---	0.00	2.25		0.00	0.00	44.44	
Hippobromus pauciflorus	2	---	0.00	.45		0.00	0.00	60.00	
Hippobromus pauciflorus	3	---	0.00	.45		0.00	0.00	0.00	
Lippia javanica	1	---	0.00	.45		0.00	0.00	50.00	
Lippia javanica	2	---	0.00	.45		0.00	0.00	0.00	
Lycium acutifolium	1	***	8.60	1.35	5.98	.11	.90	37.67	5.56
Lycium acutifolium	2	---	0.00	1.13		0.00	0.00	0.00	
Maerua angolensis	1	***	5.03	1.13		.03	.23	20.00	
Maerua angolensis	2	---	0.00	1.58		0.00	0.00	4.43	
Maytenus heterophylla	1	---	.35	45.72	57.26	.08	.68	64.26	55.27
Maytenus heterophylla	2	---	0.00	8.11	1.71	0.00	0.00	25.45	0.00
Maytenus heterophylla	3	---	0.00	2.70	1.71	0.00	0.00	0.00	0.00
Maytenus heterophylla	4	---	0.00	.45		0.00	0.00	0.00	
				[illegible]	[illegible]	[illegible]	5.63	37.39	14.41

TABLE 7.22 p4(i)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1% OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO) Page 4

SppName	Size	FreePrefIndex		TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Maytenus nemorosa	4	--	.47	.53	.57	2.09	.50	1.92	96.85	290.60	96.85	298.60	1.14	1.00
Maytenus senegalensis	1	---	0.00	0.00	.28	.44	.39	.49	47.10	61.20	75.90	73.50	.71	.83
Maytenus senegalensis	2	---	0.00	0.00	.26	.14	.36	.12	43.63	18.80	69.93	18.80	.71	1.00
Melanthus didyma	1	--	.40	.16	.07	.08	.16	.09	11.22	11.17	31.64	13.16	.40	.85
Melia azedarach	2	***	7.86	7.15	.02		.02		2.88		3.60		.91	
Monanthotaxis caffra	1	---	0.00	0.00	.01		.02		1.91		4.50		.48	
Olea europaea	2	---	0.00	0.00	.11		.10		18.22		18.47		1.32	
Olea europaea	3	---	0.00	0.00	.42	1.10	.37	1.02	71.17	153.85	71.17	153.85	1.14	1.00
Olea europaea	4	---	0.00	0.00	.15	1.41	.13	1.30	25.00	196.58	25.00	196.58	1.14	1.00
Ormocarpum trichocarpum	1	**	2.49	2.00	.19	.08	.24	.12	32.81	10.53	46.40	17.52	.80	.60
Ormocarpum trichocarpum	2	*	.78	.85	.03		.03		5.78		6.08		1.08	
Ormocarpum trichocarpum	3	***	8.85	9.16	.03		.02		4.50		4.50		1.14	
Ozoroa engleri	1	---	0.00	0.00	.00	.00	.00	.01	.02	.34	.90	1.71	.02	.20
Ozoroa engleri	3	---	.34	.38	.16		.14		27.03		27.03		1.14	
Pappia capensis	1	*	1.67	1.59	.06	.00	.07	.04	18.88	.32	12.95	6.41	.96	.05
Pappia capensis	2	*	1.39	1.53	.02		.02		3.27		3.38		1.10	
Pappia capensis	3	***	3.47	3.95	.08	.34	.07	.32	13.06	47.86	13.06	47.86	1.14	1.00
Pappia capensio	4	**	.45	.52	.35	0.00	.31	0.00	59.91	0.00	59.91	0.00	1.14	0.00
Plectroniella armata	1	*	1.79	1.44	.22	.02	.28	.02	38.02	3.42	53.60	3.42	.81	1.00
Plectroniella armata	2	---	.16	.17	.34	.12	.31	.12	57.95	16.85	59.46	18.80	1.11	.90
Plectroniella armata	3	---	.06	.07	1.70		1.50		289.19		289.19		1.14	
Plectroniella armata	4	---	0.00	0.00	.05		.05		9.01		9.01		1.14	
Pyrostria hystrix	1	---	0.00	0.00	.07	.18	.08	.17	12.15	25.64	15.99	25.64	.86	1.00
Pyrostria hystrix	2	-	.51	.57	.16	.49	.14	.45	26.69	68.38	27.03	68.38	1.12	1.00
Pyrostria hystrix	3	---	0.00	0.00	.20	1.12	.18	1.03	34.68	155.56	34.68	155.56	1.14	1.00
Rhoicissus rhomboidea	1	---	.14	.14	.19	.46	.19	.49	32.15	63.93	35.81	73.50	1.02	.87
Rhoicissus rhomboideo	2	*	1.72	1.85	.12	.19	.12	.18	21.13	26.50	22.30	26.50	1.08	1.00
Rhus gueinzii	1		1.12	.70	.10	.33	.15	.31	16.18	46.15	29.28	46.15	.63	1.00
Rhus gueinzii	2	---	.22	.22	.37	.28	.36	.26	62.91	39.16	69.03	39.32	1.04	1.00
Rhus gueinzii	3	-	.52	.59	.26	.44	.23	.41	43.69	61.54	43.69	61.54	1.14	1.00
Rhus gueinzii	4	---	0.00	0.00	.09		.08		14.86		14.86		1.14	
Rhus pentheri	1	---	0.00	0.00	.10	.27	.13	.40	16.63	36.97	25.23	59.83	.75	.62
Rhus pentheri	2	--	.48	.34	.56	1.26	.73	1.52	95.11	174.91	142.12	229.91	.76	.76
Rhus pentheri	3	---	0.00	0.00	.56	.66	.50	.61	95.95	92.31	95.95	92.31	1.14	1.00
Rhus rehmanniana	1	---	0.00	0.00	.00		.01		.11		2.25		.06	
Rhus rehmanniana	2	---	0.00	0.00	.01		.02		1.77		3.94		.51	
Schotia brachypetala	1	---	0.00	0.00	.02		.02		3.99		4.73		.96	
Schotia brachypetala	2	---	0.00	0.00	3.60		3.17		611.49		612.61		1.14	
Schotia brachypetala	4	---	0.00	0.00	.03	0.00	.03	0.00	5.86	0.00	5.86	0.00	1.14	0.00
Schotia capitata	1	-	.75	.80	.07	.25	.07	.25	12.12	34.62	12.84	38.46	1.07	.90
Schotia capitata	2	---	0.00	0.00	.06	.98	.05	.91	10.36	136.75	10.36	136.75	1.14	1.00
Schotia capitata	3	*	1.26	1.43	1.72	3.68	1.51	3.39	291.89	512.82	291.89	512.82	1.14	1.00
Schotia capitota	4		1.11	1.26	.72	1.46	.64	1.35	122.97	203.42	122.97	203.42	1.14	1.00
Sclerocarya birrea	1	---	0.00	0.00	.05		.05		8.47		9.46		1.02	
Sclerocarya birrea	3	---	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sclerocarya birrea	4	---	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scolopia zeyheri	1	***	2.98	2.83	.05		.06		9.12		10.92		.95	
Sesbania punicea	3	---	0.00	0.00	.03		.02		4.50		4.58		1.14	
Sesbania sesban	2	---	0.00	0.00	.11		.09		18.02		18.02		1.14	
Sida cordifolia/rhombifolia	1	***	2.95	2.43	.14	.17	.18	.24	24.61	23.89	33.90	35.90	.83	.67
Sideroxylon inerme	1	---	0.00	0.00	.06	.08	.06	.08	10.92	10.94	12.16	11.97	1.02	.91
Sideroxylon inerme	2	---	0.00	0.00	.13		.12		21.96		23.65		1.06	
Sideroxylon inerme	3	---	0.00	0.00	.21		.18		35.14		35.14		1.14	
Sideroxylon inerme	4	---	0.00	0.00	.11	.25	.10	.23	18.47	34.19	18.47	34.19	1.14	1.00
Solanum	1	*	1.32	.95	.12	.07	.17	.07	20.65	9.49	32.43	10.26	.72	.93
Solanum	2	*	1.65	1.63	.02		.02		2.75		3.15		.99	

TABLE 7.22 p4(ii)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1%
OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO)

SppName	Size	FreqPrefIndex		N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassInt%YES	MeanGrassInt%NO
Maytenus nemorosa	4	--	.47	2.70	5.13	.27	2.25	0.00	0.00
Maytenus senegalensis	1	---	0.00	18.92	13.68	0.00	0.00	37.95	16.74
Maytenus senegalensis	2	---	0.00	6.08	3.42	0.00	0.00	37.61	0.00
Melanthus didyma	1	--	.40	51.13	17.78	.03	.23	64.54	15.13
Melia azedarach	2	***	7.86	.45		.13	1.13	20.00	
Monanthotaxis caffra	1	---	0.00	2.25		0.00	0.00	57.50	
Olea europaea	2	---	0.00	1.58		0.00	0.00	1.34	
Olea europaea	3	---	0.00	2.25	3.42	0.00	0.00	0.00	0.00
Olea europaea	4	---	0.00	3.60	6.84	0.00	0.00	0.00	0.00
Ormocarpum trichocarpum	1	**	2.49	30.63	15.38	.48	4.05	29.28	39.84
Ormocarpum trichocarpum	2	*	.78	1.80		.03	.23	5.00	
Ormocarpum trichocarpum	3	***	8.05	.45		.21	1.80	0.00	
Ozoroa engleri	1	---	0.00	.45	1.71	0.00	0.00	98.00	80.00
Ozoroa engleri	3	---	.34	.45		.05	.45	0.00	
Pappia capensis	1	*	1.67	9.91	4.27	.11	.90	16.00	95.00
Pappia capensis	2	*	1.39	2.25		.03	.23	3.33	
Pappia capensis	3	***	3.47	1.80	11.97	.27	2.25	0.00	0.00
Pappia capensis	4	--	.45	6.76	1.71	.16	1.35	0.00	0.00
Plectroniella armata	1	*	1.79	18.24	3.42	.40	3.38	29.08	0.00
Plectroniella armata	2	---	.16	8.56	3.42	.05	.45	2.53	10.36
Plectroniella armata	3	---	.06	23.42		.11	.90	8.00	
Plectroniella armata	4	---	0.00	.90		0.00	0.00	0.08	
Pyrostria hystrix	1	---	0.00	6.76	4.27	0.00	0.00	24.01	0.00
Pyrostria hystrix	2	*	.51	4.95	8.55	.08	.68	1.25	0.00
Pyrostria hystrix	3	---	0.00	3.15	8.55	0.00	0.00	0.00	0.00
Rhoicissus rhomboidea	1	---	.14	10.59	25.64	.03	.23	10.22	13.02
Rhoicissus rhomboidea	2	*	1.72	2.93	10.26	.21	1.80	5.25	0.00
Rhus gueinzii	1		1.12	6.76	9.40	.11	.90	44.75	0.00
Rhus gueinzii	2	---	.22	6.98	5.98	.08	.68	8.87	.39
Rhus gueinzii	3	*	.52	1.80	3.42	.13	1.13	0.00	0.00
Rhus gueinzii	4	---	0.00	.90		0.00	0.00	0.00	
Rhus pentheri	1	---	0.00	4.50	17.09	0.00	0.08	34.06	38.21
Rhus pentheri	2	--	.48	10.59	9.40	.27	2.25	33.07	23.92
Rhus pentheri	3	---	0.00	2.70	3.42	0.00	0.00	0.00	0.00
Rhus rehmanniana	1	---	0.00	1.13		0.00	0.00	95.00	
Rhus rehmanniana	2	---	0.00	1.13		0.00	0.00	55.00	
Schotia brachypetala	1	---	0.00	1.80		0.00	0.00	15.71	
Schotia brachypetala	2	---	0.00	2.25		0.00	0.00	.18	
Schotia brachypetala	4	---	0.00	3.60	1.71	0.00	0.00	0.00	0.00
Schotia capitata	1	*	.75	2.03	8.55	.05	.45	5.61	10.00
Schotia capitata	2	---	0.00	2.03	12.82	0.00	0.00	0.00	0.00
Schotia capitata	3	*	1.26	9.46	17.09	2.16	18.24	0.00	0.00
Schotia capitata	4		1.11	4.05	8.55	.80	6.76	0.00	0.00
Sclerocarya birrea	1	---	0.00	1.35		0.00	0.00	10.48	
Sclerocarya birrea	3	---	0.00	.45	1.71	0.00	0.00	0.00	0.00
Sclerocarya birrea	4	---	0.00	1.35	3.42	0.00	0.00	0.00	0.00
Scolopia zeyheri	1	***	2.98	6.08		.16	1.35	16.49	
Sesbania punicea	3	---	0.00	.45		0.00	0.00	0.00	
Sesbania sesban	2	---	0.00	.45		0.00	0.00	0.00	
Sida cordifolia/rhombifolia	1	***	2.95	44.59	32.48	.43	3.60	27.41	33.45
Sideroxylon inerme	1	---	0.00	2.93	3.42	0.00	0.00	10.19	8.57
Sideroxylon inerme	2	---	0.00	3.15		0.00	0.00	7.14	
Sideroxylon inerme	3	---	0.00	2.25		0.00	0.00	0.00	

TABLE 7.22 p5(i)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1%
OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO) Page 5

SppName	Size	FreePrefIndex		TotalPrefIndex	FreeBB%YES	FreeBB%NO	TotalBB%YES	TotalBB%NO	FreeBB/HaYES	FreeBB/HaNO	TotalBB/HaYES	TotalBB/HaNO	FB:TBYES	FB:TBNO
Spirostachys africana	1	*	1.95	1.63	1.84	.59	2.21	.95	313.28	81.73	427.70	144.02	.83	.57
Spirostachys africana	2	**	2.13	2.32	3.81	1.09	3.50	1.22	647.06	152.14	676.80	184.62	1.09	.82
Spirostachys africana	3	*	1.70	1.94	7.20	4.66	6.33	4.30	1,223.87	649.57	1,223.87	649.57	1.14	1.00
Spirostachys africana	4	*	1.56	1.78	.43	.37	.38	.34	72.52	51.28	72.52	51.28	1.14	1.00
Strychnos madagascariensis	4	---	0.00	0.00	.10		.09		17.12		17.12		1.14	
Strychnos spp.	1	***	7.45	7.63	.01		.01		1.22		1.35		1.02	
Strychnos spp.	2	---				.18		.17		25.64		25.64		1.00
Strychnos spp.	3	---	0.00	0.00	.01		.01		1.35		1.35		1.14	
Tarchonanthus camphoratus	1	--	.45	.22	.47	.34	.98	1.05	80.45	47.52	189.86	158.97	.48	.30
Tarchonanthus camphoratus	2	--	.47	.40	.96	3.35	1.12	3.15	163.47	467.01	217.12	475.21	.86	.98
Tarchonanthus camphoratus	3	---	0.00	0.00	1.21	3.08	1.07	2.84	206.31	429.06	206.31	429.06	1.14	1.00
Tarchonanthus camphoratus	4	---				.06		.06		8.55		8.55		1.00
Unknown 1	1	---				.06		.06		8.55		8.55		1.00
Unknown 15	1	***	3.27	2.76	.07		.08		12.45		16.67		.85	
Unknown 15	3	---	0.00	0.00	.09		.08		15.77		15.77		1.14	
Unknown 15	4	---	0.00	0.00	.13		.11		21.62		21.62		1.14	
Unknown 2	1	---				.01		.01		1.71		1.71		1.00
Unknown 3	1	---	0.00	0.00	.00		.00		.43		.45		1.08	
Unknown 4	2	---	0.00	0.00	.05		.04		8.11		8.11		1.14	
Unknown 5	1	***	20.11	22.89	.00		.00		.45		.45		1.14	
Unknown 6	1	***	13.87	15.26	.01		.01		1.31		1.35		1.10	
Zanthoxylum capense	1	---	0.00	8.00	.00		.00		.19		.23		.97	
Zanthoxylum capense	2	---				.09		.08		11.97		11.97		1.00
Zizyphus mucronata	1	***	3.12	.92	.03	.10	.09	.12	4.36	13.50	16.89	17.95	.29	.75
Zizyphus mucronata	2	*	1.99	2.20	.13	.52	.12	.48	22.75	71.79	23.42	71.79	1.11	1.00
Zizyphus mucronata	3	---	0.00	0.00	.42	.10	.37	.09	70.72	13.68	70.72	13.68	1.14	1.80
Zizyphus mucronata	4	***	13.41	15.26	.01		.01		1.35		1.35		1.14	

TABLE 7.22 p5(ii)

UMFOLOZI GRID STUDY AREA : SPIZE AVAILABILITY AND GRASS INTERFERENCE COMPARISONS BETWEEN THE 79.1%
OF PLOTS WITH FEEDING (YES) AND THE 20.9% OF PLOTS WITH NO FEEDING (NO)

SppName	Size		freePrefIndex	TotalPrefIndex	FreqBB%YES	FreqBB%NO	N/HaYES	N/HaNO	%Diet	Browsing/Ha	MeanGrassInt%YES	MeanGrassInt%NO
Spirostachys africana	1	*	1.95	1.63	1.84	.59	113.51	69.23	3.60	38.41	26.75	43.25
Spirostachys africana	2	**	2.13	2.32	3.81	1.09	78.50	14.53	8.10	68.47	4.39	17.59
Spirostachys africana	3	*	1.70	1.94	7.20	4.66	49.55	23.93	12.26	103.60	0.00	0.88
Spirostachys africana	4	*	1.56	1.78	.43	.37	14.41	17.09	.67	5.63	0.88	3.80
Strychnos madagascarensis	4	---	0.00	0.88	.10		.45		0.88	0.00	8.80	
Strycnos spp.	1	***	7.45	7.63	.81		.90		.05	.45	10.00	
Strycnos spp.	2	---				.18		4.27				0.08
Strycnos spp.	3	---	0.08	0.00	.01		.45		0.08	0.00	0.00	
Tarchonanthus camphoratus	1	--	.45	.22	.47	.34	28.38	23.93	.21	1.80	57.63	70.11
Tarchonanthus camphoratus	2	--	.47	.40	.96	3.35	15.54	33.33	.45	3.83	24.71	1.73
Tarchonanthus camphoratus	3	---	0.00	0.00	1.21	3.08	7.66	22.22	0.00	0.00	0.00	0.00
Tarchonanthus camphoratus	4	---				.06		1.71				0.00
Unknown 1	1	---				.06		1.71				0.00
Unknown 15	1	***	3.27	2.78	.07		6.08		.24	2.03	25.27	
Unknown 15	3	---	0.00	0.00	.09		1.35		0.00	0.00	8.00	
Unknown 15	4	---	0.00	0.00	.13		.90		0.00	0.00	0.00	
Unknown 2	1	---				.01		3.42				0.00
Unknown 3	1	---	0.00	0.00	.00		.45		0.00	0.00	5.00	
Unknown 4	2	---	0.00	0.00	.05		.45		0.00	0.00	0.00	
Unknown 5	1	***	20.11	22.89	.00		.45		.05	.45	0.00	
Unknown 6	1	***	13.87	15.26	.01		.90		.11	.90	3.33	
Zanthoxylum capense	1	---	0.00	0.00	.00		.45		0.00	0.00	15.00	
Zanthoxylum capense	2	---				.09		1.71				0.00
Zizyphus mucronata	1	***	3.12	.92	.03	.10	4.73	6.84	.08	.68	74.20	24.76
Zizyphus mucronata	2	*	1.99	2.20	.13	.52	1.35	6.84	.27	2.25	2.88	0.80
Zizyphus mucronata	3	---	0.00	0.00	.42	.10	5.86	1.71	0.00	0.00	0.00	0.08
Zizyphus mucronata	4	***	13.41	15.26	.01		1.35		.11	.90	0.00	

Of the nine common spizes in Hluhluwe that were rated as preferred (**) using ALL data (Table 7.15), one was rated as highly preferred (***), none as preferred (**), three as slightly preferred (*) and five as intermediate using only YES plot data.

All seven of the slightly preferred common spizes in Hluhluwe using ALL plot data (Table 7.15) were either reclassified as intermediate ( ) or slightly rejected (-) using only YES plot data.

Abutilon/Hibiscus2 was the only one of the 22 common spizes in Hluhluwe to be allocated to a higher preference category using only YES plot data compared to ratings derived from ALL plot data. The remaining 21 spizes were all rated lower using YES plot data.

A similar, but much less marked pattern of patch selection emerged in Umfolozi. This is perhaps to be expected, given the higher proportion of plots with browsing in Umfolozi. Of the 23 common spizes in Umfolozi to be given a preference rating using ALL plot data (Table 7.16), all but four were given a lower preference score using YES plot data compared to ALL plot data. The discrepancies, however, were not as marked as in Hluhluwe. 17 of the 23 spizes were listed in the same preference category. Five spizes were rated one preference ranking lower using YES plot data. Only one spize, *A.nigrescens1*, was re-classified up a class from slightly preferred (ALL) to preferred (YES).

In Umfolozi the key food species, *S.africana* accounted for 13.28% of Free bottles in YES plots but only 6.71% in NO plots. The ratio of percentage canopy cover to percentage Free bottles was higher in NO plots. This indicated that plots without feeding on average contained more taller *S.africana* individuals.

The density of the most preferred spize in Umfolozi (*A.nilotica1*) was 3.4 times greater in YES plots. Densities of preferred *A.nilotica2* and *A.nilotica3*'s were also greater in YES plots. On the other hand, rejected tall *A.nilotica4*'s occurred at a higher density in NO plots. In NO plots *A.nilotica4* contributed 35% to total *A.nilotica* canopy cover, but only 11% in YES plots.

TABLE 7.23 Feeding levels, grass height, bush clearing and fire frequencies for the main communities in Hluhluwe identified by a Twinspan Spize Braun-Blanquet Classification analysis. Results refer to the Hluhluwe Grid Study Area

Twinspan Divisions: 0100
Community Description: A.glabrata dominated riverine community

Mean Offtake (Bottles/Ha)	687
Mean Modal Grass Height/Plot	8
Frequency of Chemical Clearing of "Acacia's"	.39
Overall Frequency of Clearing "Acacia's"	.25
Mean Fire Frequency 1955-87	10.4

Twinspan Divisions: 0101
Community Description: S.africana dominated lowland communities

Mean Offtake (Bottles/Ha)	1567
Mean Modal Grass Height/Plot	28
Frequency of Chemical Clearing of "Acacia's"	0.00
Overall Frequency of Clearing "Acacia's"	.03
Mean Fire Frequency 1955-87	6.2

Twinspan Divisions: 0110
Community Description: Mature E.racemosa,B.zeyheri,R.pentheri,A.nilotica Lowland Forest

Mean Offtake (Bottles/Ha)	268
Mean Modal Grass Height/Plot	44
Frequency of Chemical Clearing of "Acacia's"	.81
Overall Frequency of Clearing "Acacia's"	.22
Mean Fire Frequency 1955-87	7.5

Twinspan Divisions: 0111
Community Description: Developing Lowland Forest from A.nilotica Closed Woodland

Mean Offtake (Bottles/Ha)	487
Mean Modal Grass Height/Plot	46
Frequency of Chemical Clearing of "Acacia's"	0.08
Overall Frequency of Clearing "Acacia's"	.04
Mean Fire Frequency 1955-87	6.6

Twinspan Divisions: 1000
Community Description: Mixed A.caffra, A.karroo dominated hillslope community

Mean Offtake (Bottles/Ha)	380
Mean Modal Grass Height/Plot	91
Frequency of Chemical Clearing of "Acacia's"	.19
Overall Frequency of Clearing "Acacia's"	.36
Mean Fire Frequency 1955-87	10.5

Twinspan Divisions: 1001
Community Description: A.caffra dominated hillslope community

Mean Offtake (Bottles/Ha)	280
Mean Modal Grass Height/Plot	100
Frequency of Chemical Clearing of "Acacia's"	.17
Overall Frequency of Clearing "Acacia's"	.27
Mean Fire Frequency 1955-87	11.3

Twinspan Divisions: 101
Community Description: A.karroo dominated communities

Mean Offtake (Bottles/Ha)	287
Mean Modal Grass Height/Plot	91
Frequency of Chemical Clearing of "Acacia's"	.08
Overall Frequency of Clearing "Acacia's"	.29
Mean Fire Frequency 1955-87	10.5

Twinspan Divisions: 1100
Community Description: D.lycioides dominated low lying communities

Mean Offtake (Bottles/Ha)	87
Mean Modal Grass Height/Plot	114
Frequency of Chemical Clearing of "Acacia's"	.63
Overall Frequency of Clearing "Acacia's"	.88
Mean Fire Frequency 1955-87	9.6

Twinspan Divisions: 1110
Community Description: L.javanica dominated low lying communities

Mean Offtake (Bottles/Ha)	87
Mean Modal Grass Height/Plot	113
Frequency of Chemical Clearing of "Acacia's"	.83
Overall Frequency of Clearing "Acacia's"	1.92
Mean Fire Frequency 1955-87	11.3

A similar pattern was shown in Hluhluwe:

Densities of *A.nilotica1*'s were 2.78 times greater and *A.nilotica2*'s were 2.14 times greater in YES plots than in NO plots. Densities of *A.nilotica*'s over 2m were 56% higher in NO plots. The proportion of *A.nilotica*'s in YES plots that were less than 1 metre was also higher in YES plots (YES 64.4% vs. NO 40.1%).

82.4% of *A.nilotica*'s in YES plots were less than 2 metres tall; while 45.3% of *A.nilotica*'s in NO plots were greater than 2 metres tall. This was reflected in the canopy cover of A.nilotica's over 2m tall in Hluhluwe, which was 2.12 times greater in NO plots. In NO plots in Hluhluwe, *A.nilotica4* again contributed a higher proportion of total *A.nilotica* canopy cover (NO 47% ; YES 31%). Although Hluhluwe's *A.nilotica*'s were on average taller and more mature than in Umfolozi, patch selection still favoured younger stands of *A.nilotica*.

Besides *A.nilotica*, the canopy cover of taller individuals (>2m) of five key *E.racemosa/B.zeyheri* lowland forest species was higher in NO plots (*B.zeyheri* 67% higher in NO plots, *C.caffra* 71% higher, *E.racemosa* 52% higher, *S.inerme* 312% higher and *R.pentheri* 27% higher). In the case of *S.inerme* the high value may reflect its contribution to patches of true evergreen forest, which were rejected in the Grid survey by black rhinos). In the case of *R.pentheri* individuals of less than 2m, canopy cover was 37% higher in YES plots, while canopy cover of tall *R.pentheri* (>4m) was 228% higher in NO plots.

Absolute canopy cover of tall *A.karroo4*'s in Hluhluwe NO plots was almost double that in YES plots indicating that mature *A.karroo* woodlands were less preferred.

In Hluhluwe, total canopy cover of *A.caffra* was 52% higher in YES plots. The density of *A.caffra* was also 41% higher in YES plots. The density of Free bottles on *A.caffra*'s 2-4m high was 2.23 times greater in YES plots. Clearly black rhinos appreciate scrubby *A.caffra* dominated areas in Hluhluwe more than some field workers do!

In Hluhluwe, black rhinos chose to feed in patches with an average 3.66 times more Free bottles of *Acalypha* species. Patch selection was particularly strong for *A.glabrata* dominated patches.

In Umfolozi:

Densities of size class 1 and 2 "Acacias" were higher in YES plots (Size1: YES 642/Ha NO 293/Ha Size2: YES 161/Ha NO 14/Ha) but similar for "Acacias" over 2m (Size34 : YES 105/Ha NO 99/Ha). Densities of 24 out of 25 "*Acacia*" spizes less than 2m (sizes12) were higher in feeding patches. However, only 6 out of 11 "*Acacia*" spizes above 2m occurred at higher densities in feeding plots (YES).

Thus densities of the preferred smaller "Acacias" were higher in plots where there was feeding. In addition, a greater proportion of "Acacias" were over 2m tall in plots without feeding (YES 11.6% NO 24.4%). These findings corroborate the Pilot study ridge regression analysis.

Densities of *C.bispinosa, C.menyhartii, M.nemorosa, S.capitata* and *Tarchonathus camphoratus* were on average higher in plots with no feeding. This again indicates that patches of dense, non "*Acacia*" dominated bush were rejected. *B.zeyheri, Brachylaena ilicifolia, E.rigida/amoena, E.divinorum, E.racemosa* and *S.africana* densities were higher in feeding plots. Densities of *E.undulata* were similar in eaten and uneaten plots.

The comparatively higher densities of *B.ilicifolia* in feeding plots can be explained by its wider ecological tolerance, and its association both with "Acacias" in more open thicket patches and *E.divinorum/S.africana* communities, as well as its representation in dense bush clump communities. Similarly, the rejected *E.divinorum* is often associated with short grass cover and highly palatable *S.africana, A.borleae, M.nemorosa* and *A.tortilis.* In plots which contained *E.divinorum, S.africana* was the most important species, contributing 25% more Free bottles than *E.divinorum. E.undulata* was also commonly associated with *E.divinorum/S.africana* communities, probably explaining its higher rating than other dense bush species.

Although densities of the rejected *A.grandicornuta* were higher in Umfolozi feeding patches, this apparently contradictory result can also be explained by its common association with the highly preferred and important *S.africana*.

Mean levels of browsing in YES plots were similar in the two study areas (Hluhluwe-YES 909 bottles/Ha Umfolozi-YES 845 bottles/Ha)

Tree densities were 35% higher in Umfolozi YES plots and 22% higher in Hluhluwe YES plots, than in NO plots. Pilot survey data corroborated this finding.

IMPORTANT, PREFERRED AND REJECTED COMMUNITIES

An attempt was made to subjectively allocate Grid plots to habitat types based on plot species composition and structure data. However, this proved very difficult, and the attempt was abandoned after having over thirty different habitat types after only examining data for 70 odd plots. Clearly continua were much more appropriate for describing Hluhluwe vegetation than trying to classify vegetation into discrete habitat types.

Despite these problems 34 *A.nilotica* woodland, 21 *S.africana* thicket and 17 drainage line/riverine thicket plots were flagged in the dataset. Mean black rhino browsing offtake varied considerably. In *A.nilotica* woodland mean browse offtake was only 153 bottles/ha compared to 4,334 bottles/ha in *S.africana* thicket and 10,634/Ha in drainage line/ riverine thicket.

True evergreen forest patches appear to have been rejected for woody plant feeding by black rhino. The combined canopy cover of the tallest spizes of the following 14 evergreen forest species: *C.africana4, C.aristata4, C.pulchella3, Cola greenwayi4, Dalbergia armata4, D.obovata4, Erythroxylum emarginatum3, Harpephyllum caffrum4, Manilkara concolor3, M.caffra3, Oricia bachmannii2, Pancovia golungensis3, Trichocladus grandiflorus4* and *Z.capense4* was 14½ times greater in NO plots (14.95 CPts/Ha YES; 217.00 CPts/Ha NO).

The Grid data suggest that black rhinos prefer evergreen forest margins over evergreen forest in Hluhluwe. The combined canopy cover of the tallest spizes of the following 7 forest species described by Coates-Palgrave (1990) as often associated with evergreen forest margins: *Bequaertiodendron natalense3, C.aethiopica4, H.natalensis4, H.pauciflorus4, S.zeyheri3, S.myrtina4, and Teclea gerrardii4*, was only 17% greater in NO plots (209.91 CPts/Ha YES; 247.61 CPts/Ha NO).

In Umfolozi, *C.menyhartii* thickets were obviously avoided by feeding black rhino. This one species accounted for 33.91% of all available browse in Umfolozi NO plots but only 9.71% in YES plots.

RESULTS OF PRELIMINARY TWINSPAN ANALYSIS

Table 7.23 presents the results of a preliminary TWINSPAN Analysis of Hluhluwe Braun-Blanquet Spize Cover Abundance data. Outlier nodes were discarded.

For each node relational database querying was used to derive:

1) Mean offtake levels
2) Mean modal grass height per plot
3) Mean frequencies of "*Acacia*" bush clearing
4) Mean fire frequencies from 1955-1987

S.africana dominated communities were again rated the most important. *A.glabrata* dominated communities were also very important food sources.

The TWINSPAN analysis corroborated the earlier conclusion that black rhino habitat suitability declined as *A.nilotica* closed woodland changed into *E.racemosa, B.zeyheri, R.pentheri* dominated lowland forest. Mean offtake levels in mature *E.racemosa* lowland forest were only about half those in transitional lowland forest developing from *A.nilotica* closed woodland. In addition the TWINSPAN analysis provided further confirmatory evidence that *A.nilotica* was a key pivotal species in the change from open communities to closed woodland/forest communities (see Chapter 20).

The least important communities were low lying and dominated by either *D.lycioides* or *L.javanica*. It should be noted that these two communities had the tallest grass heights and substantially higher levels of past "*Acacia*" bush clearing.

Mean fire frequencies in the different habitat nodes were similar, with the exceptions of *S.africana* dominated communities and developing and mature *E.racemosa* dominated lowland forest, which had markedly lower fire frequencies.

CHAPTER 7 NOTES

#1: For example, to estimate confidence levels around species or spize abundance estimates it would be necessary to generate at least a thousand spatially stratified bootstrap samples of the raw data.

#2 Species with the *most available browse* were defined as those which were common enough not to be downweighted using Emslie's combination weighting. Species that were *still important contributors to available browse* were defined as those species that had downweights greater than the critical passive weight of 0.4. *Less abundant species* had downweights between 0.25 and 0.4. *Rare species that contributed little to browse availability* had downweights less than 0.25. See Chapter 5 for full details of downweighting used.

#3: Since 1989 both key observers (Keryn Adcock and myself) have noted that the alien, *C.odorata* has spread extensively through many areas of Hluhluwe. If the survey was repeated today this species would undoubtedly have got a higher abundance rating.

CHAPTER 8

BLACK RHINO FEEDING PATTERNS III: GRID SURVEY RESULTS - PART ii : EFFECTS OF GRASS INTERFERENCE AND GRASS HEIGHT ON BLACK RHINO FEEDING

INTRODUCTION

The Pilot survey results indicated strongly that grass height, and especially grass biomass, negatively affected habitat quality for black rhino. In the previous chapter we also saw that the two least important "communities" for black rhino feeding (based on a preliminary TWINSPAN Habitat Classification) had the tallest grass. This chapter continues the analysis of the Grid survey data, and presents the results of detailed examinations of the influences of grass height and interference on black rhino feeding in the extensive Grid surveys.

The primary aim of the analyses in this chapter was to obtain a clearer idea of how grass influenced black rhino habitat suitability. This knowledge could be used later in building black rhino habitat suitability models; and in assessing the probable influence of past heavy-culling of grazing herbivores and high rainfall years on black rhino. Much of this chapter focuses on the effects of grass on "*Acacias*". This is because of their high dietary importance and preference values; and because "*Acacias*" tend to grow in more open sites, and are especially prone to grass interference.

Grass was measured using two variables in the Grid survey - modal grass height and percentage of browse bottles hidden by grass (hereafter termed grass interference). The questions that needed to be answered were:

> Were both grass variables synonymous, or if they had different effects what were they?
>
> Was there a linear relationship between black rhino feeding and grass amount; and if not, what were the non linear crossover points?
>
> As modal grass height data were much easier and cheaper to collect than grass interference data; could one get away with only measuring grass height in future habitat assessments?

Did the incorporation of grass interference directly into multivariate habitat descriptions using Resource based data improve black rhino habitat quality assessments?

Results of Grid survey analyses of the influence of grass on black rhino feeding have been split into five main sections:

1) The first section studies the influence of grass on patch selection by contrasting the difference in grass interference between plots with and without feeding.

2) Black rhino feeding on the ten main food "*Acacias*" under two metres is then examined in detail. This second section concentrates on contrasting the effects of grass height compared to grass interference levels on "*Acacia*" feeding, and provides information about how black rhinos perceive grass.

3) An overlay of a modal grass height contour map onto a contour map of Hluhluwe Study Area feeding levels is then used to examine the influence of grass height on black rhino habitat use at a landscape level.

4) The influence of grass on small-medium food "*Acacia*" availability in Hluhluwe and Umfolozi is then compared, to shed more light on black rhino habitat suitability in the two study areas.

5) Finally we examined whether incorporating grass interference directly into the multivariate habitat descriptions using resource based analysis (Emslie 1991d) explained more of the black rhino feeding than the simpler spize or species-based community descriptions.

PATCH SELECTION : DIFFERENCES IN GRASS INTERFERENCE BETWEEN PLOTS WITH (YES) AND WITHOUT (NO) BLACK RHINO FEEDING

Mean grass interference was greater in Hluhluwe NO plots (27.6%) than in Hluhluwe YES plots (18.9%). Readers should be aware that these figures will be slight underestimates of true grass interference, as no estimates of grass interference were made on trees greater than 2 metres. Mean Grass interference levels were higher in Hluhluwe than in Umfolozi.

Umfolozi YES plots had more grass interference than NO plots (YES 12.1%, NO 7.8%). Reasons for this are, firstly, grass levels were low in the rejected *C.menyhartii*, and dense bush clump communities. Secondly, areas with preferred Acacias were usually more open, and hence often had more grass, which was often taller than in dense areas with higher woody canopy covers.

In Hluhluwe:

Although Free bottle availability of preferred spizes *A.karroo1* and *A.karroo2* did not differ between YES and NO plots (Size1 YES: 119 FreeBB/Ha NO: 120 FreeBB/Ha Size2 YES: 628 FreeBB/Ha NO: 635 FreeBB/Ha), mean levels of grass interference were higher in NO plots (Size1 YES: 59% NO: 74% Size2 YES: 33% NO:45%). **In Hluhluwe, 72.50% of the *A.karroo2* browsing occurred in plots with less than 40% grass interference, yet these plots only contained 19.36% of Total *A.karroo2* bottles.**

Mean percentage grass interference was also lower in YES than NO plots for a number of other important and preferred small "*Acacia*" spizes - *A.nilotica1* (YES:51% NO:61%) *A.nilotica2* (YES:20% NO:38%) and *D.cinerea2* (YES:20% NO:39%).

Grass interference levels on many common size class 2 trees (1-2m) appeared to be a better indicator of whether a plot was fed in or not, than interference levels on size class 1 individuals (<1m).

When black rhinos in Hluhluwe used more open patches, they clearly selected areas with lower grass interference. Mean grass interference was higher in NO plots for all of the following size2 spizes which commonly occur in more open areas of Hluhluwe:

D.lyciodes2 YES:20% NO:45%
E.crispa2 YES:31% NO:46%
L.javanica2 YES:28% NO:51%
P.reticulatus2 YES:20% NO:48%
Solanum2 YES:17% NO:37%
A.caffra2 YES:36% NO:43%
H.pauciflorus2 $^{\#1}$ YES:17% NO:43%
M.senegalensis2 YES:8% NO:26%
Rhus rehmanniana2 YES:32% NO:65%

In Umfolozi:

The 10 most preferred and common size 1 and 2 "Acacia" spizes were examined to see if mean grass interference levels consistently differed between YES and NO plots:

Grass interference was lower in YES plots for *D.cinerea1* (YES:47% NO:62%), *A.nilotica1* (YES:59% NO:67%), and *A.gerrardii1* (YES:41% NO:72%).

Mean Grass interference was similar for *A.karroo1* (YES:72% NO:70%) and *D.cinerea2* (YES:20% NO:23%).

Grass interference levels were low around *A.borleae*, which was not recorded in NO plots - *A.borleae1* (YES:12%), and *A.borleae2* (YES:0%).

A.karroo2 (YES:38%) and *A.nilotica2* (YES:12%) were also only sampled in YES plots.

Interference levels were also low in both YES and NO plots for *A.tortilis* trees under two metres - *A.tortilis1* (YES:27% NO:10%), *A.tortilis2* (YES:11% NO:1%).

FIGURE 8.1.

Mean grass interference in plots where spize 1 *"Acacias"* were browsed, versus interference in plots where these were unbrowsed.

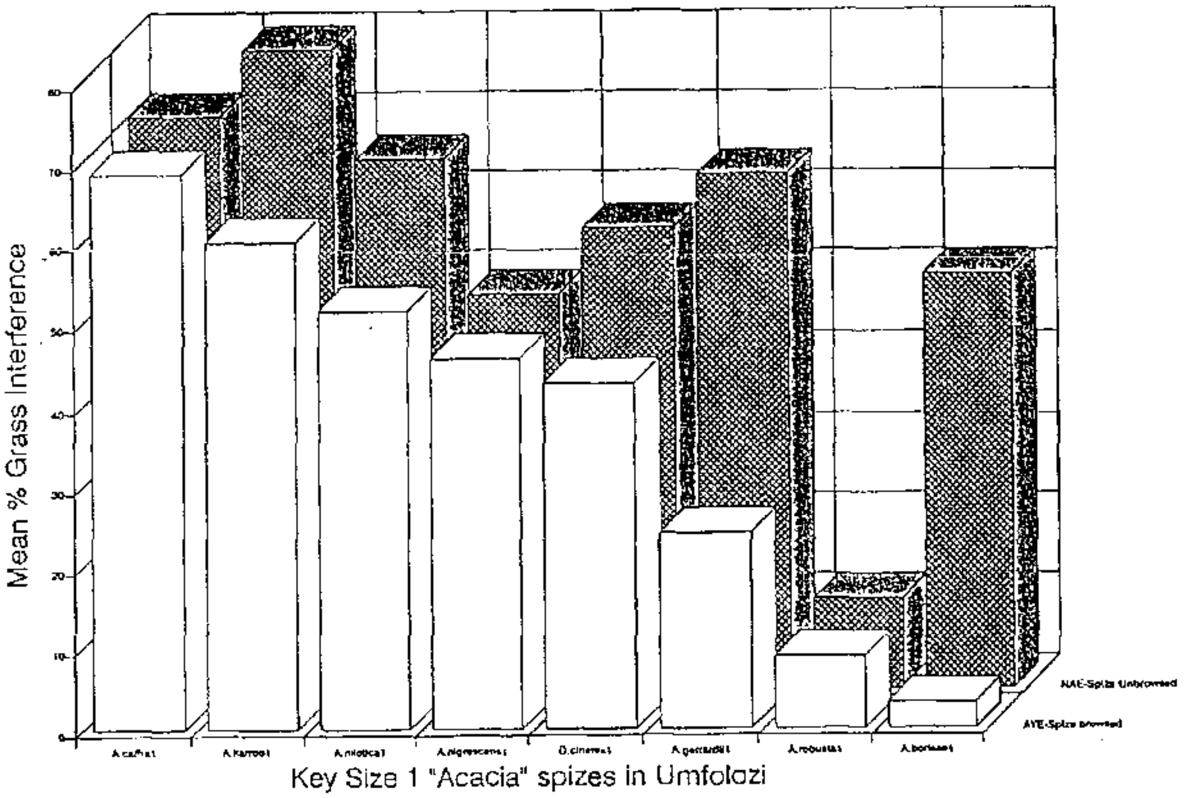
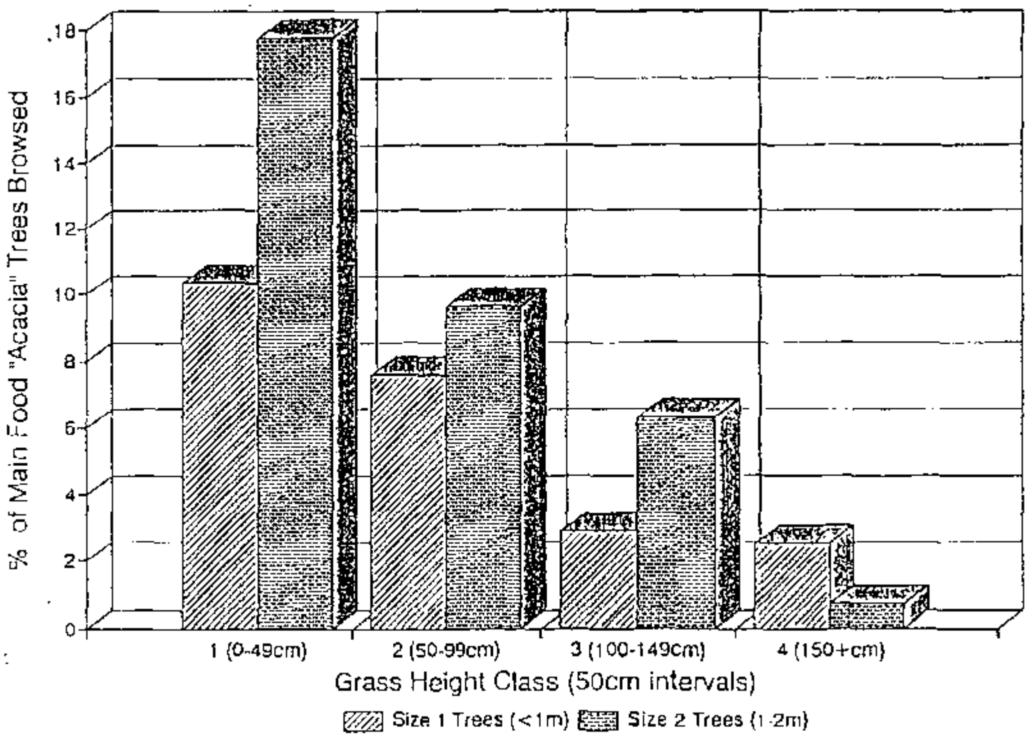


FIGURE 8.2

Influence of plot modal grass height and tree size on the proportion of individuals of the 10 main food "Acacia's" eaten by black rhino - Based on pooled Grid Survey data Size1 n = 4,192 Size2 n = 1,720



> Mean grass interference of *A.nigrescens1* was higher in YES plots (YES:53% NO:23%). However, not too much should be made of this as this spize only contributed 0.59% of the total woody diet compared to 13.38% for *D.cinerea1*, *A.nilotica1* and *A.gerrardii1*, which were eaten on plots with lower grass interference. A further 9.89% of the diet was made up by *A.tortilis1*, *A.tortilis2*, *A.borleae1* and *A.borleae2* that occurred in short grass areas.

The mean grass interference on key "*Acacia*" spizes listed above, was calculated for plots with (YES) and without feeding (NO) irrespective of whether the particular spize in question was eaten or not. It was also decided to compare mean grass interference levels between plots where the spize in question was eaten (AYE) or not (NAE). Figure 8.1 presents the results for Size1 spizes of 8 important "Acacias" in Umfolozi. **Clearly black rhinos were selecting for plots where less of their preferred small "Acacias" were hidden by grass.** A similar pattern was shown for key size 2 "Acacias" in Umfolozi. Grass interference levels were higher in NAE plots for the ubiquitous *D.cinerea2* (AYE 14% NAE 29%) and *A.karroo2* (AYE 33%, NAE 45%). Minimal grass interference was recorded on *A.borleae2*, *A.robusta2* and *A.gerrardii2*. Grass interference was lower in NAE plots for *A.nilotica2* (AYE 19% NAE 5%), although such plots were rare. This really indicates low levels of interference on *A.nilotica2* in Umfolozi.

INFLUENCE OF GRASS HEIGHT COMPARED TO GRASS INTERFERENCE ON BROWSING OF "Acacias" LESS THAN 2 METRES

Paradox relational database querying was used to obtain most of the results in this section.

RESULTS BASED ON SUMMARIES OF POOLED FOOD "ACACIA" DATA IGNORING EFFECTS OF RESERVE, SPECIES AND BROWSE ABUNDANCE

The influence of grass height and grass interference on small and medium "*Acacia*" browsing was first studied using pooled Grid data for plots containing the ten main food "Acacias" in Hluhluwe-Umfolozi Park - *A.borleae, A.caffra, A.gerrardii, A.karroo, A.nigrescens, A.nilotica, A.robusta, A.senegal, A.tortilis* and *D.cinerea*. Plots that did not contain any size 1 or 2 main food "*Acacias*" were excluded from the analyses. These summary analyses did not consider reserve or species differences, and were therefore more heavily influenced by the more abundant "*Acacia*" species.

INFLUENCE OF GRASS HEIGHT ON BLACK RHINO FEEDING

Only 16.7% of the main "*Acacia*" plots with modal grass height over 1.5 metres had browsing. This contrasts with 44.0% with browsing among "*Acacia*" plots with modal grass heights of less than a metre, and 33.8% with browsing among plots with grass from 1-1.5 metres. **Thus at a broad patch-level feeding scale, very tall grass "*Acacia*" areas were rejected by black rhino.** The comparison of modal grass height and Grid browsing contour maps later in this chapter clearly show this was the case in the Hluhluwe.

As plot modal grass height increased, the proportion of small to medium "*Acacia*" trees browsed per plot declined. This effect was especially marked for size 2 trees (Figure 8.2). Black rhinos were again selecting food at a hierarchy of scales. **Although grass height influenced whether black rhinos fed in the plot; on a finer level, grass height further influenced the proportion of individual "*Acacia*" trees eaten in each plot.** Figure 8.2 also showed that except in very tall grass, a higher proportion of medium height "Acacias" (1-2 metres) were eaten compared to small "Acacias" (<1m).

Figure 8.3 indicated that the proportion of Total available bottles eaten on small and medium "Acacias" (<2m) was strongly influenced by the proportion of trees eaten, which in turn was influenced by modal plot grass height. Except for very tall grass areas, offtake levels expressed as a percentage of standing crop were slightly higher from

FIGURE 8.3

Influence of plot modal grass height and tree size on the proportion of total available bottles of the 10 main "Acacia's" browsed by black rhino - Pooled Grid Survey data base used. The graph is based on an examination of 11,934 Size 1 and 16,764 Size 2 Total available "Acacia" browse bottles.

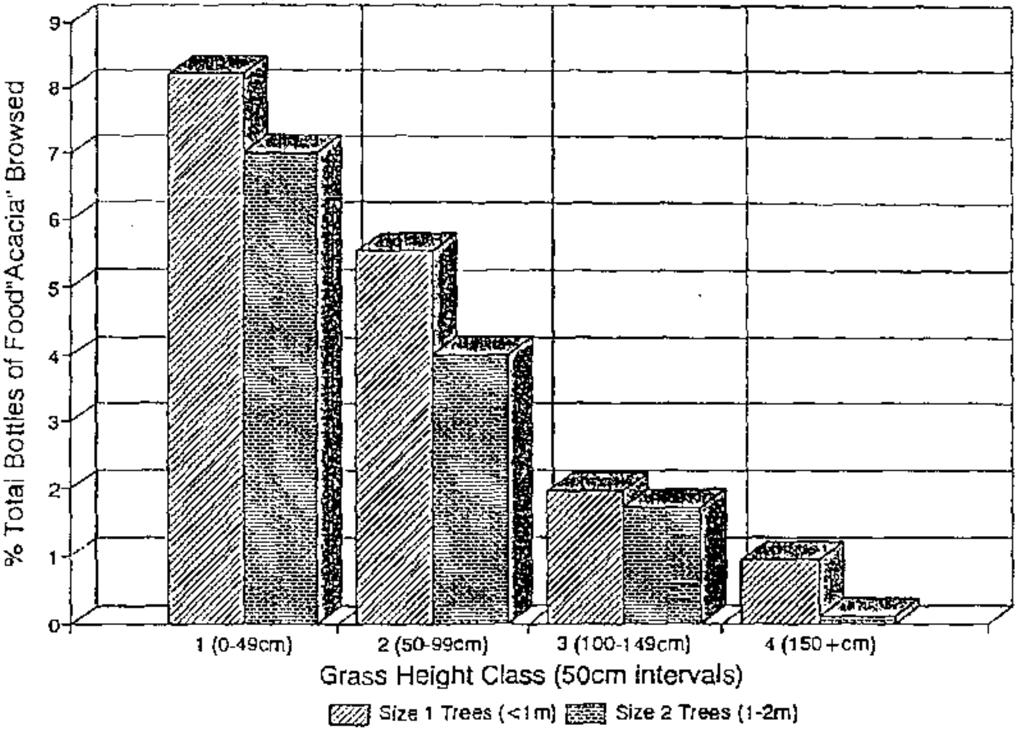


FIGURE 8.4

Influence of plot modal grass height and tree size on the mean browsing offtake (bottles) per tree of the 10 main "Acacia's" browsed by black rhino - Pooled Grid Survey data base used. The graph is based on a sample of 4,192 Size 1 and 1,720 Size 2 trees.

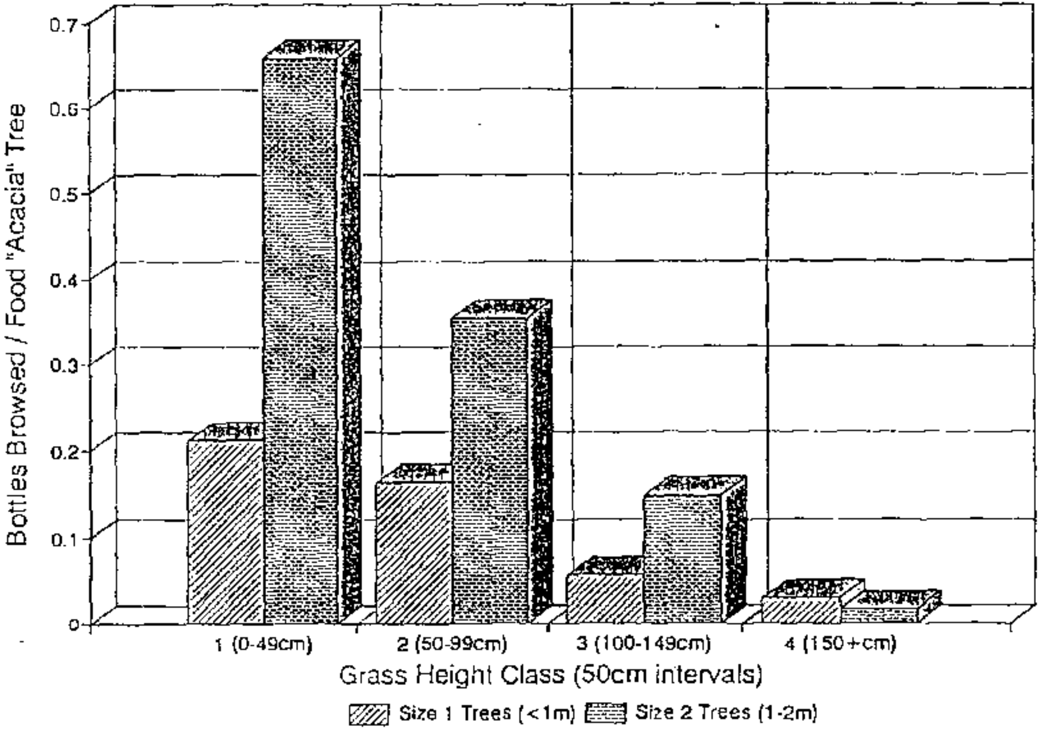


FIGURE 8.5

Influence of plot modal grass height and tree size on the mean browsing offtake (bottles) per browsed tree of the 10 main "Acacia's" browsed by black rhino - Pooled Grid Survey data base used. The graph is based on a sample of 293 browsed Size 1 and 149 browsed Size 2 trees.

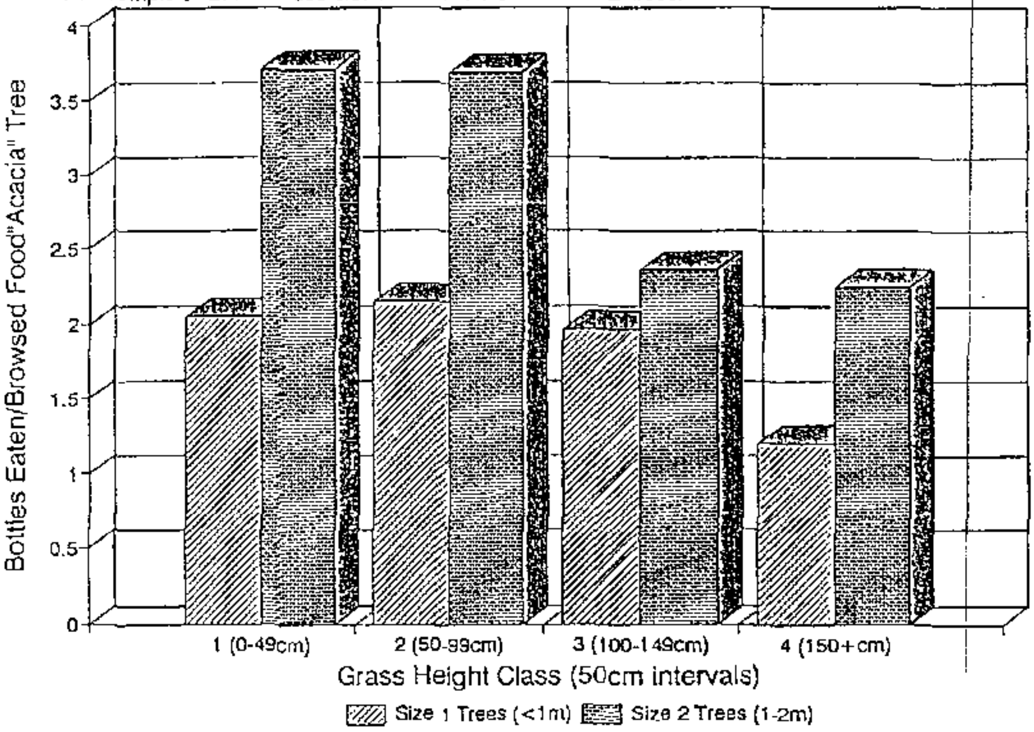
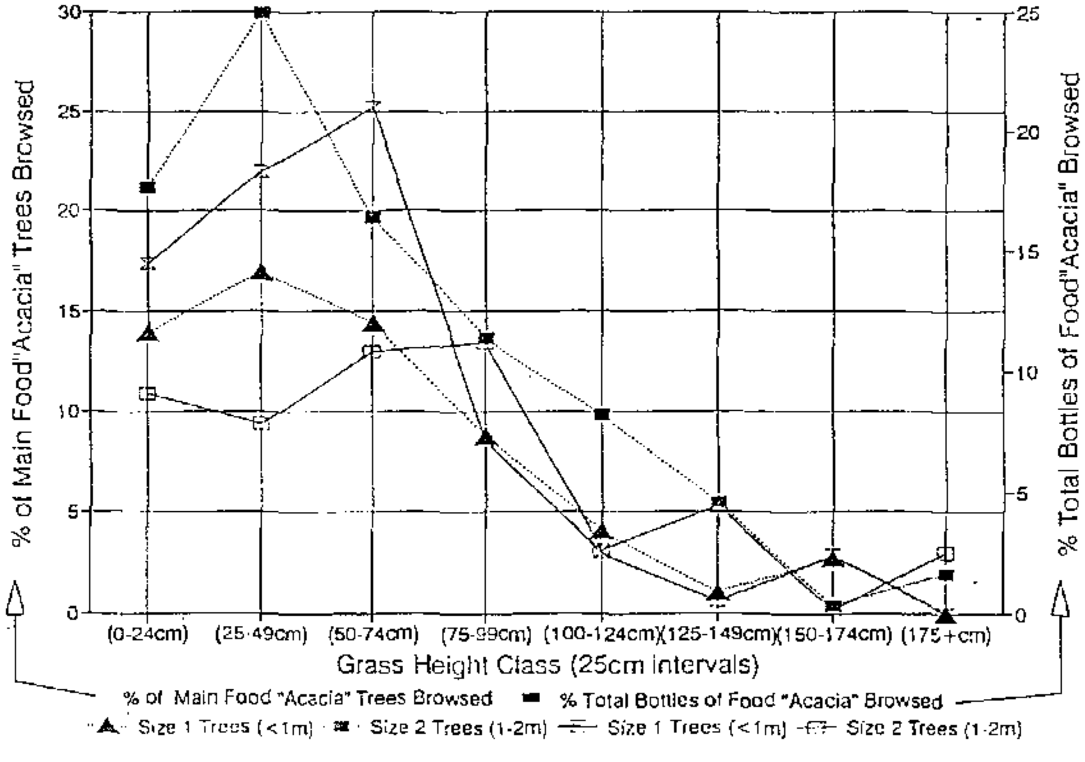


FIGURE 8.6

Influence of plot modal grass height and tree size on 1) the proportion of individual food "Acacia" trees browsed (Dashes / Filled symbols), and 2) the percentage of total available food "Acacia" bottles browsed (Solid Lines /Open Symbols). Total sample sizes : Size 1 = 4,192 trees and Size 2 1,720 trees.



small "Acacias" (<1m) than medium (1-2m).

Mean offtake/tree throughout the plots (Figure 8.4) was strongly correlated with the proportion of individual trees browsed; although the difference in mean offtake/tree between size classes was more marked. Absolute offtake/tree was lower on small (<1m) compared to medium (1-2m) "*Acacias*"; although mean offtake per medium tree decreased markedly as grass height increased.

Figure 8.5 illustrates how mean offtake per browsed "*Acacia*" tree was influenced by tree size and grass height. Figure 8.5 also confirms that mean offtake/tree was greater on size 2 "Acacias".

However, **the main point to emerge from Figures 8.2 through to 8.5, was that grass height primarily affected browsing levels by influencing 1) whether feeding occurred in the plot and 2) the proportion of available trees eaten - rather than the mean offtake per browsed tree.** Mean offtake per browsed tree was relatively stable, only partially declining when grass height increased over 1m (Size2) to 1.5m (Size1). Figure 8.6 presents average feeding level data for eight 25cm modal grass height classes. **Key points to note are that the proportion of "Acacias" of less than 2 metres eaten, starts to decline when grass height exceeds 75cm. Figure 8.6 shows that by the time grass height has reached a metre or more, feeding levels on small-medium "Acacias" have declined substantially.**

Overall, 87.1% of all browsing on food "Acacias" less than 2 metres occurred in plots with modal grass heights of less than 1 metre. These plots only contributed 59.0% of Total available *"Acacia"12* bottles.

One unexpected finding, was that the recorded density of "Acacias" less than 2 metres increased as grass height increased (Figure 8.7). Figure 8.7 also shows that the density of food "Acacias was higher in "*Acacia*" plots with feeding (AYE) than without (NAE) for all grass height classes. This corroborated the Pilot survey findings.

FIGURE 8.7

Relationships between plot modal grass height and densities of the 10 main food "Acacia's". Plots containing black rhino "Acacia" browsing (AYE) are contrasted with unbrowsed plots (NAE). The graph is based on a pooled grid subset of 365 main "Acacia" plots and a total sample of 5,912 "Acacia's" <2 metres.

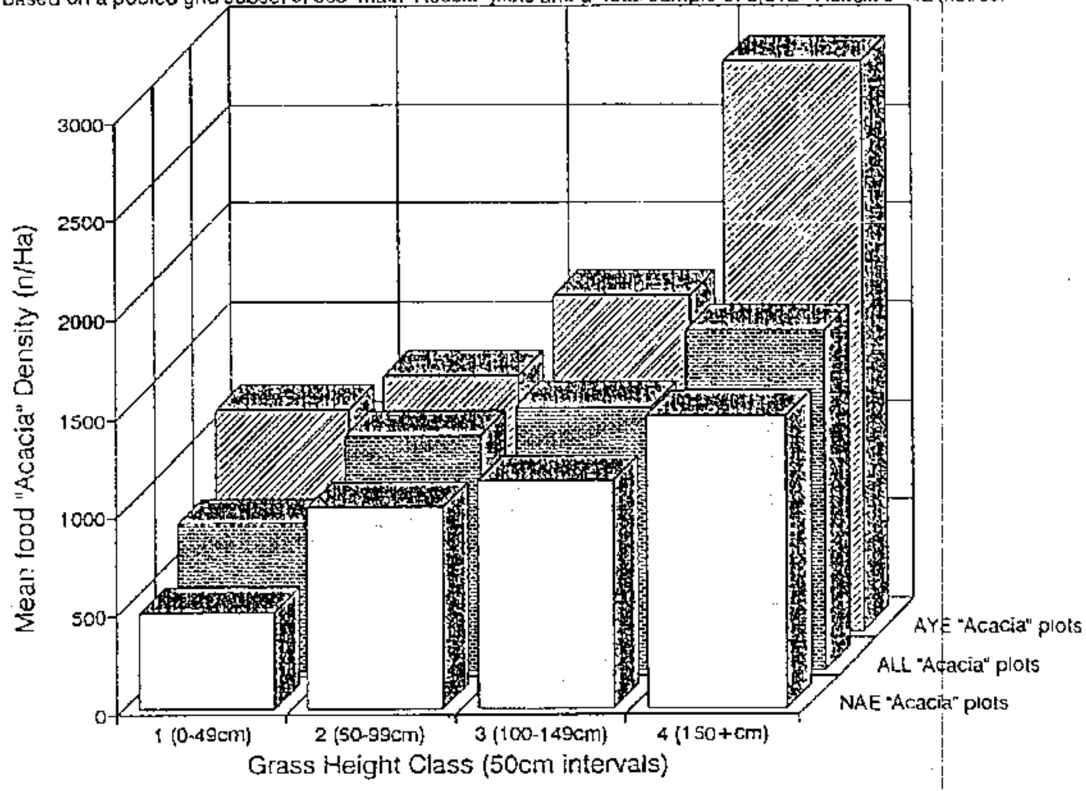
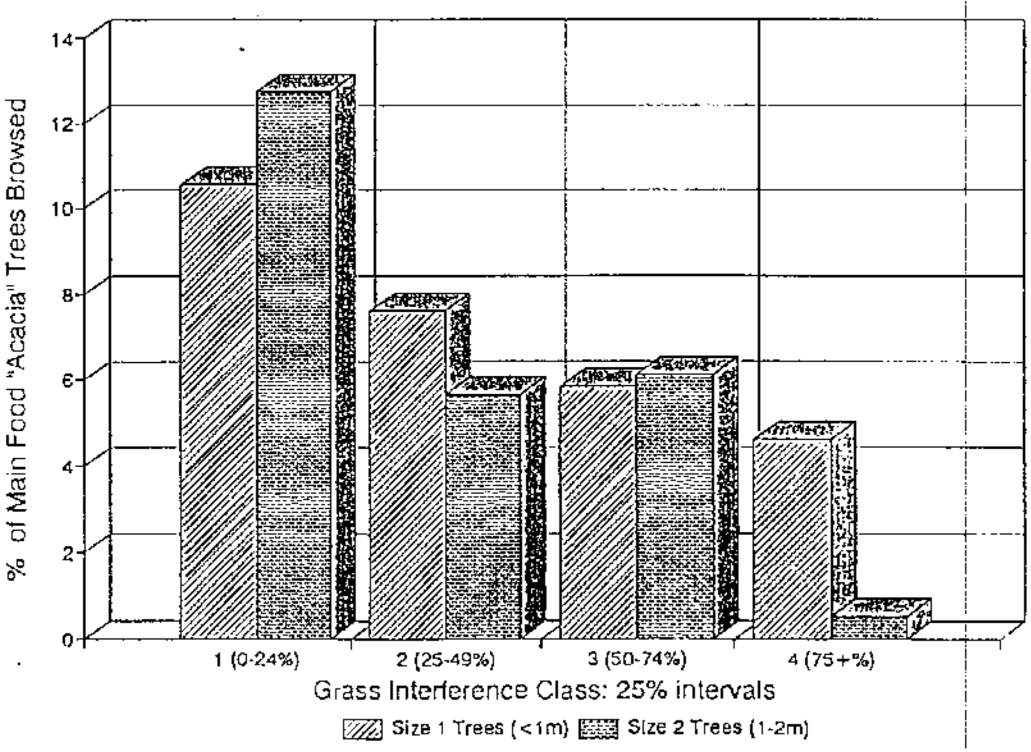


FIGURE 8.8

Influence of modal grass interference/spize/plot and tree size on the proportion of individuals of the 10 main food "Acacia's" browsed - Based on pooled Grid Survey data Size1 n = 4,192 Size2 n = 1,720



While looking at Figure 8.7, readers should be aware that there were only three AYE food "*Acacia*" plots where modal grass height exceeded 1.5 metres. The corresponding tree density estimate in this case (AYE/GHt4) is therefore only a rough approximation of the true value.

INFLUENCE OF GRASS INTERFERENCE ON BLACK RHINO FEEDING

Figure 8.8 shows that as Grass Interference increases, the proportion of food "*Acacia*" trees browsed decreases. However, a comparison with Figure 8.2 indicates that plot modal grass height had a greater influence on the proportion of food "*Acacia*" trees browsed than grass interference levels. Again grass interference appeared to have a bigger influence on browsing of medium (size 2: 1-2m) compared to small (size 1: <1m) food "Acacias".

The percentage of Total available bottles browsed on small food "Acacias" (<1m) declined markedly as grass interference increased above 50% (Figure 8.9). However, as soon as grass interference on medium food "*Acacias*" increased above 25%, the proportion of Total available bottles browsed dropped markedly. The difference between tree size and critical grass interference level again indicated that Grass Height was a better explanatory variable. This can be more easily appreciated by examining mean modal plot grass heights per grass interference class by tree size (Figure 8.10).It is worth noting that mean grass heights for food "*Acacia*" size 1 grass interference 25-49% (58cm), and for food "*Acacia*" size 2 grass interference less than 25% (54cm) were similar (Arrowed in Figure 8.10). The grass height midpoints between grass interference classes 2 and 3 for small "Acacias", and between 1 and 2 for medium "Acacias" were used to give an approximation of the critical modal grass height below which the percentage of Total "*Acacia*" bottles browsed declines. This produced estimates of critical grass heights of 64cm for small, and 76 cm for medium "Acacias" respectively. Figure 8.6 supports this conclusion, indicating that the critical grass height is somewhere between 75cm and 1 metre.

Figure 8.11 shows that the average offtake per food "*Acacia*" tree decreases as grass interference increases. Again, the pattern is not as clear-cut as the one shown by Figure 8.4, and grass interference has a greater influence on

FIGURE 8.9

Influence of modal grass interference/spize/plot and tree size on the proportion of total available bottles of the 10 main food "Acacia's" browsed by black rhino - Pooled Grid Survey data base used. The graph is based on an examination of 11,934 Size 1 and 16,764 Size 2 Total available "Acacia" browse bottles

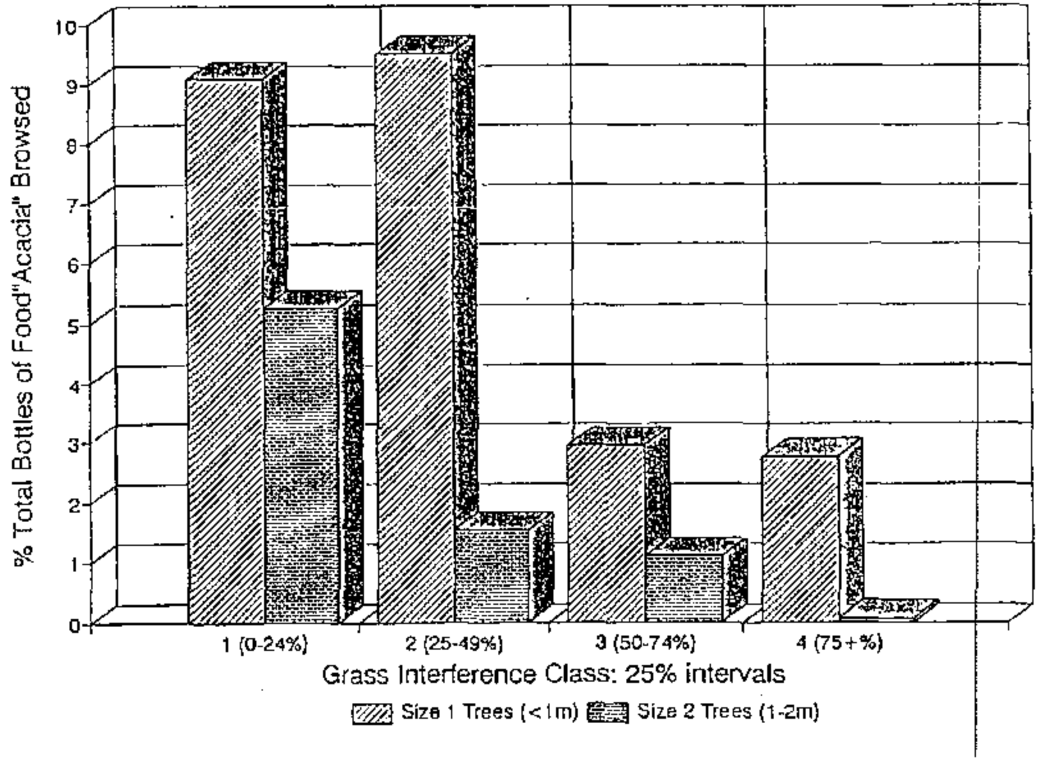


FIGURE 8.10

Mean modal grass height /plot for each main food "Acacia" grass interference class/plot by size class. The histograms were derived from a pooled Grid Survey data base for plots containing the 10 main food "Acacia's". The figure is based on a sample of 4,192 Size 1 and 1,720 Size 2 "Acacia" trees.

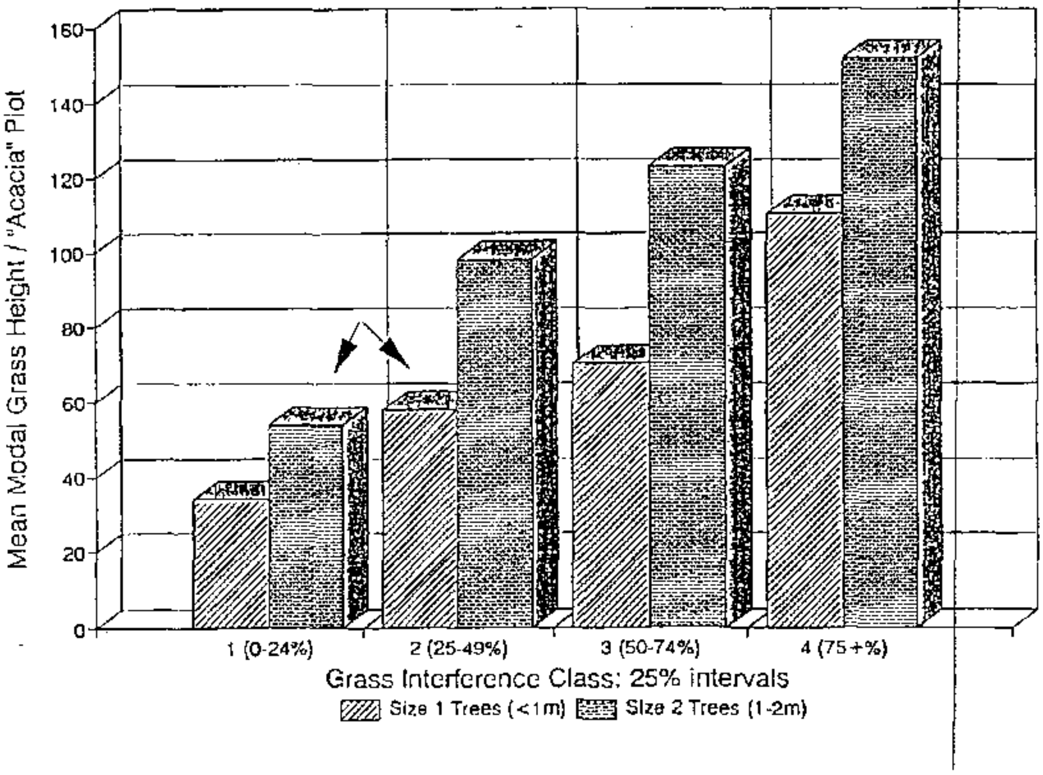


FIGURE 8.11

Influence of modal grass interference/spize/plot and tree size on the mean browsing offtake (bottles) per tree of the 10 main food "Acacia's" browsed by black rhino - Pooled Grid Survey data base used . The graph is based on a sample of 4,192 Size 1 and 1,720 Size 2 trees.

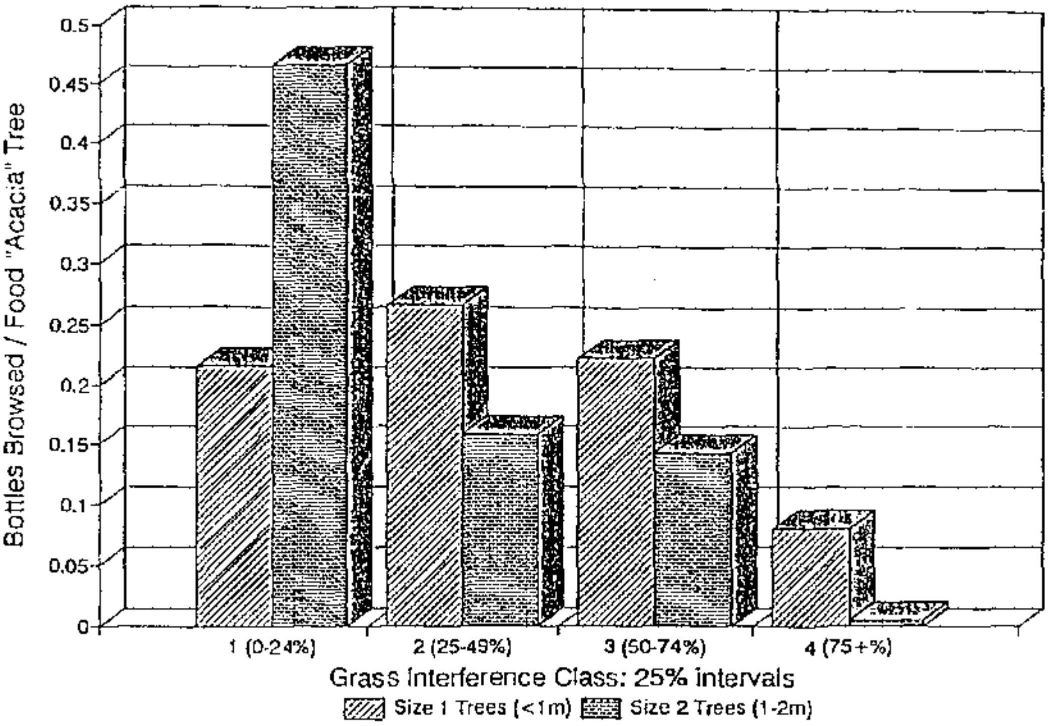
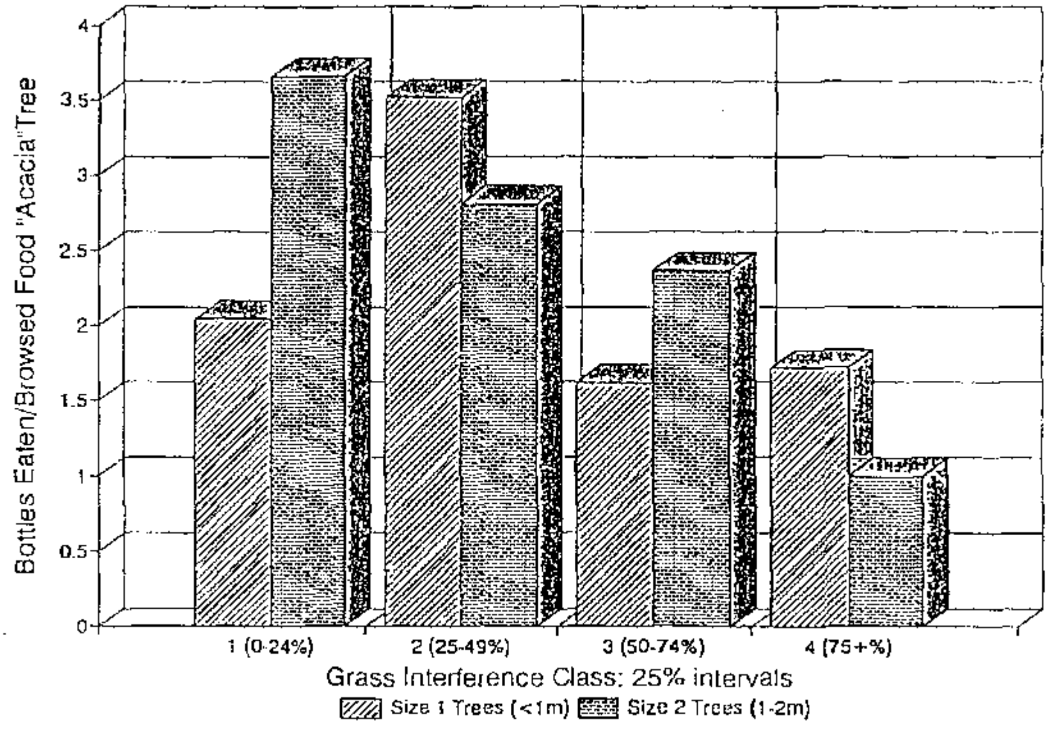


FIGURE 8.12

Influence of modal grass interference/spize/plot and tree size on the mean browsing offtake (bottles) per browsed tree of the 10 main food "Acacia's" browsed by black rhino - Pooled Grid Survey data base used . The graph is based on a sample of 293 browsed Size 1 and 149 browsed Size 2 trees.



feeding levels on medium food "Acacias". The greatest offtake per medium-tall food "*Acacia*" tree browsed occurred when grass interference levels were low (<25%). Similarly, the lowest offtake/medium "*Acacia*" browsed occurred at high interference levels (>75%).

Somewhat surprisingly, the above pattern was different for **small** "Acacias", with offtake levels per tree reaching a peak at between 25% and 50% interference, but otherwise appearing constant (Figure 8.12). However, black rhinos generally ate a lower proportion of small "Acacias" than medium "Acacias" in a plot, and they may have simply selected for small "Acacias" within the plot that had lower than average grass interference. Furthermore, black rhinos selected to feed in plots with higher densities of small/medium "*Acacias*" (<2m).

Maximum offtake per browsed small and medium "*Acacia*" occurred when the mean modal plot grass heights were between 55 and 60 cm (see also Figure 8.10). As densities of small/medium "Acacias" were found to increase with grass height - this may in part explain peak selection for small "Acacias" for areas with a some grass rather than no grass. This makes sense, as such big animals should maximise intake of suitable quality food where possible. Soils in some of the plots with little or no grass may also have been shallow or eroded, with a lower nutrient status and increased levels of moisture stress. In such plots browse abundance and quality may therefore may also have been lower than in other sites.

DETAILS OF THE INFLUENCE OF GRASS HEIGHT AND INTERFERENCE ON SMALL-MEDIUM "ACACIA" FEEDING LEVELS

Due to multicollinearity of the explanatory variables, ridge regression was used to examine the factors influencing small-medium "*Acacia*" browsing levels. The results of the following analyses were based on pooled subset of the Grid plots containing the ten main food "Acacias".

For unfamiliar readers, it is perhaps worth mentioning again that ridge regression is always based on standardised data (i.e. data transformed to have a mean of 0 and standard deviation of 1). This means that the derived ridge regression coefficients for each of the explanatory variables are directly comparable; even though they may have been measured in different units [#2].

Analysis firstly examined key variables that governed small-medium "*Acacia*" (<2m) browse offtake per plot :

> Small-medium "*Acacia*" browse offtake per plot was primarily a function of two variables: 1) the number of "*Acacia*" trees browsed per plot; and 2) to a lesser extent the mean offtake per browsed "*Acacia*" tree (Ridge Regression coefficients **[RRc's]** - Browsed "*Acacia*" density Size 1: 0.5218 Size 2: 0.4961 ; Mean offtake per browsed "*Acacia*" Size 1: 0.3254 Size 2: 0.2994). Thus rhino increase their feeding in a plot by eating on more trees, and to a lesser extent by taking more from each tree.
>
> For both size classes, **the influence on browsing (shown by RRc's) of Grass Height and Free Bottles per Plot were larger** than those for Percentage Grass Interference and Total Bottles per Plot.

Factors influencing the number of small-medium "*Acacia*" trees browsed per plot were then examined:

> The number of small-medium "*Acacias*" browsed per plot (dependent variable) was largely positively related to 1) small-medium "*Acacia*" density, and 2) the mean offtake per browsed small-medium "*Acacia*" tree (RRc's - "Acacia" Density Size 1: 0.2854 Size 2: 0.1659; Offtake per browsed "*Acacia*" Size 1: 0.2672 Size 2: 0.4157).
>
> The importance of tree density was to be expected, due to the simple fact that large numbers of trees need to be present for large numbers of trees to be eaten per plot. The results also corroborate earlier Grid survey analyses which indicated that the most preferred "*Acacia*" species had the highest mean offtake levels per browsed tree.

It is interesting that although the absolute density of small-medium food "Acacias" was higher in Hluhluwe than Umfolozi, the absolute density of the most preferred species of small-medium "Acacias" was higher in Umfolozi. This may in part have been why the density of browsed small-medium "Acacias" was also higher in Umfolozi than Hluhluwe (RRc - Reserve Dummy Variable - Umfolozi=1 Size1: 0.1798 Size 2: 0.2009).

The ridge regression also indicated that modal **Grass Height was inversely related to the density of small-medium "Acacias" browsed** (RRc- Grass Height Size1: -0.0805 Size 2: -0.0898). By way of contrast, RRc's indicated that the influence of percentage grass interference on the number of "Acacias" browsed per plot was comparatively small.

Ridge Regression then examined the factors influencing the mean offtake (bottles) per browsed small-medium "*Acacia*" (the other major variable influencing small-medium "*Acacia*" browse offtake per plot):

Mean offtake levels per browsed "*Acacia*" tree were greater in Umfolozi than Hluhluwe (RRc's Reserve Size 1: 0.1862 Size 2: 0.1235). This may reflect the greater absolute and proportional contribution of the most preferred "*Acacia*" species to total "*Acacia*" densities in Umfolozi.

In contrast to the number of "Acacias" browsed per plot, **mean offtake levels per browsed tree were influenced more by percentage grass interference than plot modal grass height**. The relationship appeared to be more marked for size 2 "Acacias (RRc's Grass Interference Size 1: -0.0354 Size 2: -0.0787; Grass Height Size 1: -0.0243 Size 2: 0.0078).

In addition mean offtake levels per browsed "*Acacia*" tree were positively related to mean Free bottles available per tree (RRc's Free bottles per tree Size 1: 0.0773 Size 2: 0.0625)

Decomposition of multiple correlation coefficients into their various components, confirmed that **grass height was the more important of the two grass variables in determining the number of "Acacias" browsed per plot; while Grass Interference primarily influenced mean offtake per browsed "*Acacia*".** This relationship was again more apparent for medium compared to small "Acacias". Pooling the data from both small and medium "Acacias" per "*Acacia*" plot produced the most clear cut result:

Only 8.05% of the variation in the number of small-medium "Acacias" (<2m) browsed per plot accounted for by the two grass variables could be ascribed to Mean Percentage Grass Interference per Plot (of small-medium "Acacias") alone. Plot Modal Grass Height uniquely accounted for 76.49% of the total grass explained variation. The joint effects of grass height and percentage interference together made up the remaining 15.46% of the grass explained variation. This joint effect was because grass interference levels tended to increase with grass height.

In the case of mean offtake levels per browsed small-medium "*Acacia*", the variation explained by the two grass variables was decomposed as follows: Grass Interference alone 56.21%, Grass Height alone 6.23% and joint Grass Height/Interference 37.56%.

When the two size classes were analysed separately, Grass Height and Interference jointly accounted for as much as 70% of the grass explained variation in the two parameters above. However, the overall pattern remained the same for both small and medium "Acacias" - Grass Height influenced the number of "*Acacias*" eaten more; while Grass interference better explained mean offtake levels per browsed "*Acacia*" tree.

RESULTS BASED ON POOLED DATA AVERAGES PER "*ACACIA*" SPIZE PER "*ACACIA*" PLOT AFTER DETRENDING TO REMOVE EFFECTS OF RESERVE, TREE SIZE AND BROWSE ABUNDANCE

Corroborative statistical analyses were also undertaken using summary data for the 1,061 unique food "*Acacia*" size 1 or 2 spize/plot combinations in the data set. Pooled Hluhluwe-Umfolozi data were again used. However, in analyses with these data, the effects of covariables (for reserve, species and tree density or total browse volume) on feeding were removed before Multifactor Analysis of Variance (MANOVA) analysis (Neter *et al* 1978).

In layman's terms this means analysing to see if grass height and tree size significantly explained any of the remaining variation in feeding levels, that had not already be explained by reserve, species and an appropriate measure of browse abundance.

Rarer species were given more weight in this analysis as results were expressed as the mean per "*Acacia*" spize per plot, rather than the overall "*Acacia*" mean per plot (as in the earlier analyses). Despite technical statistical problems [#3], significance levels were so high in many of the analyses that one could be very confident that the recorded factor level differences were real.

INFLUENCE OF MODAL GRASS HEIGHT ON BLACK RHINO FEEDING

F values and probabilities derived from MANOVA's corroborated earlier conclusions that both the proportion of individuals of an "*Acacia*" spize eaten/plot (Grass Height F=7.434 df 3,1050 p= 0.0001 : Grass Interference F=3.139 df 3,1050 p= 0.0247); and the absolute offtake (all bottles) /plot (Grass Height F=7.129 df 3,1050 p= 0.0001 :
Grass Interference F=3.490 df 3,1050 p= 0.0153) were more strongly related to Grass Height Class than Grass Interference Class.

The greater explanatory power of modal plot grass height compared to modal grass interference levels per spize was repeatedly confirmed by stepwise multiple regression modelling using the same pooled 10 main "*Acacia*" dataset.

FIGURE 8.13

Influence of plot modal grass height and tree size on the mean proportion of individuals of the **10** main food "Acacia's" eaten by black rhino after statistically removing the effects of reserve, species and tree density (MANOVA Size F 23.56 (1,1050) p 0.0000 GHt F 7.43 (3,1050) p 0.0001 Interaction F 1.90 (3,1050) p 0.1272)

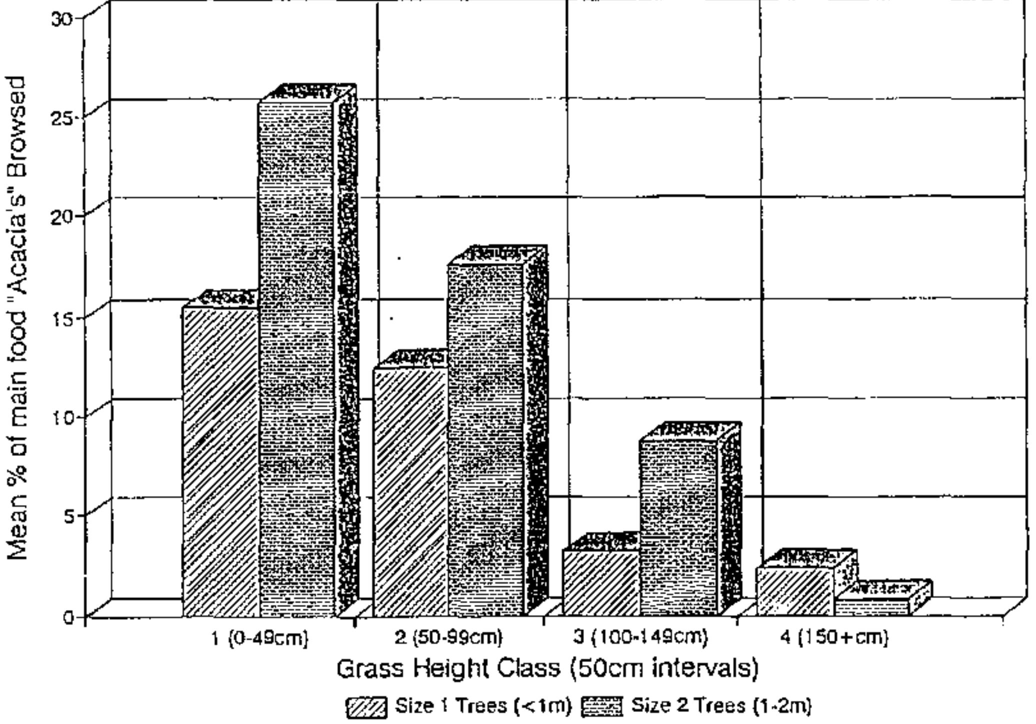


FIGURE 8.14

Influence of modal plot grass height and tree size on mean browsing (browse bottles eaten) /spize per plot on the 10 main food "Acacia's" after statistically removing effects of reserve, species and tree density (MANOVA Size F 2.62 (1,1050) p 0.1054 GHt F 7.13 (3,1050) p 0.0001 Interaction F 3.71 (3,1050) p 0.0113)

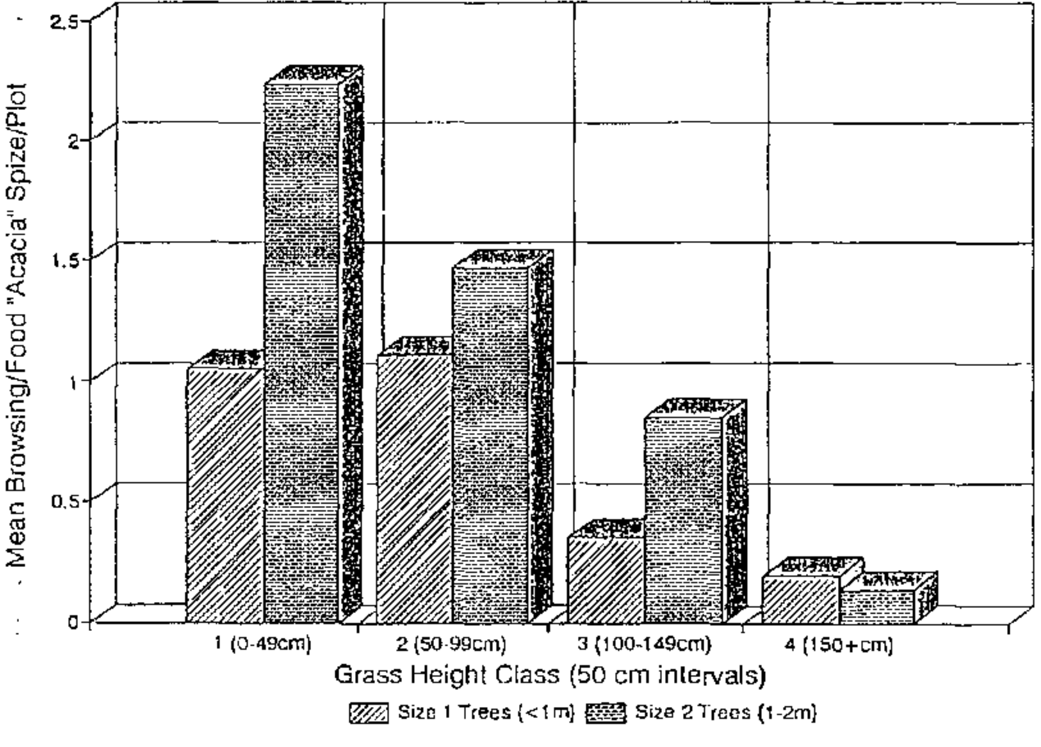


FIGURE 8.15

Influence of modal grass height and tree size on black rhino browsing levels expressed as the mean % of Total Bottles (TB) available on the 10 main food "Acacia's" after statistically removing effects of reserve, species and TB/Plot (MANOVA Size F 0.24 (1,1050) p 0.6291 GHt F 3.525 (3,1050) p 0.0146 Interaction F 0.68 (3,1050) p 0.5653)

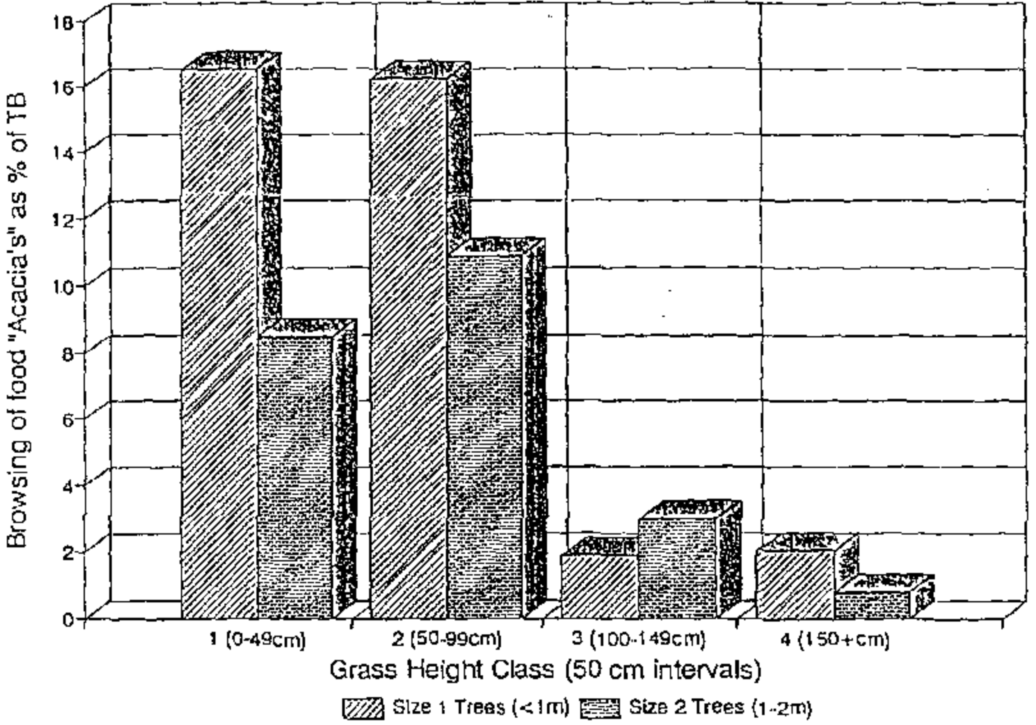
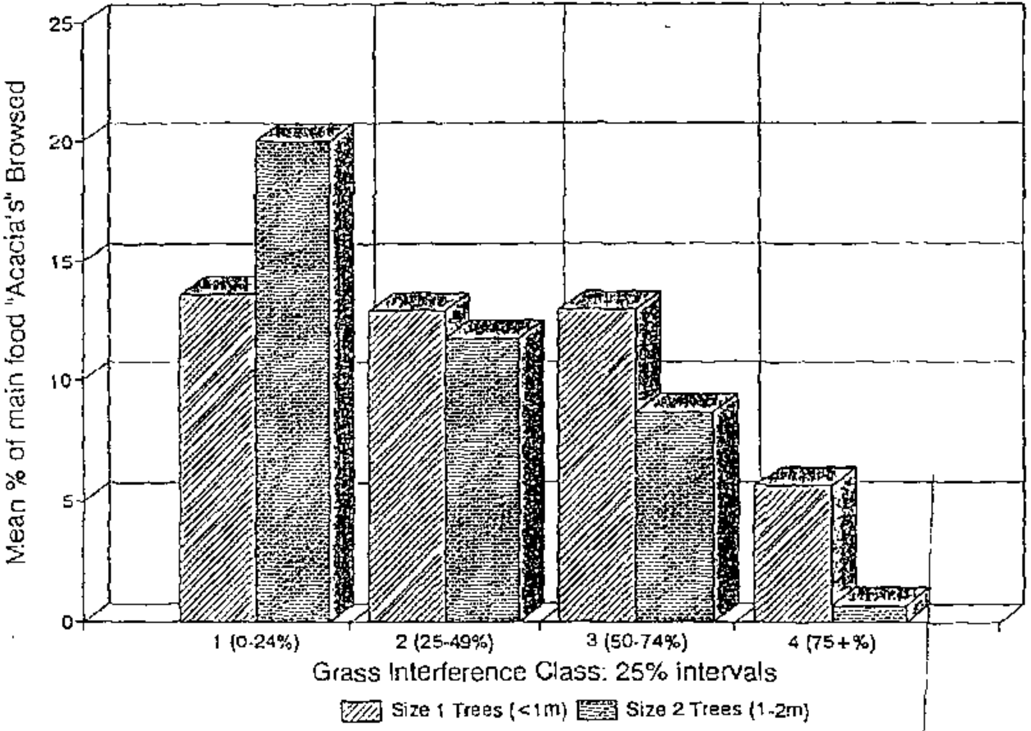


FIGURE 8.16

Influence of modal grass interference/spize and tree size on the mean proportion of individuals of the 10 main food "Acacia's" eaten by black rhino after statistically removing the effects of reserve, species and tree density (MANOVA Size F 13.07 (1,1050) p 0.0003 Gint F 3.14 (3,1050) p 0.0247 Interaction F 2.56 (3,1050) p 0.0535)



In addition the t value was greater when Free bottles were used as an explanatory variable instead of Total available bottles although p values for both were less than 0.0001. When Free bottle density was chosen as the first variable to include, the significance of Grass Height was reduced from p = 0.0002 to p = 0.0094. Again grass interference was not chosen for the final model.

The results also suggested that **grass height has a stronger influence on the amount of new bottles browsed, than on the amount of old bottles eaten** (New Bottles/Spize per Plot F=5.196 (3,1050) p 0.0014 Old Bottles/Spize per Plot F=3.771 (3,1050) p 0.0104). This is to be expected, as old bottle offtake covered a longer period than new browsing. Increased levels of browsing could be expected early in the growing season in taller grass areas before grass height and biomass reached its maximum.

Figures 8.13 through to 8.15 show how grass height influenced browsing levels after the effects of reserve and species and browse abundance had been statistically removed.

The shapes of the histograms in figures 8.13 and 8.2 are almost identical. However because the influence of the common "*Acacia*" species has been downweighted, the Y axis values are higher in Figure 8.13. The F values indicate that **tree size had the biggest influence on the proportion of trees browsed, and that both tree size and grass height were highly significant**.

The mean offtake per food "*Acacia*" spize per "*Acacia*" plot (Figure 8.14) showed a similar pattern to Figure 8.13. Again this indicates that mean offtake levels were strongly controlled by the proportion of trees browsed. However, in this case, size class was significant as an interaction variable with grass height, but not on its own. It is worth noting that **the sums of squares accounted for by modal grass height class was 5.58 times greater than that explained by the covariable dummy variable set for the different food "*Acacia*" species.**

Figure 8.15 showed that the proportion of Total bottles browsed per "*Acacia*" spize per plot declined markedly as soon as modal plot Grass Height increased over 1 metre. In this analysis only Grass Height was significant.

FIGURE 8.17

Influence of modal grass interference/spize and tree size on mean browsing (bottles eaten) /spize per plot on the 10 main food "Acacia's" after statistically removing effects of reserve, species and tree density (MANOVA Size F 0.02 (1,1050) p 0.9038 GInt F 3.49 (3,1050) p 0.0153 Interaction F 3.71 (3,1050) p 0.0113)

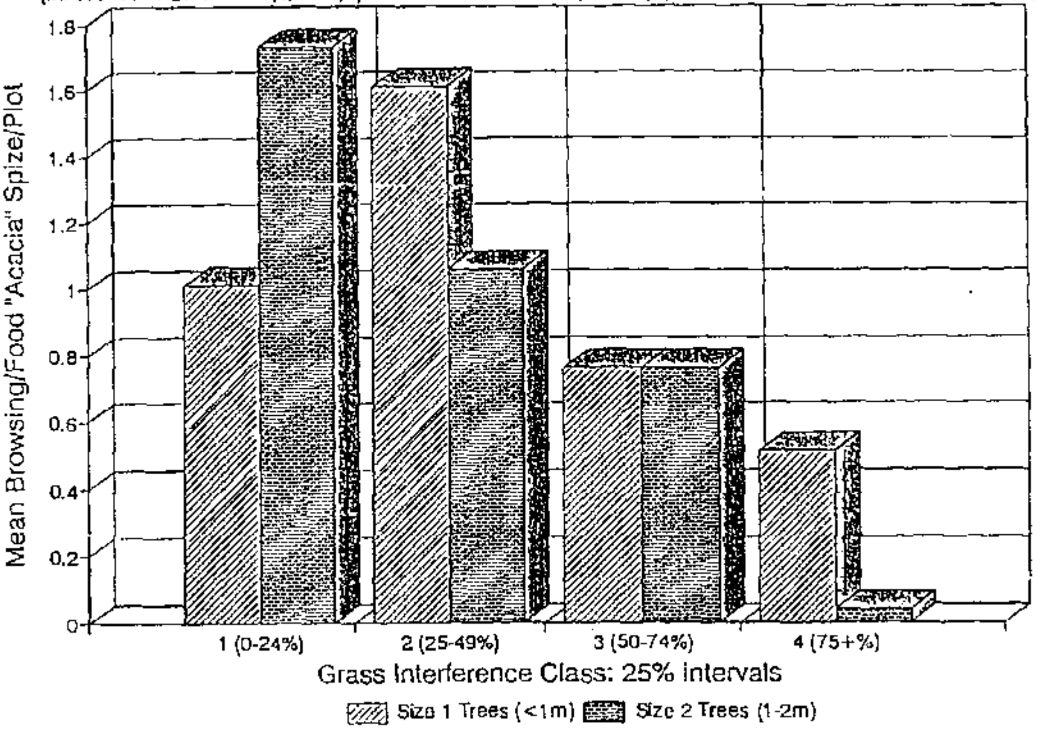
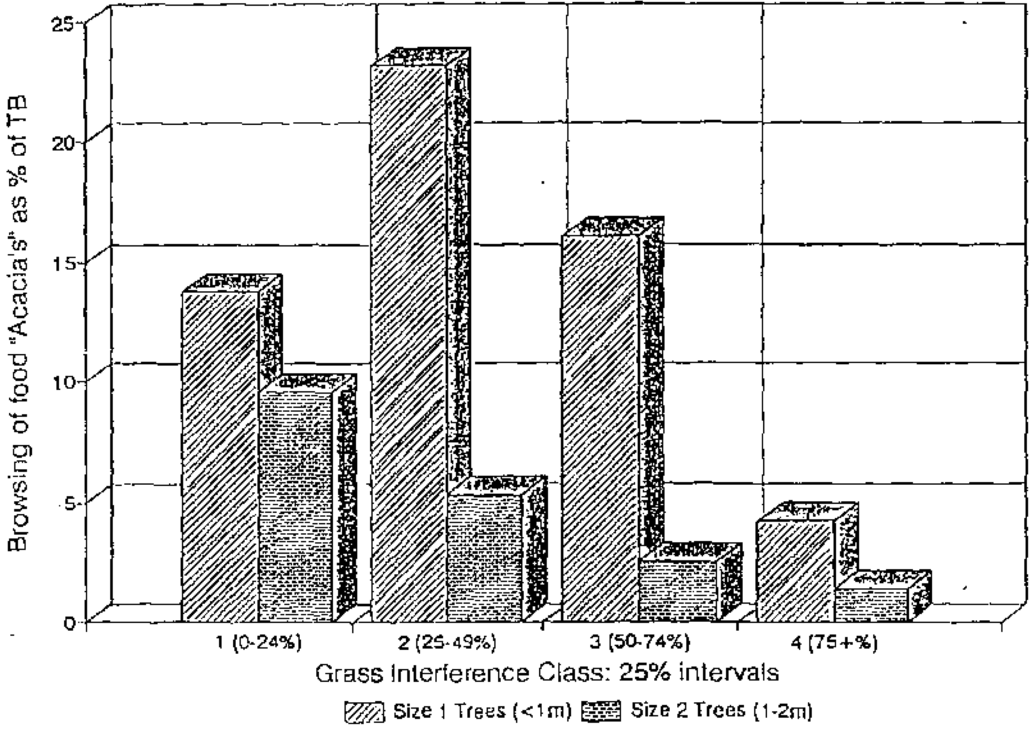


FIGURE 8.18

Influence of modal grass interference/spize and tree size on browsing levels expressed as the mean % of Total Bottles (TB) available on the 10 main food "Acacia's" after statistically removing effects of reserve, species and TB/Plot (MANOVA Size F 0.96 (1,1050) p 0.3383 GInt F 3.31 (3,1050) p 0.0195 Interaction F 1.35 (3,1050) p 0.2575)



Mean browsing levels (bottles of food "*Acacia*" browsed per "*Acacia*" spize) for small-medium "*Acacia*" spizes (<2m) for the four grass height classes were 14.20%, 14.32%, 2.32% and 1.39% respectively.

Further analysis revealed that the mean browsing per small-medium "*Acacia*" spize in plots with modal grass heights below 75 cm was 15.7% (n=599). However with modal grass heights of between 75cm and 1 metre tall, the percentage of bottles browsed dropped by almost half to 8.6% (n=149). Between 1 and 1.25 metres, browsing levels declined to only 2.5% (n=184). Plots with modal grass heights over 1.25 metres had even less browsing (1.6% n=129). This confirms the finding that **75cm appears to be a critical modal grass height, with little "*Acacia*" browsing occurring in plots with grass over 1 metre high.**

INFLUENCE OF GRASS INTERFERENCE ON BLACK RHINO FEEDING

The shapes of the histograms in figures 8.16 and 8.8 are also almost identical. However, because the influence of the common "*Acacia*" species has been downweighted, the Y axis values are again higher in Figure 8.16. The F values indicate that **tree size had the biggest influence on the proportion of trees browsed. Grass interference was also significant**; while the interaction term grass interference*size was almost significant at the 5% level.

Figure 8.17 and Figure 8.18 revealed a similar pattern of declining browsing levels per medium "*Acacia*" spize per plot. However the pattern for small "Acacias" was very different. **Browsing offtake per small "*Acacia*" spize per plot was greatest when grass interference was between 25% and 50%** (Figure 8.17). This is also indicated by Multiple Comparison testing at the 95% level using Tukey's Honestly Significant Difference test, which only differentiated between grass interference classes 2 (25-49%) and 4 (75%+).

FIGURE 8.19 Kriged contour maps of A) Black rhino feeding levels recorded between plots during the 1989 grid survey (the darker the more feeding); and B) Late summer 1989 modal grass height.

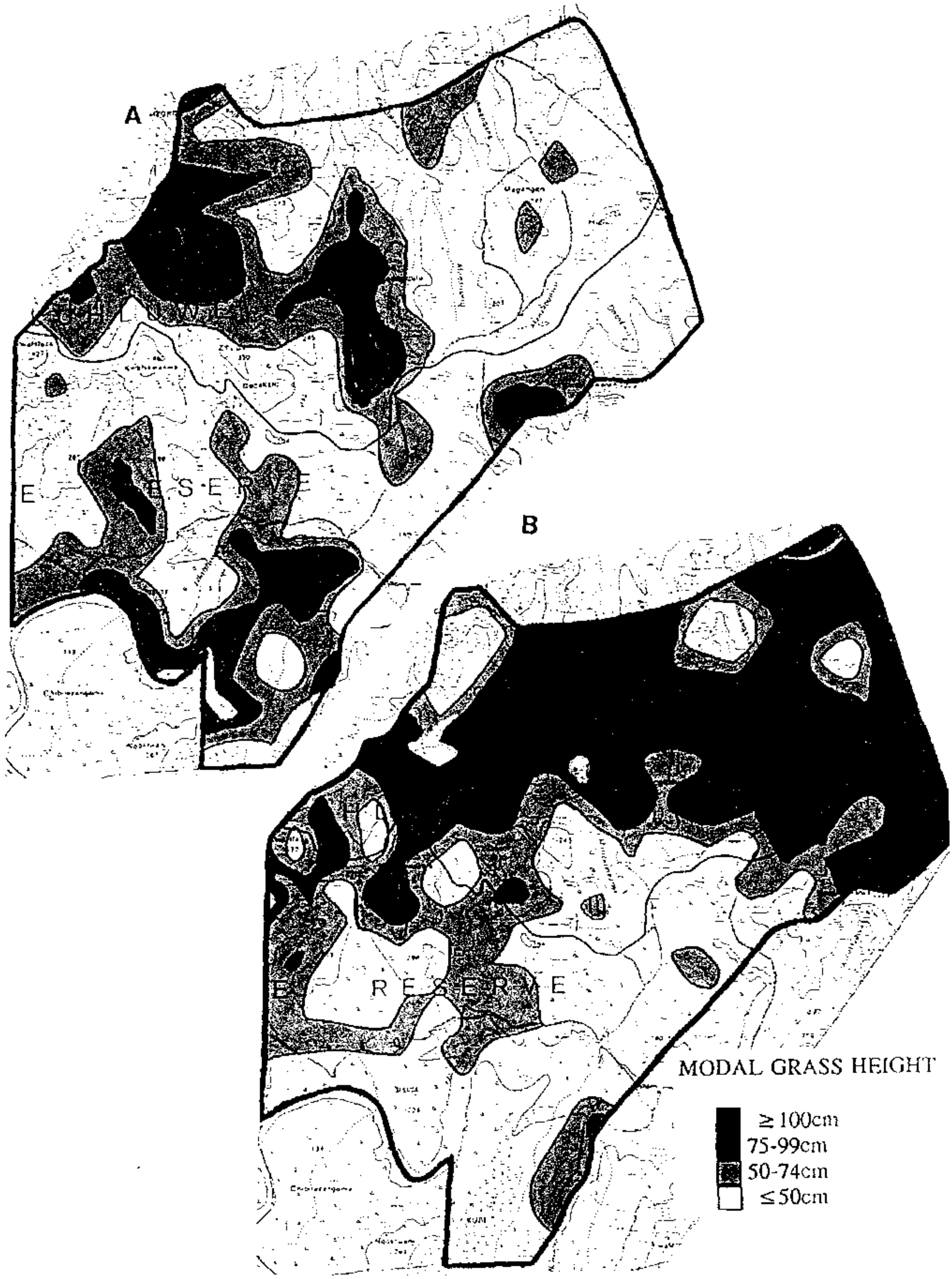


Figure 8.20. Photograph showing very tall grass in North Hluhluwe during the grid survey (late summer of 1989). Black rhinos were found to avoid such areas.

COMPARISON OF MODAL GRASS HEIGHT AND HLUHLUWE GRID SURVEY FEEDING CONTOUR MAPS

o The rejection of tall grass areas for feeding is clearly apparent when one compares a kriged contour map of late summer 1989 modal grass height in Hluhluwe with a kriged contour map of feeding intensity recorded while walking between plots during the Grid surveys (Figure 8.19). Tall grass areas such as those shown in Figure 8.20 were largely avoided, and what feeding there was in these northern areas was largely centred on areas with less tall grass.

THE INFLUENCE OF GRASS ON SMALL-MEDIUM FOOD "ACACIA" AVAILABILITY IN HLUHLUWE AND UMFOLOZI

This section examines the different impact of grass on food "*Acacia*" availability in Hluhluwe and Umfolozi. Differences in the availability of the 10 main food "*Acacia*" species (listed above) are also examined [#4].

Superficially, it appeared that habitat conditions would be more suitable for black rhino in Hluhluwe than in Umfolozi, as Hluhluwe's overall density of food "*Acacias*" was just over double Umfolozi's (n/Ha H: 1,374 U: 655). Furthermore, the density of Total available bottles of food "*Acacia*" (all sizes) was 2.83 times greater in Hluhluwe.

However, if one excludes the two most ubiquitous, important, but generally less preferred food "*Acacias*" - *D.cinerea* and *A.karroo* (BIG2), the densities of the remaining food "*Acacias*" (TOP8) were similar in the two

reserves (n/Ha H:387 U:354). The BIG2 species made up 71.86% of the food "*Acacias*" in Hluhluwe but only 46% in Umfolozi.

The discrepancy between reserves in the density of **Free** bottles of food "*Acacia*" available was only slightly less than for Total bottles (H:U Ratio Free 2.60:1, Total 2.83:1). Superficially this seems to imply that grass interference did not differ much between reserves. However, as will be demonstrated this was not the case when looking at the more preferred small-medium spizes (<2m).

The difference between reserves narrows further if one looks at the amounts of **Free bottles** available on the TOP8 species (H:U Ratio 1.95:1). This result is a function of the higher absolute and relative densities of **taller** TOP8 trees (>2m) in Hluhluwe (number >2m/Ha= H:106, U:56 ; % >2m= H:27.4%, U:15.7%).

A further important difference between reserves is that mean Free bottles per TOP8 tree is greater in Hluhluwe (H: 7.98 U: 4.48).

The **densities** of small-medium (<2m) TOP8 "*Acacias*" were much more similar between reserves - although this time densities were marginally higher in Umfolozi (<2m H:281 U:298). Despite this similarity, the mean **Free** bottles per small-medium TOP8 tree was again greater in Hluhluwe (H: 4.47 U: 3.28). **This result reflects the higher absolute and relative densities of medium TOP8 trees in Hluhluwe, which have more bottles on them** (Medium(1-2m) number/Ha= H:111 U:44 ; %Medium Trees= H:39.5% U:14.9%).

Finally, the discrepancy between the reserves in the amount of **Free bottles of small-medium** TOP8 "*Acacia*" was less than for Total bottles (H:U Ratio Free 1.29:1 Total 2.27:1). This difference between the two ratios indicated that grass interference levels were substantially higher in Hluhluwe. The absolute amount of bottles on small-medium TOP8 "*Acacias*" hidden by grass was 2.69 times greater in Hluhluwe. This was reflected in the **mean percentage grass interference level on small-medium TOP8 trees was 68% higher in Hluhluwe** (Mean% Grass Interference on Small/Medium TOP8 "*Acacias*" H:38.17% U:22.76%).

To recap, black rhino feeding markedly declines as modal grass height increase above about 75cm. In addition, browsing levels were highest on medium "*Acacias*" when grass interference levels were less than 25%. Feeding levels on small "*Acacias*" also declined once grass interference levels rose above about 50%-75%. **We therefore defined trees as *unhindered* by grass when 1) plot modal grass was less than or equal to 75cm; and 2) grass interference was less than 25% on medium (1-2m) trees, and less than 50% on small (<1m) trees.**

The amounts of **unhindered Free bottles** on all ten small-medium food "*Acacias*" was only 17.8% higher in Hluhluwe (Unhindered Free Bottles Small-Medium Food "*Acacias*"/Ha H:1,524 U:1,294).

One major difference between the reserves was that 64.21% of all unhindered Free bottles on small-medium food "*Acacias*" in Hluhluwe was made up by the BIG2 species - *A.karroo* and *D.cinerea*. In Umfolozi the corresponding BIG2 proportion was only 33.38%. The unhindered Free bottles (n/Ha) on small-medium BIG2 "*Acacias*" were correspondingly higher in Hluhluwe (H:979/Ha U:406/Ha).

The pattern was reversed for the unhindered Free bottle densities on the more preferred small-medium TOP8 "*Acacias*", with availability levels being 63% higher in Umfolozi (H:545/Ha U:888/Ha).

Densities of unhindered small-medium "*Acacias*" showed a similar pattern. The density of small-medium TOP8 trees was 1.87 times higher in Umfolozi (H:90 n/Ha U:169 n/Ha), while the density of small-medium BIG2's was 2.15 times greater in Hluhluwe (H:287 n/Ha U:133 n/Ha).

We then took the analysis a stage further to look separately at small and medium trees:

The **density** of the unhindered medium BIG2 "*Acacias*" (Grass Height ≤ 75cm and Grass Interference <25%) was almost 2½ times greater in Hluhluwe (H: 91/Ha U:37/Ha). Unhindered Free available bottle densities on medium BIG2's were about three times greater in Hluhluwe (H:623/Ha, U:204/Ha).

Again the pattern was very different for the TOP8 compared to BIG2 species. The densities of the unhindered medium TOP8 "*Acacias*" were the same in both reserves (n/Ha H:36 U:36). However, unhindered Free available bottle densities on medium TOP8's were 25% higher in Umfolozi (H:431/Ha U:539/Ha).

Both the Grid and Pilot surveys have shown that small "*Acacias*" (<1m) were the most preferred size. The difference between reserves in the densities and Free bottles available on small unhindered BIG2 "*Acacias*" was similar to that for medium trees, although it was less marked (cf. Medium trees). Densities in Hluhluwe were about double those in Umfolozi (H:196/Ha U:96/Ha). Unhindered Free bottle availability was 76% higher in Hluhluwe (H:356/Ha U:202/Ha).

An examination of the influence of grass interference on common and important small-medium *A.karroo* in Hluhluwe (a BIG2 species) illustrated both the large impact of grass on habitat suitability in Hluhluwe, and the increased selection shown by black rhino for unhindered small "*A.karroo*". Feeding levels on small-medium *A.karroo* declined substantially as soon as grass interference increased above 50% (Figure 8.21), and was greatest on both *A.karroo* spizes when grass interference levels were less than 25%. Figure 8.20 also showed that in Hluhluwe, about three quarters (77.3%) of small *A.karroo* and a third (33.3%) of medium *A.karroo* trees represented poor food as more than half of their foliage was hidden by grass.

A pooled database for both Grid datasets showed a pattern of declining preferences for small *A.karroo, A.nilotica* and small-medium *D.cinerea* as grass interference increased (Figure 8.22).

In contrast to the small BIG2 "*Acacias*", densities of the more preferred small TOP8 "*Acacias*" were almost 2½ times higher in Umfolozi (H:54 U:134). This directly influenced the unhindered Free available bottle density on small TOP8's which was three times greater in Umfolozi (Free Unhindered Bottles TOP8(<1m)/Ha H:115 U:376). One reason for these differences between reserves was that a much higher percentage of small TOP8's were hindered by grass in Hluhluwe (H:40.2% U:21.1%).

Figure 8.21.

The relationship between browsing levels on small (<1m) and medium (1-2m) Acacia karroo in Hluhluwe and degree of grass interference (HISTOGRAMS). The LINES show the proportion of small and medium A.karroo's in Hluhluwe which experienced different degrees of grass interference.

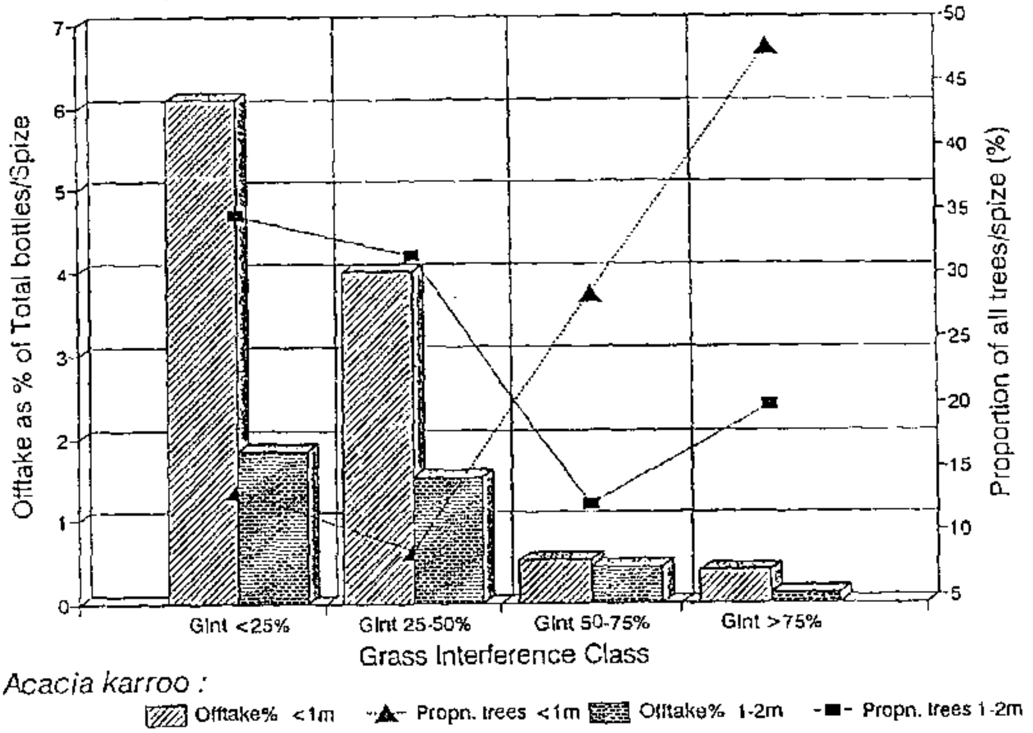
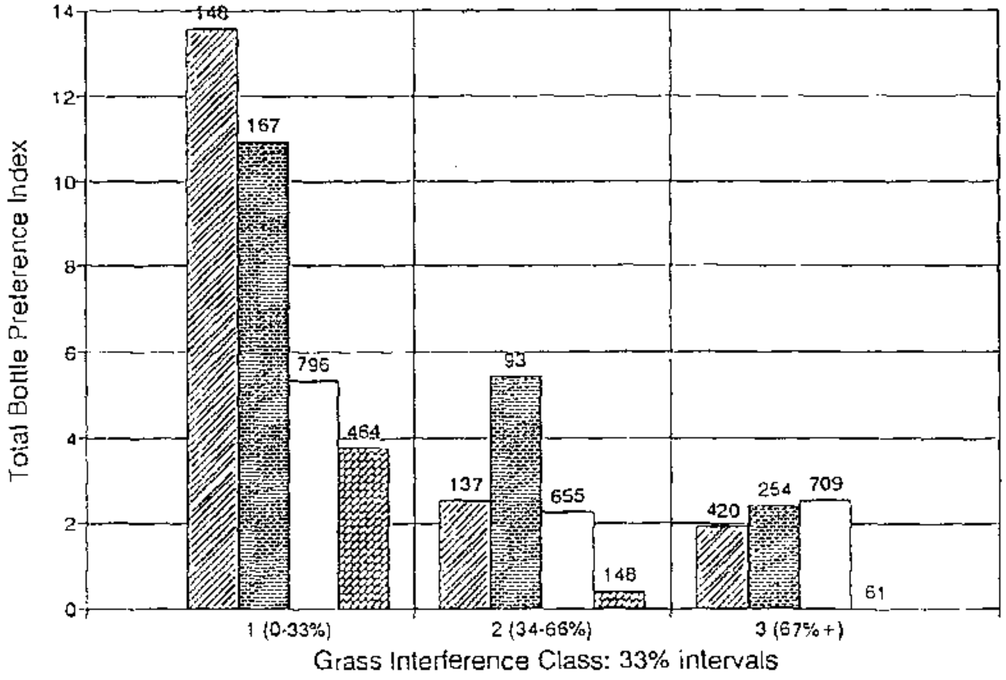


Figure 8.22.

The relationships between Grass interference and Total bottle preference indices for four key spizes. The histogram is derived from a pooled Grid database for both study areas. Sample sizes (number of trees) are given above the bars.



In Umfolozi, the proportion of unhindered Free bottles on small-medium TOP8's made up by the most preferred small trees (<1m) was almost double that in Hluhluwe (H:21.05% U:39.24%). Unhindered TOP8 Free bottle densities (n/Ha) were as follows... Hluhluwe: <1m:115 1-2m:431 Umfolozi: <1m:348 1-2m:539. The disparity between reserves was especially marked when one expressed the unhindered TOP8 Free bottle density for small and medium trees as a percentage of the Total available browse bottles on small and medium TOP8 trees. While over half (53.86%) of size 1 Total TOP8 bottles were Free and unhindered in Umfolozi, only about a fifth were available in Hluhluwe (21.05%). Almost all the Total bottles on Size 2 TOP8 "*Acacias*" were available in Umfolozi (87.24%). Yet, in Hluhluwe, only 28.63% of Total Size 2 TOP8 bottles were free and unhindered. Thus although Total bottle densities on small-medium TOP8's were much higher in Hluhluwe (H:2026 U:1265), the available (unhindered and free) bottle densities on small-medium TOP8's were greater in Umfolozi (H:545 U:888). When expressed as a percentage of Total bottles the corresponding figures for small-medium TOP8 "*Acacias*" were Hluhluwe - 26.9% available and Umfolozi 70.2% available.

Thus, although there was an average of 7,870 Total food "*Acacia*" bottles per hectare in Hluhluwe only 6.93% of these bottles (545) were on unhindered small-medium TOP8 "*Acacias*". The corresponding percentage for Umfolozi was 31.97% (888/2,777).

○ In Hluhluwe only 1.46% of Total food "*Acacia*" bottles per hectare in Hluhluwe (115/7870) were on the most preferred unhindered small (<1m) TOP8 "*Acacias*". The equivalent proportion in Umfolozi was 12.54%.

Thus to summarise:

Although Total food "*Acacia*" bottle densities were 2.83 times higher in Hluhluwe; Umfolozi in many ways provided more favourable "Acacia" habitat having...

A less mature "*Acacia*" age structure favouring the more preferred small "*Acacias*"

> **A more equitable distribution of available browse amongst a range of food "*Acacia*" species, rather than predominantly being made up of the two important but generally less preferred dominants *A.karroo* and *D.cinerea*. The earlier finding that there appeared to be a limit to the amount of an individual species that a black rhino could eat, indicates that the more equitable distribution of available browse amongst a range of "*Acacias*" in Umfolozi represents better black rhino habitat.**

and of particular relevance to this section ...

> **That grass in Umfolozi had a much lower negative effect on the availability of key small-medium "*Acacia*" browse.**

This resulted in the density of available unhindered Free bottles of small food "*Acacias*" being 16.9% higher in Umfolozi (H:471 U:550). What is perhaps more important, was that the density of available unhindered Free bottles on the most preferred small TOP8 food "*Acacias*" was three times greater in Umfolozi (H:115 U:348).

Hluhluwe "*Acacia*" habitat was only better than Umfolozi's in two ways as ...

> The densities of available unhindered Free bottles on the small-medium BIG2 species (*A.karroo* and *D.cinerea*) were substantially greater in Hluhluwe compared to Umfolozi (H:979 U:406)
>
> The density of available unhindered Free bottles on medium sized food "*Acacias*" was 41.7% higher in Hluhluwe (H:1,053 U:743); although this was largely due to the higher densities of *A.karroo* and *D.cinerea* in Hluhluwe.

RESULTS OF CONSTRAINED ORDINATION ANALYSIS TO STUDY THE STRENGTHS OF THE RELATIONSHIPS BETWEEN BLACK RHINO BROWSING AND MULTIVARIATE COMMUNITY DESCRIPTIONS BASED ON 1) SPECIES, 2) SPIZE, AND 3) RESOURCE BASED ABUNDANCE DATA

Correspondence analyses of Hluhluwe species, spize and resource based cover abundance data were constrained using feeding data (see Appendix 4.1 for a non-technical explanation of methods). Analysis was detrended by polynomials. The research question addressed was:

> Did *resource*-based multivariate habitat descriptions (which directly included measures of grass interference) improve assessments of black rhino habitat suitability compared to *species* or *spize* based analyses (which did not incorporate grass interference into habitat descriptions)?

In canonical correspondence analysis, the higher the canonical axes eigenvalues are - the stronger the relationship between the habitat data and set of explanatory variables (see Appendix 4.1). The highest eigenvalues for 1) the first canonical (DCCA) axis, 2) the second canonical axis, and 3) the canonical trace were all obtained using resource-based data. As could be expected, the poorest relationship was between species-based data and feeding levels. The sum of the eigenvalue for the first two canonical axes was 0.167 for species based analysis, 0.238 for spize-based analysis and 0.266 for resource-based analysis. The increase in eigenvalue sum (Axes 1 and 2) from species to spize-based analysis was 42.51%, and from spize to resource a further 11.6% increase. The overall increase between species and resource-based analysis was 59.2%. When expressed as a percentage of the corresponding eigenvalue sum derived for the first two axes of unconstrained detrended correspondence analysis (DCA), a similar although less marked pattern emerged (Species 24.65% Spize 29.60% and Resource 30.25%). Besides higher eigenvalues; significance levels of the first canonical axis and canonical trace were also higher using spize and resource compared to species-based data. The species:environment correlations [R(Spec,Env)] on the first axis showed corresponding increases (Species 0.642, Spize 0.738 and Resource 0.748).

Comparative DCCA spize and resource-based constrained ordinations were undertaken using Umfolozi data. The length of the first canonical axis was almost 25% greater for resource compared to spize-based analysis. Size 1, Size 2, Modal grass height, and grass interference were included as passive explanatory variables. The angle between the biplot arrows for the two grass variables was minimal indicating these variables worked in the same direction. In addition both grass arrows were long indicating the important influence of grass on black rhino feeding.

In Umfolozi the arrow for Grass Height was almost as long as that for Grass Interference. The greater relative importance of grass interference in Umfolozi probably reflects the generally lower grass modal heights compared to Hluhluwe.

These results mean that black rhino feeding levels were better explained using spize rather than species based multivariate community data. Resource-based data (which describes habitat in terms of the degree of grass interference and spize composition) was even better at explaining feeding patterns than spize data.

In Hluhluwe, the increase in explanatory power from species to spize based analysis was greater than that from spize to resource based analysis; indicating that although grass interference was important, the species composition and size class structure and successional stage of communities had a bigger influence on black rhino feeding.

There was not enough time to do a resource based analysis using grass height instead of grass interference to subdivide spizes. The results in the previous section indicate that such an analysis would almost certainly have further increased eigenvalue levels.

One of the objectives of the project was to determine how best to assess black rhino habitat. To assess the relative ability of different measures of abundance (used in habitat descriptions) on rhino feeding levels, spize-based constrained and unconstrained polynomialy detrended canonical ordinations were also carried out using Hluhluwe 1) Braun-Blanquet cover abundance 2) Tree density 3) Total bottle density and 4) Free bottle abundance data:

The constrained eigenvalue trace ranged from a low of .380 (Braun-Blanquet) to .678 (Tree Densities) to .901 (Total bottles) to reach a maximum at 1.022 (Free bottles). When the constrained eigenvalue traces were expressed as a percentage of the corresponding unconstrained traces a similar pattern emerged (Braun-Blanquet 35.48%, Tree Densities 43.09%, Total Bottles 50.23% and Free Bottles 55.86%).

These results indicated that the best relationships between spize-based multivariate community composition and black rhino feeding were obtained using Free bottle density data. The weakest relationships were obtained when Cover abundance data was used to describe habitat. These findings indicate that black rhinos primarily view their habitat in terms of the composition and volume of browse available 1) within reach and 2) not interfered with by grass. This finding is reasonable as tall *A.nilotica, E.racemosa, S.africana* or *B.zeyheri* (key spizes in canopy cover based habitat descriptions) are all of almost no effective food value to black rhino; yet smaller sizes of the same species are of markedly differing food value.

The eigenvalue trace of a polynomial detrended canonical correspondence analysis (DCCA) using resource-based analysis of Total bottle data was 7.86% higher than that obtained using a spize based analysis (Spize: .901 Resource .972). The trace for a DCCA of spize-based Free bottle data (1.022) was only marginally larger than the resource-based analysis of Total bottle data. This was corroborated by exploratory regression analysis that indicated that Free bottle data explained marginally more variation in feeding than both Total bottle and Percentage Grass Interference together.

Somewhat surprisingly the sum of the DCCA trace when expressed as a percentage of the sum of the eigenvalues of the first four axes of DCA runs was always marginally lower for resource-based compared to spize-based analysis (Spize:Resource Braun-Blanquet 35.48% : 33.82% Tree Density 43.09% : 39.42% Total Bottles 50.23% : 47.73% Free Bottles 55.86% : 52.52%). This may have been because the sums of the first four unconstrained detrended (DCA) axes' eigenvalues were between 10.2% and 18.6% higher using resource compared to spize-based analyses.

To summarise:

Habitat descriptions using browse bottle data produced the best descriptor of black rhino habitat suitability, and cover abundance data the worst.

The incorporation of grass interference into habitat descriptions improved habitat suitability assessments, although not as markedly as the incorporation of size class data into community descriptions.

Free bottle density was the best abundance measure to use when describing habitat suitability for black rhino. However in describing habitat suitability resource-based total bottle descriptions were almost as good as spize-based Free bottle descriptions.

There are implications of the above results for those assessing black rhino habitat. Rather than assessing the abundance of different habitat types, the results indicate that all one needs to do is to assess the abundance of unhindered key preferred spizes in an area. The latter approach is vindicated by 1) the observations that the bulk of a black rhinos woody diet is made up of a limited number of key spizes (see Chapters 6, 7, 9, 12 and 2) the difficulty of allocating vegetation plots to discrete habitat types in the field (as Hluhluwe vegetation is better described using a continuum model - Chapters 6 and 7). Thus armed with a list of key spizes, size class selection patterns, and the rule of thumb about what constitutes unhindered browse, a manager can easily assess black rhino habitat suitability while walking through an area.

Clearly, measuring "*Acacia*" densities alone when assessing black rhino habitat suitability is not enough. In order of importance, "*Acacia*" *size* class, grass height/interference levels, and species of "*Acacia*" (including mix of species) also must be considered.

Finally, it should be borne in mind that the fieldwork for this study was undertaken during a period of above average rainfall. We therefore could expect habitat conditions to improve for black rhinos in drier years as grass interference levels will decline.

CHAPTER 8 NOTES

#1 The inclusion of *H.pauciflorus* in this list may seem surprising to readers not familiar with Hluhluwe conditions. Apart from its association with forest margins, this species also commonly grows in moist open low-lying grassland areas in NE Hluhluwe.

#2: Technical note: The critical value of theta was set at 0.3 in all ridge regressions to aid comparison. In all runs ridge traces had largely stabilised by the time theta was 0.3 .

#3: Technical readers, should be aware that MANOVA residual analysis generally revealed slight heteroscedasticity. Unfortunately, this is quite usual when dealing with ecological datasets containing a large number of observations with small values of X (in this case feeding) relative to those with large values (Johnston 1980). Thus we have to conclude that the derived regression coefficients may be biased. Standardised coefficients of skewness and kurtosis also invariably showed that the residuals were not normally distributed. Some key MANOVA assumptions were therefore violated, and so strong statistical inferences should not be drawn from the MANOVA results. Fortunately this violation of assumptions does not represent a major practical problem, as the primary goal of the MANOVA analysis was heuristic. Furthermore, Zar (1984) concluded that ANOVA and t tests are usually robust enough to perform well even if the data deviate somewhat from the requirements of normality, homoscedasticty and additivity. Significance levels were so high in many of the analyses that one could be very confident that the recorded factor level differences were real.

#4: As mentioned in the introduction, small-medium (<2m) food "*Acacia's*" were chosen for study due to their high dietary importance and preference values; and because "*Acacia's*" tend to grow in more open sites and are especially prone to grass interference.