UTILIZATION OF THE VEGETATION ON GABBRO BY BURCHELL'S ZEBRA AND BLUE WILDEBEEST IN THE TIMBAVATI AREA

by

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Dedicated to my mother

Miemie Bodenstein

"How can you buy or sell the sky – the warmth of the land? The idea is strange to us. We do not own the freshness of the air of the sparkle of the water. Every part of this earth is sacred to my people. Every shining pine needle, every sandy shore, every mist in the dark wood, every clearing and humming insect is holy in memory and experience of my people .....

There is no quiet place in the white man's cities. No place to hear the leaves of spring or the rustle of insects' wings. And what is there to life if a man cannot hear the lovely cry of a whippoorwill of the arguments of the frogs around a pool at night? The air is precious to the red man. For all things share the same breath – the beast, the trees, the man .....

The white man must treat the beasts of this land as his brothers. What is man without the beasts? If all the beasts were gone, man would die from great loneliness of spirit, for whatever happens to the best also happens to the man. ***All things are connected. What ever befalls the earth befalls the sons of the earth."***

Part of a letter written to the President of the United States of America by Chief Seathl in 1855

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ABSTRACT

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ABSTRACT

The food selection pattern of zebra and blue wildebeest in terms of quality and quantity was studied in the Northern Province Lowveld on a site originating from gabbro geological formations. At the same time a comparison was drawn between the two species.

The botanical composition of the grass layer in the study area was determined, the dominant species being *Heteropogon contortus, Themeda triandra, Panicum maximum* and *Enneapogon spp.* Forage selection and grass species utilized by the zebra and blue wildebeest were determined through the measurement of forage before and after grazing. The grass

species *P. maximum*, *H. contortus* and *Urochloa mosambicensis* were mostly utilized by both zebra and blue wildebeest.

Forage and faeces samples were hand collected. Regression equations were used to calculate intake from the average amount of grass species utilized (difference before and after grazing). The monthly dry matter intake as calculated through the plant based technique, did not compare well with the monthly dry matter intake as calculated through the animal based technique with an R^2 value of 0.48.

Although monthly differences in quality parameters of forage occurred, the same quality and quantity of forage were available for both animal species at a specific time time during the sampling period. The mean lignin (ADL) content of the available forage utilized was 8.04 % for zebra and 8.17 % for blue wildebeest with the mean *in vitro* digestibility of organic matter of the forage being 44.2 % (zebra) and 43.1 % (blue wildebeest) respectively. There was a significant ($p<0.05$) difference in the mean intake (expressed as % of body weight) between zebra (2.58 %) and blue wildebeest (1.80 %). The mean *in vivo* digestibility of the dry organic matter (DOM) for the zebra (42.2 %) was significantly ($p<0.05$) lower than that of the blue wildebeest (47.9 %) as well as the fibre (NDF) digestibility (respectively 38 % and 49 %).

The climatologically dry conditions under which the study was done did not represent a typical year, and therefore the results were not used to test the carrying capacity equivalents that are officially being used for game animals. The quantitative results, however, confirmed contentions of other literature.

OPSOMMING

Voedselseleksiepatrone van sebras en blouwildebeeste is bestudeer in terme van kwaliteit en kwantiteit van inname. Hierdie studie is gedoen in die Laeveld, Noordelike Provinsie, op 'n grondtipe wat uit gabbroformasies ontstaan het. Terselfdertyd is 'n vergelyking getref tussen die twee spesies.

Die botaniese samestelling van die graslaag is in die studie-area bepaal. Die dominante spesies was *Heteropogon contortus, Themeda triandra, Panicum maximum* en *Enneapogon spp*. Weidingseleksie en grasspesies benut deur die sebras en blou wildebeeste is bepaal deur 'n meting voor en na beweiding. Grasspesies wat die meeste deur beide sebras en wildebeeste benut was sluit in *P. maximum*, *H. contortus* en *Urochloa mosambicensis*. Die maandelikse droë materiaalinname soos bereken deur die plant-gebaseerde tegniek het swak vergelyk met die maandelikse droë materiaal inname soos bereken met die dier-gebaseerde tegniek met 'n R^2 waarde van 0.48.

Alhoewel daar verskille in die kwaliteit van voedsel tussen maande voorgekom het was dieselfde kwaliteit en kwantiteit beskikbaar vir beide dier spesies op enige spesifieke stadium van monsterneming. Die gemiddelde lignien (ADL) inhoud van die beskikbare weiding was 8.04 % vir sebras en 8.17 % vir blouwildebeeste terwyl die gemiddelde organiese materiaal *in vitro* verteerbaarheid van die weiding 44.2 % en 43.1 % was vir sebras en blouwildebeeste onderskeidelik. Betekenisvolle verskille ($P<0.05$) is ook waargeneem tussen die gemiddelde inname (uitgedruk as persentasie van liggaamsmassa) van sebras (2.58 %) en blou wildebeeste (1.80 %). Die gemiddelde *in vivo* verteerbaarheid van organiese materiaal (DOM) en vesel (NDF) verteerbaarheid vir sebras (42.2 % en 38 %) was voorts ook betekenisvol ($P<0.05$) laer as vir blouwildebeeste (47.9 % en 49 %).

Die klimatologiese droë kondisies waaronder die studie uitgevoer is, verteenwoordig nie 'n tipiese jaar nie en gevolglik kon resultate nie gebruik word om drakrag ekwivalente wat tans amptelik vir wild gebruik word, te toets nie. Die kwantitatiewe data bevestig egter gevolgtrekkings van ander literatuur.

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CHAPTER 1

1 PREFACE

1.1 TERMINOLOGY

Ash determination - Subsequent to dry matter (DM) analysis, dried samples undergo complete combustion at 600°C in a muffle furnace for four hours after which ash percentage can be calculated.

Browser – An animal that feeds mostly on the leaves, flowers and fruits of woody plants, and on forbs (Bothma 1999).

Browser stocking rate - The browser stocking rate specifically provides for the browser – which relies on shrubs and trees – as feeding class. This is measured in Browser units (BU) which can be defined as the equivalent of a kudu (140 kg) (Snyman 1991).

Browsing capacity - This is primarily a function of the shrub and tree component of the vegetation.

Bulk grazer (non-selective grazer) - A large grazing animal that does not exercise a high degree of selective grazing (Bothma 1999).

Carrying capacity - the area of land required to maintain an animal unit in order to achieve maximum profit in the short term, while maintaining the condition of the vegetation and soil in such a way as to be able to fulfil the needs and aspirations of future land users (Danckwerts & Teague 1989). It is measured in hectare / Large Stock Unit (LSU) or LSU/ha.

Cell wall - The non-living rigid structure surrounding the cell membrane of most plant cells, usually made of cellulose in green plants, sometimes impregnated by other materials such as lignin or cutin.

Cell wall constituents (cellulose, hemicellulose and lignin):

NDF - Cell solubles are extracted by neutral detergent solution, the residue being neutral detergent fibre (NDF) which approximates the cell wall.

ADF - An acid detergent solution is used to extract the more soluble cell wall or hemicellulose. The residue called acid detergent fibre (ADF) consists mainly of cellulose, cutin and lignin.

ADL - After exposure to 72% H_2SO_4 the residue is acid detergent lignin (ADL) after which lignin is determined by ashing in a muffle furnace at 550°C.

%Hemicellulose: %NDF - %ADF
%Cellulose: %ADF - %ADL
%Lignin: %ADL - %Ash

CP - The nitrogen (N) content of forage utilized by the animals can be determined as well as in the animal faecal samples. Crude protein (CP) can then be calculated as:

$$CP = \%N \times 6.25$$

Digestion - The process by which nutrient materials are rendered soluble and absorbable by action of various juices containing enzymes.

Digestibility (Dig) of cell wall constituents - From knowledge of the percentage of cell wall constituents in the food and faeces, the amount of cell wall constituents consumed and excreted could be calculated indirectly which enabled calculations of the approximate digestibilities of these constituents.

DM - Dry matter content of all the samples were analysed so those results could be portrayed on a DM basis.

Forage - The vegetation actually grazed by or fed to an animal.

Grazer stocking rate – The grazer stocking rate is measured in Large Stock Units (LSU) which is normally defined as the equivalent of one head of cattle (450 kg) that has to rely on grass pasture (Snyman 1991).

Grazing capacity - This is primarily a function of the grass component of the vegetation.

Stocking rate - This is the operator's estimate of what land to animal relationship will provide the most beneficial returns (often in economic terms)(Bothma, 1999).

Herbage - The vegetation available to a grazing animal (herbage is more inclusive than forage).

In vitro - Biological processes occurring experimentally in isolation (in glass or flask).

***In vitro* micro digestion** - refers to the artificial rumen technique for estimating forage digestibility. Once the *in vitro* digestibilities are calculated, the *in vivo* digestibility of the pasture can be estimated using regression equations that describe the relationship between *in vitro* and *in vivo* digestibilities.

In vivo - Biological processes occurring within the living organism.

Large/Live Stock Unit (LSU) - This is a standard unit which was developed to describe the biomass of an animal in terms of its energy requirements. It can be defined as follows: the equivalent of a steer with a mass of 450 kg which has a growth rate of 500 g/day on pasture with a digestible energy content of 55%.

OM - Organic matter content (OM) = Dry matter (DM) content of samples - ash content of the samples.

Rumen - In ruminants, the first compartment of the stomach in which food undergoes bacterial digestion and from which it can be regurgitated into the mouth for further chewing.

Ruminant - An animal which chews the cud.

Rumination - The act of ruminant animals in returning food from first stomach to mouth in small quantities for thorough mastication and resalivation, chewing cud.

1.2 INTRODUCTION

There has been a general increase in game ranching during the past 25 years with a subsequent urgent need for proper grazing management strategies. In order to determine this, information is needed on the quality and quantity of the grazing available on the one hand, and the preference and needs of the animals on the other hand.

The management of veld stocked with game is extremely complex. Generally, the smaller the area being used for wildlife, the more intensively it must be managed (Bothma 1996). According to Van Rooyen, Bredenkamp & Theron (1996), veld management can generally be described as the science that deals with the utilization and conservation of the natural veld to ensure maximum animal production without detrimentally affecting the vegetation. The quality and productivity of the vegetation should thus be maintained or improved. The most important factors to consider in formulating a veld management program are the assessment of veld condition, the setting of realistic stocking rates of wildlife, grazing and browsing management, water provision and veld burning (Trollope 1990).

Veld degradation and changes in habitat quality in Mpumalanga and the Northern Province Lowveld have been of concern for a number of years and are being monitored by various authorities. Both aspects can largely be ascribed to overstocking and/or poor management, resulting primarily from overestimation of the carrying capacity of veld for various animal species. Carrying capacity is simplistically defined as the dynamic equilibrium between forage supply and ungulate requirements (herbivory). Ungulate herbivory is a function of nutrient and energy requirements, and of food preference and availability (Meissner 1996). Carrying capacity is influenced by a number of factors, i.e. the nutritional requirements and preferences for particular plants or plant parts by animals, and in general also by changes in soil formation and nutritive status, plant composition and biomass, burning regime and climate. A study of the nutritional requirements and selection patterns of the more prominent game species would assist in refining estimates of carrying capacity on reserves and private game ranches. It is also important to increase our knowledge of the dynamic interaction between the animal species and the animal and its environment.

According to Collinson & Goodman (1982) the distribution of animals is influenced by the habitat composition, which in turn is influenced by the animals themselves. There is also a mutual influence between the animals caused by their grazing habits that can be proposed as a succession. Zebra *Equus burchelli* is classified as a Type I species that are capable of changing an unused climax habitat drastically. Type I species are therefore primary modifiers of a grazing system. In turn blue wildebeest *Connochaetes taurinus* is classified as Type III species that will increase their numbers after the habitat has been modified by Type I species. Over utilization of an area can occur if the numbers of these animal species are not controlled.

Zebra and blue wildebeest are two species that normally graze in association with each other and also occur in large numbers on reserves and game ranches in the Mpumalanga and the Northern Province Lowveld. They, therefore, may have a profound effect on the composition of the vegetation. According to Van Hoven

(1996), the blue wildebeest is classified as a short grass feeder and the zebra as a tall grass feeder. The question then arises whether this distinction is always applicable in different areas.

Limited, if any, direct measurements of the intake of free-roaming antelope seem to have been made, as only limited published data have been found. If the actual food intake of wild animals can be determined, these figures could also be used to estimate carrying capacity.

1.3 OBJECTIVES

The two main objectives of the project were:

- To determine the seasonal nutritive requirements of the zebra and the blue wildebeest in terms of quality and quantity and at the same time to draw a comparison between the two species.
- To evaluate whether present estimates of energy requirements used for purposes of calculating carrying capacity (Meissner, Hofmeyr, Van Rensburg & Pienaar 1983) of these two species are adequate.

1.4 REVIEW OF TECHNIQUES

Although quantitative data on forage selection by African ungulates, especially grazers, are limited (Stewart & Stewart 1970), the following methods were developed to obtain the necessary information:

1.4.1 Diet preference

Various methods are used to determine the diet preference of livestock and game (Potgieter 1991). These methods can be divided into two categories namely plant-based and animal-based methods.

1.4.1.1 Plant-based methods

These methods imply the estimation of the relative or real contribution of the plant species to the diet of the herbivore. This is determined by the amount of plant material removed from the herbage.

As explained by Potgieter (1991), plant based techniques can be divided into methods appropriate for grass and herb communities and methods for tree and shrub communities. Zebras and blue wildebeest, however are mainly grazers and therefore only the methods for grass and herb communities are discussed.

a. Differing method.

This method indicates the removal of forage from the grazing which can be determined through the difference in dry material available before and after grazing. It can also be the comparison between grazed and non-grazed areas and is then referred to as the, so called, exclusion plots (Linehan, Lowe & Stewart 1952).

According to Raymond (1969), one can estimate forage utilized whenever an exclusion plot was used in the growing season, through the use of the following equation:

$$A = \frac{(c + d)}{2} - f$$

where :

A = degree of utilization
c = material available before grazing
d = material available in exclusion plot after grazing
f = material available on grazed area after grazing

b. Grazed plots without exclusion.

This technique can possibly be used successfully in situations where many animals are confined to a small area and graze that area over a short period of time (Barnes, 1976).

c. Utilized-plant method.

In this method, estimation of the diet preference of the herbivore based on the utilization of grass species is made through observation. According to Barnes (1976), a relationship was found between the estimated utilization of a specific grass species and the actual measurement of the grass species utilized, however the technique could be used in a subjective way.

1.4.1.2 Animal-based methods

Animal-based methods used to determine diet preference of herbivores could be divided into the following:

a. Observation techniques such as the bite-count technique
b. Microhistological techniques (MHT) where botanical composition of the diet can be determined from the faeces contents, rumen contents or samples taken from oesophageally fistulated (OF) animals (Potgieter 1991).
c. Marker techniques as described by Dove & Mayes (1991) and Meyer, Geerthsen & Homan (1996), where N-alkanes, for example, are used as markers for determination of diet selection.

a. Bite-count technique.

The amount and type of plant material utilized are estimated through observation. The advantage of this technique is that the data are immediately available but there are also disadvantages:

- Data can not be quantified
- Animals must be tamed
- The observer must know the species composition exactly

- Observations can be subjective

b. Microhistological technique

It is important to do a thorough anatomical and taxonomical study of the dominant plant species in the area before this method can be used (Potgieter 1991). According to Botha (1981), more information is still needed, especially on grass species.

i. Faecal analysis

The diet preferences of livestock and game can be determined through the plant residues in the faeces (Potgieter 1991). Successful application of this method requires the microscopic and macroscopic identification of the various food plants, and a knowledge of the relative digestibility of the species involved (Talbot & Talbot 1962). The resistance of the grass leaf cuticula against digestibility is an important factor (Potgieter 1991). This technique implies the collection, drying, grinding and colouring of the faeces and then the identifying of the plant residues in the faeces (Liversidge 1970). The data are noted according to the frequency of the species occurrence in the sample and are then converted through a formula (Fracker & Brischle 1944 cited in Potgieter 1991) to a percentage of relative density.

It is quite easy to collect the material for this technique but one must keep in mind that the data cannot be quantified.

ii. Analysis of rumen content

The botanical analysis of the rumen content is carried out in the same way as the faeces analysis (Potgieter 1991). This technique is being used quite often in the game industry. The only disadvantage is that the animal must be killed for its rumen contents and in the case of rare animal species this is undesirable.

iii. Analysis of samples collected from oesophageally fistulated animals

Samples taken from oesophageally fistulated animals represent the best available estimate of diet selection and qualitative intake of grazing animals (Pietersen 1991; Pieterse 1993). The botanical composition of the fistula sample, in contrast to the

faeces analysis technique, is estimated from the morphological composition. It is therefore important to have a good reference framework of the morphology of the plant species in the study area.

Although the advantages of this technique are substantial and the method has been used successfully on game animals in previous studies (Usenik, Kreulen & Duncan 1977; Pietersen 1991; Pieterse 1993), there are a few disadvantages that must be taken into account:

- Fistulated animals need intensive care
- Fistulated animals must be handled regularly which will be stressful to the animals
- Botanical analysis is time consuming

c. N-alkane marker technique

Dove & Mayes (1991) did a study on the use of plant wax alkanes as marker substances in studies of the nutrition of herbivores. The ideal marker should be chemically discrete for ease of identification and analysis, and it should be indigestible in the digestive tract. Many taxonomic studies have shown between-species difference in alkane levels in plant cuticular waxes, both in grasses and other plants. The difference between species in their individual alkane concentrations can be exploited to provide information on the composition of available and consumed herbage. The carbon-chain lengths of the main alkanes detected are usually in the range C_{25} (pentacosane) to C_{35} (pentatriacontane). Between-species difference in alkane composition can be expressed as the ratio of adjacent odd-chain alkanes as a proportion of the total alkane content or the absolute concentrations of alkanes.

1.4.2 Quality and quantity of the diet

The study of the quality and quantity of the diet of grazing animals has three basic components:

- Estimates of the chemical and botanical composition of the diet.
- Estimates of the digestibility of the diet.
- Estimation of total herbage intake of grazing animals. For this the following methods have been documented:

1.4.2.1 Plant-based techniques

There are various methods available to determine food intake of domestic animals, however the direct measurement of pasture intake under free grazing conditions is basically impossible (Pietersen, 1991).

1.4.2.2 Animal-based techniques

To calculate intake as accurately as possible, animals must graze under natural conditions. Direct measurements are not possible and therefore an indirect approach is followed. Four animal-based techniques that are in use today which measure the intake of herbage indirectly are described by Streeter (1969) and summarized by Pietersen 1991.

One method involves water turnover (Benjamin, Brieghet & Tahhan 1975), but is not used often because of poor accuracy.

Three of the techniques are based on the quantification of faeces excretion in grazing ruminants whereafter herbage intake can be calculated in various ways. The knowledge of faeces excretion per unit time is imperative for determining the quantitative food intake of free-grazing animals (Arnold 1960). Total daily faeces excretion can be measured using one of the following methods:

- indirectly, using internal or external indicators or
- directly, using faeces bags harnessed to the animals

The use of natural or internal markers (markers which occur naturally in the diet e.g. lignin, nitrogen and acid insoluble ash) and external markers (markers which are added to the diet) are common to determine faeces excretion. The most popular external marker according to Hodgson and Rodriguez (1970) cited in Pietersen (1991), is chromic oxide (Cr_2O_3). Morgan, Pienaar and Clark (1976) had better recoveries with Cr-EDTA though neither were 100 % accurate.

Another method to measure faeces excretion is the use of faeces collection bags harnessed to the animals. This method is the most accurate if bags are designed to keep faeces loss to a minimum and with care, this method has been used successfully in previous studies (Pietersen 1991 and Pieterse 1993).

Once faeces excretion has been quantified, there are basically three techniques with many variations that allow digestibility and thus intake to be estimated (Morgan, Pienaar & Clark 1976, cited by Pietersen 1991):

i. Marker-ratio technique.
ii. Faeces index technique.
iii. Digestibility technique.

i. Marker-ratio technique

According to Kotb and Luckey (1972) cited in Pietersen (1991), digestibility is calculated from the relative contents of a naturally occurring indigestible marker in samples of herbage grazed and in samples of faeces. This method may only be used if a representative sample of the herbage consumed and of the faeces produced can be obtained and if the indicator is completely indigestible.
With an indigestible natural marker, intake is calculated as:

$$\text{Intake of organic matter (OM)(g/day)} = \frac{\text{Quantity of indicator excreted per day}}{\text{Quantity of indicator /g of ingested herbage OM}}$$

ii. Faecal index technique

This technique involves the prediction of digestibility from the composition of the faeces.

Intake is calculated as:

$$\text{Intake of OM (g/day)} = \frac{\text{Faeces OM (g/day)}}{\text{100 - \% digestibility of OM}} \times 100$$

iii. Digestibility technique

Digestibility of herbage is measured directly by the *in vitro* technique (Tilley & Terry 1963, modified by Engels and Van der Merwe 1967). This technique involves incubation of the forage sample with rumen fluid and pepsin. Food intake is then calculated indirectly, using the appropriate formula once the *in vitro* figures had been converted to *in vivo* figures:

$$\text{Intake of OM (g/day)} = \frac{\text{Faeces OM (g/day)}}{\text{100 - \% digestibility of OM}} \times 100$$

According to Alexander and McGowan (1961), Tilley and Terry (1963), Engels and Van der Merwe (1967), Raymond (1969) and Engels, Baard and Malan (1974) there is a close relationship between the *in vitro* digestibility of organic matter (IVDOM) and *in vivo* digestibility of organic matter. The IVDOM data could therefore be used to predict the *in vivo* digestibility of the organic matter (OM) on condition that the forage sample is representative of the diet.

1.5 STUDY IN BRIEF

1.5.1 Animals and management

Six zebra and six blue wildebeest were obtained from the Kruger National Park at an age when they were still nursing. This facilitated easier handling and taming. To facilitate faeces collection, only male animals were captured. They were castrated to prevent fighting. The animals were initially housed together and then separately in a 2,3 m x 4,7m brick enclosure with an outside courtyard of the same size. The brick enclosure was fitted with an automatic water trough. They were fed good quality lucerne in the brick enclosures and were habituated to humans. The *in vitro- in vivo* digestibility studies were also conducted in the brick enclosures.

For the purpose of the field study, only six test animals consisting of three zebras and three blue wildebeest were used. They were kept separately in 3 m high enclosures of shade cloth reinforced with angle iron gates (bomas). Each boma had a circumference of 40 m and covered an area of approximately 128 m^2. The bomas were erected next to each other in the 10 ha camp. The fence surrounding the 10 ha camp was electrified to prevent predators from entering. A second group of bomas was also erected adjacent to these to ensure that the animals could be moved from one boma to the next when required. During data collection the test animals were moved and the enclosures shifted every second day to allow sufficient food material for free selection (Section 3.4). Between the measurement the test animals remained in the enclosures where their natural diet was supplemented with lucerne for about two weeks before the adaptation period. This was to ensure that enough food material was available for sufficient intake during that time. An adaptation period of 1 week was then allowed on natural forage before sampling was done to prevent any carry-over effect of the lucerne.

Every 4 months all the animals were weighed with a cattle weigh-bridge in the brick enclosures. For that purpose, the test animals were moved back to the brick enclosures through a corridor erected with game capture sheeting. The mass of

each animal was used to scale intake according to size for comparative purposes. The mean mass for the zebra was 225 kg (n = 12) and for the blue wildebeest 154 kg (n = 12).

1.5.2 Exposition of techniques used

In the preliminary study, the forage available in the 10 ha fenced camp had to be determined. The step-point method (2000 points) as described by Mentis (1981a) was used to determine the grass species composition and percentage distribution.

Fieldwork was conducted in a 10 ha fenced camp that was not grazed for four years. During sampling periods the six test animals used (3 zebra and 3 blue wildebeest) were enclosed in bomas (confined areas). Direct measurements (total height and widest diameter of tufts expressed in cm) of the grass species available (species composition) and the total biomass of the grass layers (kg material per ha) in each boma were determined before and after grazing. Observations on the utilization of grass species were also made during these sampling periods (Further discussion in Chapter 3).

Furthermore, an attempt was made to establish a correlation between direct measurements of grass species i.e. height x diameter (index), and their respective weights (expressed in grams on a dry matter basis). These regression lines were compiled to calculate monthly utilization of grasses (intake) from a plant based perspective and at the same time to substantiate the animal-based measurements of intake (Section 3.2.1).

The use of plant wax alkanes as marker and the faeces analysis technique were used in the current study to determine diet selection. Because the study animals were tamed and kept apart in confined areas during the sampling periods, faeces and forage could be hand-collected effectively (Section 4.2.3). Although faeces bags were successfully used in previous studies (Morgan, Pienaar & Clark 1976;

Pietersen 1991 and Pieterse 1993), it was decided to hand collect the faeces for the following reasons:

- Both the zebra and the blue wildebeest are large animals and thus not easy to manhandle.
- Zebras, especially, have a high excretion rate and if faeces bags were used, they would have had to be emptied regularly to avoid it from becoming too heavy. This would have increased the stress placed on the animals and would have interfered with grazing behaviour.

The faeces of both the zebra and the blue wildebeest were easy to detect in the enclosure. Therefore hand-collected sampling was adequate for quantification of excretion.

Digestibility of herbage was measured by the *in vitro* technique (Tilley & Terry 1963, modified by Engels & Van der Merwe 1967). It was also necessary to determine the relationship between the *in vitro* and the *in vivo* digestibility of forage for the blue wildebeest as well as the difference between the *in vivo* digestibility of the organic matter (DOM) utilized by the blue wildebeest (ruminant) and the zebra (non-ruminant) (Section 4.2.2). This had to be determined in order to calculate the forage intake of each animal (Section 4.2.6.3).

Chemical composition of the forage utilized by the zebra and the blue wildebeest were also determined as discussed in Section 4.2.6.

CHAPTER 2

2 STUDY AREA

2.1 Locality

The study was conducted in the area surrounding the Hans Hoheisen Wildlife Research Station (24°29' S, 31°23' E at altitude 500 m), of the former Transvaal Chief Directorate of Nature Conservation, now the Northern Province Department of Agriculture and Environmental Affairs. The research station is situated in the Timbavati Private Nature Reserve bordering the Kruger National Park.

2.2 Climate

The annual rainfall is between 300 and 650 mm and is largely confined to the summer months of October to April. The weather data as collected during the study period appear in Figure 1. During the sampling period from February 1993 to February 1994 the actual rainfall received was 496 mm over 13 months. This is below the long-term mean annual rainfall of 645 mm (February to February) for the Kruger National Park, taken over a period 36 years for that area (Kingfisherspruit Ranger Section) (Unpublished data, Kruger National Park).

The summers are hot to extremely hot, with the highest absolute maximum temperature (Abs max temp) recorded in November and December 1993 at 38° C. The winters are mild with an absolute minimum temperature (Abs min temp) of 10.5° C recorded in June 1993.

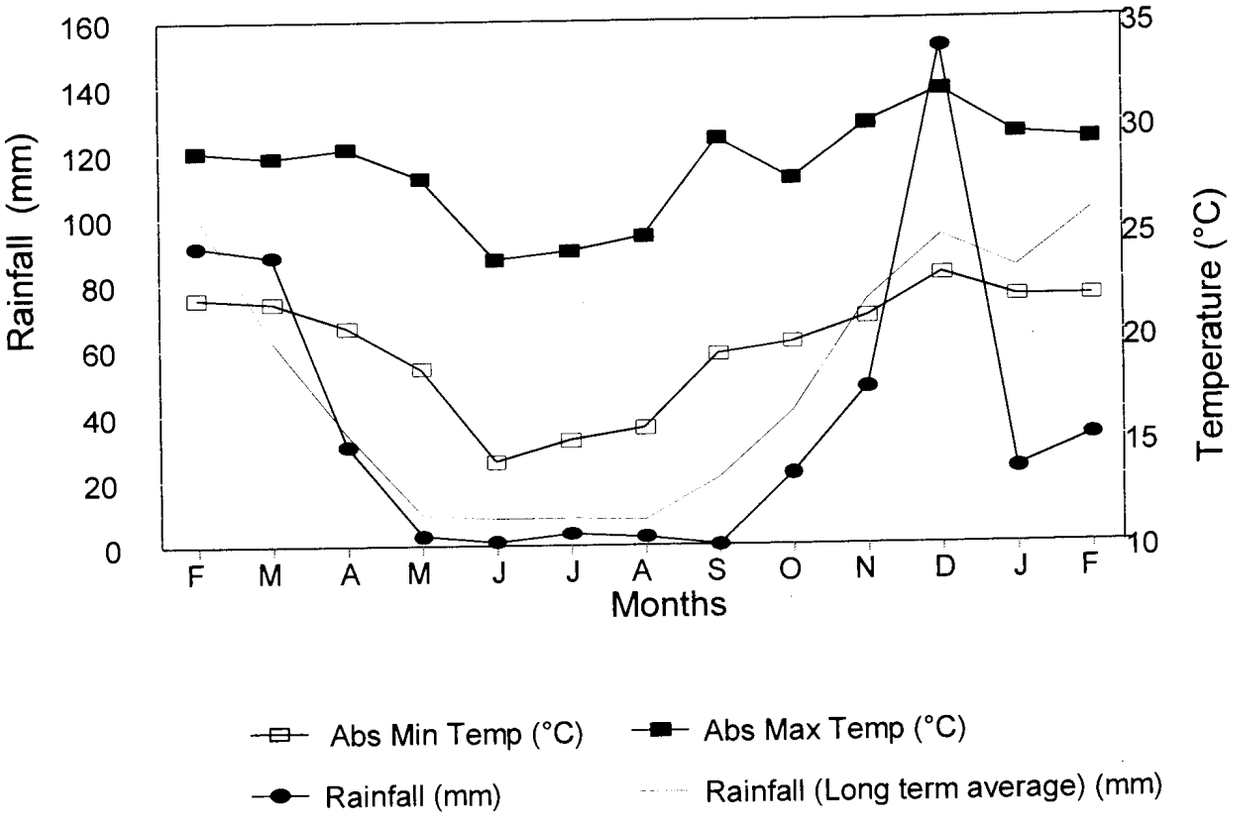

Figure 1 Monthly rainfall (mm) and mean maximum and minimum temperatures (°C) recorded at Hans Hoheisen Wildlife Research station in the Northern Province Lowveld from February 1993 to February 1994.

2.3 Geology

Fieldwork was conducted in a 10 ha camp at the research station. The underlying geological formation of this area is gabbro which forms an intrusion into granite rock (Gertenbach, 1983). According to Gertenbach (1983) the gabbro intrusions in the Kruger National Park extend from Malelane in the south to Phondaheuwels west of Shingwedzi. The southernmost section of this intrusion is in the vicinity of Orpen where the study was conducted. Soils originating from gabbro are rich in dark-coloured minerals such as Fe and Mg. The parent rock of these soil formations erode easily to deep fertile soils with a good water-holding capacity but slow absorption (Brady, 1984).

2.4 Botanical Composition

The veld type of this area is known as the Mixed Lowveld Bushveld (Bredenkamp & Van Rooyen 1996). The woodland vegetation in the research camp consists mainly of open woodland dominated by *Acacia nigrescens* and *Sclerocarya birrea*. The landscape is described by Gertenbach (1983) as Thornveld on Gabbro and the community known as *Sclerocarya birrea* / *Acacia nigrescens* - savanna. The most dominant shrubs were several *Grewia* spp., *Ziziphus mucronata*, *Flueggia virosa* and *Ormocarpum trichocarpum*.

A grass survey (2000 points) conducted in the 10 ha camp, revealed the species composition and percentage distribution as shown in Table 1. The grass stratum was dominated by *Heteropogon contortus*, *Themeda triandra*, *Panicum maximum* and *Enneapogon* spp. Various forbs were also present.

Table 1 Grass species composition and percentage distribution in a 10 ha research camp at the Hans Hoheisen Research Station in the Northern Province Lowveld.

Grass species	Total (n)	Percentage composition
Heteropogon contortus	645	32.30
Themeda triandra	469	23.50
Panicum maximum	249	12.50
Enneapogon spp.	197	9.85
Digitaria eriantha	108	5.40
Urochloa mosambicensis	93	4.65
Cenchrus ciliaris	87	4.35
Schmidtia pappophoroides	68	3.40
Aristida spp.	27	1.35
Fingerhuthia africana	23	1.15
Bothriochloa radicans	9	0.45
Eragrostis spp.	7	0.35
Sporobolus africana	9	0.45
Tragus berteronianus	5	0.25
Brachiaria serrata	4	0.20
Total	2000	100.00

CHAPTER 3

3 DIET PREFERENCE AND THE QUALITY AND QUANTITY OF FORAGE UTILIZED BY THE ZEBRA AND THE BLUE WILDEBEEST DETERMINED THROUGH PLANT-BASED TECHNIQUES.

3.1 INTRODUCTION

Scientific wildlife management requires the application of ecological knowledge to achieve predetermined goals. Wildlife management is the science of conservation through wise use and can be subdivided into animal management and vegetation management (Bothma 1999). Grazing or browsing capacity is primarily a function of the vegetation (habitat). Forage supply is determined by forage production, which is a function of climate, soil, water, fire and vegetation composition. Ungulate herbivory is a function of nutrient and energy requirement, and food preference and availability. The preference an animal may show for a particular feed is defined as the extent to which the animal will take that feed in a larger proportion than that in which it occurs with other types of feed (Mentis 1981b). Therefore, in order to determine the nutritional requirements and selection patterns of zebra and blue wildebeest, scientific knowledge of the grass layer and forage utilized, was needed.

3.2 MATERIAL AND METHODS

The field study was divided into non-sampling and sampling periods. During sampling periods the zebra and the blue wildebeest grazed on the natural forage in the confined areas (bomas) and data were collected accordingly. Other vegetation surveys that were executed while the test animals were not directly involved are described under non-sampling periods.

3.2.1 Non-sampling period

The grass species composition and percentage frequency in the 10 hectare fenced camp were determined through the step-point method (2000 points) as described by Mentis (1981a)(Table 1). This information was used to identify the dominant grass species in the area.

An attempt was made to formulate a correlation between the index (total height x widest diameter of grass tufts expressed in cm) of the dominant grass species and their respective mass (dry matter) expressed in grams. These regression lines were formulated to calculate monthly utilization of grasses (intake) from a plant-based perspective and at the same time to substantiate the animal-based measurements of intake.

The samples needed for the regression formulation were collected during four different time periods that is, August 1992 (time 1); February 1993 (time 2); May 1993 (time 3) and November 1993 (time 4). This was done in order to represent the four different seasons in a year.

The eight dominant grass species determined from the above step point survey were used in the first regression study. *Panicum coloratum* was included in the second and third time period, whilst *Bothriochloa radicans* and *Brachiaria serrata* were only collected during the last time period. The project animals during the latter part of the study also utilized the reason being that those species. The grass species were numbered as follows:

1. *Urochloa mosambicensis*
2. *Cenchrus ciliaris*
3. *Schmidtia pappophoroides*
4. *Panicum maximum*
5. *Digitaria eriantha*
6. *Enneapogon* spp.

7. *Themeda triandra*
8. *Heteropogon contortus*
9. *Panicum coloratum*
10. *Bothriochloa radicans*
11. *Brachiaria serrata*

During these sampling periods, 20 individuals of each of the above grass species, differing in height and size were collected to ensure a representative sample of each species. Each individual grass was measured (total height and widest diameter of tuft expressed in cm). The samples were then hand cut about one centimetre above the ground. The chances are little that the project animals (zebra and blue wildebeest) will graze lower than one centimetre (De Wet 1988).

The hand cut samples were then oven-dried by 60 °C and weighed. The height and diameter of each species were multiplied and expressed as an index (cm^2). The mass and index of each individual grass species were expressed on a line function (xy) to formulate a correlation between the index and mass of various grass species applicable to the main study.

Four different line functions were used in an attempt to find the best correlation between the mass and the index of the various grass species. They were the following:

- Mass / Index $y = ax + b$
- Ln mass / Ln index $\ln y = a (\ln x) + b$
- Mass / Ln index $y = a (\ln x) + b$
- Ln mass / Index $\ln y = ax + b$

The correlation with the best fit (highest R^2 - value) for a grass species over a specific time period was then used to calculate grass utilization of the test animals.

3.2.2 Pasture sampling and preparations

During sampling, the grass layer was surveyed in each boma before the test animals entered. After 2 days of grazing the survey was repeated. Each survey comprised the following - before and after grazing, the biomass of the grass layer was determined with the aid of a disc pasture meter. The disc pasture meter calibration equation of Trollope and Potgieter (1986) to estimate grass biomass on the gabbro area of the Kruger National Park, was used. Ten sample points were measured in each boma (128 m^2). The mean settling height of the disc pasture meter in each boma was then processed to estimate total biomass per hectare (kg/ha) by using the linear regression of Trollope and Potgieter (1986) for the specific area. This result was then expressed as kg material available in the boma (kg/128 m^2).

Sampling was done each month over a period of 12 months within each boma for the six individual animals. The species composition of the grass layer as well as individual measurements for each grass species (total height and widest diameter of tufts in cm) were determined. This was done after random distribution of three survey areas of approximately 0.5 m^2 each within the boma. The height (cm) x diameter (cm) measured were express as an index (cm^2).

This was considered adequate for an area of 128 m^2, as Dörgeloh (1997) found that a sample size of 20 quadrants of 0.25 m^2 per site is needed to measure vegetation species richness and grass density in most Mixed Bushveld communities adequately. The main purpose of the study focussed on the utilization of the grass species by zebra and blue wildebeest and the same method was used for both the zebra and the blue wildebeest to reduce the margin of error.

The three survey areas within each boma were delineated using a wire square (0.5 m^2) and marked for successive surveys. Surveys were conducted before grazing in the separate bomas. Three zebra and three blue wildebeest from adjacent bomas were then allowed to enter each individual boma after opening the gates that

connected the two sets of bomas. The first set of bomas was pulled down and re-erected on a new area adjacent to the second set of bomas to form a chain system. After two days of continual grazing the test animals were then moved to the third set of bomas. The same technique was then used to conduct the post grazing surveys in the marked areas. These surveys were repeated in every boma before and after grazing over a six day period. The material of each grass species grazed in the squares could thus be determined through a simple subtraction (difference in index (cm^2) before and after grazing).

The bomas were shifted three times (every two days), during each sampling period (six days). The above-mentioned information was thus collected three times during the sampling period for each individual animal (3 zebra and 3 blue wildebeest). Data for each individual animal were then added for that month (sampling period) and was thus representative of an area that covered 4.5 m^2 (9 squares x 0.5m^2). This information was then used as follows:

1. Determination of the percentage of the grass species utilized as well as the relative amount (length x diameter in cm) of material utilized for each grass species by each individual animal.

   For example:
   (10 % *Panicum maximum* available in delineated areas)(mean height utilized = 20 cm) = 200 cm of use. For practical reasons the final amount of use for all the grass species was then divided by 5 to yield more manageable figures, in order to collect hand-samples.

   These hand-collected samples were cut with equal heights of each grass species utilized, in order to represent the selected diet for each individual animal as closely as possible. The hand-collected samples were subsequently used in diet selection (alkane marker and microhistological technique) (Section 4.2.4) and qualitative utilization studies (Section 4.2.5).

2. Quantification of the grass species utilized on daily basis by each individual animal. The following procedures were used:

i. The material grazed (index, cm) for each individual grass species in the randomly distributed squares (3x 0.5 = 1.5 m^2) within each boma was determined.

ii. The best fit regression line for each specific grass species during that specific time period was then used to predict the mass (g) corresponding with the known index (cm).

Example:	**Month**	**Grass species**	**Index grazed (cm2)**
	March '93	*Urochloa mosambicensis*	6 cm^2
	(Time 2)	(Species 1)	(x)

Regression: ln y = ax + b Where: a = 0.0224 and b = -1.479

ln y = (0.0224)(6) + (-1.479)

= 0.1344 - 1.479

= -1.345

y = 0.2605

Mass = 0.2605 g

The mass of individuals of the same species was then added for the nine squares (4.5m^2) that represent the diet of each individual animal (3 zebra and 3 blue wildebeest).

iii. The percentage distribution of each grass species in the randomly distributed squares was also measured in each boma and the information summed for each individual animal. The assumption was then made that the distribution of grass species in the squares are representative of the grass species distribution in the bomas.

The mass contribution of each grass species as calculated above was then adapted according to the percentage distribution of that specific grass species.

Example: In the three bomas (128m^2 x 3) that represented the forage utilized by zebra 1 for that specific sampling period (6 days),

Grass species	**n Individuals**	**Total mass**	% **Distribution(384 m^2)**
Heteropogon contortus	653	620 g	42.4 %

42.4 % of 384 m^2 (Area of three bomas)
= 384 x 0.424
= 162.8 m^2

The mass *Heteropogon contortus* utilized in the nine squares (4.5 m^2) was 620 g. The mass utilized in the three bomas was therefore:

$$\frac{162.8\ m^2}{4.5\ m^2} \times 620\ g$$

= 22 430 g

The three bomas however represented six grazing days. Therefore, the daily intake for *H. contortus* = the above mass (intake) divided by six
= 3 738 g

iv. The contribution of the rest of the grass species was then calculated in the same way. The final mass for all the grass species was then summed to calculate the daily intake of that individual animal for that sampling period.

3.3 STATISTICAL ANALYSIS

Linear regression analysis was performed to determine the correlation between grass index (cm^2) and grass mass. The Excel program package was used. The GLM (General Linear Models) procedure by the SAS (Statistical Analysis Systems)(1990) was used to draw a comparison between the animal-based and plant-based data. The Excel program package was used to draw linear graphs.

Other data of the vegetation surveys were used directly without modification through statistical analysis.

3.4 RESULTS

The species composition and percentage distribution for the 10 ha research camp can be seen in Table 1 (Section 2.4). The grass stratum was dominated by *Heteropogon contortus, Themeda triandra*, *Panicum maximum* and *Enneapogon* spp.

The correlations compiled between the index (total height x widest diameter of grass tufts expressed in cm) of the dominant grass species and their respective mass (dry matter) expressed in grams, was highly significant (Table 2 & 3). There were only a few exceptions. *Schmidtia pappophoroides* had a non-significant correlation coefficient coefficient for the equation tested with the ln mass versus ln index line function during Time 3 (May 1993). This can possibly be explained through the fact that this grass species has little leaf material. *Brachiaria serrata* was only collected during Time 4 (November 1993) and had a non-significant correlation coefficient for all the line functions used.

Table 2 The correlations between grass mass and index (height x diameter, cm^2), expressed as mass / index and ln mass / ln index, for 11 grass species at four different time periods at Hans Hoheisen Research Station in the Northern Province Lowveld

		mass/index y = ax + b			ln mass/ln index lny = a(lnx) + b		
Species	Time	Pr > F R^2	A	B	Pr > F R^2	a	B
U. mosambicensis	1	0.7867 **	0.0389	1.061	0.7753 **	0.7115	- 1.646
	2	0.5562 **	0.0249	- 0.2503	0.4501 **	0.9817	- 4.000
	3	0.6468 **	0.0249	- 0.4429	0.6173 **	1.402	- 5.864
	4	0.8838 **	0.0532	- 4.123	0.9153 **	1.759	-7.787
C. ciliaris	1	0.8382 **	0.0885	- 2.774	0.5868 **	0.7415	- 1.070
	2	0.5378 *	0.0930	- 20.18	0.5646 *	1.349	- 5.202
	3	0.7771 **	0.0747	59.98	0.8649 **	0.8447	- 1.096
	4	0.7794 **	0.1157	- 9.897	0.9167 **	1.246	- 4.062
S. pappophoroides	1	0.7736 **	0.0481	2.077	0.7366 **	0.9333	- 2.467
	2	0.6104 **	0.0471	- 2.999	0.6288 **	1.561	- 6.582
	3	0.4760 **	0.0301	- 0.9496	0.1871 NS	0.7383	- 3.083
	4	0.5747 **	0.0091	- 0.0576	0.5334 **	1.043	- 5.170
P. maximum	1	0.7127 **	0.0915	0.8027	0.6545 **	0.9261	- 2.072
	2	0.7005 **	0.0364	0.6298	0.8163 **	1.469	- 6.075
	3	0.8247 **	0.0556	- 2.058	0.8415 **	1.739	- 7.229
	4	0.8939 **	0.0433	- 6.312	0.8502 **	1.609	- 7.477

		mass/index y = ax + b			ln mass/ln index lny = a(lnx) + b		
Species	Time	Pr > F R^2	a	b	Pr > F R^2	a	b
D. eriantha	1	0.7430 **	0.1701	- 10.80	0.7950 **	1.149	- 3.294
	2	0.7690 **	0.0198	- 0.6965	0.7985 **	1.628	- 7.561
	3	0.8309 **	0.0534	- 1.589	0.8844 **	1.102	- 3.695
	4	0.7169 **	0.0362	- 0.6391	0.7953 **	1.159	- 4.365
E.nneapogon spp	1	0.5085 **	0.1140	- 6.700	0.7600 **	1.272	- 4.366
	2	0.6603 **	0.0650	4.077	0.6681 **	0.9528	- 2.390
	3	0.8800 **	0.1019	- 0.8373	0.6376 **	1.187	- 3.576
	4	0.9724 **	0.0815	- 1.521	0.9361 **	1.152	- 3.554
T. triandra	1	0.8188 **	0.0630	- 0.1246	0.8527 **	1.152	- 3.722
	2	0.8911 **	0.0336	- 0.6819	0.7279 **	0.8560	-2.590
	3	0.9147 **	0.0297	- 0.6501	0.8291 **	1.158	-4.522
	4	0.7770 **	0.0252	- 1.697	0.8292 **	1.439	- 6.549
H. contortus	1	0.9059 **	0.1263	- 3.826	0.8807 **	1.250	- 3.850
	2	0.9085 **	0.1079	- 7.079	0.8976 **	1.403	- 4.973
	3	0.6857 **	0.0591	- 6.535	0.7393 **	1.858	- 8.348
	4	0.7472 **	0.0350	-3.451	0.8011 **	1.513	- 6.975
P. coloratum	2	0.3367 *	0.0372	1.958	0.6265 **	1.375	- 5.127
	3	0.4801 **	0.0101	0.5036	0.4076 **	0.5265	- 2.062
B. radicans	4	0.8374 **	0.0179	- 0.2958	0.8071 **	1.581	- 6.980
B. serrata	4	0.0759 NS	0.0055	0.3039	0.1741 NS	0.4512	- 2.468

** - $p < 0.01$ = highly significant

* - $p < 0.05$ = significant

NS - non significant

Time 1: August 1992
2: February 1993
3: May 1993
4: November 1993

Table 3 The correlations between plant mass and index (height x diameter, cm^2), expressed as mass / ln index and ln mass / index, for 11 grass species at four different time periods at Hans Hoheisen Research Station in the Northern Province Lowveld.

		mass/ln index y = a(lnx) + b			ln mass/index lny = ax +b		
Species	Time	Pr > F R^2	a	b	Pr > F R^2	a	b
U. mosambicensis	1	0.6156 **	3.649	- 9.227	0.6382 **	0.0061	0.4900
	2	0.4466 **	1.105	- 3.106	0.5735 **	0.0224	- 1.479
	3	0.6092 **	1.853	- 6.362	0.5962 **	0.0180	- 1.319
	4	0.7494 **	12.35	- 55.99	0.7694 **	0.0064	- 0.0687
C. ciliaris	1	0.4995 **	26.20	-115.1	0.6661 **	0.0021	2.287
	2	0.5828 *	189.8	- 1262	0.5111 *	0.0007	3.638
	3	0.7723 **	151.7	- 912.9	0.6765 **	0.0004	4.445
	4	0.7058 **	79.57	- 417.9	0.7946 **	0.0016	2.507
S. pappophoroides	1	0.7665 **	6.359	- 20.19	0.5819 **	0.0062	0.9127
	2	0.5165 **	5.509	-23.38	0.6999 **	0.0129	- 0.7531
	3	0.2484 *	1.177	- 3.300	0.3995 **	0.020	- 1.707
	4	0.4806 **	0.4815	- 1.381	0.5975 **	0.0191	-2.262
P. maximum	1	0.5908 **	20.64	-83.42	0.6337 **	0.0040	1.808
	2	0.8526 **	12.35	- 55.42	0.6158 **	0.0041	0.6414
	3	0.6653 **	6.560	- 24.28	0.6986 **	0.0121	- 0.9143
	4	0.7407 **	13.09	- 66.40	0.8933 **	0.0050	0.0199
D. eriantha	1	0.3834 **	19.07	- 71.81	0.6848 **	0.0068	0.9826
	2	0.6987 **	2.753	- 10.99	0.6991 **	0.0104	- 1.243
	3	0.7428 **	21.96	- 123.7	0.7706 **	0.0020	1.826
	4	0.7023 **	11.66	- 54.08	0.7026 **	0.0034	1.0261
Enneapogon spp	1	0.4148 **	19.92	- 81.06	0.6950 **	0.0063	0.6188
	2	0.5971 **	39.82	- 205.3	0.6283 **	0.0014	2.696
	3	0.6470 **	34.55	- 149.4	0.4996 **	0.0027	1.910
	4	0.7907 **	35.53	- 161.4	0.7209 **	0.0021	1.891

		mass/ln index y = a(lnx) + b			ln mass/index lny = ax +b		
Species	Time	Pr > F R^2	a	b	Pr > F R^2	a	b
T. triandra	1	0.7504 **	10.64	- 38.73	0.7350 **	0.0061	0.6031
	2	0.5966 **	17.05	- 83.74	0.6863 **	0.0013	1.807
	3	0.8073 **	5.978	- 25.41	0.7383 **	0.0051	0.3873
	4	0.5966 **	4.399	- 18.95	0.7344 **	0.0068	- 0.5446
H. contortus	1	0.5489 **	11.17	- 33.70	0.6962 **	0.0098	0.0085
	2	0.7881 **	32.10	- 147.9	0.7797 **	0.0041	1.358
	3	0.5804 **	11.48	- 54.39	0.7682 **	0.0090	- 0.4560
	4	0.4998 **	6.169	- 26.65	0.7248 **	0.0067	- 0.7034
P. coloratum	2	0.4402 **	7.705	- 30.18	0.4399 **	0.0064	0.6595
	3	0.4743 **	05070	- 0.6747	0.3924 **	0.0103	- 0.8272
B. radicans	4	0.7302 **	0.8351	- 2.496	0.7990 **	0.0315	- 2.692
B. serrata	4	0.2025 *	0.1860	- 0.0771	0.0484 NS	0.0114	- 1.508

** - $p < 0.01$ = highly significant

* - $p < 0.05$ = significant

NS - non significant

Time 1: August 1992
2: February 1993
3: May 1993
4: November 1993

This grass species is small in relationship with the other grasses with accompanying low weight. *Cenchrus ciliaris* had a significant correlation at Time 2 (February 1993) for all the line functions and *Panicum coloratum* had a significant correlation at Time 2 for the mass/index line function. All the above-mentioned grass species however, were utilized to a lesser extent by the zebra and the blue wildebeest.

Cenchrus ciliaris had a significant correlation at Time 2 (February 1993) for all the line functions and *Panicum coloratum* had a significant correlation at Time 2 for the mass/index line function. All the above-mentioned grass species however, were utilized to a lesser extent by the zebra and the blue wildebeest.

The line function with the highest R-values was the mass/index correlation although ln mass/ln index also had highly significant correlations.

The grass species with the best correlation between mass/ index was *Enneapogon* sp. (R^2 = 0.972) during November 1993(Time 4) and *Themeda triandra* (R^2 = 0.915) during May 1993.

The best correlations between ln mass/ln index was *Cenchrus ciliaris* (R^2 = 0.917) during November 1993 (Time 4) and *Urochloa mosambicensis* (R^2 = 0.915) during November 1993 (Time 4). *Themeda triandra* and *Heteropogon contortus* had the best correlations between mass and index taken over all the Time periods.

There were highly significant correlations between mass and index of the grass species during all four Time periods although Time 4 (November 1993) tend to produce the most highly significant regression lines.

The regression lines (xy) with the highest R - values as formulated for *Urochloa mosambicensis* and *Heteropogon contortus* over four different time periods, can be seen in Figures 2 - 9.

The mean amount of forage available for each zebra and blue wildebeest per boma (2 days of grazing) during each sampling period (6 days) for that month, is listed in Table 4. It is expressed as kilogram of forage available in a boma of 128 m^2. The mean material available for the zebras was 47.93 kg/128 m^2 (3.75 ton / ha) and for the blue wildebeest 45.45 kg/128 m^2 (3.55 ton / ha). This difference was not significant ($p<0.05$).

The grass species that were mostly utilized were *Panicum maximum*, Heteropogon *contortus*, *Urochloa mosambicensis* and *Themeda triandra* (Table 5). Other species that were utilized were *Schmidt pappophoroides*, *Enneapogon scoparius*, *Panicum coloratum*, *Brachiaria deflexa*, *Cenchrus ciliaris*, *Digitaria eriantha*, Aristida *congesta* subsp. *barbicollis*, *Eragrostis* spp., *Bothriochloa radicans* and to a lesser extent, *Tragus berteronianus* and *Fingerhuthia africana*.

The average daily intake for each animal (3 zebra and 3 blue wildebeest) as determined with the aid of the regression equations over a period of three months, can be seen in Table 6.

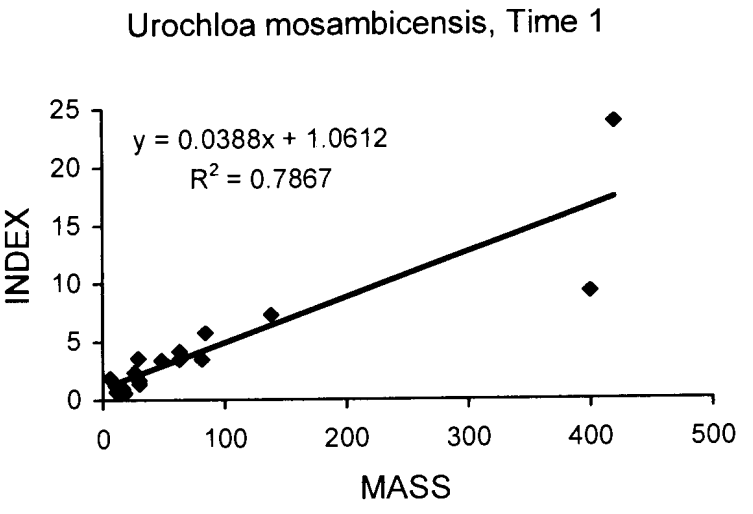

Figure 2 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Urochloa mosambicensis* during August 1992 (Time 1) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

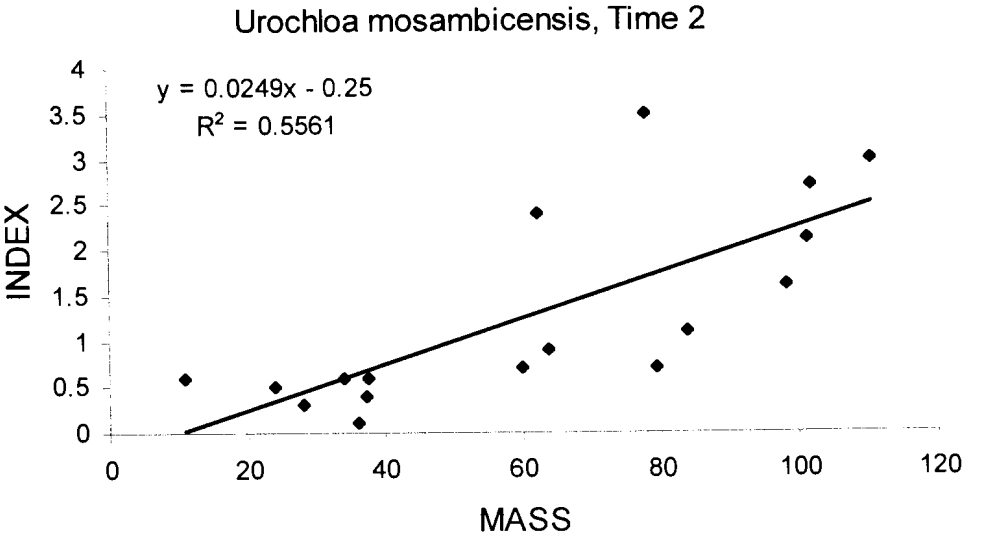

Figure 3 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Urochloa mosambicensis* during February 1993 (Time 2) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

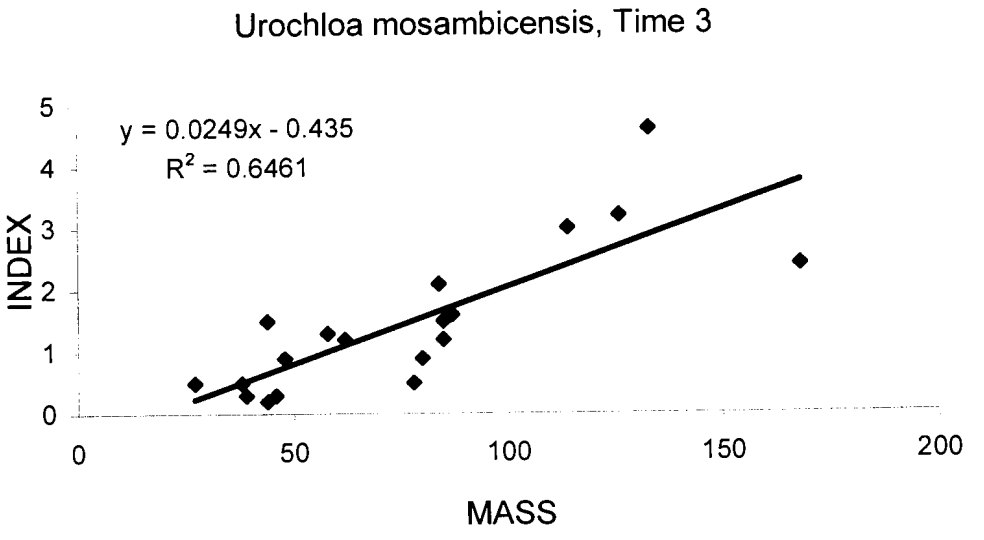

Figure 4 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Urochloa mosambicensis* during May 1993 (Time 3) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

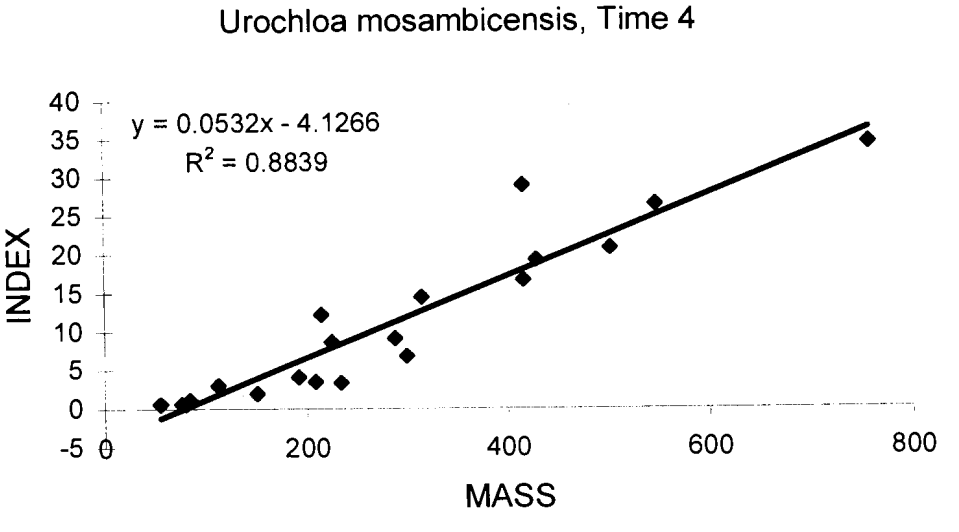

Figure 5 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Urochloa mosambicensis* during November 1993 (Time 4) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

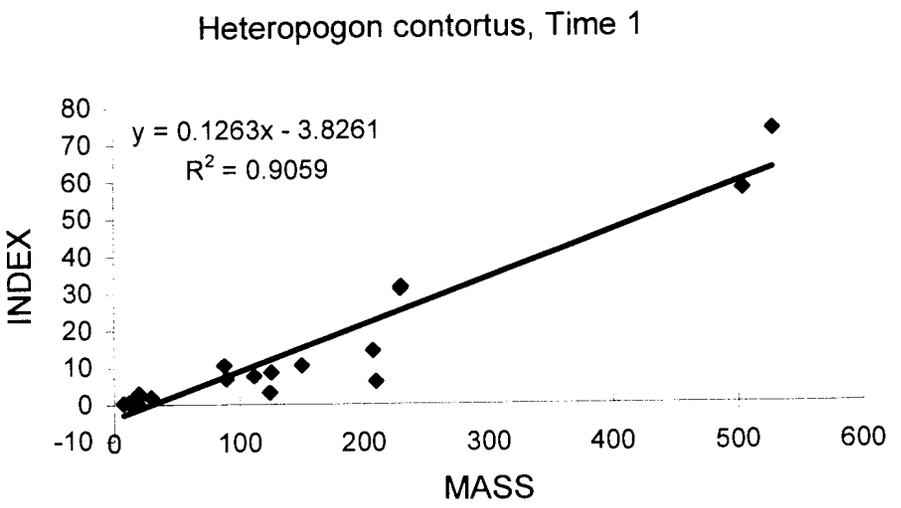

Figure 6 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Heteropogon contortus* during August 1992 (Time 1) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

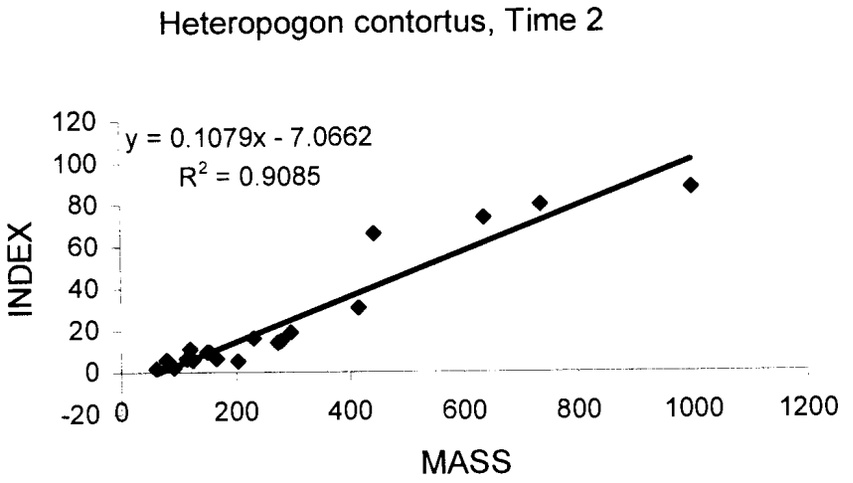

Figure 7 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Heteropogon contortus* during February 1993 (Time 2) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

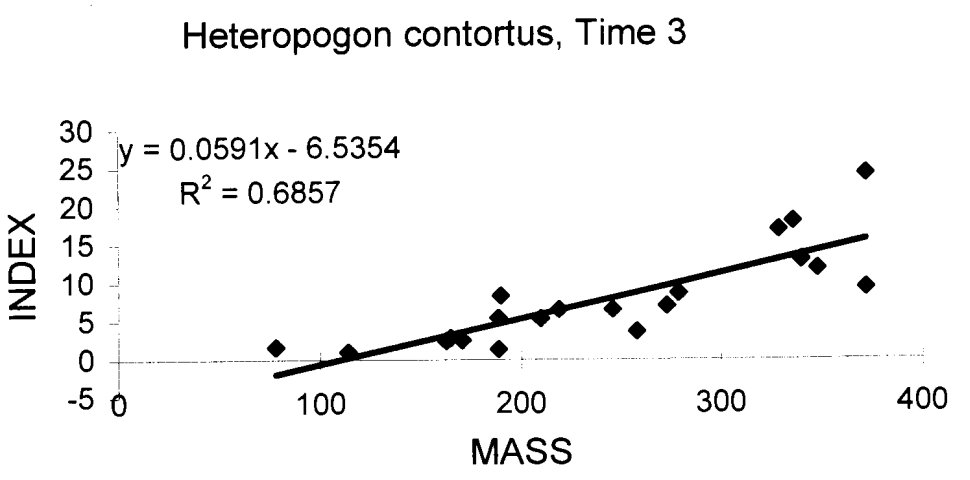

Figure 8 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Heteropogon contortus* during May 1993 (Time 3) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

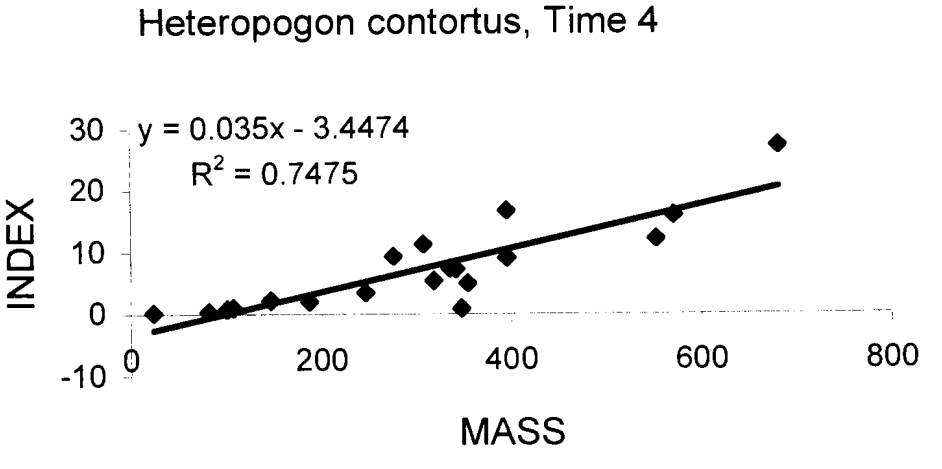

Figure 9 The best fit regression equation between mass (g) and index (height x diameter, cm) for *Heteropogon contortus* during November 1993 (Time 4) at the Hans Hoheisen Research Station in the Northern Province Lowveld.

Table 4 The mean amount of forage available (kg/128m^2) for each zebra and blue wildebeest per boma (2 days of grazing) during each sampling period (6 days) for that month at Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

	Months											
	Feb.	Mar.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.
Animal	Forage available (kg/128m^2)											
Zebra 1	41.59	72.01	39.28	49.74	48.74	55.12	58.62	42.38	43.53	48.95	54.57	27.54
Zebra 3	35.73	79.49	35.37	54.90	53.41	46.50	71.86	52.82	43.04	35.15	50.20	30.12
Zebra 5	32.75	65.53	33.92	49.73	61.41	51.26	66.59	45.15	34.43	37.95	45.38	30.62
Bwb 1	43.22	41.50	43.13	42.16	65.35	58.77	72.91	44.69	39.48	33.97	55.19	23.99
Bwb 2	43.07	47.96	38.60	49.26	50.83	50.90	63.61	31.51	35.85	21.25	63.52	22.56
Bwb 3	46.82	48.40	44.72	53.87	54.65	61.51	52.99	51.03	39.04	28.14	45.98	25.93

Mean (zebra) = 47.9
Mean (blue wildebeest = 45.5

Table 5 Mean forage height grazed (cm) of the dominant grass species per unit area (13.5 m²) by the zebra and the blue wildebeest at Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

Zebra					Blue wildebeest			
Month	Grass species	* n/ 13.5m²	** % composition	*** Average grazed (cm)	Grass species	* n/ 13.5m²	** % composition	***Average grazed (cm)
Feb	*H. contortus*	1 960	42.4	13.5	*H.contortus*	1286	36.0	13.6
	P. maximum	1594	34.5	14.6	*P.maximum*	620	17.5	11.8
	U. mosambicensis	305	6.60	17.5	*U. mosambicensis*	588	16.6	15.8
	P. coloratum	232	5.02	21.3	*P. coloratum*	243	5.36	20.6
March	*P. maximum*	661	40.7	15.6	*P. maximum*	663	47.7	12.4
	U. mosambicensis	572	35.2	13.6	*H. contortus*	321	23.1	16.9
	H. contortus	133	8.19	16.9	*U. mosambicensis*	167	12.0	17.4
	T. triandra	101	6.22	21.0	*T. triandra*	140	10.1	21.1
May	*U. mosambicensis*	292	26.8	12.9	*U. mosambicensis*	279	29.0	13.7
	H. contortus	247	22.6	17.3	*H. contortus*	199	20.7	17.4
	P. maximum	158	14.5	16.2	*P. maximum*	185	19.2	18.2
	T. triandra	139	12.7	23.1	*Aristida sp.*	81	8.41	9.37
June	*P. maximum*	812	56.7	18.5	*P. maximum*	598	45.7	14.3
	U. mosambicensis	262	18.3	17.1	*T. triandra*	223	17.1	23.5
	T. triandra	135	9.43	24.3	*U. mosambicensis*	214	16.4	13.9
	H. contortus	115	8.03	19.8	*H. contortus*	133	10.2	17.9
July	*P. maximum*	508	44.8	16.2	*P. maximum*	418	40.6	15.2
	U. mosambicensis	295	24.6	15.8	*U. mosambicensis*	265	18.2	16.5
	H. contortus	148	11.3	17.1	*T. triandra*	152	14.5	13.1
	T. triandra	122	9.64	20.3	*H. contortus*	135	10.3	16.3
Aug	*H. contortus*	316	32.6	16.5	*H. contortus*	292	36.4	17.1
	P. maximum	268	26.4	15.6	*U. mosambicensis*	242	24.3	16.9
	U. mosambicensis	253	24.2	14.8	*P. maximum*	215	21.5	16.4
	E. scoparius	135	9.60	7.40	*E. scoparius*	118	9.80	6.30

	Zebra				Blue wildebeest			
Month	Grass species	* n/ 13.5m²	** % composition	***Averaged grazed (cm)	Grass species	* n/ 13.5m²	** % composition	***Average grazed (cm)
Sep	*P. maximum*	334	30.2	10.10	*P. maximum*	444	44.9	9.62
	H. contortus	215	24.6	14.70	*T. triandra*	152	15.4	17.30
	U. mosambicensis	91	10.4	13.10	*U. mosambicensis*	151	15.3	8.25
	T. triandra	89	10.2	24.10	*H. contortus*	68	6.9	10.70
Oct	*H. contortus*	197	30.5	8.45	*H. contortus*	232	37.5	11.00
	U. mosambicensis	126	19.5	8.11	*U. mosambicensis*	161	26.1	7.74
	P. maximum	119	18.4	13.80	*P. maximum*	86	13.9	10.10
	S. pappophoroides	52	8.0	15.40	*E. scoparius*	35	5.7	8.67
Nov	*H.contortus*	168	34.3	8.74	*U. mosambicensis*	116	24.8	7.51
	U.mosambicensis	94	19.2	7.43	*H. contortus*	103	22.0	8.09
	T. triandra	62	12.7	12.20	*E. scoparius*	78	16.7	6.83
	P. maximum	52	10.2	18.00	*P. maximum*	59	12.6	6.11
Dec	*H. contortus*	176	40.5	10.00	*H. contortus*	132	46.8	7.75
	T. triandra	79	18.2	9.22	*U. mosambicensis*	66	23.4	10.50
	U. mosambicensis	70	16.1	8.43	*P. maximum*	29	10.3	5.02
	P. maximum	42	9.7	6.42	*T. triandra*	25	8.9	16.70
Jan	*U. mosambicensis*	632	38.5	9.48	*P. maximum*	291	41.0	14.80
	H. contortus	372	22.7	12.30	*H. contortus*	205	28.9	10.30
	P. maximum	315	19.2	14.00	*T. triandra*	125	17.6	10.70
	P. coloratum	135	8.2	7.09	*U. mosambicensis*	33	4.7	7.66
Feb	*U. mosambicensis*	395	32.6	6.58	*H. contortus*	406	34.7	6.40
	H. contortus	351	28.9	6.05	*P. maximum*	196	16.8	12.70
	P. maximum	277	22.8	13.40	*U. mosambicensis*	188	16.1	5.28
	B. serrata	55	4.5	19.20	*T .triandra*	123	10.5	13.20

Table 6 Intake of forage (kg) by the zebra and the blue wildebeest (Bwb) calculated through the plant-based technique over a 3 month period at the Hans Hoheisen Research Station in the Northern Province Lowveld.

Month	Animal species	Plant-based daily intake (kg)
February 1993	Zebra 1	7.211
	Zebra 3	11.11
	Zebra 5	13.01
	Bwb 1	3.154
	Bwb 2	4.157
	Bwb 3	4.183
March 1993	Zebra 1	6.414
	Zebra 3	7.019
	Zebra 5	4.721
	Bwb 1	3.863
	Bwb 2	2.239
	Bwb 3	3.170
May 1993	Zebra 1	5.707
	Zebra 3	4.303
	Zebra 5	5.982
	Bwb 1	2.448
	Bwb 2	1.594
	Bwb 3	1.746

3.5 DISCUSSION

The correlation equation between the index (total height x widest diameter of grass tufts expressed in cm) of the dominant grass species and their respective mass (dry matter) expressed in grams, was highly significant for all the grass species over all four time periods, with only a few exceptions. Most of the grass species had a highly significant relation between mass and index (xy line function), tested over all four time periods. The regression equations could therefore be used to calculate intake from the average amount of grass utilized (difference before and after grazing).

Although the zebra and the blue wildebeest were confined to bomas during the sampling periods, the attempt to simulate natural grazing conditions and free selection was satisfactory. The mean amount (kg) of grass material available during sampling periods for both the zebra and the blue wildebeest did not differ significantly, although differences occurred between some of the individual bomas. *Cenchrus ciliaris* was one of the grass species that had an influence on the biomass of the grass material available because of the height and width of the tufts. During March the mean amount of grass material available to the zebra amounted to 72.3 kg/128m^2 and for the blue wildebeest to 46.0 kg/128m^2. This big difference could possibly be explained by the presence of more *C. ciliaris* in the zebras' bomas.

There was an overlap in the grass species selected by zebra and blue wildebeest. This is in accordance with other literature (De Wet 1988, Owaga 1975, Stewart & Stewart 1970 and Wentzel 1990). Through observations in the bomas it was noticed that the zebra and the blue wildebeest had a preference for

U. *mosambicencis*. This corresponded with work done by [1] Mark van der Walle (pers. comm.) in Botswana (1994) and also with data from De Wet (1988) and Wentzel (1990), from studies done in the Kruger National Park.

Other species selected for, were *P. maximum*, *Heteropogon contortus* and *Themeda triandra*. This also corresponds with Atwell (1977), De Wet (1988) and Wentzel (1990). Zebra that are normally seen as a tall grass feeder will also utilize shorter grass. Compared to blue wildebeest, however, their bite size is bigger and therefore they can take bigger portions of the grass at a time. During October, it was noticed that both zebra and blue wildebeest browsed on the leaves of the woody shrubs *Grewia* spp., probably as a nutritive supplement. This coincided with the period when the grass had the lowest phosphorous and protein percentages.

The average daily intake for each animal (3 zebra and 3 blue wildebeest) was estimated with the aid of the regression equations over a period of three months. The available results will be compared with the data of the animal-based intake calculated in the next chapter (Section 4.4.2).

[1] Mark Joost - Van der Walle, Department of Wildlife and National Parks, P.O. Box 17, Kasane, Botswana.

CHAPTER 4

4 DIET PREFERENCE AND THE QUALITY AND QUANTITY OF FORAGE UTILIZED BY THE ZEBRA AND THE BLUE WILDEBEEST DETERMINED THROUGH ANIMAL-BASED TECHNIQUES.

4.1 INTRODUCTION

The game industry has developed rapidly over the past decade. The establishment of game ranches is an important landmark on the South African conservation horizon, provided they are planned and managed on a sound ecological basis (Bothma 1996). Amongst other factors, this requires realistic standards whereby carrying capacity of veld for game species can be determined.

This implies extensive knowledge of the potential of the animal (ungulate) habitat (forage supply) on the one hand as well as the needs and potential of the animals (ungulates) on the other hand.

Studies on the evolutionary adaptations of the ruminant digestive system only started not much more than 25 years ago. The first observations recorded suggested that there are ecophysiological differences in the digestion of wild ruminants compared with that in domestic cattle and sheep (Hofmann 1973). The adaptive variations of typical ruminant features involve all portions of the digestive system and most of these variations relate to food quality and composition (Hofmann 1983).

Food intake also plays a major role because carrying capacity is primarily a function of the grazing and browsing capacity of the veld (Trollope 1990).

Owen-Smith and Cooper (1988) suggest that dietary intake for large herbivores may be characterized either in terms of the plant species eaten, the plant parts ingested, or the nutrient contents of the ingested material. The leaves of grasses have higher contents of fibrous cell wall components, and digest more slowly, than the leaves of

woody and herbaceous dicots. However, the leaves of woody dicots are ultimately less digestible than those of the grasses, due to a higher proportion of indigestible lignin incorporated in the cell wall.

In terms of plant parts, the proportions of foliage, stemmy material and fruits in the diet are of interest. Supporting tissues such as stems and bark tend to be high in indigestible fibre, while fruit pulp and seeds contain stores of soluble carbohydrates. Leaves contain the photosynthetic enzymes and are highest in protein and minerals, although protein content declines as leaves age and fibre contents increase.

Nutrient content is most widely expressed in terms of the crude protein (nitrogen x 6.25) concentration in the dry matter. Energy available is dependant upon the digestibility of the structural carbohydrates (cellulose and hemicellulose) forming, together with lignin, the cell walls. However, the overall dry matter digestibility tends to be closely related to the crude protein content (Owen-Smith 1982).

According to Owen-Smith and Cooper (1988), nutritional balance depends most directly on the rate of food ingestion and on the nutritional value of the ingested material. Defecation rates an indication of food passage rates, and indirectly, of daily food intake (allowing for digestibility).

Bell (1971) noted that the turnover rate of rumen contents decreases with increasing fibre content of the diet. This is due to the fact that particles have to reach a certain degree of comminution before they can pass out of the ruminoreticulum through the narrow passage connecting it to the rest of the gut. According to him, this restriction does not apply to non-ruminants like zebras, which hence show a faster passage rate of material through the gut than ruminants. Thus a non-ruminant should be able to tolerate a diet of higher fibre content, and thus lower nutritional quality, than a ruminant of similar body size.

Bell (1971) also noted that digestive efficiency is influenced by passage rate. Material that passes through the fermentation chamber faster is fermented less

completely than material that is retained for longer. Thus, according to him, non-ruminants like zebras show a lower digestive efficiency, in terms of cell wall breakdown, that ruminants. Bell (1971) therefore suggests that in compensation the more rapid rate of food passage allow non-ruminants to eat more food per day than ruminants. He also noted further that on high fibre diet non-ruminants might assimilate more nutrients per unit time than ruminants, despite the superiority of the latter in extent of digestion.

This hypothesis will be tested as one of the study's objectives which is to determine the seasonal nutritive requirements of the zebra (non-ruminant) and the blue wildebeest (ruminant) in terms of quality and quantity. At the same time a comparison will be drawn between the two species.

4.2 MATERIAL AND METHODS

4.2.1 Study period

The animals were tamed beforehand and measurement and handling procedures established. It was necessary to determine the relationship between the *in vitro* digestibility and the *in vivo* digestibility of the forage for zebra and the blue wildebeest. Furthermore, a relationship had to be developed between the *in vivo* digestibility of the organic matter (DOM) utilized by the blue wildebeest (ruminant) and the *in vivo* digestibility of the organic matter (DOM) utilized by the zebras (non-ruminant) to enable calculation of intake (Section 4.2.2).

The field study was conducted from February 1993 to February 1994. For the purpose of the field study six test animals (three zebra and three blue wildebeest) were kept separately in 3 m high enclosures of shadecloth, reinforced with angle iron gates (bomas). Each boma covered an area of approximately 128 m^2. Because it was a relative dry year, the study period was not divided into seasons but taken over

a 12 month period. Monthly differences in the quantity and quality of the forage selected by the zebras and the blue wildebeest were determined as well as monthly differences in the intake and digestibility of the forage.

4.2.2 In vitro/In vivo regressions

According to Alexander and McGowan (1961), Tilley and Terry (1963), Engels and Van der Merwe (1967), Raymond (1969) and Engels, Baard and Malan (1974) there is a close relationship between the *in vitro* (IVDOM) and *in vivo* digestibility of forage organic matter. The IVDOM data could therefore be used to predict the *in vivo* digestibility of the OM on condition that the forage sample is representative of the diet. As discussed under Chapter 3 (Section 3.2.2), diet preference of the zebra and the blue wildebeest was determined in order to collect hand-samples of the forage utilized.

Two important prediction equations had to be compiled before any intake data could be calculated. Firstly, the relationship between *in vitro* digestibility of organic matter (IVDOM) and the *in vivo* digestibility of forage for the blue wildebeest and the zebra was determined. Secondly, a relationship between the *in vivo* digestibility of OM for the blue wildebeest (ruminant) and for the zebra (non-ruminant) was determined.

In vivo digestibility was determined in the brick enclosures with six blue wildebeest and six zebras. Lucerne hay of different qualities and *Eragrostis* sp. hay was used to cover a wide enough spectrum of forage for the purpose of compiling a regression equation. An adaptation period of approximately 2 weeks was allowed for the animals on each type of hay before sampling. The procedure adopted for each animal species was as follows: weighing of the specific hay each day, weighing the forage that was not utilized and weighing the faeces of each animal over a 24-hour period for 1 week. If there were any signs of contamination by urine or faeces in the forage, the data for that day were omitted. The *in vivo* digestibility of the forage utilized by the zebra and the blue wildebeest was then calculated as:

i. *in vivo* digestibility (%) = [(Intake - Faeces) / Intake] x 100
All intake and faecal data were measured in kg OM per day.

The *in vitro* Digestibility of Organic Matter (IVDOM) of the same forage samples (hand collected) was simultaneously determined in the laboratory. These values were then plotted against the corresponding *in vivo* Digestibility of Organic Matter (DOM) data of the blue wildebeest to compile the following linear regression equation:

ii. *in vivo* DOM (%) = 0.627 (IVDOM %) + 21.02
r^2 = 0.94 ; Error of estimate = 2.11 %

The second phase of the study was to determine the relationship between the *in vivo* DOM for the zebra (Z) and the *in vivo* DOM for the blue wildebeest (BWB).

Due to restrictions imposed on the study by using feed of low quality and the stress induced in feeding behaviour, the data collected were considered inaccurate and therefore abandoned in favour of a general relationship between cattle and horses because: Firstly, it was taken into consideration that the digestive system of the blue wildebeest (ruminant) is closely related to that of cattle, whereas zebras (non-ruminants) are closely related to horses. Secondly, initial data obtained closely resembled the data pattern of cattle versus horses. A wide spectrum of digestibility data found in various publications [1] (Meissner, *pers. comm.*) led to the following regression equation between the *in vivo* DOM's of cattle and horses:

iii. *in vivo* DOM % (horses) = 1.28 [*in vivo* DOM % (cattle)] - 20.2
$r^2 > 0.95$

[1] Agricultural Research Council - Animal Nutrition and Animal Products Institute, Private Bag X2, Irene 0062

This equation was used to calculate the *in vivo* DOM for the zebra from the *in vivo* DOM of the blue wildebeest.

Once the *in vitro* digestibilities were calculated and the *in vivo* digestibilities estimated using the above regression equations, the organic matter intake could then be calculated by using the *in vivo* DOM percentage of the forage and the total faeces OM excreted:

$$\text{Intake of OM (kg/day)} = \frac{\text{Faeces OM (kg/day)}}{100 - \%\ \textit{in vivo}\ \text{DOM}} \times 100$$

4.2.3 Collection and preparation of faecal and grass samples

The following procedures were followed monthly before, during and after sampling periods:

i) **Week 1:** The six test animals went through an adaptation period in the bomas. During this time they only fed on natural grazing without any lucerne to supplement their diet. It is necessary for the microbes in the digestive system to adapt to the natural forage before any sampling can be conducted. This adaptation period on natural forage was also necessary before sampling was done to prevent any carry-over effect of the lucerne. At the end of this period a new group of bomas were erected and the necessary vegetation surveys within those bomas completed (before grazing)(See Section 3.2.2).

ii) **Week 2:** The test animals were now moved to the newly erected bomas, where the samples were then collected. During the monitoring period of six days, faeces were hand-collected regularly (more or less every three hours). The faeces

of both the zebras and the blue wildebeest were easy to detect in the enclosure. Therefore, hand-collected sampling was adequate.

Faeces samples were collected over a 24-hour period and weighed each morning at 08:00. A representative sample of 10% of the daily excretion of each animal was kept frozen in separate plastic bags. Daily samples were pooled for individual animals.

During this time the test animals were moved and the bomas shifted every second day to allow sufficient material for free selection. This also coincided with the accompanying vegetation surveys (before and after grazing)(Section 3.2.2).

At the end of the weekly monitoring period, the data from the vegetation surveys (Section 3.2.2) were used to determine grass species composition available to each animal and also the average utilization of the dominant grass species by each animal over that period (Table 5). This information was then used to collect hand samples, representative of the diet. These samples were used to determine the following:

- Diet preference of zebra and blue wildebeest (alkane marker technique, microhistological technique)
- Quantity and quality of forage selected by zebra and blue wildebeest

Part of the pooled faeces sample for each animal and the forage collected were dried at 60°C, ground in a Tecator mill fitted with a 1 mm sieve and stored in sealed containers. These samples were then used for laboratory analyses to determine diet preference of zebra and blue wildebeest (alkane marker technique) and quantity and quality of forage selected by zebra and blue wildebeest.

For the quantitative identification of foodplants in the faeces (microhistological technique), another part of the pooled faeces was kept in formalin acetic alcohol (FAA) for further analysis.

iii) **Week 3 and 4**: The test animals were kept in the bomas on natural forage, but their diet was supplemented with good quality lucerne to ensure that enough nutritional material for intake was available. No fieldwork sampling was done during this time.

The samples and information collected during Week 2 were analysed. Part of the sample analysis was done in the laboratory as well as *in vitro* digestibility of the forage samples selected by individual animal species for that month. The necessary calculations were made and results recorded.

4.2.4 Diet preference

4.2.4.1 N-alkane marker technique

Alkane profiles were determined for the different forage components of the forage samples selected by each individual animal (zebra and blue wildebeest). Alkane profiles were also determined for the dried faeces samples of each individual animal. According to the technique described by Dove and Mayes (1991) and Meyer *et al.* (1996), a data set on dietary selection can be generated. Dietary selection per animal can then be calculated using the total alkane profile (C25 to C35) of all the forage components and the specific faeces profiles. The calculations were done on a computer.

4.2.4.1 Microhistological technique

Successful application of this technique requires a thorough anatomical-taxonomic study of the dominant plants (grass species) in the research area.

Representative samples of the 10 dominant grass species (Table 1) in the research camp were collected and stored in formalin acetic acid (FAA). The epidermis of

each sample was removed and used in the preparation of a reference collection of slides, descriptions and microphotographs as described in Potgieter (1991).

The preserved faeces samples collected on a monthly basis for each individual animal (Section 4.2.3), were used to determine the botanical composition of the forage selected by that animal species.

The following procedures were followed as described by Potgieter (1991).

- The preserved sample was rinsed over a fine strainer while stirred carefully with a glass rod. Once refined, the sample was removed and coloured with methylene blue.
- Sub-samples were spread evenly on 10 microscopic slides and temporarily mounted in glycerol.
- Prepared slides were viewed under a microscope at a magnification of x 100.
- A mechanised guide was used to move the slide and thus avoid duplication.
- Taxonomical characteristics of the different grass species were used in the identification of fragments. Fragments were categorized as follows:

    1. Fragments that cannot be identified as plant material.
    2. Fragments that can be identified as plant material but without any positive species identification.
    3. Plant material fragments where the grass species can be positively identified.

- About 100 identifiable grass fragments were needed for each sample.

The data were then used to note the relative abundance of each grass species in the relevant sample. The percentage relative density of each grass species in the sample was then calculated through a formula described by Fracker and Brischle (1944), as cited by Potgieter(1991).

4.2.5 Quality and Quantity Parameters

Forage and faeces samples collected on a monthly basis (as described in Section 4.2.3) were analysed to determine chemical composition. The digestibility of the forage selected by the zebra and blue wildebeest was also determined. All samples were analysed in triplicate for each parameter.

The parameters under discussion were the following:

In vitro digestibility of organic matter (IVOM) of forage selected by the zebra and the blue wildebeest
In vivo digestibility of organic matter (DOM) (calculated)
Dry matter (DM) intake (calculated)
Crude protein (CP)
Phosphorous (P) content
Neutral detergent fibre (NDF)
Acid detergent fibre (ADF)
Acid detergent lignin (ADL)
Hemicellulose (calculated)
Cellulose (calculated)
Digestibility (calculated) of:
Neutral detergent fibre (NDF)
Acid detergent fibre (ADF)
Hemicellulose
Cellulose

4.2.6 Analytical methods

4.2.6.1 Dry matter (DM), organic matter (OM) and ash determination.

Dry matter content was determined by accurately weighing off a sample, drying it at 60°C to constant weight and weighing it again. Subsequent to the DM analysis,

samples were then incinerated at 600°C for four hours after which ash percentage was calculated. Organic matter was calculated by subtraction of ash from dry matter. These procedures are described in the publication of the Association of Analytical Chemists (AOAC 1984).

4.2.6.2 Digestibility

Digestibility of the hand-sampled dietary OM was determined with the *in vitro* fermentation technique of Tilley and Terry (1963) as modified with respect to N addition (Engels & Van der Merwe 1967). Inoculum was obtained from ruminally fistulated domestic ('boer') goats kept on good quality lucerne hay. Once the *in vitro* digestibilities were calculated, the *in vivo* digestibilities were estimated using the regression equations, as discussed in Section 4.2.2.

4.2.6.3 OM Intake

Organic matter intake could be calculated using the estimated *in vivo* DOM percentage of the forage and the total faeces OM excreted:

$$\text{Intake of OM (kg/day)} = \frac{\text{Faeces OM (kg/day)}}{100 - \textit{in vivo}\ \text{DOM}} \times 100$$

By adding the forage ash content, DM intake could be calculated.

4.2.6.4 Crude protein content

The N content of forage and faeces samples was determine, using the macro-kjeldahl method (AOAC 1984). Once this was determined, crude protein (CP) was calculated as:

$$CP = \%\ N \times 6.25$$

Protein percentage was expressed on dry matter (DM) basis.

4.2.6.5 Phosphorous content

Exactly 1.5 g sample was used and digested using wet digestion according to Heckman (1968). The sample was then accurately diluted with distilled water to 250 ml and read against the following standards: 10, 30, 50, 80 and 100 mg/l P in a Technikon Auto Analizer II, industrial method number 334/74 w/d (March 1977). Phosphorous was expressed on a dry matter basis.

4.2.6.6 Cell wall constituents (cellulose, hemicellulose and lignin)

The cell wall constituents of forage and faeces samples were determined according to the methods described by Van Soest and Wine (1967). Cell solubles were extracted by neutral detergent solution. The residue approximates the cell wall and is known as neutral detergent fibre (NDF). The next step comprised the extraction of the more soluble cell wall or hemicellulose. This was done with an acid detergent solution. The residue called acid detergent fibre (ADF) consists mainly of cellulose, cutin and lignin. After exposure to 72% H_2SO_4 the residue is acid detergent lignin (ADL). The following components can then be calculated:

$$\%\text{Hemicellulose} = \%\text{NDF} - \%\text{ADF}$$

%Cellulose = %ADF - %ADL

4.2.6.7 Digestibility (D) of cell wall constituents

Knowledge of the percentage cell wall constituents in the forage and faeces was used to indirectly calculate the amount of cell wall constituents consumed and excreted. This information enabled calculation of the approximate digestibilities of these constituents.

4.3 STATISTICAL ANALYSIS

A two-way analysis of variance procedure of the linear models programme (Anova) of SAS (Statistical Analizing System)(1990) was used to determine the significance of quantity, quality and digestibility differences of forage. The significance of the monthly differences and overall difference in intake and quality selected by the zebra and the blue wildebeest were also determined. Significant differences were accepted at a probability level of 5%. Means and standard deviations of the means were calculated. The level of significance was corroborated with *post hoc* range tests. Here the Tukey test was the most prominent.

4.4 RESULTS

4.4.1 Diet preference

The N-alkane marker technique was discarded after the first trial run when poor results were obtained. During the same time a project was done by Meyer, Geerthsen and Homan (1996) to determine the evaluation of N-alkanes as a marker for determination of amongst other, diet selection. The outcome of their studies

(Discussion, Section 4.4.3), could possibly explain the poor results obtained in the present study.

The results from the microhistological technique (faecal analysis) were also unsuccessful in the determination of diet preference. Plant material was digested to such an extent that only a few and very small fragments were still intact. This made positive identification of grass species very difficult. Only 10% of the samples could be identified positively. These data were therefore not representative of the analysis and discarded accordingly.

4.4.2 Quantity and quality parameters

There were no significant animal/month interactions, consequently all observations were processed irrespective of individual animals. The monthly differences in quality of forage selected by the zebras and the blue wildebeest as well as the digestibility of the cell wall constituents of the forage were determined (Table 7 and 8). The monthly differences in the digestibility of forage utilized by zebras and blue wildebeest as well as the forage available and the accompanying intake of forage by the zebra and the blue wildebeest were also determined. These results are depicted in Tables 9 and 10.

During sampling periods, both zebras and blue wildebeest had the same quality of forage available. The results in Table 7 show that the means of the quality of food selected by the two species did not differ significantly. For example, the average difference between the forage selected by zebras and blue wildebeest was 0.87% for crude protein (CP), 6.5% for phosphorous, 0.21% for acid detergent fibre (ADF), 0.27% for neutral detergent fibre (NDF) and 1.6% for acid detergent lignin.

The crude protein of the forage selected by the animals varied between 2.93% and 7.01% for zebras and 2.70% and 7.70% for blue wildebeest (Table 7). Although, in general, it was a dry year, the CP content was significantly higher in the wet season

when there was more regrowth available than during the drier months between May and November. The average of 4.61% for the zebras and 4.57% for the blue wildebeest, however, is not significantly different (Figure 10).

The phosphorous content of forage selected by the zebra varied between 0.0520% and 0.2177% and for the blue wildebeest between 0.0150% and 0.1970% (Table 7). Although monthly differences occurred, there was no significant difference between the mean percentage of 0.1034 for the zebra and 0.0967 for the blue wildebeest (Figure 11).

Table 7 Monthly differences in the quality of forage selected by the zebra and the blue wildebeest at Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994. All the parameters are expressed in percentage dry matter.

	Zebra					Blue wildebeest				
Month	Protein	P	ADF	NDF	ADL	Protein	P	ADF	NDF	ADL
Feb	7.01^{a}	0.1583^{b}	47.2^{bcd}	74.8^{ab}	6.13^{d}	7.03^{ab}	0.1430^{bc}	42.1^{ef}	72.7^{bc}	5.96^{e}
Mar	6.03^{ab}	0.1227^{bcd}	35.6^{f}	67.9^{d}	6.01^{d}	4.66^{cd}	0.1033^{de}	38.8^{f}	70.5^{c}	6.25^{de}
May	4.56^{cd}	0.2177^{a}	46.6^{cde}	73.6^{abc}	7.85^{c}	4.85^{cd}	0.1970^{a}	48.7^{bcd}	74.1^{abc}	8.11^{cd}
Jun	2.93^{e}	0.0683^{ef}	46.8^{bcde}	74.6^{ab}	7.16^{cd}	2.70^{e}	0.0593^{f}	48.3^{bcd}	75.5^{ab}	7.47^{cde}
Jul	3.08^{e}	0.0670^{ef}	50.2^{abc}	76.5^{a}	8.52^{bc}	2.71^{e}	0.0607^{f}	50.7^{ab}	77.7^{a}	8.15^{cd}
Aug	3.10^{e}	0.0847^{def}	45.1^{de}	73.8^{ab}	8.28^{c}	2.86^{e}	0.0653^{def}	45.0^{de}	73.7^{abc}	9.19^{bc}
Sep	3.17^{e}	0.1350^{bc}	51.1^{ab}	73.9^{ab}	9.66^{ab}	3.45^{de}	0.1433^{b}	49.9^{abc}	72.4^{bc}	9.31^{bc}
Oct.	3.44^{de}	0.0613^{ef}	54.4^{a}	75.6^{a}	11.0^{a}	3.40^{de}	0.0647^{ef}	53.7^{a}	73.7^{abc}	10.3^{ab}
Nov	3.93^{de}	0.0520^{f}	54.5^{a}	75.2^{ab}	11.0^{a}	3.55^{de}	0.0510^{f}	53.6^{0a}	74.7^{abc}	11.5^{a}
Dec	6.88^{a}	0.0893^{def}	45.5^{de}	69.5^{cd}	7.37^{cd}	6.36^{ab}	0.0873^{def}	46.2^{cde}	72.4^{bc}	7.60^{cde}
Jan	5.72^{abc}	0.1010^{cde}	42.8^{e}	71.3^{bcd}	6.36^{d}	7.70^{a}	0.1040^{de}	42.8^{ef}	71.8^{bc}	6.97^{de}
Feb	5.48^{bc}	0.0833^{def}	43.0^{de}	72.9^{abc}	7.28^{cd}	5.60^{bc}	0.0820^{def}	44.4^{de}	073.4^{bc}	7.27^{cde}
Mean	**4.61^{1}**	**0.1034^{1}**	**46.9^{1}**	**73.3^{1}**	**8.04^{1}**	**4.57^{1}**	**0.0967^{1}**	**47.0^{1}**	**73.5^{1}**	**8.17^{1}**
SD	**0.379**	**0.0106**	**1.40**	**1.21**	**0.442**	**0.397**	**0.0082**	**1.29**	**1.37**	**0.622**

abcdef - Means with the same letters in the same column are not significantly different ($p<0.05$)

1,2 - Means of parameters between zebra and blue wildebeest (BWB) with the same numbers are not significantly different ($p<0.05$)

SD - Standard Deviation (Mean SD over the months)

ADF - Acid detergent fibre

NDF - Neutral detergent fibre

ADL - Acid detergent lignin

Table 8 Monthly differences in digestibility of cell wall constituents of forage selected by the zebra and the blue wildebeest at Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994. All parameters are expressed in percentage digestibility of dry matter.

	Zebra				Blue wildebeest			
Month	ADF	NDF	Hemi-cellulose	Cellulose	ADF	NDF	Hemi-cellulose	Cellulose
Feb	42.35^{ab}	46.96^{a}	54.60^{a}	54.95^{a}	49.76^{abc}	57.95^{a}	69.00^{a}	62.13^{ab}
Mar	38.26^{bc}	43.77^{ab}	49.78^{a}	46.20^{abcd}	45.85^{abcd}	50.86^{bc}	56.97^{ab}	62.41^{ab}
May	29.61^{defg}	34.97^{bcd}	44.21^{ab}	38.43^{cdef}	38.93^{cd}	43.95^{d}	53.09^{abc}	52.93^{bc}
Jun	33.53^{cde}	35.80^{bcd}	39.60^{ab}	39.54^{cdef}	42.94^{bcd}	46.58^{bcd}	53.00^{abc}	54.22^{abc}
Jul	36.63^{bcd}	36.50^{bcd}	36.23^{ab}	47.95^{abc}	41.61^{bcd}	48.15^{bcd}	60.79^{ab}	50.46^{bc}
Aug	24.29^{fg}	30.25^{d}	39.60^{ab}	32.95^{f}	37.65^{d}	42.69^{d}	50.57^{bc}	49.51^{c}
Sep	30.66^{cdefg}	36.95^{bcd}	50.91^{a}	36.83^{def}	42.78^{bcd}	48.78^{bcd}	61.88^{ab}	52.80^{bc}
Oct	27.89^{efg}	31.72^{cd}	41.24^{ab}	34.91^{ef}	43.55^{bcd}	45.27^{cd}	49.78^{bc}	53.70^{bc}
Nov	32.10^{cdef}	31.00^{d}	27.92^{b}	43.81^{bcde}	46.86^{abcd}	44.21^{d}	37.35^{c}	59.92^{abc}
Dec	23.16^{g}	33.65^{cd}	53.37^{a}	36.31^{def}	38.41^{d}	44.31^{d}	54.52^{ab}	52.29^{bc}
Jan	47.37^{a}	49.68^{a}	53.15^{a}	56.16^{a}	54.68^{a}	58.35^{a}	63.76^{ab}	66.46^{a}
Feb	41.88^{ab}	40.83^{abc}	39.20^{ab}	51.00^{ab}	51.41^{ab}	52.72^{ab}	54.62^{ab}	62.54^{ab}
SD	**2.252**	**2.791**	**5.052**	**3.277**	**3.013**	**1.989**	**4.563**	**3.141**
Mean	**33.98^{1}**	**37.67^{1}**	**44.15^{1}**	**43.25^{1}**	**44.54^{2}**	**48.65^{2}**	**55.44^{2}**	**56.61^{2}**

abcdef - Means with the **same** letters in the same column are **not** significantly different
1,2 - Means of parameters between the zebra and the blue wildebeest with **different** numbers **are** significantly different ($p<0.05$)
SD - Standard Deviation (Aver. SD over the months)

Table 9 Monthly differences in the digestibility of forage utilized by the zebra and the blue wildebeest at Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994. All the parameters are expressed in percentage digestibility of organic matter.

	Zebra		Blue wildebeest	
Month	Estimated *in vivo*	*in vitro*	estimated *in vivo*	*in vitro*
Feb	50.7^{ab}	54.77^{ab}	57.93^{a}	58.83^{ab}
Mar	49.2^{ab}	52.98^{ab}	49.20^{bc}	44.15^{c}
May	38.3^{de}	39.36^{de}	43.24^{de}	35.41^{de}
Jun	39.40^{de}	40.72^{de}	45.10^{cde}	38.39^{cde}
Jul	38.7^{de}	39.85^{de}	45.13^{cde}	38.44^{cd}
Aug	34.1^{e}	34.11^{e}	40.40^{e}	30.89^{e}
Sep	41.3^{cd}	43.08^{cd}	46.77^{cd}	41.04^{cd}
Oct	36.4^{de}	36.94^{de}	45.29^{cde}	42.12^{cd}
Nov	34.8^{e}	34.88^{e}	44.18^{cde}	36.92^{cde}
Dec	41.6^{cd}	43.45^{cd}	45.65^{cde}	39.26^{cd}
Jan	54.8^{a}	59.85^{a}	58.63^{a}	59.95^{a}
Feb	46.7^{bc}	49.79^{bc}	53.48^{ab}	51.75^{b}
Mean	**42.2^{1}**	**44.15^{1}**	**47.92^{2}**	**43.10^{1}**
SD	**1.878**	**2.354**	**1.559**	**2.184**

abcdef - Means with the **same** letters in the **same** column are **not** significantly different
1,2 - Means of parameters between zebra and blue wildebeest (BWB) with the **same** numbers are not significantly different ($p<0.05$)
SD - Standard Deviation (Aver. SD over the months)

Table 10 Mean amount of forage available for each monthly study period (6 days) per boma (2 days of grazing) for the zebra and the blue wildebeest and their respective forage intake at the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994 (Components are given as % of dry matter)

	Zebra			Blue wildebeest		
Month	Forage available kg/128 m^2	Intake		Forage available kg/128m^2	Intake	
		% of body weight	g/ kg.$W^{0.75}$		% of body weight	g/ kg.$W^{0.75}$
Feb.	36.7^{def}	2.91^{ab}	107^{abcd}	44.4^{bcd}	1.65^{a}	55.4^{a}
March	72.3^{a}	2.75^{ab}	104^{abcd}	46.0^{abcd}	1.79^{a}	60.9^{a}
May	36.2^{ef}	2.48^{ab}	94.1^{abcd}	42.2^{bcde}	1.81^{a}	61.8^{a}
June	51.5^{bcd}	3.28^{a}	126^{a}	48.4^{abc}	1.87^{a}	64.7^{a}
July	54.5^{bc}	3.00^{ab}	115^{abc}	56.9^{ab}	2.14^{a}	74.2^{a}
Aug.	51.0^{bcde}	2.53^{ab}	99.4^{abcd}	57.1^{ab}	1.72^{a}	60.9^{a}
Sept.	65.7^{ab}	2.89^{ab}	113^{abc}	63.2^{a}	1.73^{a}	61.4^{a}
Oct.	46.8^{cde}	2.04^{ab}	80.9^{bcd}	42.4^{bcde}	1.70^{a}	61.2^{a}
Nov.	40.3^{cdef}	1.90^{b}	75.3^{cd}	38.1^{cde}	1.59^{a}	57.0^{a}
Dec.	40.7^{cdef}	1.73^{b}	69.2^{d}	27.8^{de}	1.50^{a}	54.9^{a}
Jan.	50.1^{cde}	2.99^{ab}	120^{ab}	54.9^{abc}	2.05^{a}	74.9^{a}
Feb.	29.5^{f}	2.44^{ab}	97.8^{abcd}	24.2^{e}	2.04^{a}	74.3^{a}
Mean	**47.9^{1}**	**2.58^{1}**	**100^{1}**	**45.5^{1}**	**1.80^{2}**	**63.5^{2}**
SD	**4.89**	**0.396**	**12.11**	**5.57**	**0.192**	**6.07**

abcdef - Means with the same letters in the same column are not significantly different
1,2 - Means of parameters between zebra and blue wildebeest (bwb) with the same numbers are not significantly different ($p<0.05$)
SD - Standard Deviation (Aver. SD over the months)

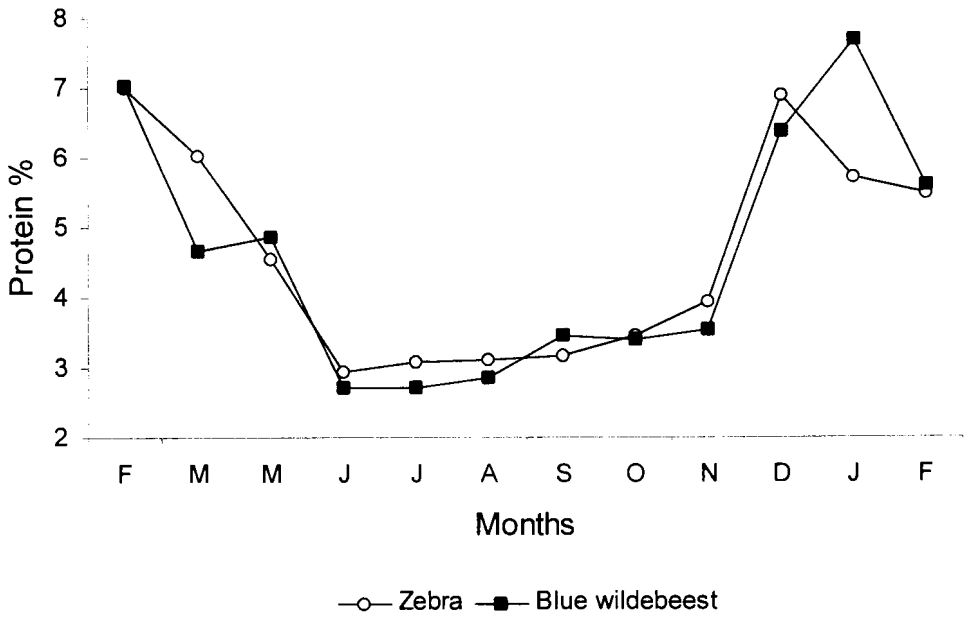

Figure 10 Monthly differences in the protein percentage of the forage selected by the zebras and the blue wildebeest on the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

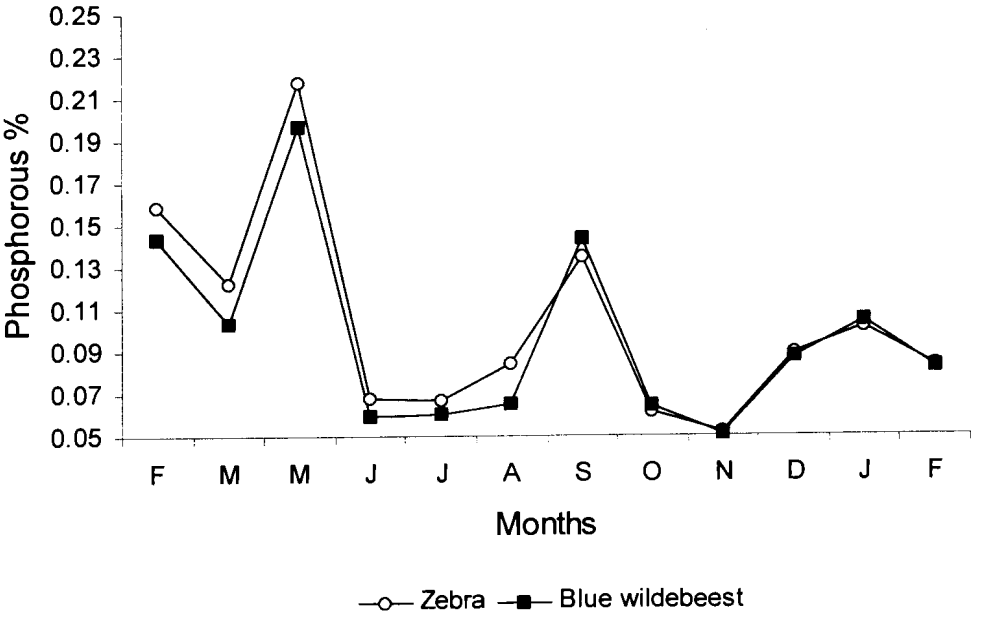

Figure 11 Monthly differences in the phosphorous percentage of the forage utilized by the zebra and the blue wildebeest at the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

The cell wall constituents ADF (Figure 12), NDF (Figure 13) and ADL (Figure 14), can also be used as an indicator of the change in quality of forage over the months and at the same time the influence it exerts on the digestibility of the forage (Figure 15). During the dry months there was a sharp increase in ADF, NDF and ADL in the forage utilized by both zebras and blue wildebeest. The highest ADL, the most indigestible cell wall constituent recorded, was 11.0% for zebras and 11.5 for blue wildebeest. This was recorded in October and November with accompanying low IVDOM of 34.9% for zebras and 36.9% for blue wildebeest (Figure 15). The mean ADF (46.9% for zebra and 47.0% for blue wildebeest), NDF (73.3% for zebra and 73.5% for blue wildebeest) and ADL percentage (8.04 for zebra and 8.17 for blue wildebeest) of the forage utilized by the zebra and the blue wildebeest are not significantly different. This is further proof that the two animal species utilized the same quality forage.

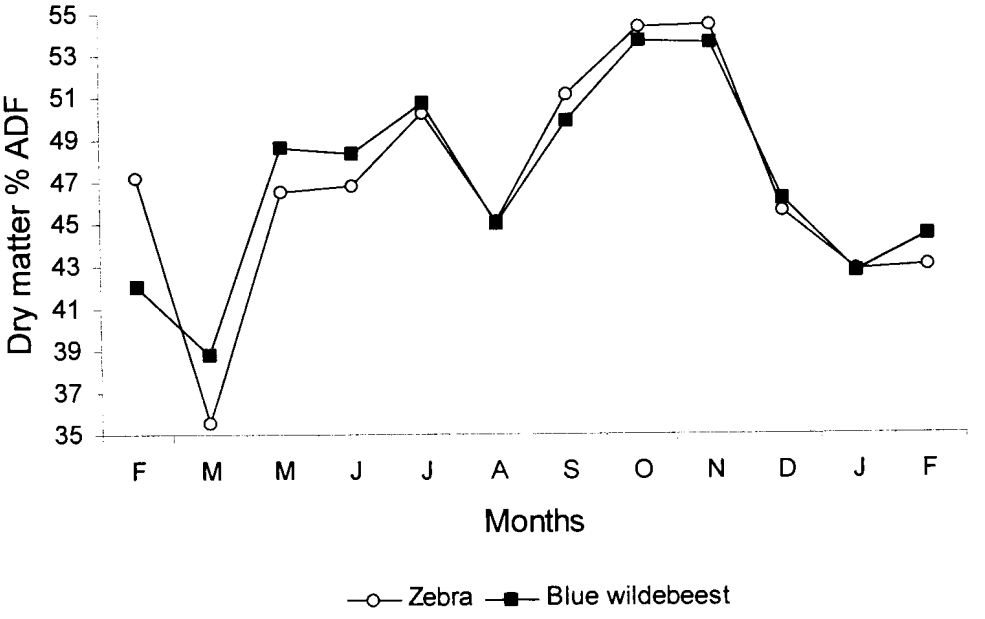

Figure 12 Monthly differences in the acid detergent fibre (ADF) percentage of the forage utilized by the zebras and the blue wildebeest on the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

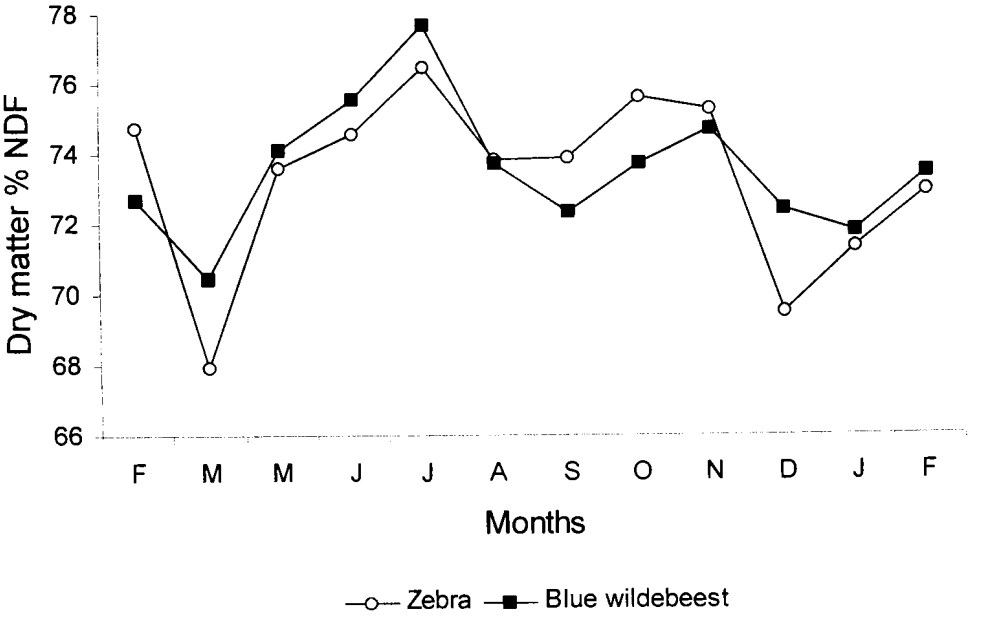

Figure 13 Monthly differences in the neutral detergent fibre (NDF) percentage of the forage utilized by the zebras and the blue wildebeest on the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

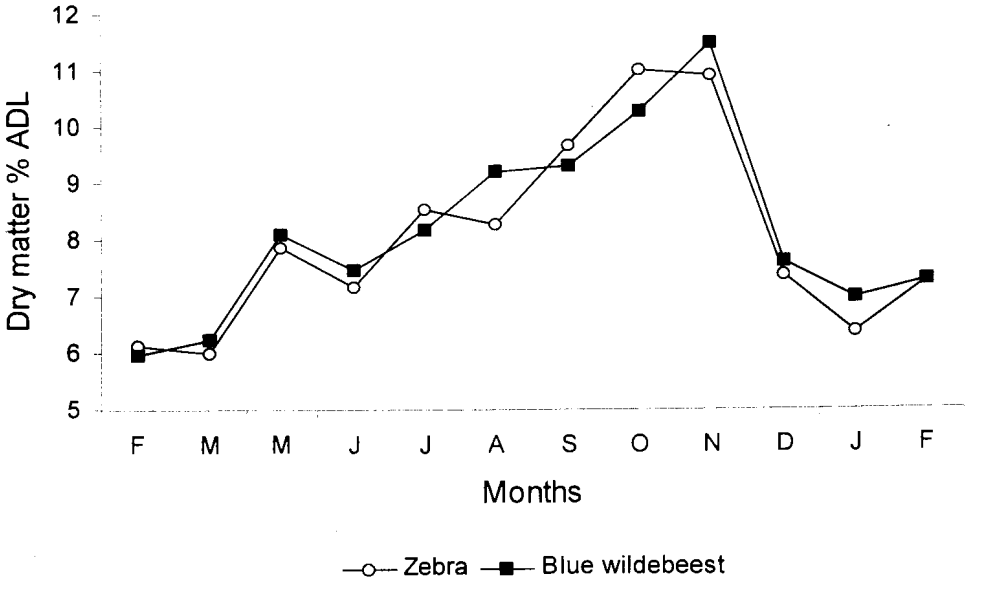

Figure 14 Monthly differences in the acid detergent lignin (ADL) percentage of the forage utilized by the zebras and the blue wildebeest at the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

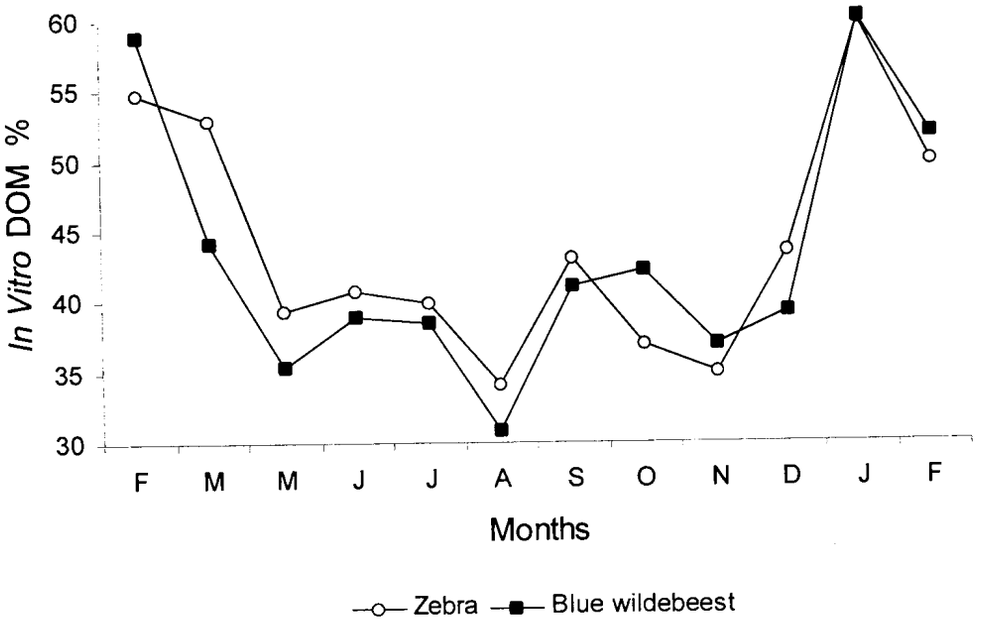

Figure 15 Monthly differences in the digestibility (*in vitro*) percentage of the forage utilized by the zebra and the blue wildebeest on the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

According to Owen-Smith (1982), energy available is dependent upon the digestibility of the structural carbohydrates (cellulose, hemicellulose) forming, together with lignin, the cell walls. The percentage digestibility of cellulose and hemicellulose of the forage utilized by the zebra and the blue wildebeest is thus also an indicator of the animals' ability to attain energy from forage utilized. As seen in Table 8 there is a significant difference between the mean hemicellulose percentage digestibility of forage utilized by the zebra (44.15%) and the blue wildebeest (55.44%) as well as the cellulose percentage digestibility of 43.25% for the zebra and 56.61% for the blue wildebeest. This can also be seen in Figures 16 and 17. There was also a 23.7% difference in ADF digestibility and a 22.6% difference in NDF digestibility of forage utilized by the zebra and the blue wildebeest. The grass species with the highest digestibility (IVDOM %) were *Urochloa mosambicensis* and *Panicum maximum* with an average of 50.7% and 49.0% respectively.

The mean *in vitro* digestibility of organic matter (IVDOM %) of forage utilized by zebra and blue wildebeest did not differ significantly between the species (44.2% and 43.1% respectively). Despite this, the zebras' estimated *in vivo* DOM percentage (mean 42.2%) was significantly lower than that of the blue wildebeest (mean 47.9%)(Table 9, Figures 15 & 18). The zebra, however compensated for the lower digestibility by a higher forage intake (Figures 19 & 21) compared to the blue wildebeest, although it is recognized that forage intake might have been the driving force for the volume of food eaten.

Monthly dry matter intake (kg) as calculated through the plant-based technique, was compared with the monthly dry matter intake as calculated through the animal-based technique (Table 10). An attempt was made to substantiate the animal-based results through the results obtained from the plant-based. Although the regression equation was significant ($p<0.01$) with a R^2 value of 0.48 (Figure 22), the relationship is inadequate to be used. Only 48% of the variation in Y is explained by the variation in X. With the data available, one therefore had to conclude that intake calculated through the plant-based technique could not be predicted reliably by intake calculated through the animal based technique.

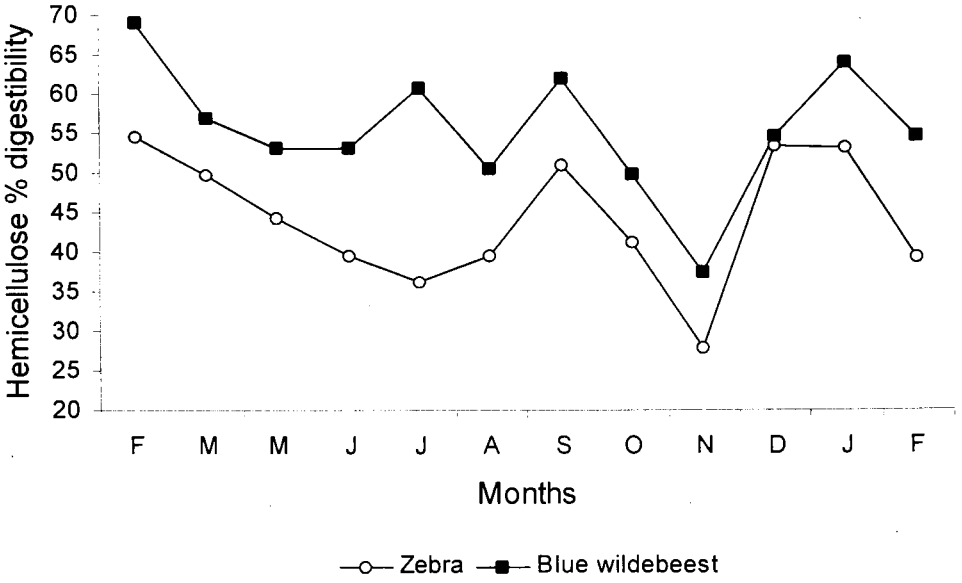

Figure 16 Monthly differences in the hemicellulose percentage digestibility of the forage utilized by the zebra and the blue wildebeest on the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

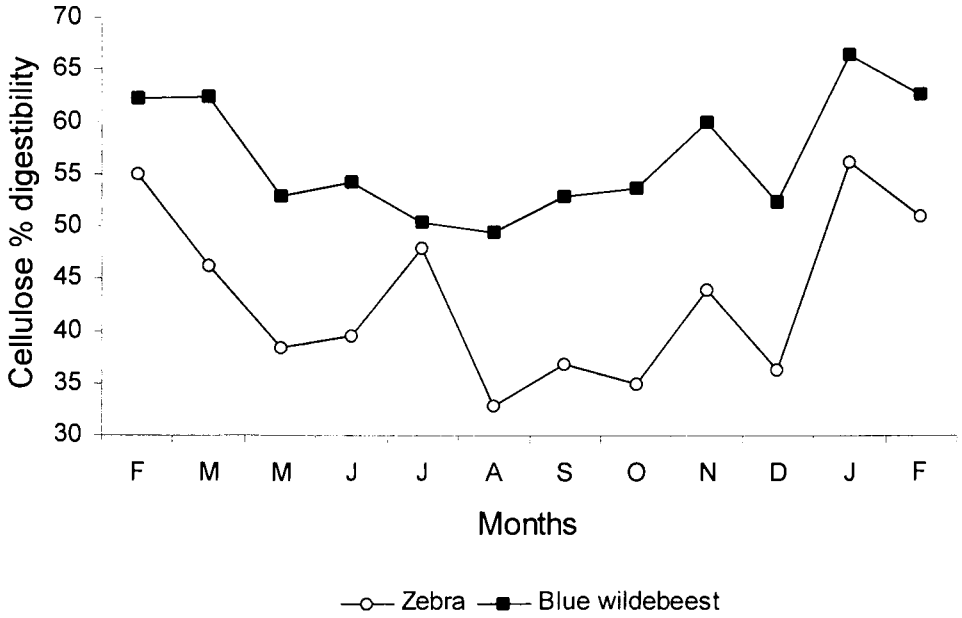

Figure 17 Monthly differences in the cellulose percentage digestibility of the forage utilized by the zebra and the blue wildebeest on the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

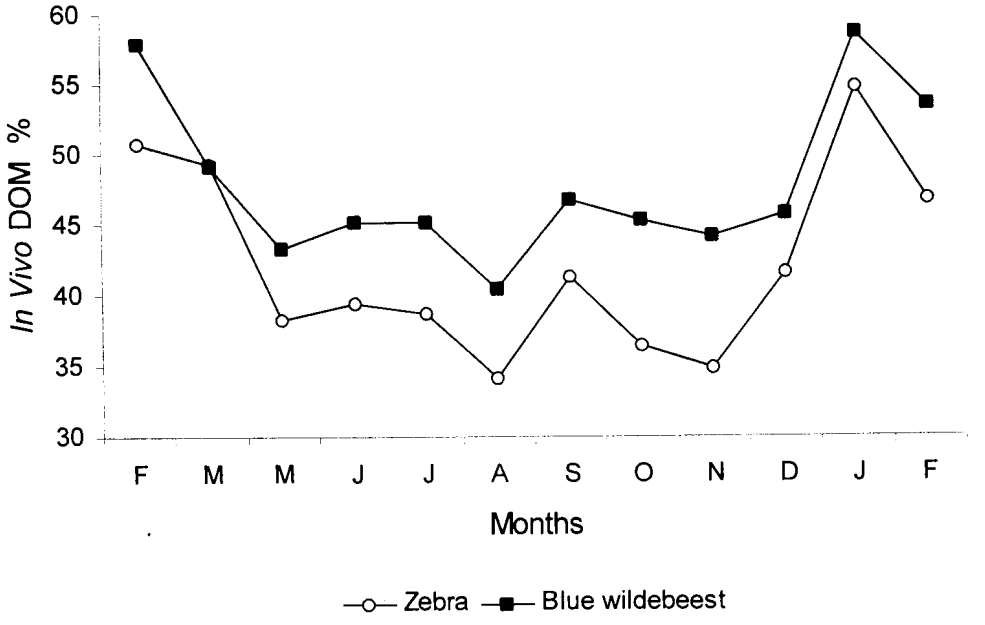

Figure 18 Monthly differences in the digestibility (*in vivo*) of the dry organic matter of the forage utilized by the zebra and the blue wildebeest at the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

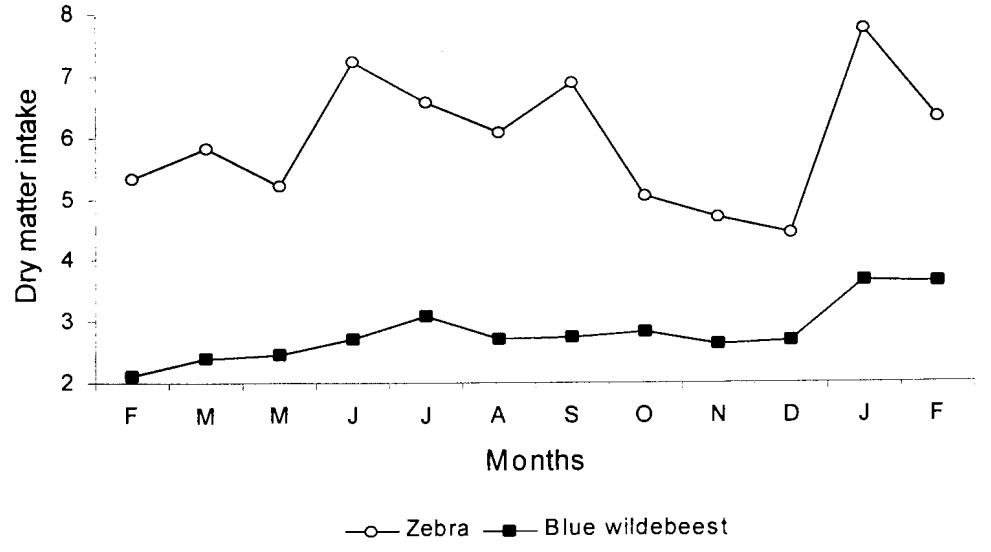

Figure 19 Monthly differences in the dry matter intake (kg) of the forage utilized by the zebra and the blue wildebeest at the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

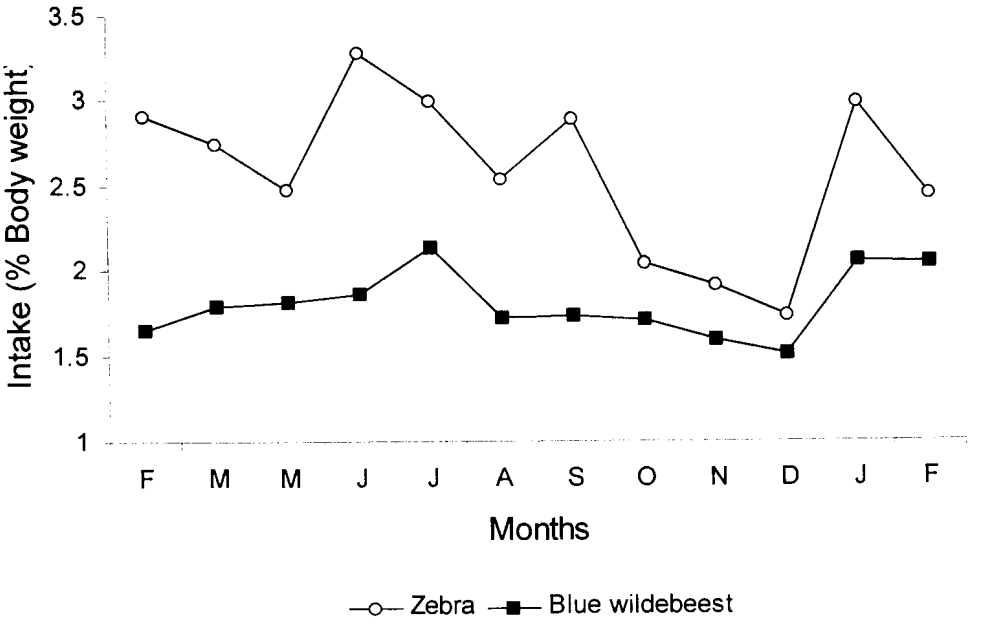

Figure 20 Monthly differences in the dry matter intake (expressed as % of bodyweight) of the forage utilized by the zebra and the blue wildebeest at the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

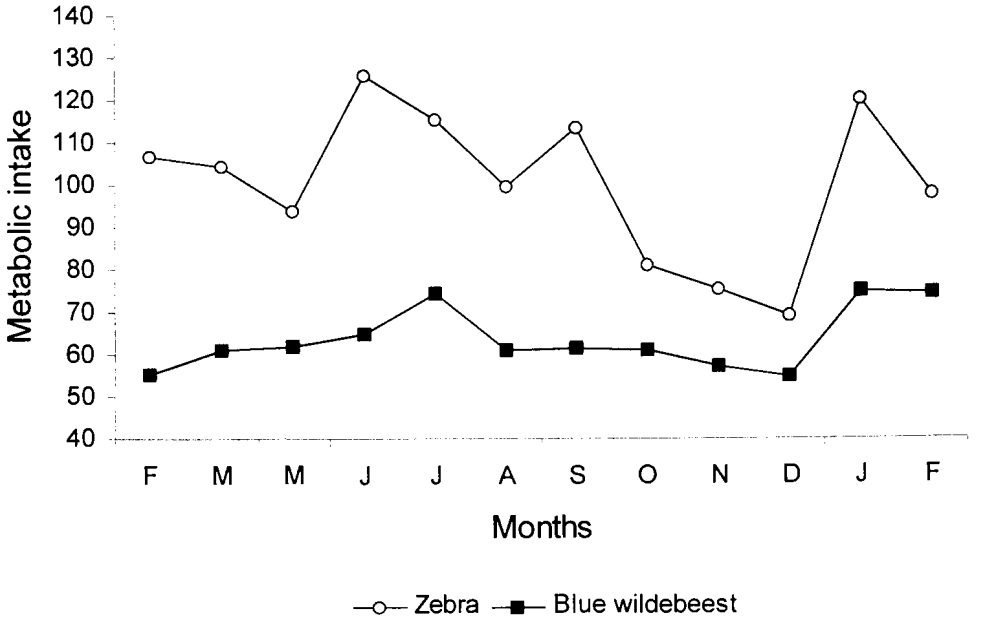

Figure 21 Monthly differences in the dry matter intake (expressed as metabolic weight, g/kg.$W^{0.75}$) of the forage utilized by the zebra and the blue wildebeest at the Hans Hoheisen Research Station in the Northern Province Lowveld from February 1993 to February 1994.

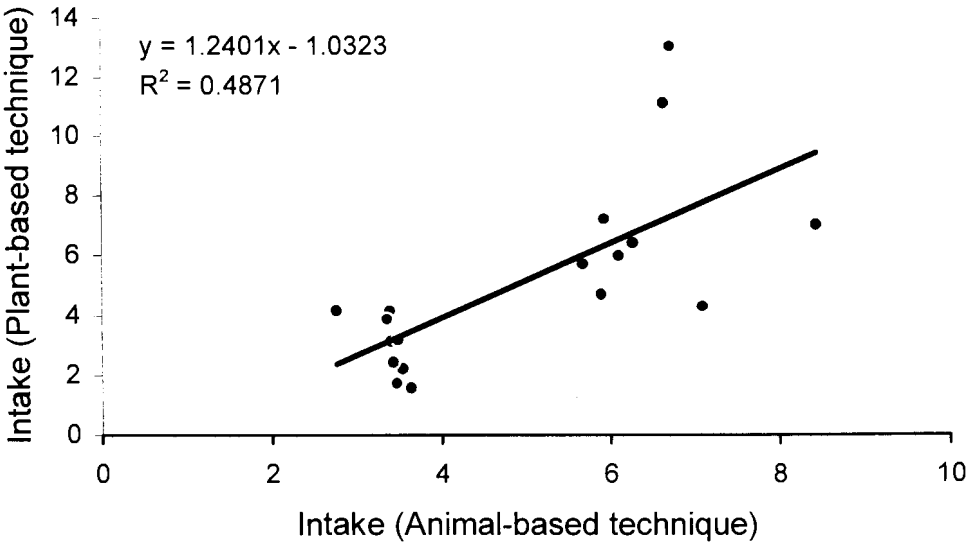

Figure 22 The regression equation was determined to draw a comparison between the dry matter intake (kg) of forage utilized by the zebra and the blue wildebeest calculated through a plant-based technique and the dry matter intake (kg) calculated through an animal-based technique over a three month period at the Hans Hoheisen Research Station in the Northern Province Lowveld.

Table 11 A comparison between intake of forage (dry matter bases) utilized by the zebra and the blue wildebeest, calculated through an animal-based and a plant-based technique over three months in the Northern Province Lowveld.

Month	Animal species	Animal-based intake (kg)	Plant-based daily intake (kg)
Feb 1993	Zebra 1	4.849	7.211
	Zebra 3	5.546	11.11
	Zebra 5	5.627	13.01
	BWB 1	2.322	3.154
	BWB 2	2.305	4.157
	BWB 3	1.675	4.183
Mar 1993	Zebra 1	5.213	6.414
	Zebra 3	7.392	7.019
	Zebra 5	4.852	4.721
	BWB 1	2.311	3.863
	BWB 2	2.490	2.239
	BWB 3	2.437	3.170
May 1993	Zebra 1	4.595	5.707
	Zebra 3	6.019	4.303
	Zebra 5	5.022	5.982
	BWB 1	2.361	2.448
	BWB 2	2.575	1.593
	BWB 3	2.401	1.746

$p < 0.01$
$R^2 = 0.4826$

4.4.3 Discussion

The effort to determine diet preference of the zebra and the blue wildebeest through N-alkane marker and microhistological techniques, were in both cases unsuccessful.

Meyer *et al.* (1996) evaluated N-alkanes as a marker for determination of amongst other, diet selection. Data generated in that study clearly indicated that the accuracy of the technique decreases as the number of herbage species being grazed increases. He suggested that the limit of grass species that can be identified to be probably in the order of five. For positive results the following conditions must also be met:

1. Herbage samples must be collected during the grazing trial - preferably plant fractions that are being utilized compared to the whole plant.
2. Plants and plant parts not consumed or included in the diet must not be included with the profiles used by the computer program to generate data sets.
3. Strict control must be exercised during grazing trials - avoiding animals from consuming foreign material.

In the present study the zebra and blue wildebeest utilized more than five grass species, and this affected the accuracy of the N-alkane marker technique.

According to Langlands (1974), it is difficult to accurately reflect the consumed forage in complex pastures through hand-plucked samples. Dove and Mayes (1991) suggested that oesophagally fistulated animals must be used to collect samples of grazed herbage that is representative of the herbage selected. This would also apply for the microhistological technique.

The mean amount of forage available during each sampling per boma of 128 m^2 and the intake of forage by the zebra and the blue wildebeest are listed in Table 10. The mean material available for the zebras was 47.93 kg/128 m^2 (3.75 ton / ha) and for the blue wildebeest 45.45 kg/128 m^2 (3.55 ton / ha). This difference was not significant ($p<0.05$). During the sampling period, the lowest amount of forage available within one boma was 29.48 kg for the zebra and 24.16 kg for the blue wildebeest (Table 4). The highest daily intake for the zebra was 7.8 kg and for the blue wildebeest 3.7 kg. During sampling the animals had 2 grazing days per boma. This indicates that the lowest amount of forage material available was still more than the estimated intake of 15.6 kg for the zebra and 7.4 kg for the blue wildebeest over 2 days. Therefore, the attempt to simulate natural grazing conditions and free selection was satisfactory. It also contributed to the overall effort to reduce stress in the experimental animals.

The quality and the quantity of the forage utilized by the zebra and the blue wildebeest were determined effectively in order to draw a comparison between the two animal species over the 12 month period.

Crude protein can usually be regarded as a reliable indicator of both overall nutrient status and of palatability (Owen-Smith 19982; Owen-Smith 1988; Rodgers 1990 and Ben-Shahar & Coe 1992). Although the average CP content in the forage selected by zebra and blue wildebeest was not significantly different, there was a significant difference during March 1993 and January 1994 (Figure 10). A possible explanation during April was the higher amount of palatable forage, especially *U. mosambicensis,* available to the zebras. The *in vitro* percentage digestibility of the organic matter (IVDOM %) of the forage selected by zebra in April was also higher (Figure 15). The difference during January, however, can not be explained because the quality and quantity of forage available was about the same.

The average CP content for both zebra and blue wildebeest (4.62 and 4.57) was low in comparison with other literature that indicates a required CP content of about 9% (Louw 1969 and Rodgers 1990). This can possibly be

explained by the rainfall (496 mm) that was below the long-term mean of 645 mm (February to February), for the Kruger National Park taken over a period of 36 years for that area (Kingfisherspruit Ranger Section)(Unpublished data, Kruger National Park). There was also an abundance of moribund material because the area was not utilized (grazed on) by animals over a period of three years. A further reason as mentioned earlier is the fact that hand cut samples and not oesophageal samples were analyzed.

The ADL content in the forage selected by zebra and blue wildebeest did not differ significantly between the two species (Table7). The digestibility of cellulose and hemicellulose, however, was significantly lower for zebra (Figure 16 and 17). It can possibly be argued that this is the result of the way in which the *in vivo* DOM of the zebra was estimated, i.e. through calculation via the blue wildebeest data (see Methods). Digestibility, however, is a function of both intake and faecal excretion and the latter was collected directly and independently. Consequently cellulose and hemicellulose digestibility differences, which were substantial, probably are a true reflection of cell wall digestibility differences between the two animal species.

Bell (1971) suggested that non-ruminants like zebras show a lower digestive efficiency in terms of cell brake down those ruminants. Non-ruminants, however, compensate through a more rapid rata of food passage, which allows them to eat more food per day. On high fibre diets non-ruminants therefore may assimilate more nutrients per unit time than ruminants, despite the superiority of the latter in extend of digestion. The higher intake of zebra (Table 10) and the accompanying lower digestibility of NDF (Table 8) would also support this hypothesis. Fibre digestion is thus more effective in ruminants (foregut-fermenters) such as the blue wildebeest than in hindgut-fermenters such as zebra (Hintz 1969; Van der Noot & Gilbreath 1970; Illius & Gordon 1992). Comparison of cell wall digestion rate in caecal and rumen fermentation by Johnson, Borman and Rittenhouse (1982), Koller, Hintz, Robertson and Van Soest (1978) and Uden and Van Soest (1984) suggest slightly lower rates in hindgut-fermenters (horses) than in ruminants (cattle). Koller *et al.* (1978) also suggests that there are greater disparity between

rates in ruminants and hindgut fermenters as signification increases. This corresponds with the larger difference between the estimated *in vivo* DOM of zebra and *in vivo* DOM of wildebeest as well as the digestibility of cellulose during October and November (Figure 17 and 18), when a sharp increase in ADL% was observed (Figure 14). Physical constraints of the rumen ensure longer retention of ingesta. Consequently, the time that ingesta in the rumen are exposed to microbes that digest fibre and cellwall constituents would be more for the blue wildebeest and should explain their higher *in vivo* DOM.

Meissner and Paulsmeier (1995) compiled a relationship between intake and the ratio of IVDOM:NDF for various ruminants. If one should incorporate zebra data into this relationship the lowest organic matter intake (OMI) of zebra would compare with the highest organic matter intake (OMI) of the blue wildebeest. This is further proof that the average OMI of zebra was significantly higher than the OMI of the blue wildebeest.

Compared with the blue wildebeest, the zebras' faster throughput, and therefore intake, can be an advantage, which outweighs their lower digestive efficiency, particularly on poor quality forage, provided that total food is limited. In other words, one suspects that as long as zebras can increase their intake they will be able to compensate for the lower digestive efficiency. These results confirm the contentions of Bell (1971); Kinnear, Cockson, Christensen and Main (1979), Owen-Smith and Cooper (1988), Duncan, Foose, Gordon, Gakahu and Lloyd (1990), Illius and Gordon (1992). Where, however, resources are limited and food intake accordingly is restricted, the more efficient digestion by ruminants would give them the advantage, provided of course that food CP and other crucial nutrients are adequate for microbial function.

CHAPTER 5

4 CONCLUSIONS AND SUMMARY

4.4 CONCLUSIONS

The correlation coefficient between the index (total height x widest diameter of grass tufts expressed in cm) of the dominant grass species and their respective mass (dry matter) expressed in grams, was highly significant for all the grass species with only a few exceptions. Most of the grass species had a highly significant relation between mass and index (xy line function), tested over all four time periods. The regression equations could therefore be used to calculate intake from the average amount of grass utilized (difference before and after grazing).

Monthly dry matter intake (kg) as calculated through the plant-based technique did not compare well with the monthly dry matter intake as calculated through the animal-based technique. The attempt to substantiate the animal-based results through the results obtained from the plant-based. Although the regression equation was significant ($p<0.01$) with a R^2 value of 0.48 (Figure 22), the relationship is inadequate to be used. Only 48% of the variation in Y is explained by the variation in X. With the data available, one therefore had to conclude that intake calculated through the plant-based technique could not be predicted reliably by intake calculated through the animal based technique.

Although the zebra and the blue wildebeest were confined to bomas during the sampling periods, the attempt to simulate natural grazing conditions and free selection was satisfactory. The mean amount (kg) of grass material available during sampling periods for both the zebra and the blue wildebeest did not differ significantly, although differences occurred between some of the individual bomas.

There was an overlap in the grass species selected by zebra and blue wildebeest. This is in accordance with other literature (De Wet 1988, Owaga 1975, Stewart 1970; Wentzel 1990). Through observations in the bomas, it was noticed that the zebra and the blue wildebeest had a preference for *U. mosambicencis, w*hich is a comparatively short grass. Therefore, zebra that are normally seen as a tall grass feeder will also utilize shorter grass if given the choice. Compared to blue wildebeest, however, their bite size is bigger and therefore they can take bigger portions of the grass at a time, whilst blue wildebeest can select more leave material.

The climatologically dry conditions under which the study was done did not represent a typical year, and therefore could have influenced one of the aims of the study which was to test the carrying capacity equivalents that are officially used for game animals. These equivalents are mainly based on a theoretical approach (Meissner *et al.* 1983)

Monthly selection patterns of the zebra and the blue wildebeest in terms of quality and quantity of forage and comparison between the two animal species were, however, possible. Significant differences existed in the quality of forage utilized between the months because of seasonal differences. The quantity and quality of forage available to the two animal species at a given time, however, did not differ significantly. The results enhanced the argument for the existence of a substantial difference in forage intake and *in vivo* DOM of the zebra compared with the blue wildebeest. These quantitative results, therefore, confirm contentions of other literature and disqualify fears of interpretations being biased because of the drought.

4.5 SUMMARY

1. The primary objective of this study was to determine the seasonal nutritional requirements of zebra and blue wildebeest in terms of quality and quantity and at the same time to draw a comparison between the two species. A second objective was to evaluate whether present estimates of energy requirements

used for the purposes of calculating carrying capacity are adequate for these two species.

2. The study was conducted in the area surrounding the Hans Hoheisen Wildlife Research Station of the former Transvaal Chief Directorate of Nature Conservation, now the Northern Province Department of Agriculture and Environmental Affairs. The research station is situated in the Timbavati Private Nature Reserve bordering the Kruger National Park.

3. Six zebra and six blue wildebeest were obtained from the Kruger National Park at an age when they were still nursing. To facilitate faeces collection, only male animals were captured. They were castrated to prevent fighting. The animals were initially housed together and then separately in a 2,3 m x 4,7 m brick enclosure with an outside courtyard of the same size.

4. Animals were tamed and measurement and handling procedures were established. It was also necessary to determine the relationship between the *in vitro* digestibility and the *in vivo* digestibility of the forage for the blue wildebeest. Furthermore, the difference between the *in vivo* digestibility of the organic matter (DOM) utilized by the blue wildebeest (ruminant) and the zebra (non-ruminant) had to be determined to calculate the forage intake of each one.

5. The field study was conducted from February 1993 to February 1994. Because it was a relatively dry year, the study period was not divided into seasons but taken as 12 months.

6. For the purpose of the field study, six test animals consisting of three zebras and three blue wildebeest were kept separately in 3 m high enclosures of shadecloth reinforced with angle iron gates (bomas). Each boma had a circumference of 40 m and covered an area of approximately 128 m^2. The bomas were erected next to each other in the 10 ha camp. The fence surrounding the 10 ha camp was

electrified to prevent predators from entering. A second group of bomas was also erected adjacent to these to ensure that the animals could be moved from one boma to the next when required.

7. Field work was divided between data collection through plant-based techniques and data collection through animal-based techniques to determine diet preference as well as monthly differences in quality and quantity of forage selected by the zebras and the blue wildebeest.

8. The field study was divided into non-sampling and sampling periods. During sampling periods the zebra and the blue wildebeest grazed on the natural forage in the confined areas (bomas) and data was collected accordingly. Other vegetation surveys that were executed while the test animals were not directly involved were described under non-sampling periods.

9. During the preliminary study, the grass species composition and percentage distribution were determined. An attempt was also made to determine a correlation between the index (total height x widest diameter of grass tufts expressed in cm) of the dominant grass species and their respective mass (dry matter) expressed in grams. These regression lines were established to calculate monthly utilization of grasses (intake) from a plant-based perspective and at the same time to substantiate the animal-based measurements of intake.

10. During sampling periods, the grass layer was surveyed in each boma before the test animals entered. After two days of grazing the survey was repeated. Before and after grazing the biomass of the grass layer was determined with the aid of a disc pasture meter. Grass species composition as well as total height and the widest diameter of individual grass species in delineated areas were also determined before and after grazing for each individual animal. The survey areas were delineated using a wire square (0.5 m^2) and placement marked for successive surveys.

11. Surveys were conducted before grazing in the boma and repeated using the same technique after a period of two days continual grazing. The average material utilised for each grass species could then be determined. This data were then used to cut hand-collected samples representative of the animals diet selected. These were further used in the quantitative and qualitative studies.

12. Faeces of both the zebra and the blue wildebeest were easy to detect in the enclosures and were therefore hand-collected during sampling periods.

13. Forage and faeces samples collected on a monthly basis were analysed to determine chemical composition. The digestibility of the forage selected by the zebra and blue wildebeest was also determined.

14. The parameters under discussion were the following:

In vitro digestibility of organic matter (OM) of forage selected by the zebra and the blue wildebeest, *in vivo* digestibility of OM (calculated)
Dry matter (DM) intake (calculated)
Crude protein (CP), Phosphorous (P) content
Cell wall constituents: Neutral detergent fibre (NDF), Acid detergent fibre (ADF), Acid detergent lignin (ADL), Hemicellulose (calculated), Cellulose (calculated)
Digestibility (calculated) of : NDF, ADF, Hemicellulose and Cellulose

Digestibility of forage utilized by the zebra and the blue wildebeest were calculated through the following equations:

i. *in vivo* DOM (%) = 0.627 (*in vitro* DOM%) + 21.02 (For the blue wildebeest)
ii. *in vivo* DOM% (horses) = 1.28 [in vivo DOM%(cattle)] - 20.2
(This equation was used to calculate the *in vivo* DOM for the zebra from the in vivo DOM of the blue wildebeest)

Intake was then calculated as follows:

$$\text{Intake of OM (kg/day)} = \frac{\text{Faeces OM (kg/day)}}{\text{100 - \% } \textit{in vivo} \text{ DOM}} \times 100$$

15. Intake was also calculated over a three month period through the plant-based technique. The average index (height x diameter, cm^2) of grass material utilized by each animal per sampling period was determined. The regression equations (mass/index) were then used to determine the actual mass of the average index (cm^2) of each grass species utilized by the zebra and the blue wildebeest. By adding the mass of all the grass species utilized by each animal per sampling period, intake was then determined.

16. The following results were obtained:

There were no significant animal/month interactions. Consequently all the observations were processed irrespective of the individual animal.

The mean amount of forage available in the bomas for the zebra and the blue wildebeest did not differ significantly.

The grasses that were mostly utilized were *Panicum maximum*, *Heteropogon contortus*, *Urochloa mosambicensis* and *Themeda triandra*. Other species that were utilized were *Schmidtia pappophoroides*, *Enneapogon scoparius*, *Panicum coloratum*, *Brachiaria deflexa*, *Cenchrus ciliaris*, *Digitaria eriantha*, *Aristida congesta* subsp. *barbicollis*, *Eragrostis spp.*, *Bothriochloa radicans* and to a lesser extent *Tragus berteronianus* and *Fingerhuthia africana*.

The attempt to draw a correlation between index (height x diameter, cm) and the mass of grass species utilized by the zebra and the blue wildebeest was successful. Most of the regression equations were highly significant, with only a few exceptions.

The attempt to determine diet preference through the alkane marker and the microhistological technique was not successful. The results were discarded.

Throughout the study period, both the zebra and the blue wildebeest had the same quality of forage available. The mean quality of the food selected by the two species did not differ significantly.

The mean *in vitro* digestibility of organic matter (IVDOM %) of forage utilized by the zebra and the blue wildebeest also did not differ significantly between the animal species. Despite this, the zebras' estimated *in vivo* DOM % was significantly lower than that of the blue wildebeest. The zebra, however, compensated for the lower digestibility by a higher forage intake compared with the blue wildebeest, although it is recognized that forage intake might have been the driving force for the volume of food eaten.

The attempt to substantiate the animal-based intake results through the intake results obtained from the plant-based technique were not successful. Although the regression equation was significant ($p<0.01$) with a R^2 value of 0.48, the relationship is inadequate to be used. Only 48% of the variation in intake calculated through the plant-based technique could be explained by intake calculated through the animal-based technique. The likelihood of a reliable prediction is therefore small.

Monthly dry matter intake (kg) as calculated through the plant-based technique did not compare well with the monthly dry matter intake as calculated through the animal-based technique. The regression equation was significant. It is thus

possible to make use of the plant-based technique in future studies in order to calculate intake directly on natural forage on condition that information on the amount of forage utilized (difference before and after grazing) is available.

17. The climatologically dry conditions under which the study was done did not represent a typical year. This could have influenced one of the aims of the study that was to test the carrying capacity equivalents, which are mainly based on a theoretical approach, and are officially used for game animals.

18. Monthly selection patterns of the zebra and the blue wildebeest in terms of quality and quantity of forage and comparison between the two animal species were, however, possible. Significant differences existed in the quality of forage utilized between the months because of seasonal differences. The quantity and quality of forage available to the two animal species at a given time, however, did not differ significantly. The results substantiated the hypothesis for the existence of a substantial difference in forage intake and *in vivo* DOM of the zebra compared with the blue wildebeest. These quantitative results, therefore, confirm contentions of other literature.

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