VERMAAK, RENéE

THE ECOLOGY AND MANAGEMENT OF WILDLIFE ON THE ROODEPLAAT DAM NATURE RESERVE

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THE ECOLOGY AND MANAGEMENT OF WILDLIFE ON THE ROODEPLAAT DAM NATURE RESERVE

BY

RENÉE VERMAAK

Submitted in partial fulfilment of the requirements for the degree

MAGISTER SCIENTIAE (WILDLIFE MANAGEMENT)

Centre for Wildlife Management

Faculty of Biological and Agriculture Sciences

University of Pretoria

Pretoria

Supervisor: Prof. Dr. W. van Hoven

Co-supervisor: Prof. Dr. N. van Rooyen

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ABSTRACT

The aim was to compile a management plan for the Roodeplaat Dam Nature Reserve based on an ecological inventory. The study involved range condition assessment, determination of the browsing capacity of the reserve, as well as the pasture yield of plant communities to be used in a burning programme. The habitat requirements of six selected herbivore species were examined. Data was analysed by frequency histograms, correspondence analysis and redundancy analysis. Nutritional value of the favoured plant species of zebra and kudu was investigated. This study covers wildlife management, range management, ecotourism, planning of a hiking trail and lookout points and identifying the problem areas on the reserve. The carrying capacity is 6.80 ha/LSU and stocked at 60.48% of maximum capacity of LSU (128). An overall protein deficiency was found in the winter months. It was found that there are great possibilities for education, walking trails and bird hides.

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-SOLI DEO GLORIA-

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CHAPTER 1

INTRODUCTION

" Nobody made a greater mistake than he who did nothing, because he could only do a little." The Roodeplaat Dam Nature Reserve is a small reserve when compared to other bigger state owned reserves in South Africa. Despite its size, the vital role of the reserve in terms of the conservation of our natural resources, is reviewed and management proposals given to intensively manage this reserve without too much interference to the natural ecosystem.

A generally accepted principle is that the smaller the area being used for wildlife the more intensively it must be managed (Bothma 1989), because such areas are not self-regulating ecological units. The most important factors to consider in the formulation of a management plan are the assessment of range condition, grazer and browser management by setting realistic stocking rates for adapted animal species, veld burning, nutritional management and monitoring.

Wildlife management is a science that has boundaries prescribed by legislation and official policy. Within the confines of these parameters, however, the wildlife manager is free to act in several ways.

Wildlife management has two major functions - conservation and preservation. Each is a true and distinct concept with its own inherent responsibilities and purposes. Conservation management is applied to safe 'species' populations, and it implies that such populations can be 'used' by man. It also stipulates 'wise' use.

Wise use is defined as means to utilise a wild animal population in an optimum and wholly sustainable fashion for the benefit of humankind; and in such a manner as to maintain ecological processes, to preserve genetic diversity, and to accommodate the optimum sustainable utilisation of all other renewable natural resources (Thomson 1992).

Preservation management, on the other hand is applied to unsafe 'species' populations, and it implies that these populations should be protected from harm (Thomson 1992). There are no unsafe species on the reserve and it means that only conservation management has to be applied.

Human beings have established nature reserves to counteract their own actions, yet many reserves are established with an inherent contradiction - they are designed to protect natural systems and to provide for public uses of the area. Management thus seeks to maintain balance, with goals dependent upon the uniqueness of the biota of the area involved. The aim should be to keep the system dynamic, with natural processes continually operating, but not in the same direction over the whole area (White & Bratton 1980).

The aim of management is the most important question when starting a management plan for an area. Without definition of this aim, no concrete decisions can be made. The aim and policies for the Roodeplaat Dam Nature Reserve was approved by the Director of Nature Conservation on 20 January 1982. The aims are stated as:

1) The creation of opportunities for the general public to experience nature.
2) Introducing the public to different facets of wildlife management on the reserve, to stimulate conservation consciousness for nature and the natural environment.
3) The conservation of limited natural resources on the reserve.

The policy as stated by the Reserves management is the following:

A: Natural Resource Management:

- The fish population of the dam must be optimally utilised by the anglers visiting the reserve.
- The plant communities must be conserved on the reserve where there are low visitor numbers.
- Aim for the biggest diversity of animals without disturbing the ecological balance.
- No exotic animal or plant, excluding fish, may be reintroduced onto the reserve.

B: Environmental/Conservation Education

- Programmes concerning natural processes and ecology must be presented on the reserve.
- Programmes must be compiled for every age class and educational standard.

C: Research

- Research aimed at management can be permitted if it falls into the normal management plan of the reserve.

The aim of this study is therefore based on these aims and policies, and deals with some of the baseline surveying techniques, habitat selection of herbivores, grazing and browsing capacities, nutrition, ecotourism and the planning of, and recommendation of some management strategies specifically formulated to benefit the utilisation and natural ecology of the Roodeplaat Dam Nature Reserve.

CHAPTER 2

THE STUDY AREA

2.1 Locality

The Roodeplaat Dam Nature Reserve is situated in the Gauteng province, about 22 km north-east of Pretoria at 25°38'S and 28°21'E (Figure 1). The area around the dam is divided into four regions, which make provision for recreational areas and a natural area which is managed as a wildlife, vegetation and birdlife reserve. The study is limited to the south-eastern natural area (Figure 2). The size of the reserve is 1670 ha of which the study area covers 870 ha and the dam 395 ha. The other 405 ha is a public area.

The reserve is situated in the Sourish Mixed Bushveld (Acocks 1988). It is an open savanna veld type where *Acacia caffra* is the dominant tree species. Sourveld grass species like *Cymbopogon plurinodes, Themeda triandra, Elionurus muticus* and *Hyparrhenia* species are commonly found on the reserve.

The vegetation of the reserve was classified by Van Rooyen (1984) by means of the Braun-Blanquet method (Werger 1974), into six plant communities (Table 1). One of the communities is divided into four and another into three variations. The presence or absence of differential species was used as the basis for the classification (Figure 3).

TABLE 1 A list of the plant communities and variations of the Roodeplaat Dam Nature Reserve (Van Rooyen 1984).

---

1. *Berchemia zeyheri* - thicket

1.1 *Berchemia zeyheri - Combretum erythrophyllum* - thicket

1.2 *Berchemia zeyheri - Acacia robusta* - thicket

1.3 *Berchemia zeyheri - Dovyalis zeyheri* - thicket

1.4 *Berchemia zeyheri - Scolopia zeyheri* - thicket

2. *Acacia karroo* - closed woodland

3. *Acacia caffra* - closed woodland

3.1 *Acacia caffra - Setaria sphacelata* - closed woodland

3.2 *Acacia caffra - Combretum apiculatum* - closed woodland

3.3 *Acacia caffra - Faurea saligna* - open woodland

4. *Burkea africana* - closed woodland

5. *Setaria sphacelata - Polygala hottentotta* grassland

6. *Melinis repens - Cynodon dactylon* - old land grassland

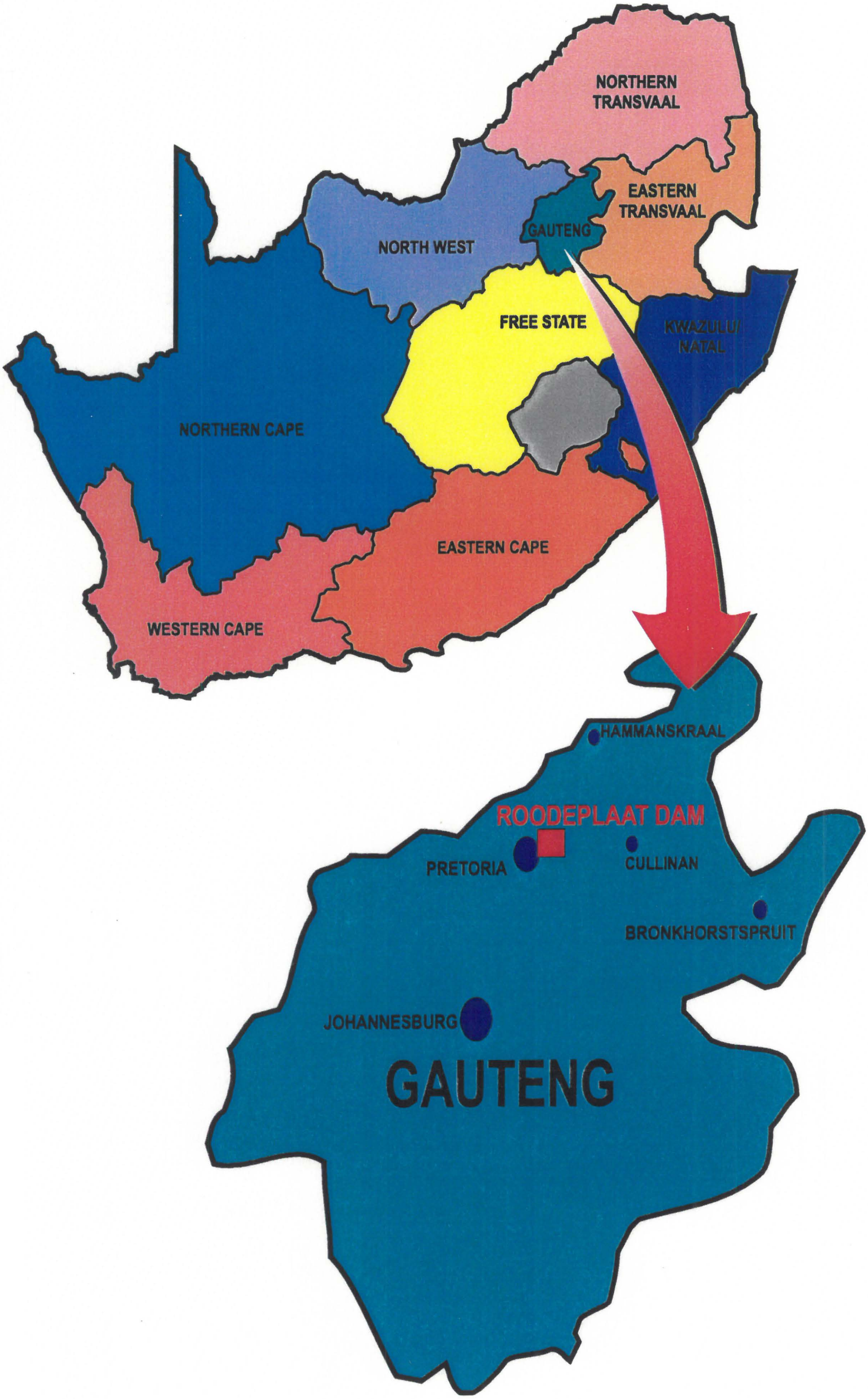
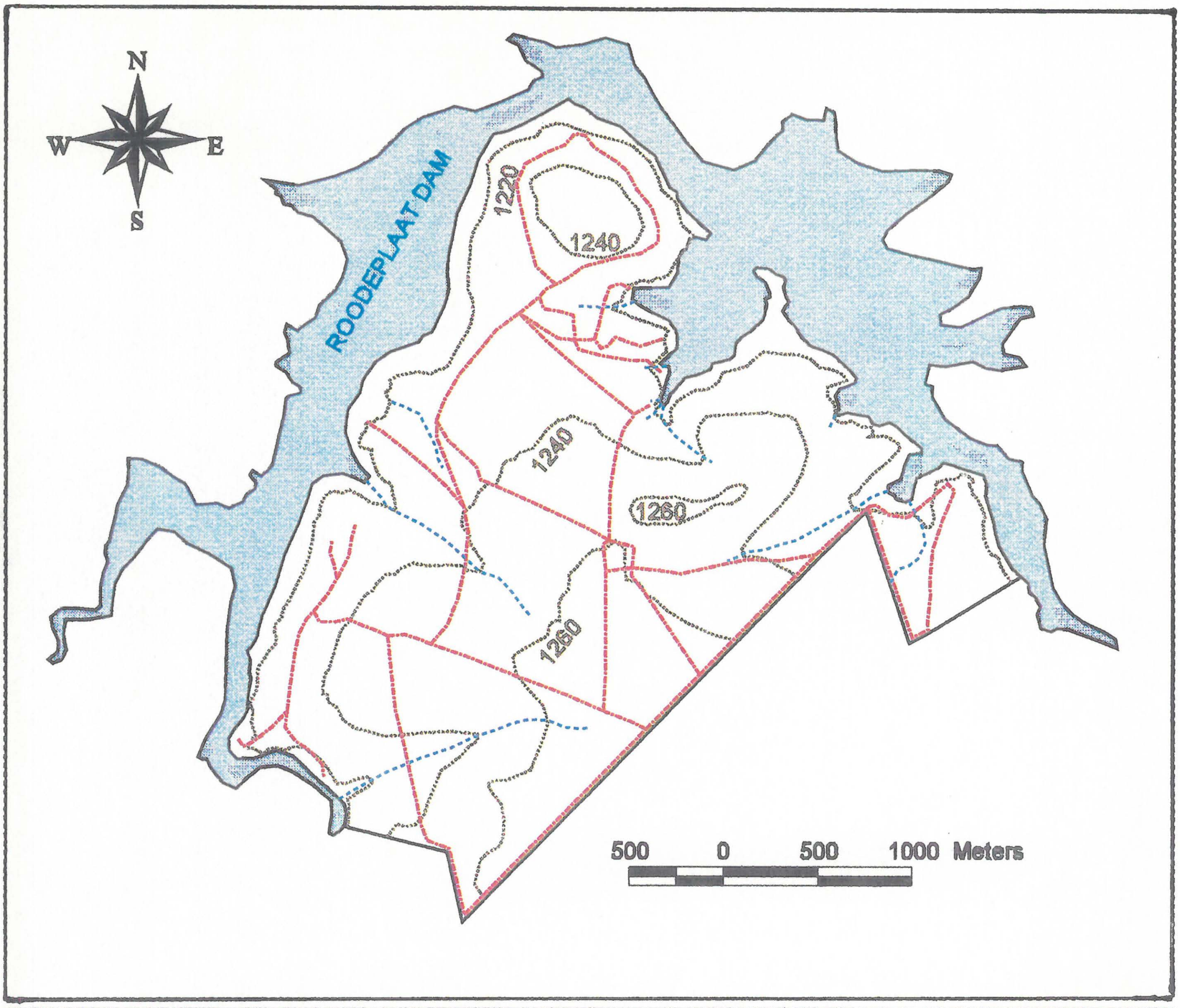
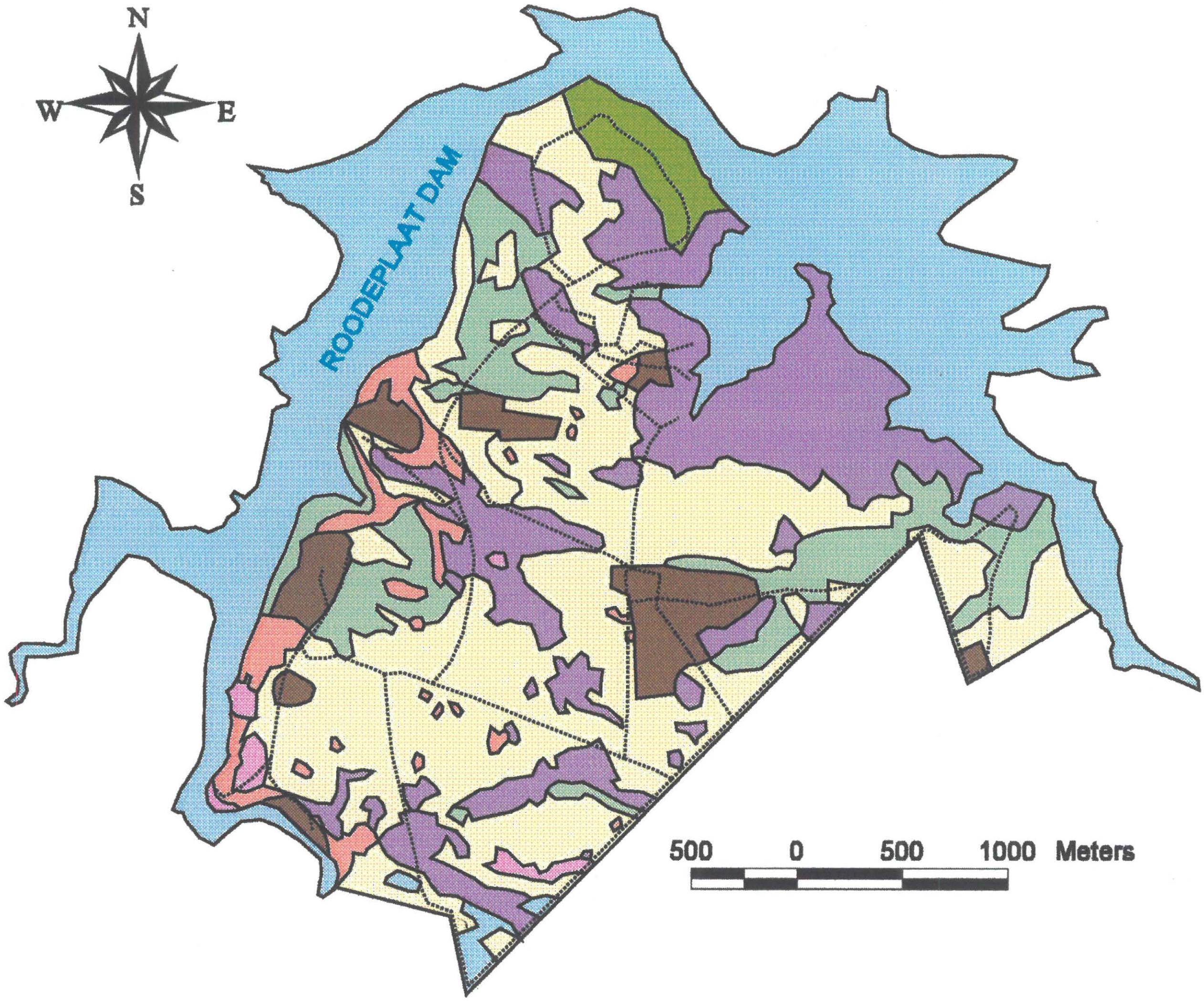


FIGURE 1 The location of the Roodeplaat Dam Nature Reserve



Roads
Drainage
Contours (20m interval)

FIGURE 2 A map of the study area, showing borders, drainage, contours and roads (Van Rooyen 1984)



Berchemia zeyheri thickets

Acacia karroo closed woodland

Acacia caffra-Setaria sphacelata closed woodland

Acacia caffra-Combretum apiculatum closed woodland

Acacia caffra-Faurea saligna open woodland

Burkea africana closed woodland

Setaria sphacelata-Polygala hottentotta grassland

Melinis repens-Cynodon dactylon old land grassland

FIGURE 3 The plant communities of the Roodeplaat Dam Nature Reserve (Van Rooyen 1984)

2.2 Climate

Climate in a broad sense, is a major determinant of the geographical distribution of species and vegetation types. Within any area of general climatic uniformity, the local conditions of temperature, light, humidity and moisture vary greatly, and it is these factors which play an important role in the production and survival of plants (Tainton 1981).

Köppen and Thornthwaite's classification of climate is mainly based on rainfall and temperature (Schulze 1947). According to the classification of Köppen the study area falls within a climatic zone indicated by the symbols Cwa, where:

C - warm, temperate climate
w - dry season in the winter
a - mean temperature of the hottest month exceed 22°C

According to Thornthwaite's (Schulze 1947) classification (CB'd), the study area falls within a semi-moist (C) warm (B') climate where a moisture shortage occurs during all seasons (d).

The characteristic climate of the study area is the warm, moist summers (especially November to January) and cold, dry winters (especially May to August) with a mean annual rainfall and temperature of 644.3 mm/year and 18.2°C respectively (Figure 4).

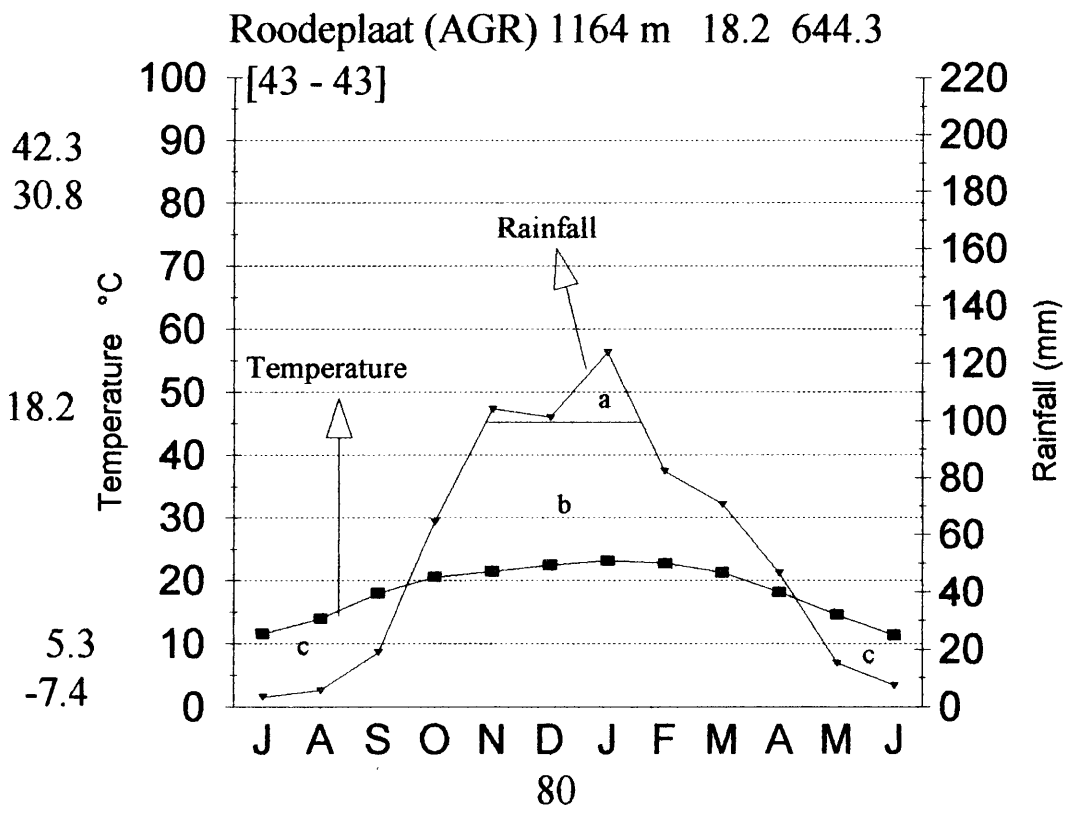


FIGURE 4 The climate of the study area according to the Walter convension (Walter 1963) displaying the mean monthly temperature and the mean monthly rainfall. Data obtained from the Institute for Soil, Climate and Water, Agricultural Research Council, Pretoria

The climate of the study area, where the past 43 years' data is summarised as a climatogram (Walter 1963) is given in figure 4. It displays the mean monthly temperature and the mean monthly rainfall. The numbers on the left handside of the diagram from top to bottom, is the absolute extreme temperature noted, the mean monthly maximum, mean daily temperature fluctuations, mean monthly minimum and the absolute minimum temperatures (respectively) as recorded for the period indicated under the weather station noted at the top (43 years). Area (c) represent the dry season. The perhumid season with the mean monthly precipitation exceeding 100 mm, is pointed out as area (a). The relatively humid season (including area b), lies between the temperature and precipitation curves. The dry period stretches from approximately May to September with July the driest month. Extreme temperatures that has been reported, vary from the highest, 42,3°C and a minimum of -7,4°C.

However, the climatic conditions which occurred throughout the study period (1991-1994), is summarised in Figure 5.

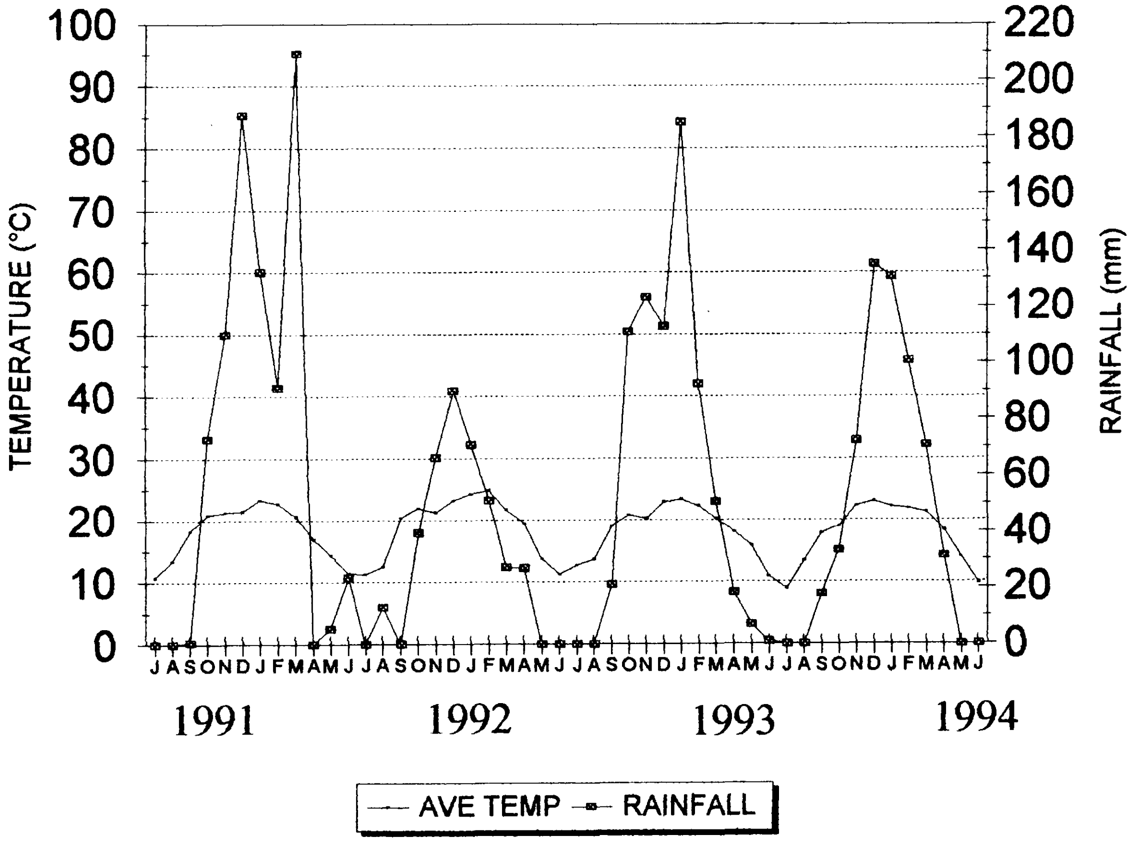


FIGURE 5 The mean monthly temperature and rainfall during the study period (1991-1994)

2.3 Physiography and Geology

The Roodeplaat Dam Nature Reserve's altitude varies from 1 220 m to 1 280 m above sea level and the undulating landscape is alternated by low ridges, drainage lines and the dam water area. The highest altitude is in the south-eastern part of the reserve and the lowest at waterlevel at about 1 220 m above sea level (Figure 2).
The primary source of water to the dam is the Pienaars River with the Hartebeestspruit, the Edendalespruit and the Morrelettaspruit the secondaries. A few small, mostly dry streams have their origin in the reserve, but contributes minimally to the water supply of the dam (Figure 2).

The central and southern parts of the reserve is covered mainly with metamorphosized sedimentary stone (quartzite, hornfels, calcareous silicates) of the Transvaal Supergroup (Figure 6). These rock formations were penetrated by patches of norite and diabaas, followed by magma from the Bushveld Igneous complex. The latter has caused the above mentioned metamorphosis of the older sedimentary rocks.
Gabbroic rocks of the Bushveld Igneous complex covers the western and central parts of the reserve. Layers of red, ferric acid-enriched conglomorates, sandstone and shale of the Waterberg Group covers the northern part of the reserve. The volcanic rocks of the Roodeplaat Suite and associated patches cut through the abovementioned older rocks and is also naturally exposed in the northern parts of the reserve. Intrusive rock formations of the Leeuwfontein Suite in turn cut through all the other rock formations, and creates an embolistic body as well as patches and passages in the eastern part of the reserve (Figure 6).
Hybrid rocks originated after liquids of the Leeuwfontein Suite and older rocks reacted. Recent alluvial and residual soils cover big areas of the central parts of the reserve. The landtype within the study area is illustrated in Figure 8.

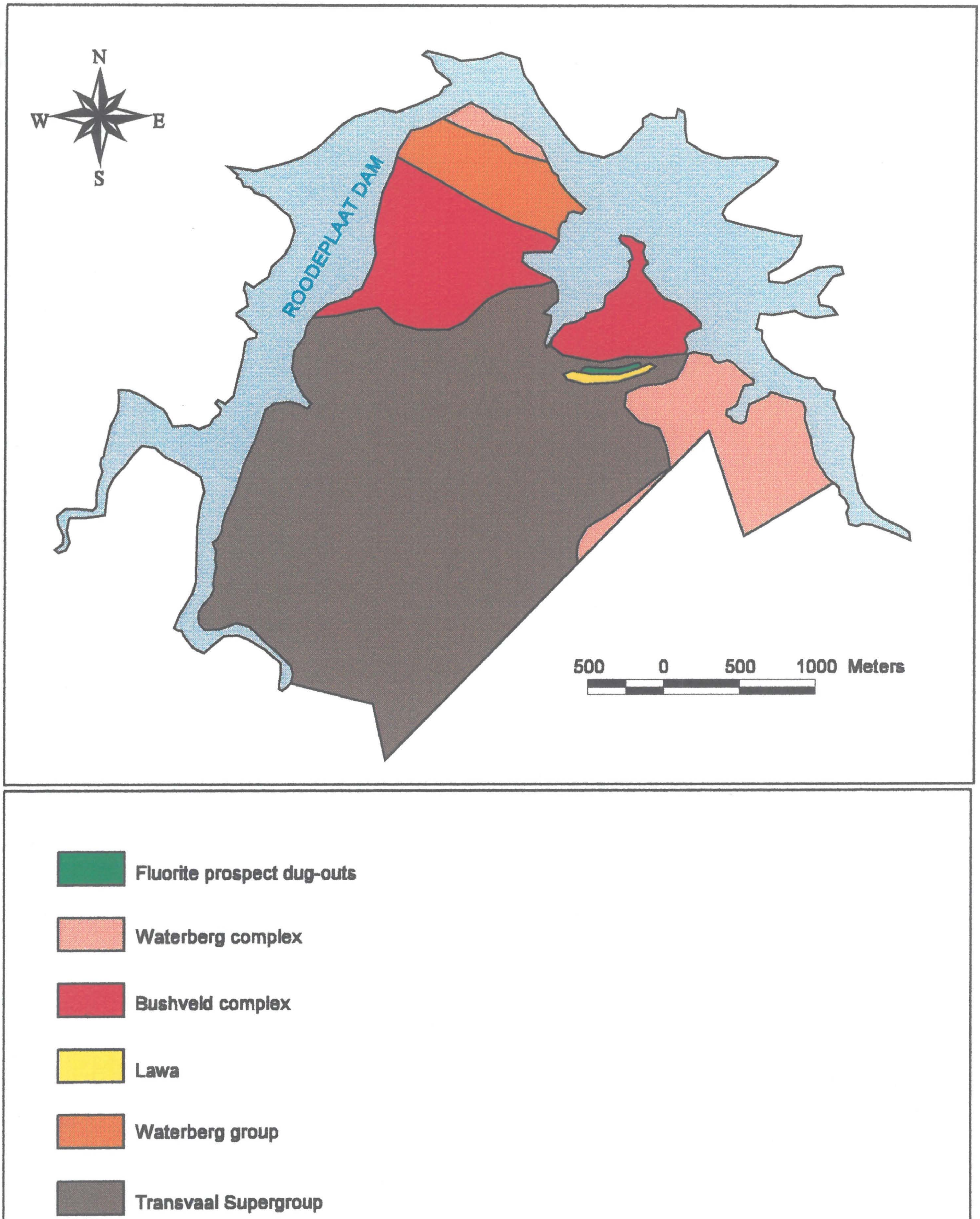


FIGURE 6 Geological formations of the Roodeplaat Dam Nature Reserve (Van Rooyen 1984)

The biggest part of the reserve consists of shallow soils with rocky outcrops. On certain smaller areas on the reserve, soils are more clearly defined and the following dominant soil forms are distinguished: Clovelly, Hutton, Shortland and Mispah (Figure 7).

2.4 Biotic factors and background

The Roodeplaat Dam Nature Reserve is under the control of the Directorate of Nature Conservation of the Department of Conservation and Agriculture of the Gauteng Provincial Administration and according to Bigalke (1968), the aim of such a division is to conserve and sensibly utilize the natural resources which is the wild animals and indigenous plants.
In 1972 the then Department of Water Affairs delegated the management of the Roodeplaat Dam area to the Division of Nature Conservation of the Transvaal Provincial Administration to develop this area as a nature reserve and outdoor recreational resort, for the city population of the Reef and Pretoria (Oates 1977). The reserve was proclaimed in 1977.

The reserve is part of the southern foothills of the Magaliesberg mountains in the Central Transvaal Bushveld, and the assumption can thus be made that most of the bushveld animals occurred in this area at some time in the past. Kudu, steenbok and common duiker have always been present in the area and until recently waterbuck moved freely up the banks of the river to the dam.
The bigger wildlife species that has been reintroduced to the reserve are impala (*Aepyceros melampus*), red hartebeest (*Alcelaphus buselaphus*), kudu (*Tragelaphus strepsiceros*), blue wildebeest (*Connochaetes taurinus*), waterbuck (*Kobus ellipsiprymnus*), zebra (*Equus burchellii*) and the sable antelope (*Hippotragus niger*), but the latter has been removed as a result of adjustment problems.

Over 224 bird species have been identified on the reserve as it is an ideal habitat for a variety of waterbird species. A large number of water associated birds also occur in and around the dam,

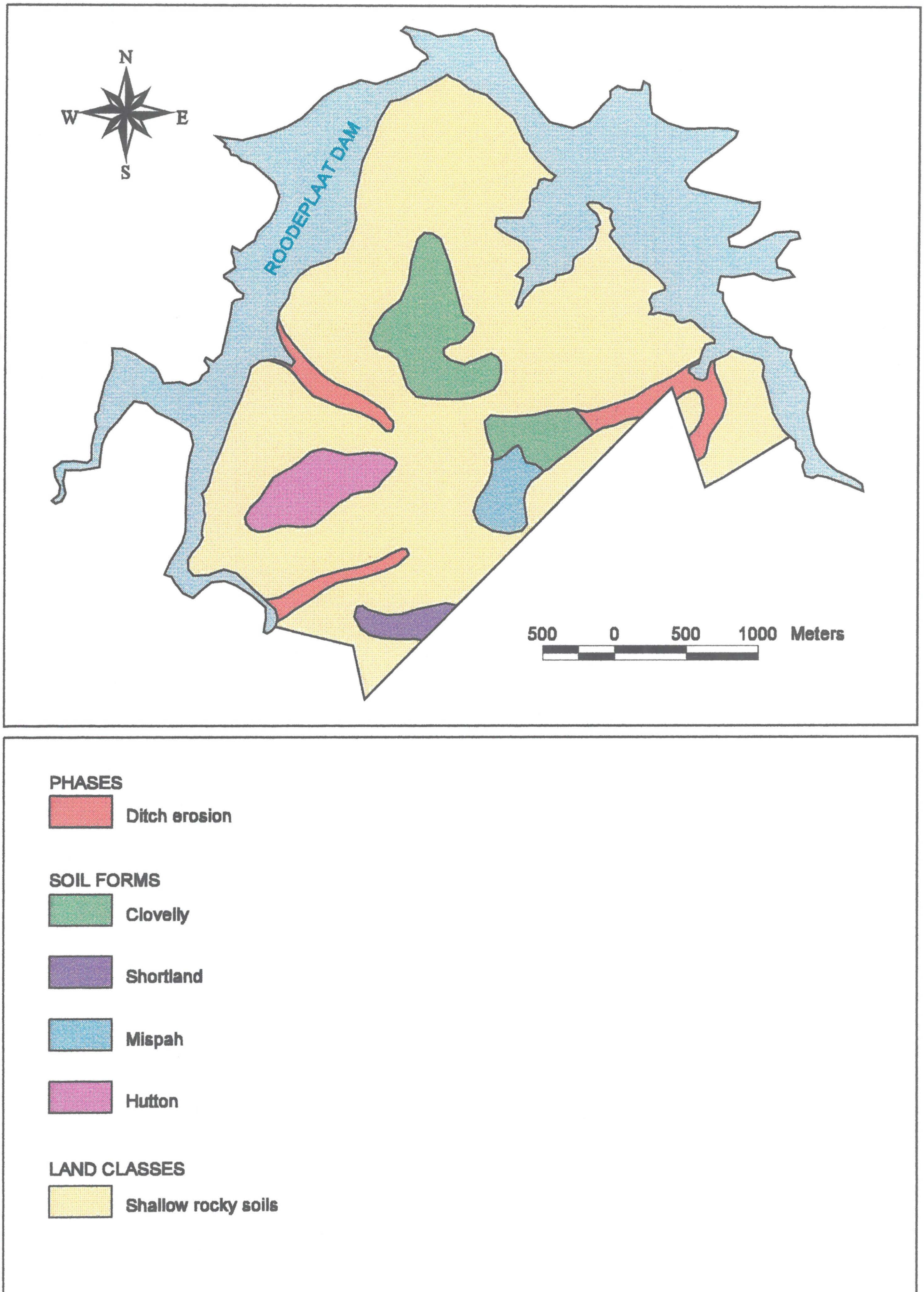
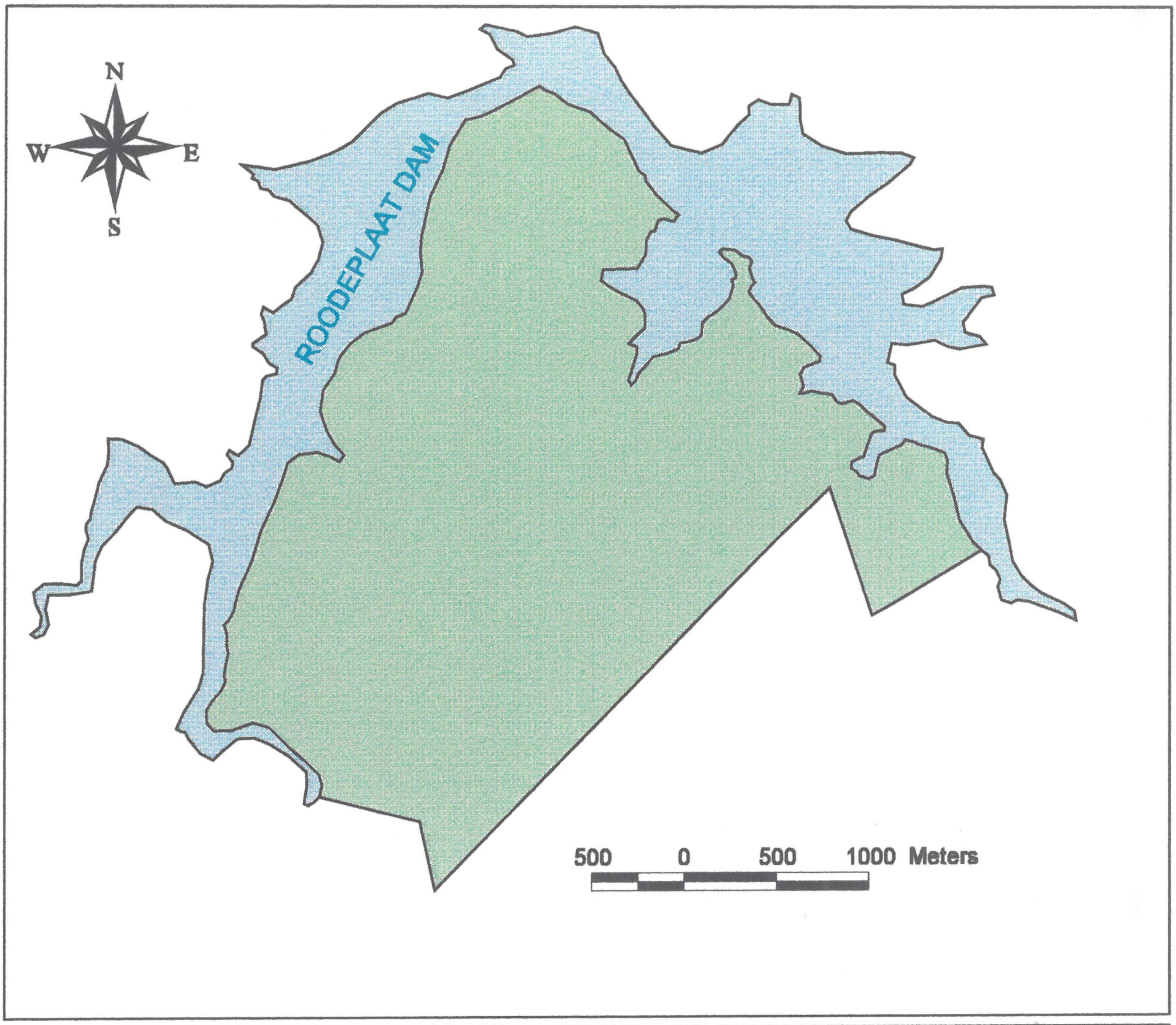


FIGURE 7 Soil forms on the Roodeplaat Dam Nature Reserve (Van Rooyen 1984)



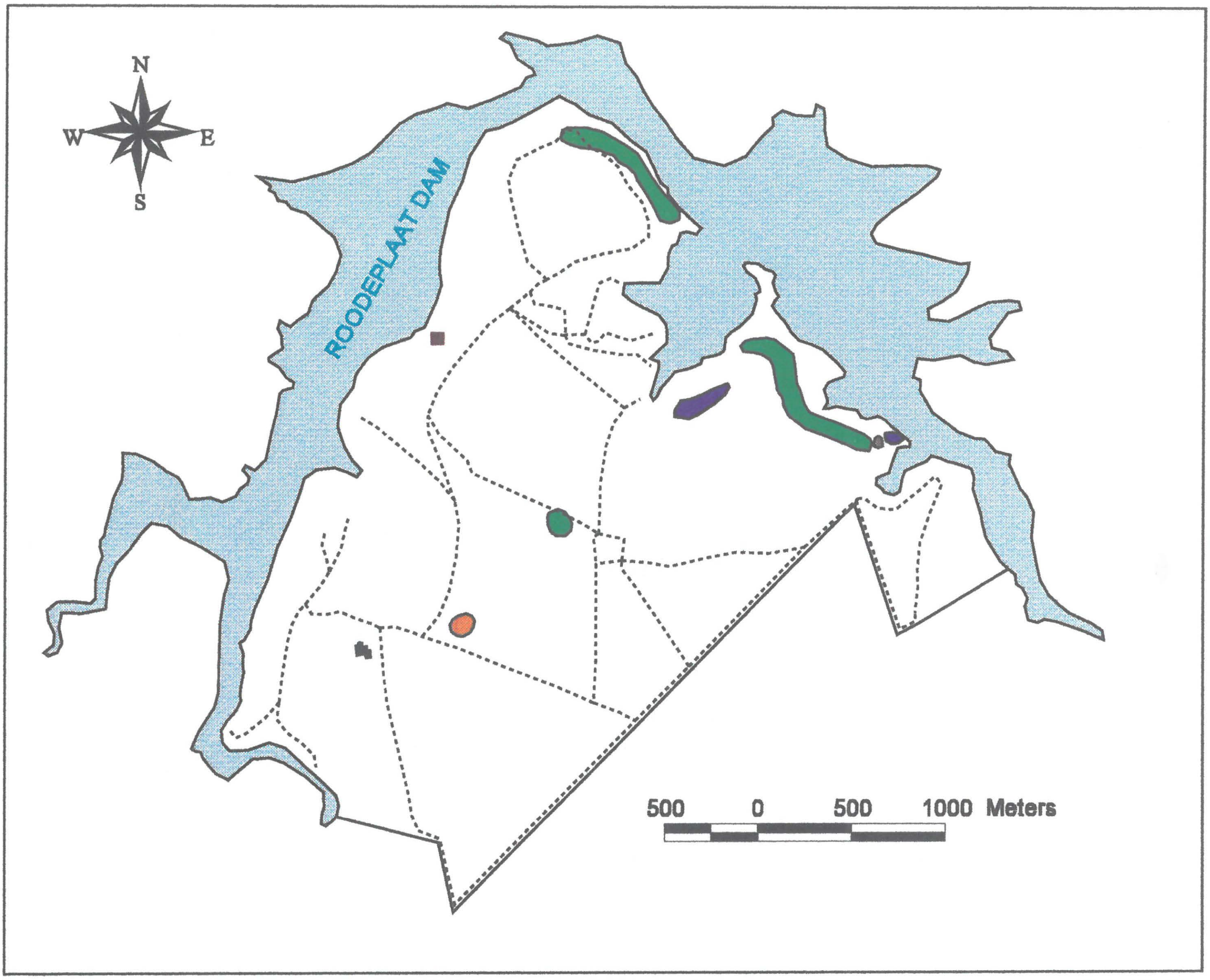
Land type Ae22a

FIGURE 8 The land type on the Roodeplaat Dam Nature Reserve (Van Rooyen 1984) in particular two pairs of breeding fish eagle.

The dominant flora of the reserve has been discussed. The flora of the dam, except for algae and a few rooted submerged plants, exhibit no floating water plants. As a result of increasing eutrophication of the water, free floating algae grows luxuriant throughout the year, but especially in the summer months. The dominant algae species which occurs are *Anabaena circinalis* and *Microcystis aeruginosa* (blue-green algae), while *Melosira granulata* (diatomes) is abundant during the winter months. Virtually the entire shore of the dam is taken over by rooted waterplants like *Typha capensis* and *Phragmites australis* as the dominant species.

A few unique features also occur on the reserve and is pointed out on the map (Figure 9). There are a few very dense stands of *Aloe marlothii* and several very old specimens.

Geologically there are shallow fluorite-rich rock formations which were prospected on a few areas. Stone ruins were identified and the northern flank of the Boer and English allies moved through the southern part of the reserve at the time of the Battle of Donkerhoek at the time of the Second War of Independence.



Dense stands of *Aloe marlothii*

Surface fluorite presipitation with prospector dug-outs

Dug-outs

Stone kraal

Graves

FIGURE 9 The unique features on the Roodeplaat Dam Nature Reserve

CHAPTER 3

HABITAT SELECTION BY UNGULATES

3.1 Introduction

From the observations of the earliest travellers it has been acknowledged that a relationship exists between animals and their environment. References to animals favouring open plains, savanna, woodland, forest and deserts are common in wildlife literature (Pienaar 1974).

A habitat is that area in which a certain animal prefers to live. Habitats are composed of geomorphological characteristics such as topography, geological formations and soil types, and also the associated vegetation (Bothma 1989). The presence or availability of water inevitably plays an important role in habitat preferences (Pettifer & Stumpf 1981; Bothma & Van Rooyen 1989; Engelbrecht 1986), but it is the physical structure of the habitat that is the decisive factor if water and food are available in more than one place.
Animals may also show preferences for specific topographical features, for example for slopes or level territory or features brought about by geological formations like rocky outcrops or broken territory, while sandy, loamy or clayey soils may also have an influence. These habitat features can largely be regarded as 'unchangeable', as change normally takes place slowly and over extensive periods of time. Animals show these preferences for certain habitats and have been studied extensively by various researchers (Bell 1971; Simpson 1972; Ferrar & Walker 1974; Pienaar 1974; Sauer, Theron & Skinner 1977; Walker 1979; Coetzee 1980; Grunow 1980; Pettifer & Stumpf 1981; Rowe-Rowe 1983; Beardall, Joubert & Retief 1984; Kok & Opperman 1985; Engelbrecht 1986; Bothma & Van Rooyen 1989; Novellie 1990; Wentzel, Bothma & Van Rooyen 1991).

Species composition and structure are the two components of the vegetation which form an important part of the habitat. The species which constitutes the vegetation will determine whether or not the food source is sufficient. The structure of the vegetation plays an equally important role in determining whether or not the habitat is suitable e.g. shelter and visibility.

There are definitely a number of reasons for the preferences shown by animals. Research has shown that forage production and degree of utilisation (Wentzel, Bothma & Van Rooyen 1991), plant association (Engelbrecht 1986), height of the grass (Bell 1971; Ferrar & Walker 1974; Grobler 1981; Smuts 1982; Bothma & Van Rooyen 1989), environmental temperature (Simpson 1972; Belovsky & Slade 1986), defence mechanisms (Freeland & Janzen 1974; Coley, Bryant & Chapin 1985; Cooper & Owen-Smith 1985; Rhoades 1985; Cooper & Owen-Smith 1986; Cooper, Owen-Smith & Bryant 1988; Hay & Van Hoven 1988; Furstenburg & Van Hoven 1994), availability of food at certain height classes (Sauer, Theron & Skinner 1977; Pellew 1983; Kok & Opperman 1985; Owen-Smith & Cooper 1989) and phenology (Sauer, Theron & Skinner 1977; Kok & Opperman 1980, 1985; Novellie 1983; Pellew 1984; Engelbrecht 1986) are possible reasons for these preferences. These factors operate in different magnitudes and directions, sometimes opposingly and at other times together (Ben-Shahar 1986).

It is reasonable to assume that variations in the patterns occurring between species inhabiting the same area would reflect their physiological adaptations or relative tolerance of the prevailing environmental conditions (Ben-Shahar & Fairall 1987).

In an intensively managed system like the Roodeplaat Dam Nature Reserve, where man has a drastic influence on the functioning of the ecosystem through management, other factors like fences, veld burning programmes and roads will definitely influence the habitat preferences of the wild herbivores.

An increasing understanding of habitat requirements forms an integral part of any wildlife research or management activity. The aim of this study was thus to examine the habitat requirements of six selected herbivore species on the basis of plant community preference. Knowledge of the plant communities on the reserve (Chapter 4) makes it possible to observe and investigate some tendencies that may occur.

The six herbivore species studied were blue wildebeest (*Connochaetes taurinus* Burchell, 1823), impala (*Aepyceros melampus* Lichtenstein, 1812), waterbuck (*Kobus ellipsiprymnus* Ogilby, 1833), Burchell's zebra (*Equus burchelli* Gray, 1824), kudu (*Tragelaphus strepsiceros* Pallas, 1766) and red hartebeest *(Alcelaphus buselaphus* Pallas, 1766).

3.2 Methods

3.2.1 Collection of data

An adapted method of Theron (1991) was used to do the habitat utilisation survey. A grid of 1 cm by 1 cm (100 X 100 m on the ground, a 1.0 ha pixel) was constructed on the four 1:10 000 orthophoto maps covering the study area. Each grid unit was allocated a reference number.

The habitat utilisation survey was conducted throughout the period March 1993 to March 1994. The study area was surveyed at least twice a week and a fixed route along roads and paths was travelled by foot and motorcycle. Elevated positions were also used to scan sections of the study area with binoculars. The area was thus divided into units that were searched alternately in the mornings and afternoons to maintain a random distribution.

When an animal was sighted, it was first established which species it was, whereafter the different environmental variables and other particulars were recorded by category on a field form. The data and time, to the nearest five minutes, were recorded. The grid reference and number of the landscape unit were noted from the orthophoto map.

The following environmental factors and other data were recorded at each sighting:

Aspect: The aspect is the compass direction towards which a slope faces, expressed as degrees relative to true North (Gabriel & Talbot 1984). The aspect N, NE, E, SE, S, SW, W or NW was determined by using a compass and a map.

Slope gradient : A slope is defined as an area which is inclined at an angle of more than 0°, but less than 45° from the horizontal. The slope of the landscape position is measured with a clinometer and categorised as : 0-3°, >3-8°, >8-16°, >16-25°, >25°

Distance from water: The distance from the nearest water was determined to the nearest meter:

*0-<20 m
*20-<100 m
*100-<200 m
*200-<500 m
*500-1000 m
*>1000 m

Vegetation structure

Vegetation structure as defined by Dansereau (1957), is the organisation in space of the individuals that form a stand (and by extension a vegetation type or a plant community), and the primary elements of structure are growth form, stratification (height class) and coverage (canopy cover).

The vegetation structure, both vertical and horizontal, were noted and the phenology of the vegetation recorded.

Vertical structure: Vertical height was categorised as:

Tree layer : woody plants higher than 2 m
Shrub layer : Woody plants 2 m and lower
Herbaceous layer: mostly grass species

Horizontal structure: The horizontal structure for the tree and shrub layer is visually estimated on the ratio of the crown and gap. The crown-gap relationship (Edwards 1983) simplifies the estimation of the percentage cover. The relationship between the crown diameter of the plants and the crown gap gives an estimate of the crown cover. The cover classes for the different strata are as follows:

DESCRIPTION	CROWN/GAP RELATIONSHIP	PERCENTAGE COVER
sparse	> 3,3	> 5
open	< 3,3 to 2	< 5 to 10
medium	< 2 to 1	> 10 to 20
dense	< 1	> 20

The herbaceous layer was defined separately into vertical and horizontal structure.

Vertical herbaceous layer: The vertical height of the herb layer was established by measurement of the standing height of the herb layer in the four main compass directions. The average was taken as the vertical herbaceous layer.

DESCRIPTION	UNITS
short	0-200 mm
medium	> 200-800 mm
tall	> 800 mm

Grass canopy cover: Horizontal structure is measured using grass canopy cover as criterion.

DESCRIPTION	DEFINITION
none	no canopy cover
sparse	grass sparsely spread in areas, with annual grasses and forbs
moderate	a good canopy cover with occasional open areas
dense	maximal canopy cover with no or little open areas

The method used for the vegetation structure is adapted from Ben-Shahar (1986) and Gertenbach (1987).

Utilization of the herbaceous layer: The degree of utilization was subjectively categorized as none, low, moderate and high.

DESCRIPTION	DEFINITION
none	no visual signs of utilization
low	tufts of grass recently grazed are wide apart; average use of current season's herbaceous phytomass is from one to ten percent.
moderate	> 10 to 50 percent of current season's herbaceous phytomass being utilized.
high	average use of current season's herbaceous phytomass is more than 50 percent (adapted from Goodman 1975).

Sunshine or rain: When it rained during observations, this was recorded.

Wind: Adapted from the Beaufort scale, the categories are as follows:

DESCRIPTION	UNITS
none	0 km/h (smoke rises vertically)
slight	2-5 km/h (Direction of wind shown by smoke drift, wind felt on face, leaves rustle)
moderate	>5-13 km/h (leaves in constant motion, raises dust, a moderate breeze)
severe	>13 km/h (Trees begin to sway, fresh to strong breeze)

Cloud cover (1/8-8/8): Categories used to describe the amount of cloud visible are given in eighths.

Erosion: The degree of erosion in an area was categorised as:

DESCRIPTION	DEFINITION
none	no visual signs of erosion or soil movement
slight	small areas with exposed soils
moderate	larger areas with exposed soils, signs of sheet erosion, with a low plant cover
severe	distinct signs of dongas and a high degree of soil loss

Landscape position: Choices included :

*Mountain plateau: on top of a hill
*Steep slope
*Middle slope
*Lower slope
*Plains
*Drainage area(streams or dams)

Rockiness (%): The proportion of the soil surface covered by rock was estimated visually and expressed in categories: 0-25%, 26-50%, 51-75%, 76-100%.

Activities:

- grazing	more than half of the animal group are engaged in grazing
- drinking	at least one of the animals is drinking water
- resting	animals lying down or standing without grazing
- flight	running from a disturbance
- moving	moving without delay, walking or running

Association: Whenever any other animal species were in the vicinity, nearer than 100 metres, it was recorded.

3.2.2 Statistical analysis

In recent years much attention has been focused on the study of herbivore/habitat relationships (Ben-Shahar 1986; Engelbrecht 1986; Wentzel 1990; Theron 1991).
Simple quantitative studies express habitat selection in terms of the proportion of animals seen in each habitat type. An extension of this concept is the comparison of observed habitat use with expected habitat use according to habitat availability (Hirst 1975). Such studies usually involve classical statistical techniques of hypothesis testing (Williams 1973). The null hypothesis tested is that the distribution of animals in an area is random over all habitat types, meaning that the expected occurrence of animals would be in proportion to the relative occurrence of the different habitats in the area.

The second main type of quantitative analysis of animal-habitat relationships is the use of multivariate analysis techniques and several methods of multivariate analysis have been used to analyse the complex interrelationships between herbivores and the many facets of their environment (Ferrar & Walker 1974; Hirst 1975; Beardall, Joubert & Retief 1984). Hypothesis generating multivariate analysis, or pattern analysis, may be distinguished from hypothesis testing classical statistics (Williams 1973). Studies using multivariate analysis techniques do not require information on the amount of habitat available and a record of habitat variables at each animal location is usually sufficient. Multivariate analyses are more accessible now because of the development of rapid, flexible computer programs such as Detrended Correspondence Analysis and Correspondence Analysis (Scogings, Theron & Bothma 1990).
A total of 760 observations were made. The data was collected by category and summarised in contingency tables. This data was then subjected to the following statistical analysis:
- Chi-square tests of frequency data (Snedecor & Cochran 1989)
- Correspondence Analysis (CA)(Greenacre 1978, 1981)
- Redundancy analysis (RA)(ter Braak & Prentice 1988)

i) Frequency histograms

Frequency histograms of the number of observations (dependent axis) against environmental factor categories were drawn for seasonal observations. Preference for the different habitat variables was tested for significant differences with the Chi-square test, with the null hypothesis that the animals in discussion did not exhibit any preference for an environmental variable from season to season.

In a situation where sets of observed and theoretical frequencies are to be compared , χ^2 is defined by χ^2 = S (O-E)²/E; where O and E denote the total observed and expected observations respectively (Snedecor & Cochran 1989).

Inspection shows that χ^2 is a descriptive measure of the magnitude of the discrepancies between the observed and expected frequencies. The larger these discrepancies the larger χ^2 will tend to be. A value of χ^2 is calculated. If this value is equal to or greater than the critical value required for significance at an accepted significance level for the appropriate df (degrees of freedom), the null hypothesis is rejected. A significant difference level of 5% (P = 0,05) was accepted (Reilly 1989).

(ii) Correspondence Analysis

A detailed account of correspondence analysis is given in Greenacre (1978, 1981).

Correspondence analysis is used to obtain a simultaneous graphical display of the relationship between the objects (rows) and variables (columns) of a matrix X, of non-negative numbers. The matrix X goes through a double-standardising process, i.e. it is rescaled, both column-wise and row-wise, and principle axes are extracted. These axes are chosen such that the inertia is maximised. This inertia is calculated as a squared distance measure. It is proportional to the X^2 statistic for testing the hypothesis of independence between rows and columns and is in fact a measure of the deviation of the data from this hypothesis.

The aim of habitat preference studies is to identify the ideal habitat, those to which different species are adapted, and in which they best survive and reproduce. The aim of applying correspondence analysis to combined habitat data, was to separate the six animal species according to their preferred habitat. Seasonal data was analysed to show any seasonal difference in habitat selection and to group habitat categories that correspond with the seasons (Baily 1984).

The data from the Roodeplaat Dam Nature Reserve was categorised into variable observations for the six selected herbivore species. Animal species analysed separately did not give satisfactory graphical display or numerical output, and was calculated using Chi-square analysis.

(iii) Redundancy Analysis

This method is a direct gradient analysis technique (canonical ordination) which attempts to explain the species responses by ordination axes that are constraint to be linear combinations of supplied environmental variables (ter Braak & Prentice 1988).

With redundancy analysis, sites are indicated by points and both species and environmental variables are indicated by arrows whose interpretation is similar to that of the arrows in the Principle Components Analysis biplot (PCA) (ter Braak & Prentice 1988). PCA fits planes to each species' abundance in the space defined by the ordination axis. Such a diagram in which sites are marked by points and species by arrows is called a biplot (Gabriel 1971). There is a useful symbolism in this use of arrows, the arrow points in the direction of maximum variation in the species abundance, and its length is proportional to this maximum rate of change. Consequently species on the edge of the diagram (far from the origin) are the most important for indicating site differences. Species near the centre are of minor importance.

The pattern of abundance of each species among the sites can be inferred in exactly the same way as in a PCA biplot, and so may the direction of variation of each environmental variable. One may also get an idea of the correlation between species abundance and environmental variables. Arrows pointing in roughly the same direction indicate a high positive correlation, angles crossing at right angles indicate near-zero correlation and arrows pointing in opposite directions indicate high negative correlation. Species and environmental variables with long arrows are the most important in the analysis: the longer the arrows, the more confident one can be about the inferred correlation.

3.2.3 Results of statistical analysis

(i) Frequency histograms

Kudu

Seasonally, kudu had a high preference for the *Acacia caffra-Setaria sphacelata* closed woodland (L3; Figure 10a) in autumn, winter, spring and summer. They were also noted to be associated with the *Acacia karroo* closed woodland (L2). They showed no significant preference for the other range types.

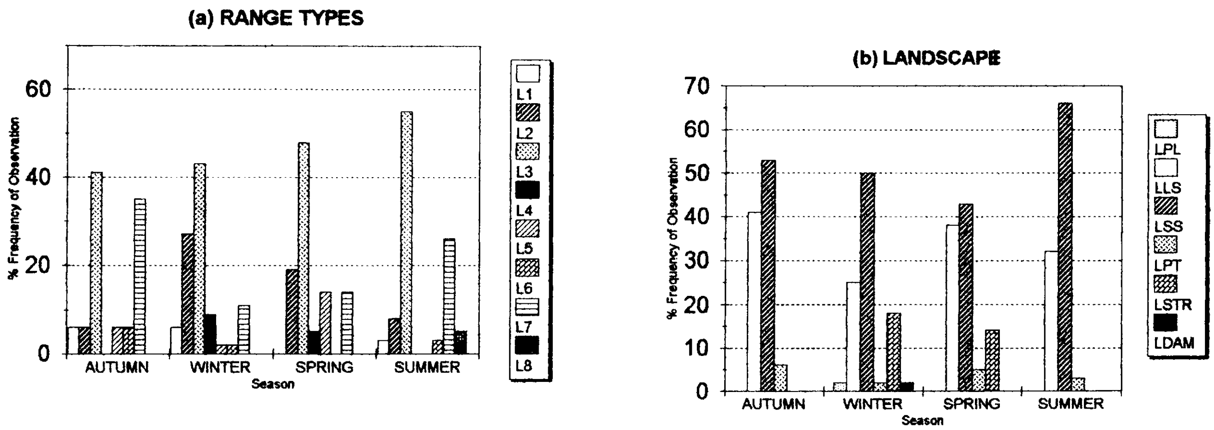
The animals utilised medium to steep slopes (Figure 10b) highly significantly in all four seasons (AUTUMN: χ^2=79.21; WINTER: χ^2=66.67;SPRING: χ^2=41.61; SUMMER: χ^2=146.03, $p<0.05$, df=1). From the chi-square values it can be seen that the significance of utilisation of lower slopes in winter is low (WINTER: χ^2=4.17, $p<0.05$, df=1) and thus a weak correlation.

The kudu occurred on different aspects throughout the year (Figure 11) and showed no clear preference for a specific aspect. In autumn the preference for aspect varied from 6-24% and the southern and western slopes were mostly preferred. In winter the northern and north-western slopes were most preferred (16% and 20% respectively). In summer the kudu showed a strong preference for the western slope (χ^2=10.58, $p<0.05$, df=1).

Throughout the year they browsed more than 50% of the time (53% in autumn and 95% in summer) (Figure 10d). In autumn they were seen moving around 29% of the time.
Kudu showed no preference for severely eroded areas (Figure 10c), and throughout the year selected areas with slight erosion (7-52%). Areas with a dominant tree layer were preferred by the kudu (82-95%) throughout the year (Figure 12a). In terms of vertical herbaceous layer, they preferred grass lengths taller than 800 mm in autumn, but they did not show a significant preference for medium grass length (χ^2=0.08, $p>0.05$, df=1). In the other three seasons, medium sward lengths were preferred. Shorter grass lengths were least preferred throughout the year

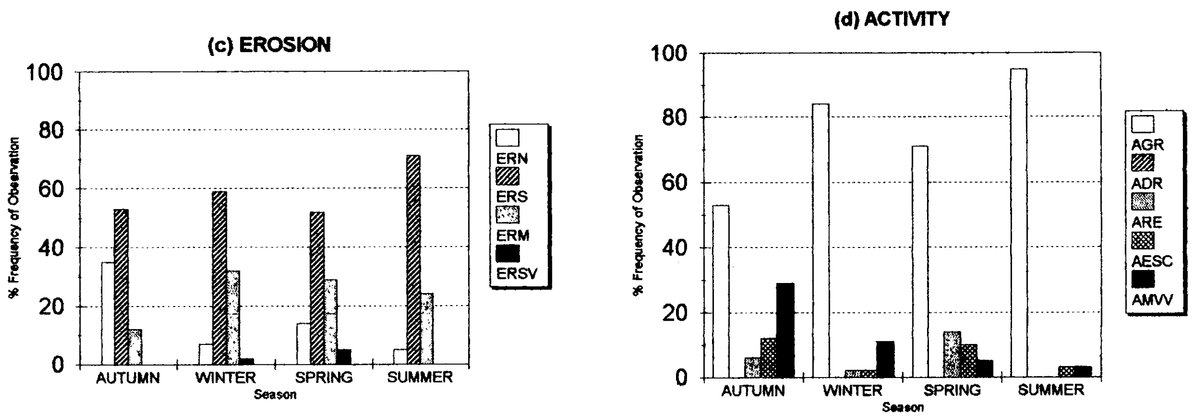
(Figure 12b).

Areas with a good grass canopy cover were selected while they avoided areas where there was no grass canopy cover (Figure 12c). There is a positive correlation between moderately utilised areas and presence of kudu on the reserve ($\chi^2 > 21.16$, $p < 0.05$, $df = 3$) for all four seasons. They had a negative relationship with severely overutilised areas (Figure 13).



L1 - Berchemia zeyheri thicket
L2 - Acacia karroo closed woodland
L3 - Acacia caffra-Setaria sphacelata closed woodland
L4 - Acacia caffra-Combretum apiculatum closed woodland
L5 - Acacia caffra-Faurea saligna open woodland
L6 - Burkea africana closed woodland
L7 - Setaria sphacelata-Polygala hottentotta grassland
L8 - Melinis repens-Cynodon dactylon old land grassland

LPL - Landscape position: plains
LLS - low slope
LSS - steep slope
LPT - plateau
LSTR - stream
LDAM - dam



ERN - Erosion: none
ERS - Erosion: slight
ERM - Erosion: medium
ERSV - Erosion: severe

AGR - Activity: grazing
ADR - Activity: drink
ARE - Activity: rest
AESC - Activity: escape
AMVV - Activity: moving

FIGURE 10 Seasonal frequency distribution of kudu in relation to a) range types; b) landscape; c) erosion; and d) activity

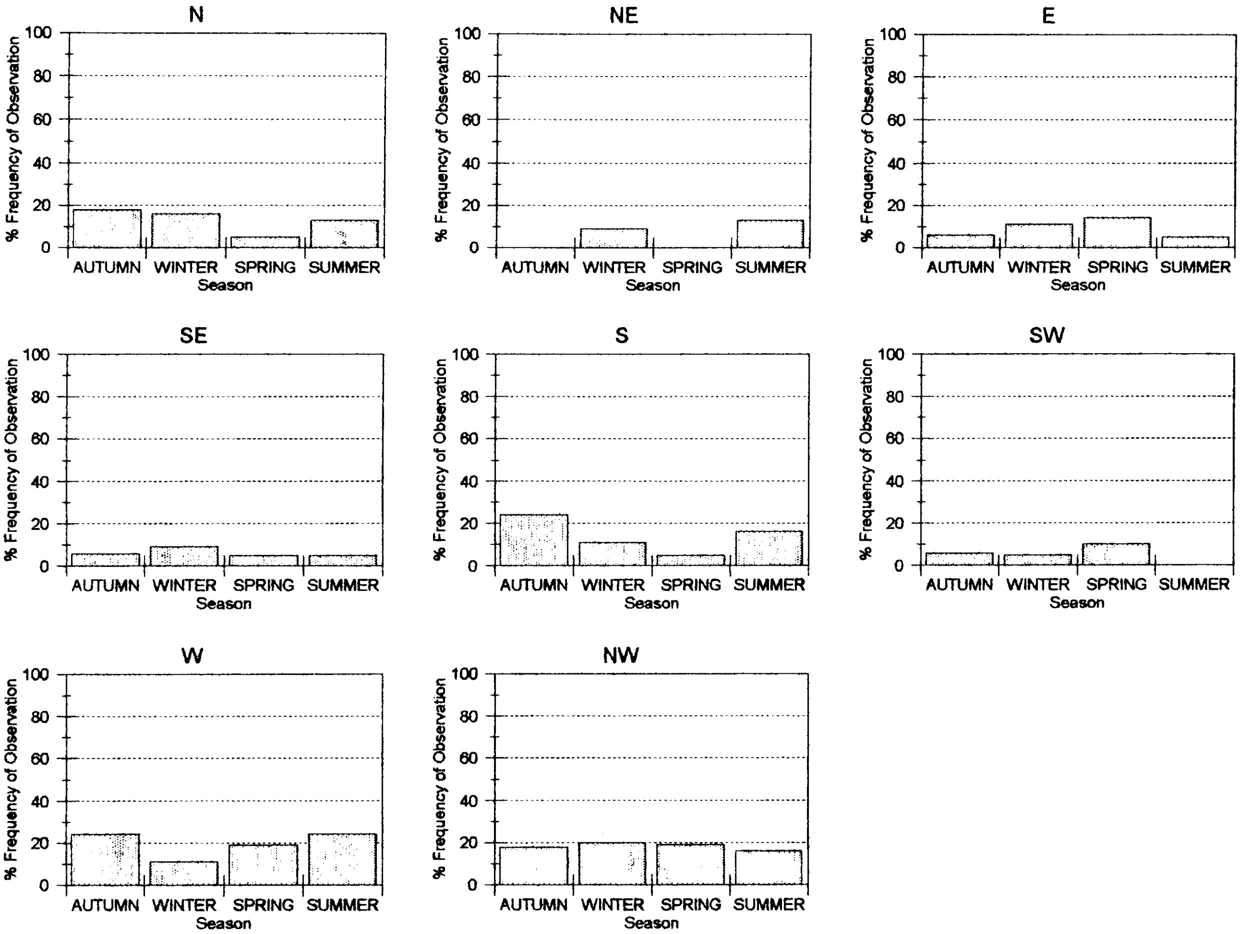
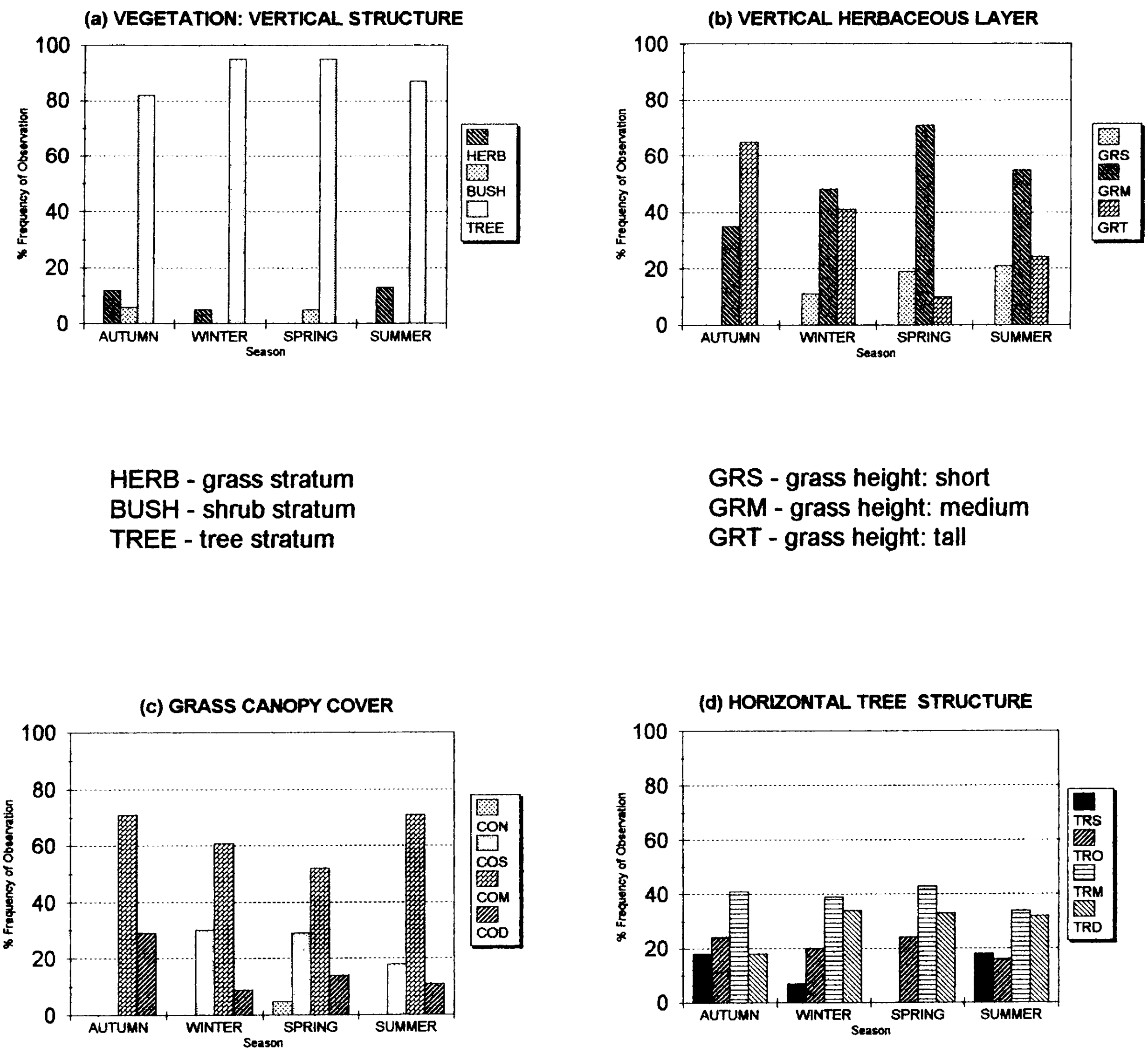


FIGURE 11 Seasonal frequency distribution of kudu in relation to aspect



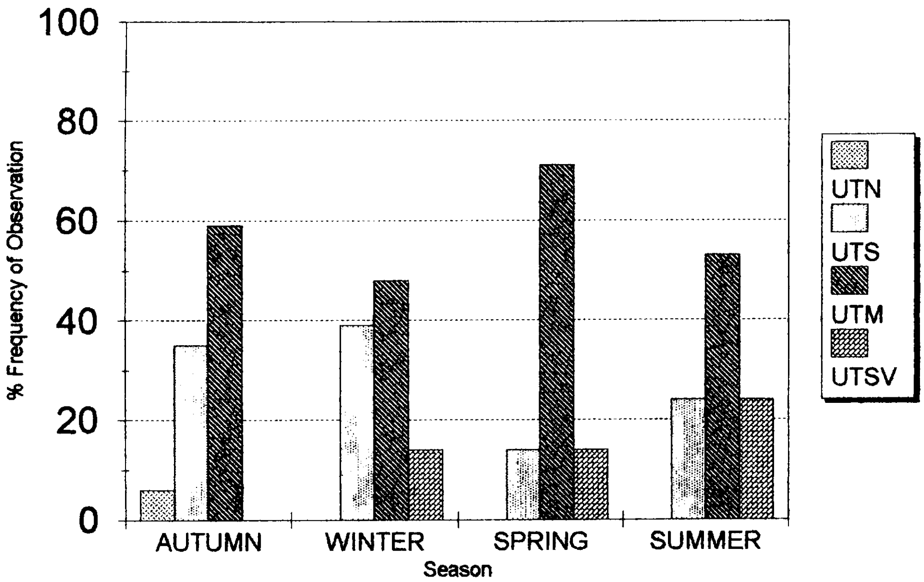
HERB - grass stratum
BUSH - shrub stratum
TREE - tree stratum

GRS - grass height: short
GRM - grass height: medium
GRT - grass height: tall

CON - cover: none
COS - cover: slight
COM - cover: medium
COD - cover: dense

TRS - tree stratum: sparse
TRO - tree stratum: open
TRM - tree stratum: medium
TRD - tree stratum: dense

FIGURE 12 Seasonal frequency distribution of kudu in relation to a) vegetation: vertical structure; b) vertical herbaceous layer; c) grass canopy cover; and d) horizontal structure



UTN - Utilisation: none
UTS - Utilisation: slight
UTM - Utilisation: moderate
UTSV - Utilisation: severe

FIGURE 13 Seasonal frequency distribution of kudu in relation to the degree of utilisation

Blue wildebeest

As indicated in Figure 14a, the *Acacia caffra-Setaria sphacelata* closed woodland(L3) and the *Setaria sphacelata-Polygala hottentotta* grassland (L7) were preferred throughout the year, while *Acacia karroo* closed woodland(L2) was utilised with equal significance. The other range types were not significantly utilised.

The lower slopes (29-43%) and steeper slopes (49-63%) were preferred but the blue wildebeest were not significantly associated with plateaus and plains (Figure 14b). The blue wildebeest were not seen near streams or veld water.

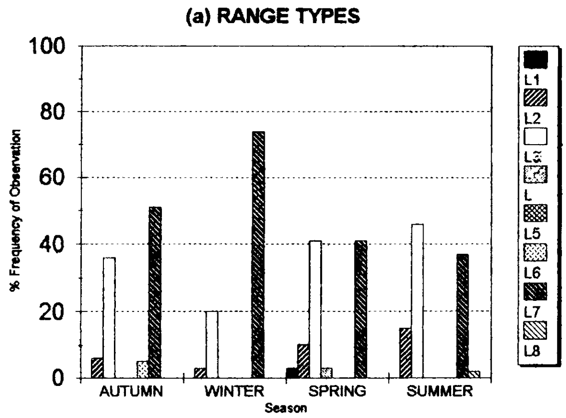
They selected the western (28-41%) and north-western (7-35%) aspects throughout the year with the western aspect selected most (AUTUMN: χ^2=27.38; WINTER: χ^2=21.78; SPRING: χ^2=19.22; SUMMER: χ^2=64.98, $p<0.05$, df=1). They were not regularly noted on the north-eastern aspect (Figure 15).

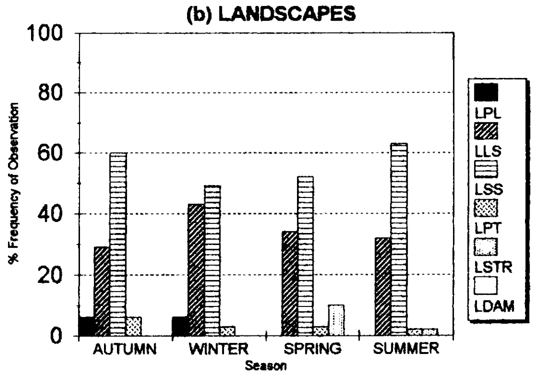
The blue wildebeest were grazing most of the time they were seen (76-100%) and showed only slight tendencies to rest and to move (Figure 14d).

Areas with a dominant tree layer were sought after in autumn, spring and summer (59%, 62% and 63% respectively), but in winter, the areas with a dominant basal layer were preferred (χ^2=38.16, $p<0.05$, df=1) (Figure 16a). The sparse tree layer was selected (58-69%). They were not observed in the very dense tree layer (Figure 16d).

The blue wildebeest showed a preference for short to medium sward lengths in spring and summer (Figure 16b). In winter they showed a distinct preference for 200-800 mm length of grass sward (77%).

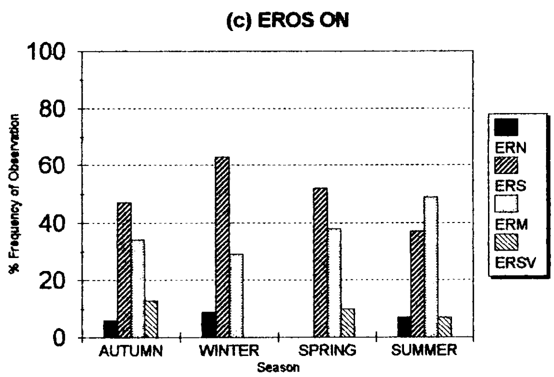
The areas selected had a moderate grass canopy cover (Figure 16c) throughout the year (χ^2>46.24, $p<0.05$, df=12) and they showed a significant preference for medium utilised areas. Under-utilised areas were not preferred (Figure 17).

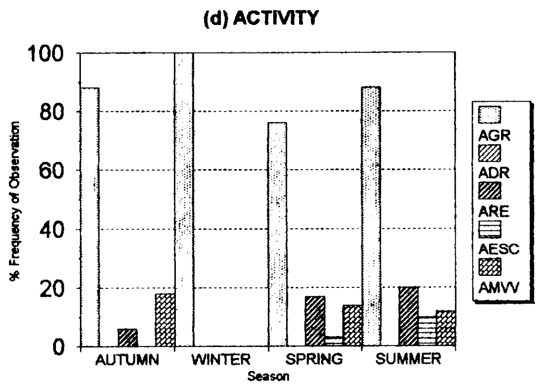




L1 - Berchemia zeyheri thicket
L2 - Acacia karroo closed woodland
L3 - Acacia caffra-Setaria sphacelata closed woodland
L4 - Acacia caffra-Combretum apiculatum closed woodland
L5 - Acacia caffra-Faurea saligna open woodland
L6 - Burkea africana closed woodland
L7 - Setaria sphacelata-Polygala hottentotta grassland
L8 - Melinis repens-Cynodon dactylon old land grassland

LPL - Landscape position: plains
LLS - low slope
LSS - steep slope
LPT - plateau
LSTR - stream
LDAM - dam





ERN - Erosion: none
ERS - Erosion: slight
ERM - Erosion: medium
ERSV - Erosion: severe

AGR - Activity: grazing
ADR - Activity: drink
ARE - Activity: rest
AESC - Activity: escape
AMVV - Activity: moving

FIGURE14 Seasonal frequency distribution of blue wildebeest in relation to a) range type; b) landscape; c) erosion; and d) activity

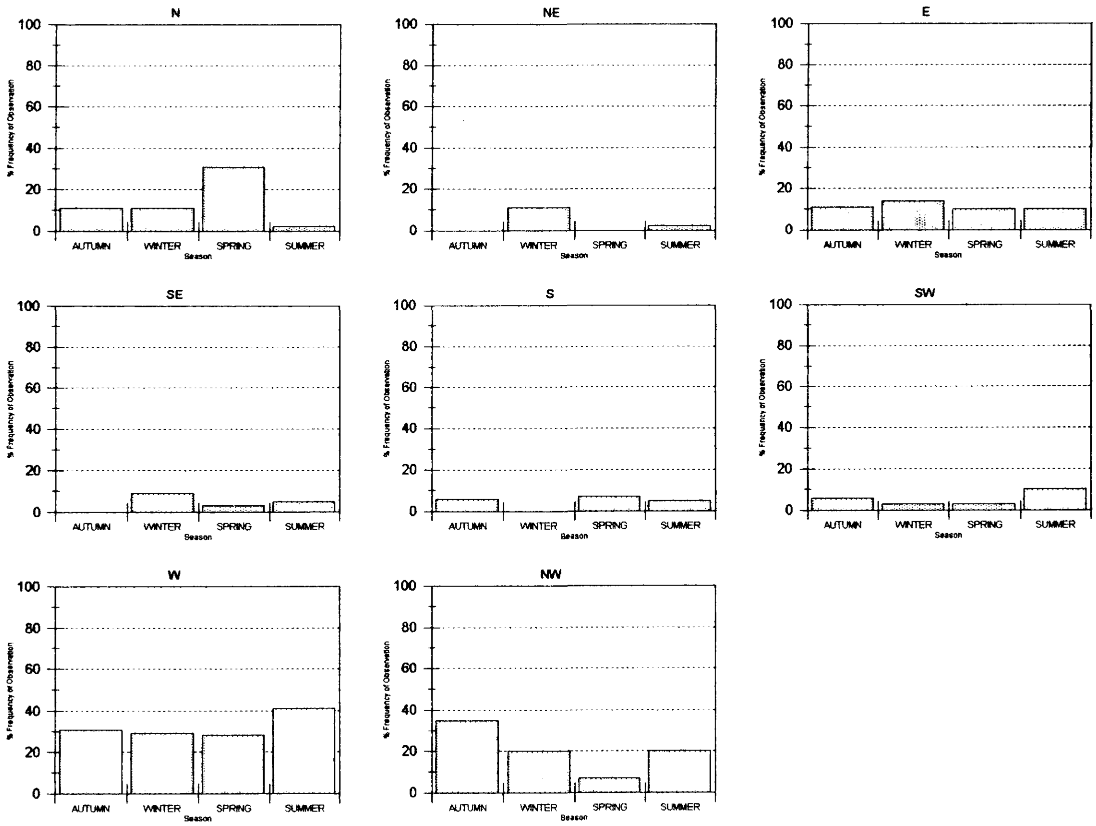
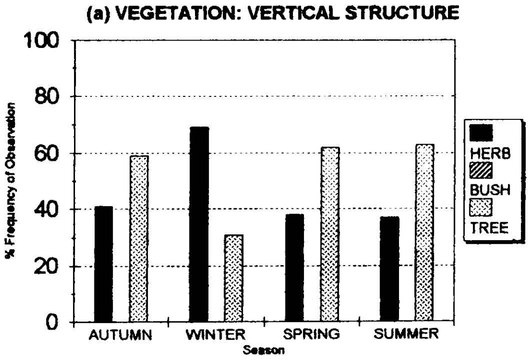
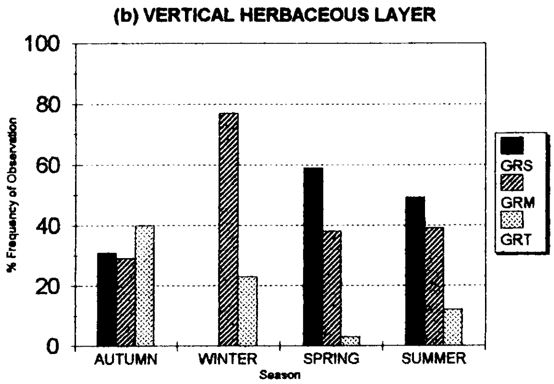


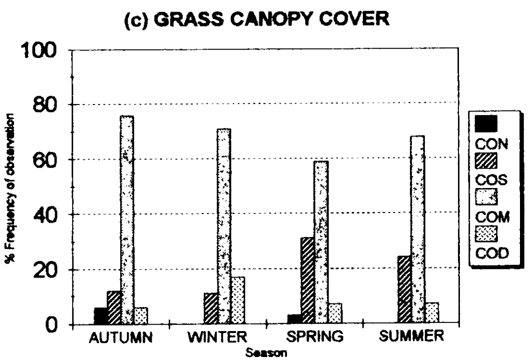
FIGURE 15 Seasonal frequency distribution of blue wildebeest in relation to aspect



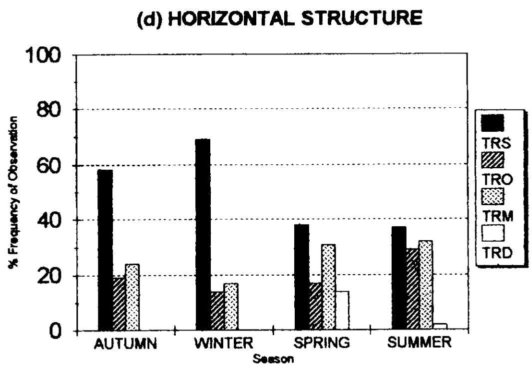
HERB - grass stratum
BUSH - shrub stratum
TREE - tree stratum



GRS - grass height: short
GRM - grass height: medium
GRT - grass height: tall

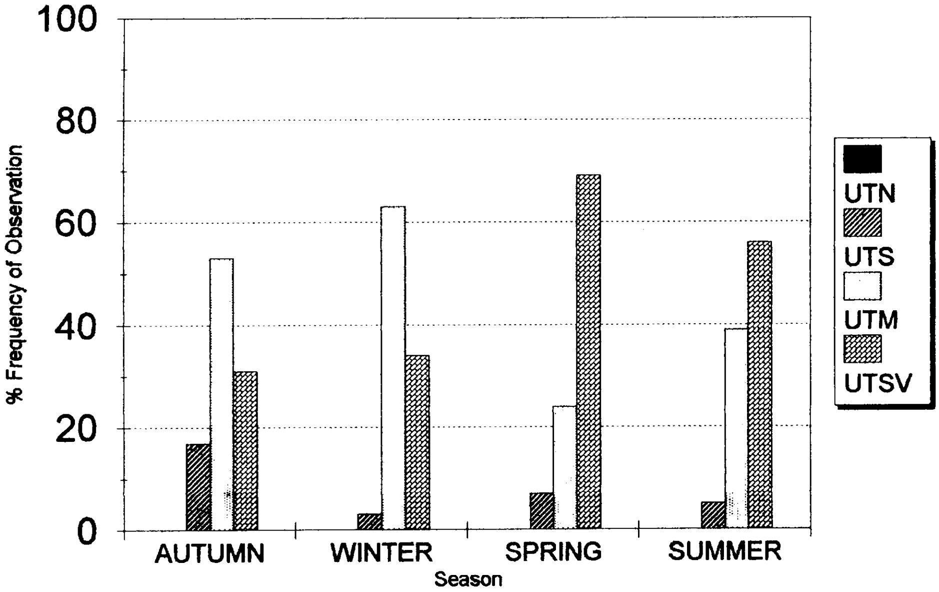


CON - cover: none
COS - cover: slight
COM - cover: medium
COD - cover: dense



TRS - tree stratum: sparse
TRO - tree stratum: open
TRM - tree stratum: medium
TRD - tree stratum: dense

FIGURE 16 Seasonal frequency distribution of blue wildebeest in relation to a) vegetation: vertical structure; b) vertical herbaceous layer; c) grass canopy cover; and; d) horizontal structure



UTN - Utilisation: none
UTS - Utilisation: slight
UTM - Utilisation: moderate
UTSV - Utilisation: severe

FIGURE 17 Seasonal frequency distribution of blue wildebeest in relation to the degree of utilisation

Waterbuck

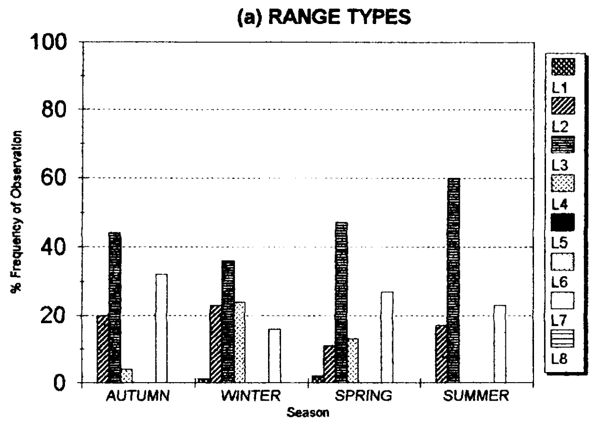
Waterbuck showed a preference for the *Acacia karroo* closed woodland(L2) and *Acacia caffra-Setaria sphacelata* closed woodland(L3) throughout the year (Figure 18a). The waterbuck mostly preferred the low and steep slopes alternatively throughout the year. In winter, spring and summer (63%, 62% and 62% respectively) they preferred the steeper slopes more than the lower slopes. The waterbuck utilised the other landscapes to a lesser extent (Figure 18b). They did not show a specific preference for any aspect, except the northern aspect in spring (χ^2=27.26, p<0.05, df=1)(Figure 19). They were observed grazing 67% of the time and resting 27% of the time (Figure 18d).

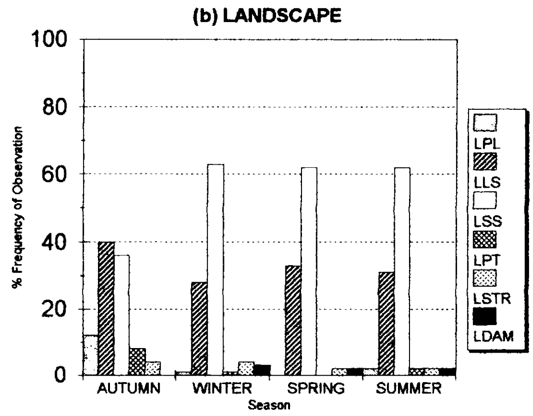
Throughout the year the waterbuck showed preference for slightly eroded areas which were small areas with exposed soil (χ^2>57.67, p<0.05, df=1). They did not show significant preference for areas which were severely eroded with a high degree of soil loss (Figure 18c).

Areas with a dominant tree layer were visited most by the waterbuck throughout the year (Figure 20a). They had a negative relationship with the herbaceous and shrub layer.
They selected no specific tree structure except in winter were they showed preference for the open tree layer areas, and the medium tree layer areas were less frequently visited (28%) (Figure 20d).

They selected grass sward lengths of 200-800 mm, with a preference for areas with a good grass canopy cover with occasional open areas (Figure 20b,c) and moderately utilised areas (Utilisation: χ^2>29.16, p<0.05, df=1) (Figure 21) on the reserve.
They did not show significant preference for no canopy cover or grass sparsely spread in the area (Figure 20c).

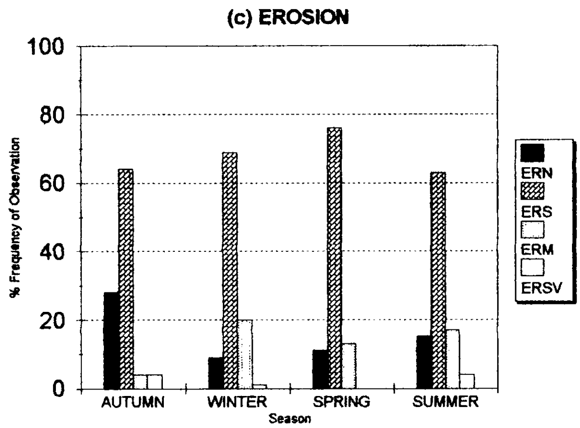
The reserve borders on the dam for almost 80% of the area, and that can be the reason why the waterbuck did not show a specific preference for an area near the dam or water.

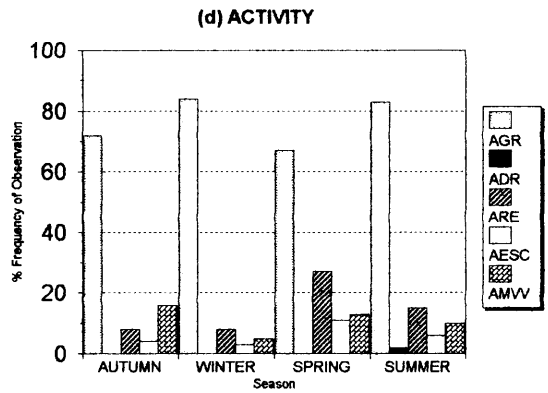




L1 - Berchemia zeyheri thicket
L2 - Acacia karroo closed woodland
L3 - Acacia caffra-Setaria sphacelata closed woodland
L4 - Acacia caffra-Combretum apiculatum closed woodland
L5 - Acacia caffra-Faurea saligna open woodland
L6 - Burkea africana closed woodland
L7 - Setaria sphacelata-Polygala hottentotta grassland
L8 - Melinis repens-Cynodon dactylon old land grassland

LPL - Landscape position: plains
LLS - low slope
LSS - steep slope
LPT - plateau
LSTR - stream
LDAM - dam





ERN - Erosion: none
ERS - Erosion: slight
ERM - Erosion: medium
ERSV - Erosion: severe

AGR - Activity: grazing
ADR - Activity: drink
ARE - Activity: rest
AESC - Activity: escape
AMVV - Activity: moving

FIGURE 18 Seasonal frequency distribution of waterbuck in relation to a) range type; b) landscape; c) erosion; and d) activity

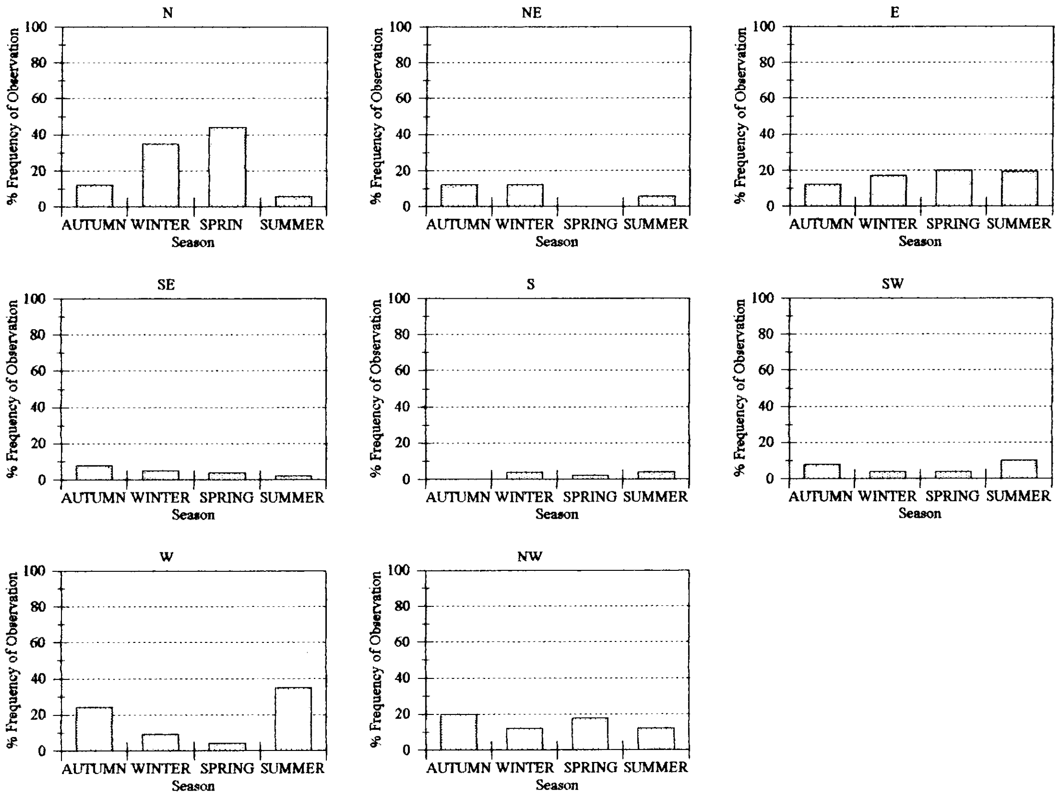
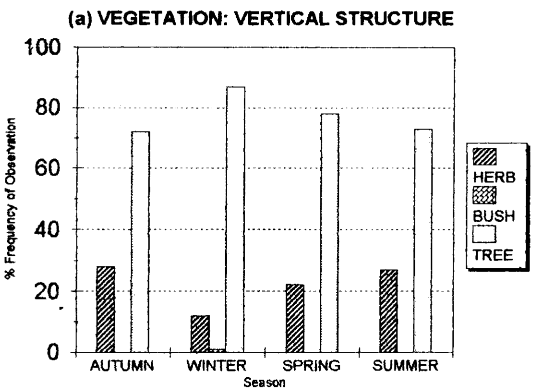
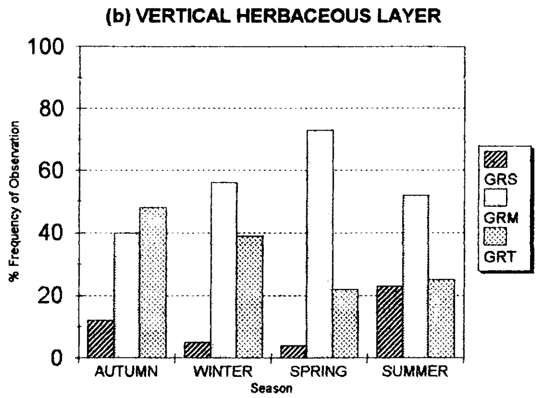


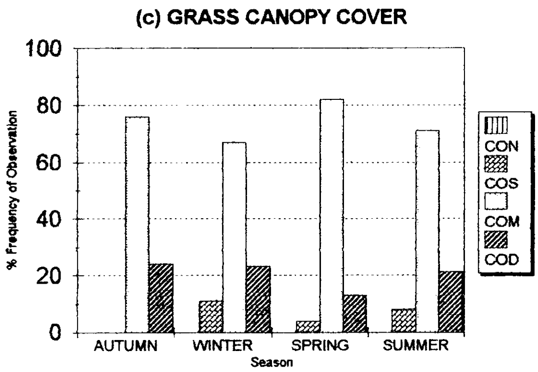
FIGURE 19 Seasonal frequency distribution of waterbuck in relation to aspect



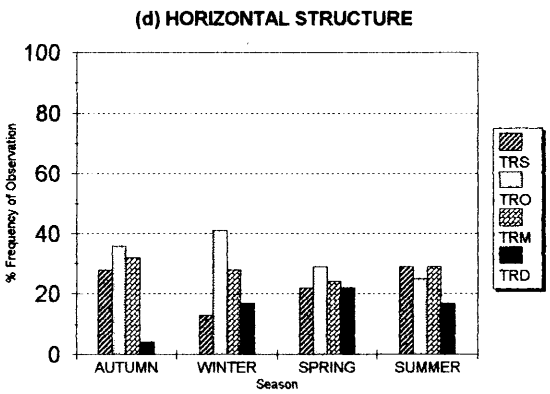
HERB - grass stratum
BUSH - shrub stratum
TREE - tree stratum



GRS - grass height: short
GRM - grass height: medium
GRT - grass height: tall

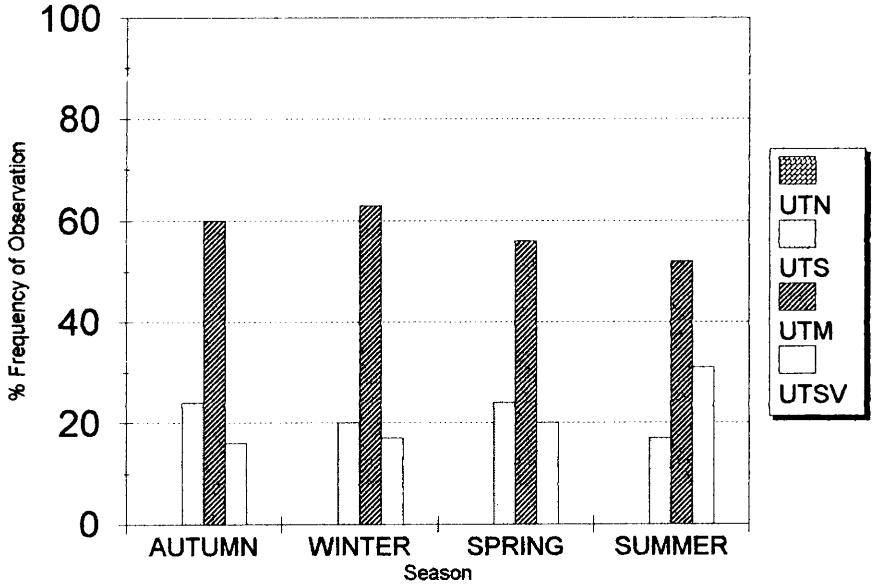


CON - cover: none
COS - cover: slight
COM - cover: medium
COD - cover: dense



TRS - tree stratum: sparse
TRO - tree stratum: open
TRM - tree stratum: medium
TRD - tree stratum: dense

FIGURE 20 Seasonal frequency distribution of waterbuck in relation to a) vegetation: vertical structure; b) vertical herbaceous layer; c) grass canopy cover; and d) horizontal structure



UTN - Utilisation: none
UTS - Utilisation: slight
UTM - Utilisation: moderate
UTSV - Utilisation: severe

FIGURE 21 Seasonal frequency distribution of waterbuck in relation to the degree of utilisation

Burchell's zebra

Zebra spent most of their time grazing in the open *Setaria sphacelata-Polygala hottentotta* grassland(L7) and also preferred *Acacia caffra-Setaria sphacelata* closed woodland(L3). They showed a slight preference for the *Acacia karroo* closed woodland (Figure 22a).

The zebra mostly preferred the steeper slopes (43-70%) throughout the year. The lower slopes were however, more preferred in the winter and spring (35-46%). Zebra only occurred randomly in the other landscapes (Figure 22b). No specific aspect was preferred throughout the year (Figure 23) except the western aspect which they preferred most of the time ($\chi^2 > 28.20$, $p < 0.05$, df=1).

They spent most of their time grazing and less time on other activities (Figure 22d).
The zebra had a significant positive preference for areas with slight erosion where only small areas of soil were exposed ($\chi^2 > 19.36$, $p < 0.05$, df=1). The zebra seldom utilised the severely eroded areas (2-8%) on the reserve. They showed only slight preference for no erosion areas (Figure 22c).

The herbaceous layer was sought after by the zebra and throughout the year they selected areas with a sparse tree stratum ($\chi^2 > 40.96$, $p < 0.05$, df=1) and specifically avoided the dense tree layers (Figure 24a,d). Zebra showed a tendency to prefer medium grass lengths in autumn, winter and spring and in summer they preferred shorter grass lengths significantly (Figure 24b). They showed no significant preference for taller grass sward lengths except in autumn when they showed a positive but non-significant relationship with them ($\chi^2 = 0.65$, $p > 0.05$, df=1).

They showed a distinct preference for moderate canopy cover (63-75%)(Figure 24c) throughout the year which was moderately or over-utilised. They showed little or no preference for slightly or under-utilised areas (Figure 25).

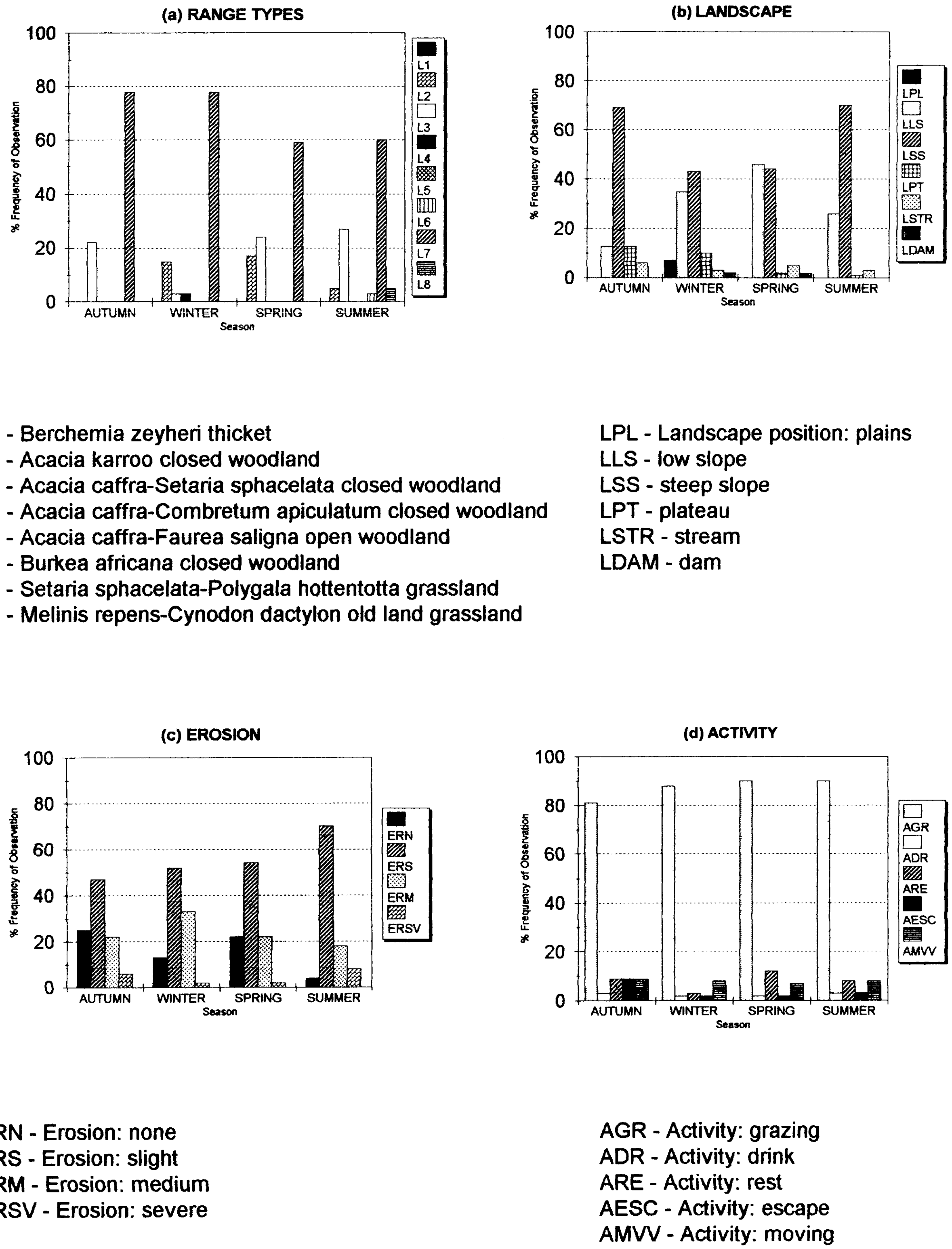


FIGURE 22 Seasonal frequency distribution of Burchell's zebra in relation to a) range type; b) landscape; c) erosion; and d) activity

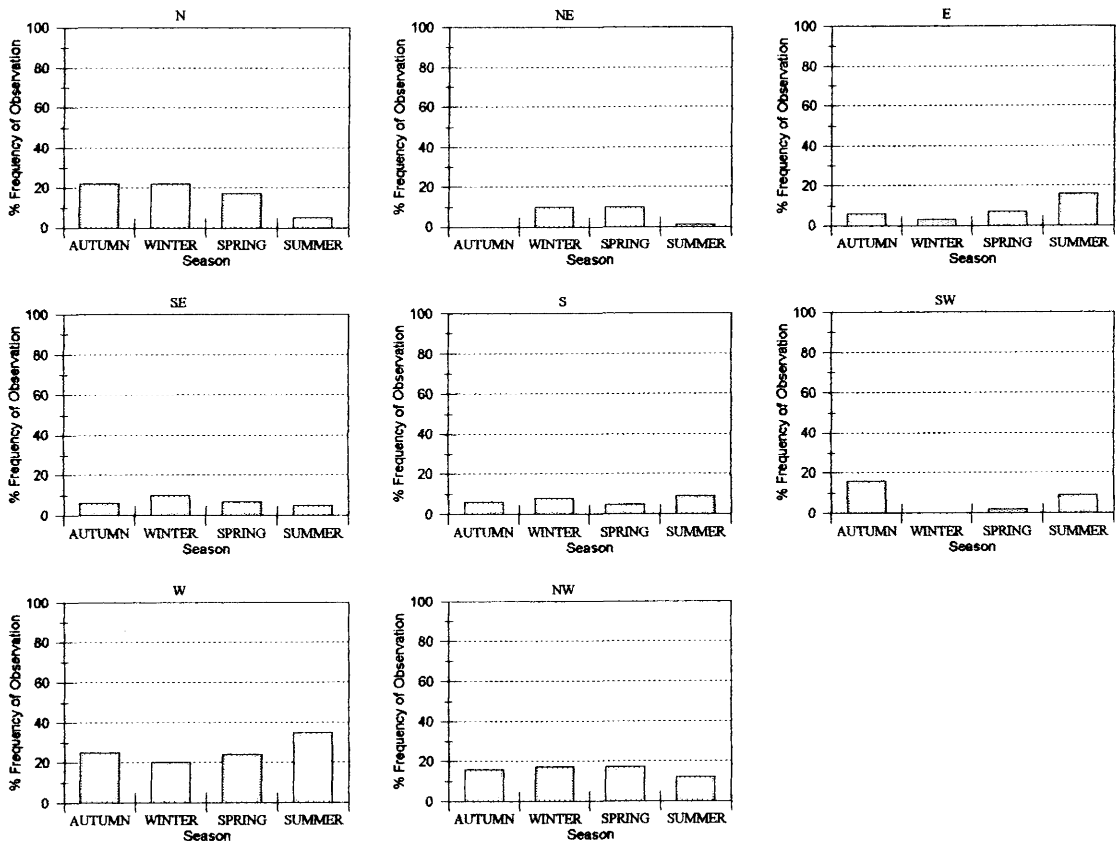
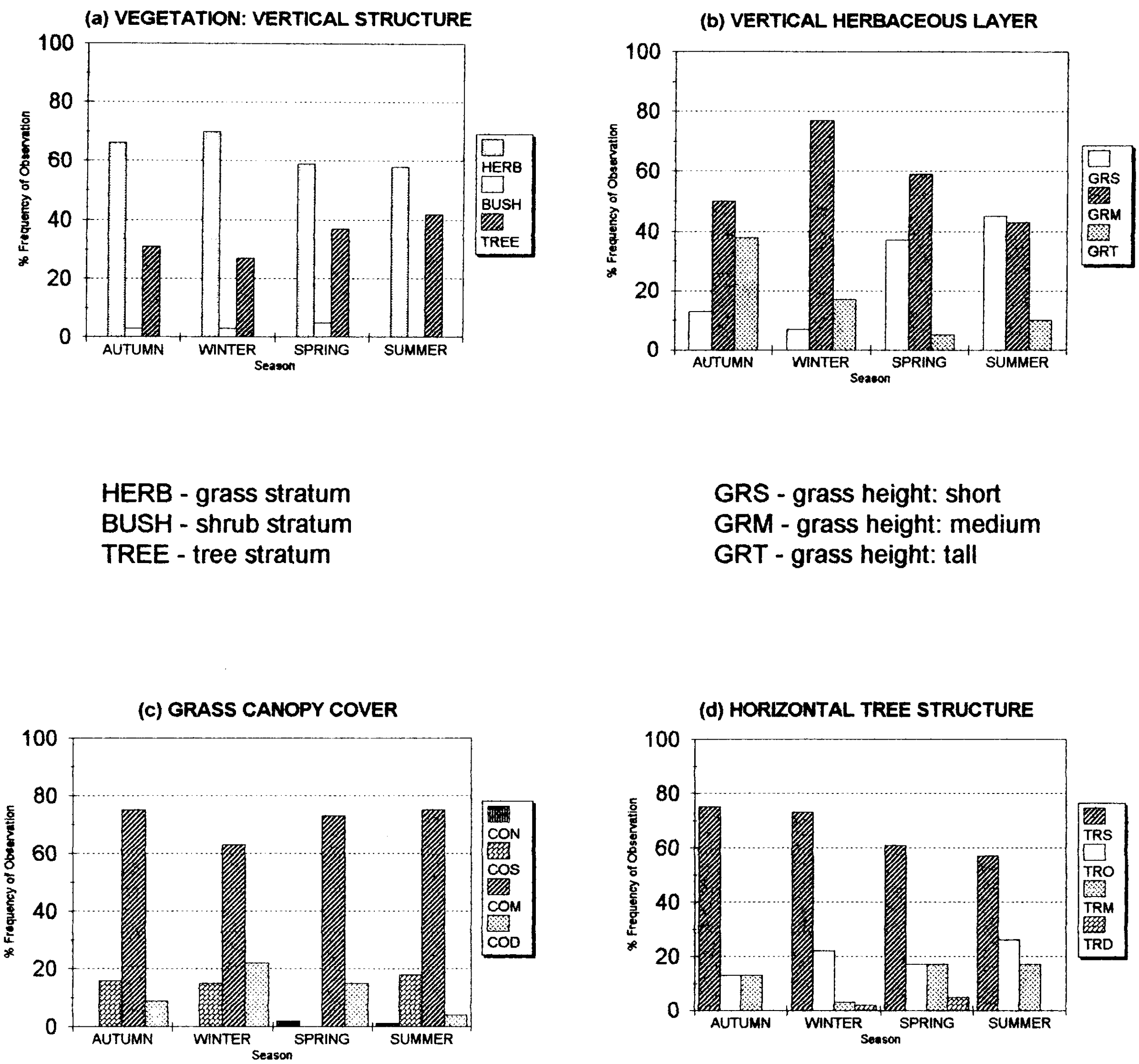


FIGURE 23 Seasonal frequency distribution of Burchell's zebra in relation to aspect



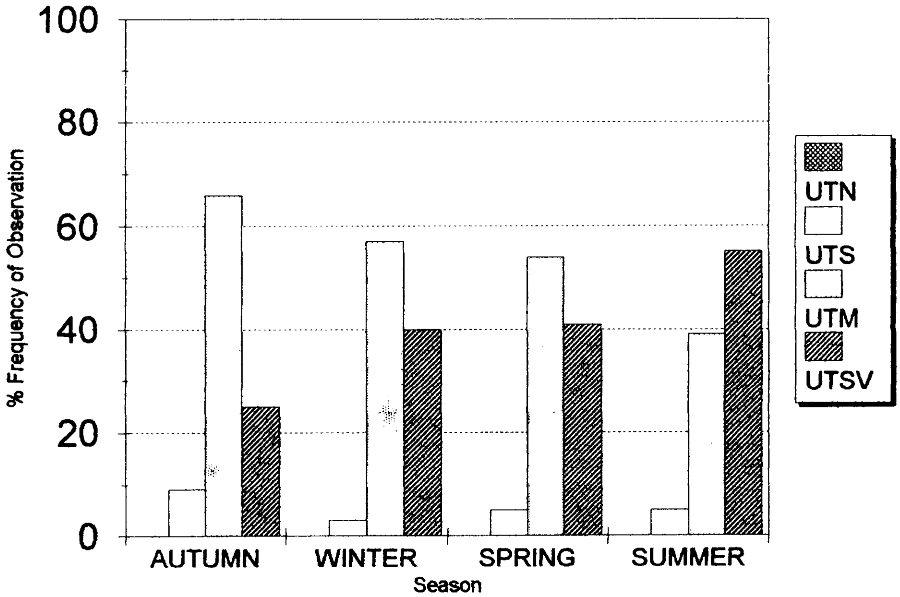
HERB - grass stratum
BUSH - shrub stratum
TREE - tree stratum

GRS - grass height: short
GRM - grass height: medium
GRT - grass height: tall

CON - cover: none
COS - cover: slight
COM - cover: medium
COD - cover: dense

TRS - tree stratum: sparse
TRO - tree stratum: open
TRM - tree stratum: medium
TRD - tree stratum: dense

FIGURE 24 Seasonal frequency distribution of Burchell's zebra in relation to a) vegetation: vertical structure; b) vertical herbaceous layer; c) grass canopy cover; and d) horizontal structure



UTN - Utilisation: none
UTS - Utilisation: slight
UTM - Utilisation: moderate
UTSV - Utilisation: severe

FIGURE 25 Seasonal frequency distribution of Burchell's zebra in relation to the degree of utilisatio

Impala

The impala, though not regularly seen, preferred the *Setaria sphacelata-Polygala hottentotta* grassland(L7) significantly, while the *Acacia caffra-Setaria sphacelata* closed woodland(L3) was also highly preferred. They did not occur significantly in the other range types (Figure 26a).

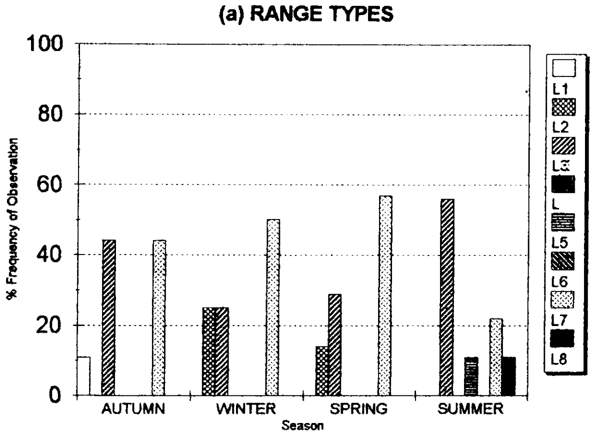
The impala showed a tendency to prefer the lower slopes in all seasons reaching a high in spring (86%) and a low but still significant preference in winter (25%).

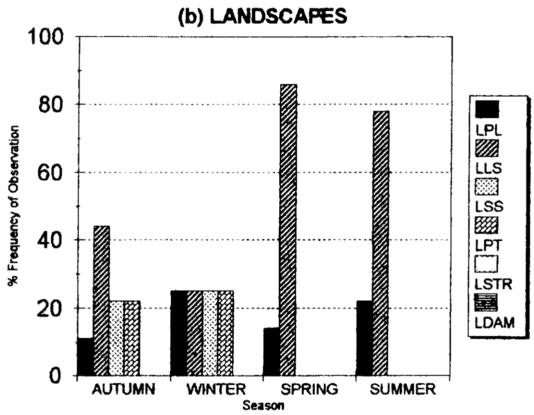
The impala had a very strong positive relationship with the lower slopes. A significant interaction was also indicated for the plains over the four seasons. Preference was also given to steep slopes and plateaus in autumn and winter (22-25%). Throughout the year streams and the dam area were not selected (Figure 26b). In autumn the impala occurred on the western slopes very often (56%) and had no definite preference for any specific aspect. In winter and spring they had a significant positive relationship with the northern slopes on the reserve, while in summer they mostly preferred the southern and western slopes (Figure 27).

The impala grazed most of the time, except in spring when they were recorded moving more often (29%). Areas with larger areas of exposed soils and low plant cover were utilised throughout the year (50-67%) except in the autumn months. Impala also utilised slightly eroded areas on the reserve but this was statistically tested as insignificant ($\chi^2<2.56$, $p>0.05$, df=1)(Figure 26c,d).

The impala utilised areas with a dominant tree layer significantly throughout the year (Figure 28a), but also showed a preference for the herbaceous layer in winter (50%). From autumn to summer selection for horizontal vegetation structure varied from sparse tree layer in autumn; sparse, open and medium tree layer in winter and spring, to medium tree layer in summer (Figure 28d).

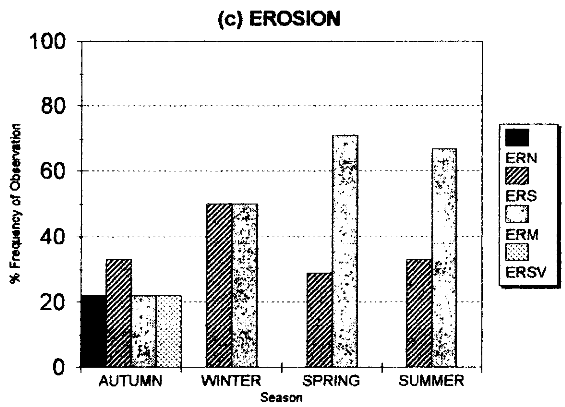
A short grass sward with a moderate grass canopy cover was preferred in autumn, spring and summer (44-57%), but most significantly in spring ($\chi^2=16.8$, $p<0.05$, df=1). They did not show any preference for grass lengths higher than 800 mm throughout the year, neither did they show preference for very dense grass canopy cover (Figure 28b,c).

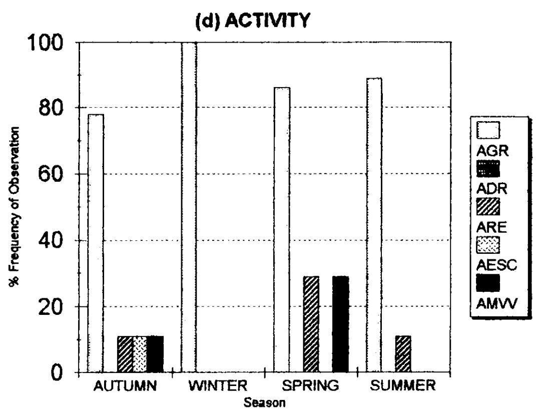




L1 - Berchemia zeyheri thicket
L2 - Acacia karroo closed woodland
L3 - Acacia caffra-Setaria sphacelata closed woodland
L4 - Acacia caffra-Combretum apiculatum closed woodland
L5 - Acacia caffra-Faurea saligna open woodland
L6 - Burkea africana closed woodland
L7 - Setaria sphacelata-Polygala hottentotta grassland
L8 - Melinis repens-Cynodon dactylon old land grassland

LPL - Landscape position: plains
LLS - low slope
LSS - steep slope
LPT - plateau
LSTR - stream
LDAM - dam





ERN - Erosion: none
ERS - Erosion: slight
ERM - Erosion: medium
ERSV - Erosion: severe

AGR - Activity: grazing
ADR - Activity: drink
ARE - Activity: rest
AESC - Activity: escape
AMVV - Activity: moving

FIGURE 26 Seasonal frequency distribution of impala in relation to a) range type; b) landscape; c) erosion; and d) activity

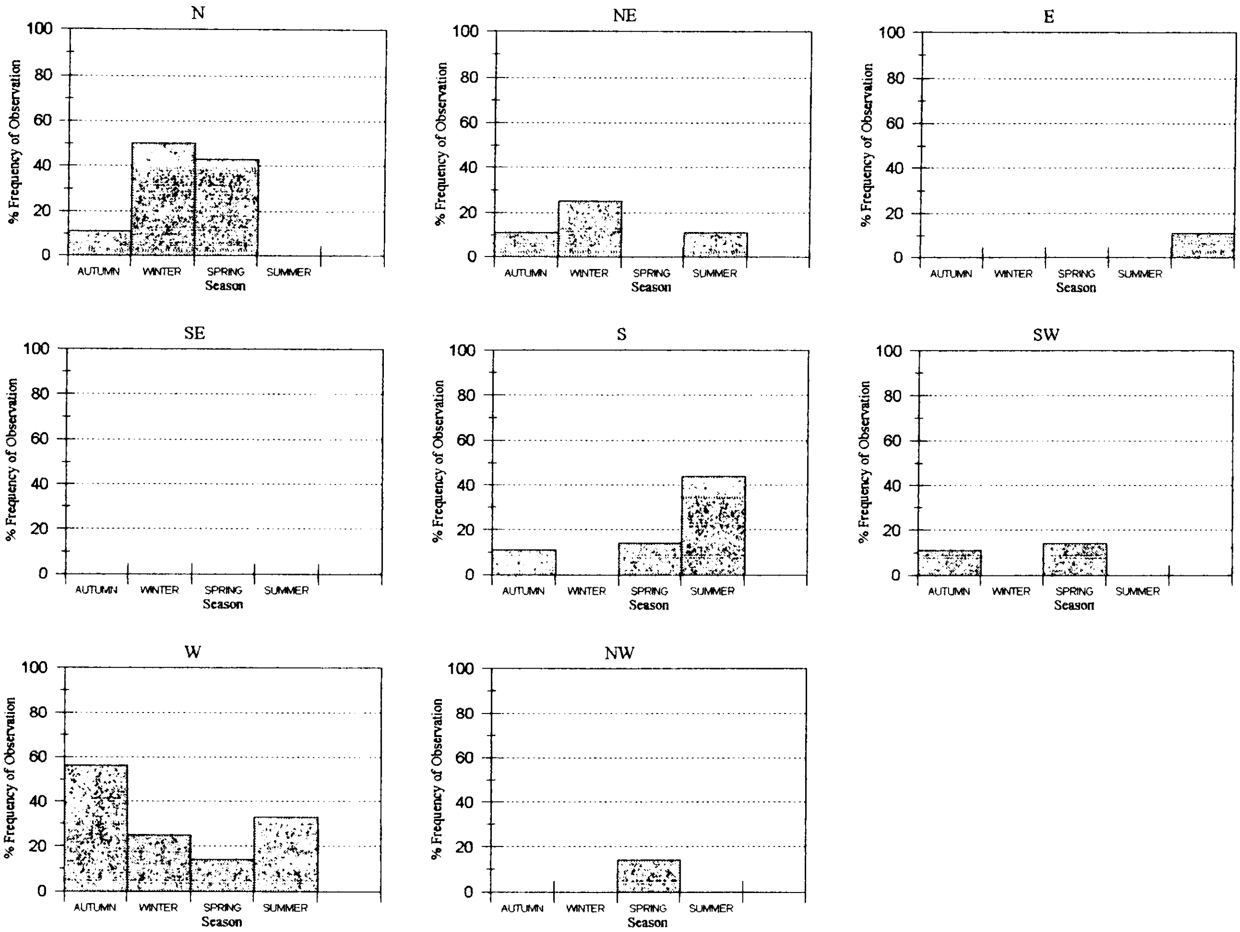
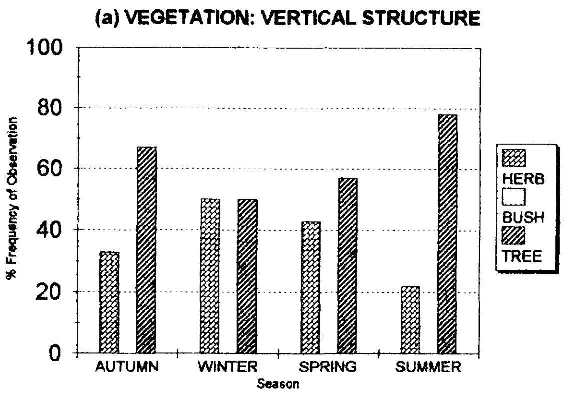
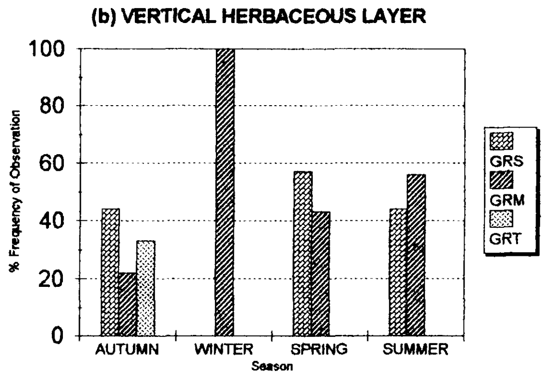


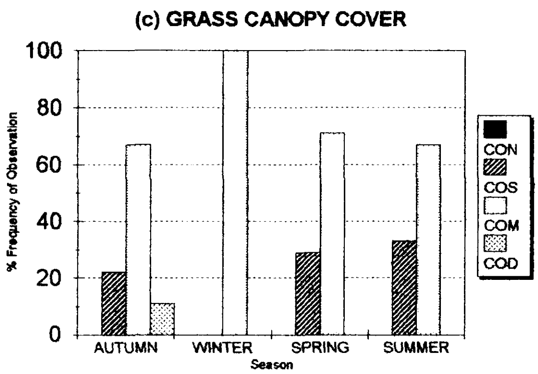
FIGURE 27 Seasonal frequency distribution of impala in relation to aspect



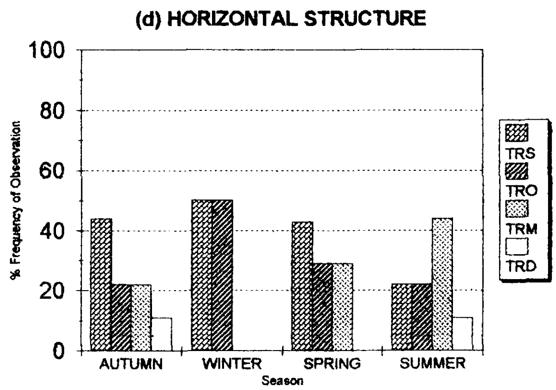
HERB - grass stratum
BUSH - shrub stratum
TREE - tree stratum



GRS - grass height: short
GRM - grass height: medium
GRT - grass height: tall



CON - cover: none
COS - cover: slight
COM - cover: medium
COD - cover: dense



TRS - tree stratum: sparse
TRO - tree stratum: open
TRM - tree stratum: medium
TRD - tree stratum: dense

FIGURE 28 Seasonal frequency distribution of impala in relation to a) vegetation: vertical structure; b) vertical herbaceous layer; c) grass canopy cover; and d) horizontal structure

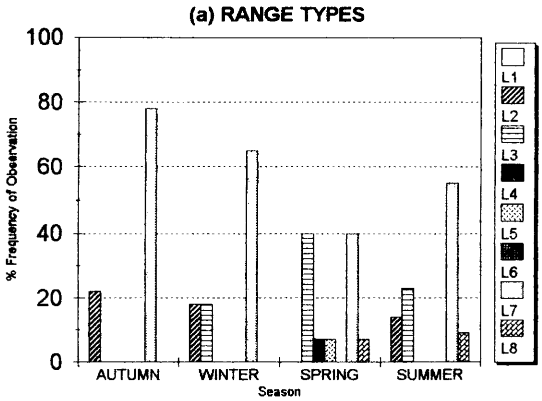
Red hartebeest

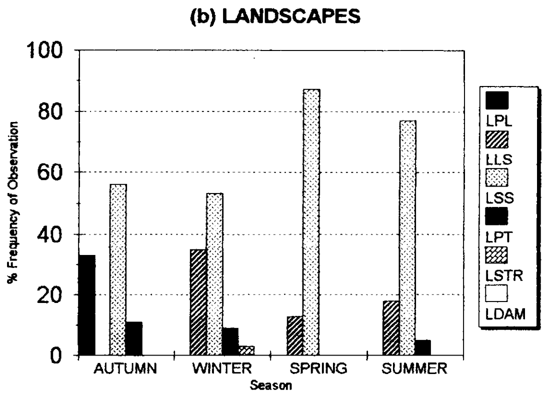
The most significantly utilised range type was the *Setaria sphacelata-Polygala hottentotta* grassland(L7). The *Acacia karroo* closed woodland(L2), *Acacia caffra-Setaria sphacelata* closed woodland(L3) and *Melinis repens-Cynodon dactylon* old land grassland(L8) were also utilised throughout the year (Figure 29a).

The red hartebeest mostly preferred the medium to steep slopes (53-87%) on the reserve and they showed a strong preference for these landscapes especially in spring and summer (χ^2=296.81 and 218.4 respectively, $p<0.05$, df=1)(Figure 29b). They moved around seasonally with regard to the aspect of the slope, but they showed a strong tendency towards the western aspect throughout the year (12-45%), the lowest percentage being in winter and the highest in summer (Figure 30). Grazing was their major activity and its frequency varied from 77-82% of the time. They were observed utilising areas with slight erosion throughout the year (Figure 29c,d). They avoided areas which were severely eroded (Figure 29c).

The herbaceous layer was frequently preferred in autumn and winter (78% and 68%) and the tree layer preferred in spring (73%), preferring open tree layer above sparse areas (OPEN: χ^2=49, $p<0.05$, df=1). Dense tree areas were avoided throughout the year (Figure 31a,d).

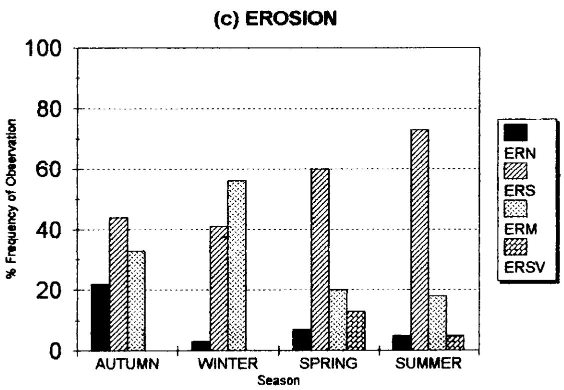
In winter, spring and summer the red hartebeest occupied areas with a medium grass length with good canopy cover and occasional open areas. In autumn they showed a preference for the grass sward length higher than 800 mm. They did not prefer areas with no grass cover (Figure 31b,c). The red hartebeest showed alternative preference for moderately and over-utilised areas throughout the year (Figure 32).

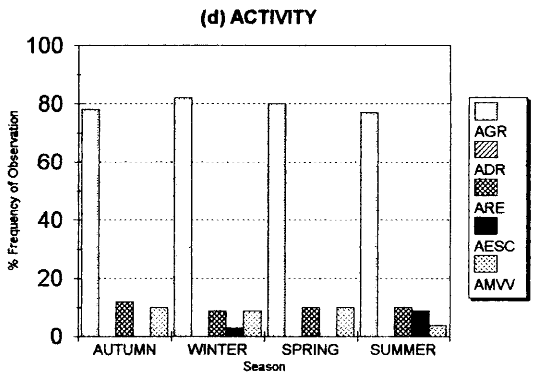




L1 - Berchemia zeyheri thicket
L2 - Acacia karroo closed woodland
L3 - Acacia caffra-Setaria sphacelata closed woodland
L4 - Acacia caffra-Combretum apiculatum closed woodland
L5 - Acacia caffra-Faurea saligna open woodland
L6 - Burkea africana closed woodland
L7 - Setaria sphacelata-Polygala hottentotta grassland
L8 - Melinis repens-Cynodon dactylon old land grassland

LPL - Landscape position: plains
LLS - low slope
LSS - steep slope
LPT - plateau
LSTR - stream
LDAM - dam



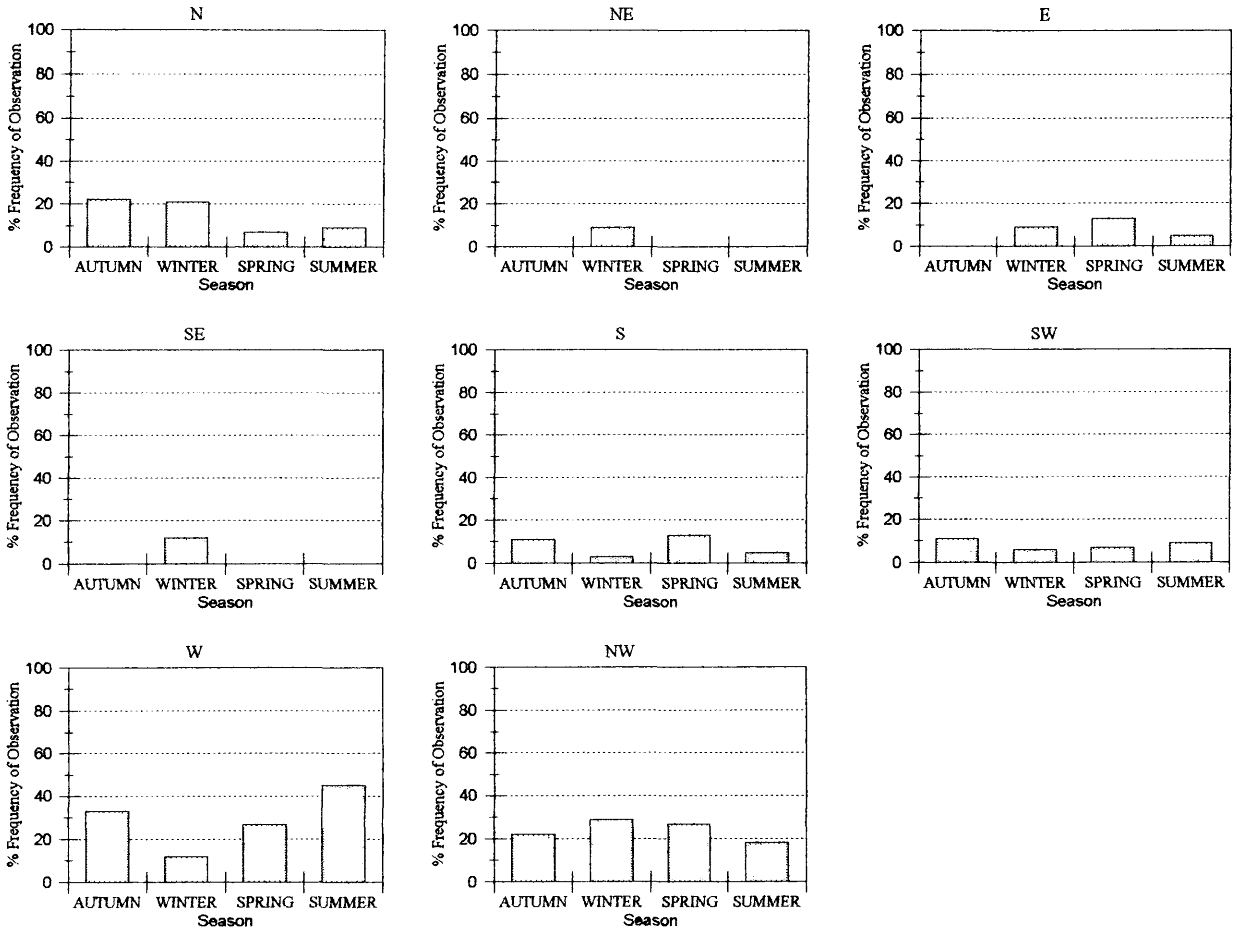


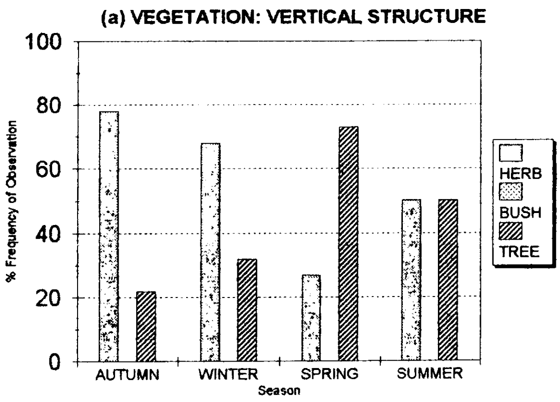
ERN - Erosion: none
ERS - Erosion: slight
ERM - Erosion: medium
ERSV - Erosion: severe

AGR - Activity: grazing
ADR - Activity: drink
ARE - Activity: rest
AESC - Activity: escape
AMVV - Activity: moving

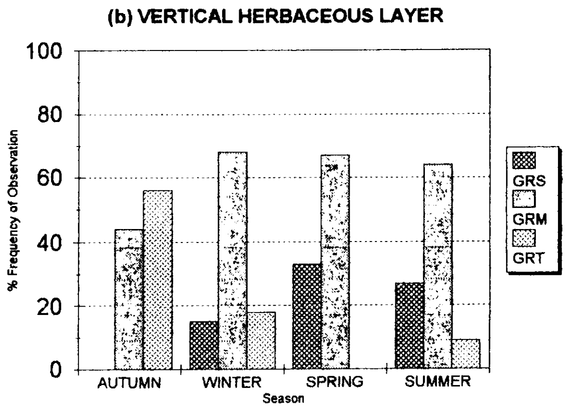
FIGURE 29 Seasonal frequency distribution of red hartebeest in relation to a) range type; b) landscape; c) erosion; and d) activity

FIGURE 30 Seasonal frequency distribution of red hartebeest in relation to aspect

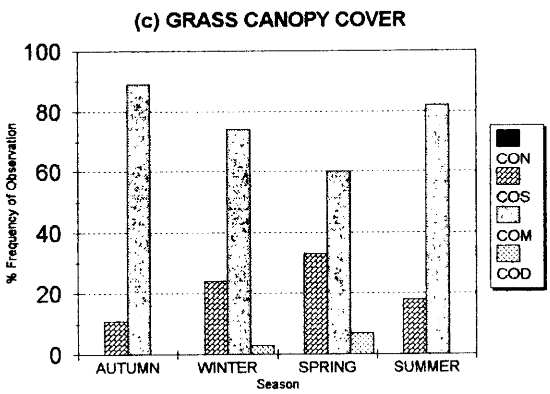

N
NE
E
SE
S
SW
W
NW
% Frequency of Observation
0
20
40
60
80
100
AUTUMN
WINTER
SPRING
SUMMER
Season



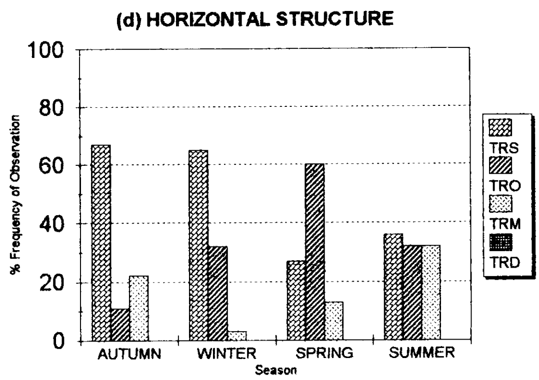
HERB - grass stratum
BUSH - shrub stratum
TREE - tree stratum



GRS - grass height: short
GRM - grass height: medium
GRT - grass height: tall

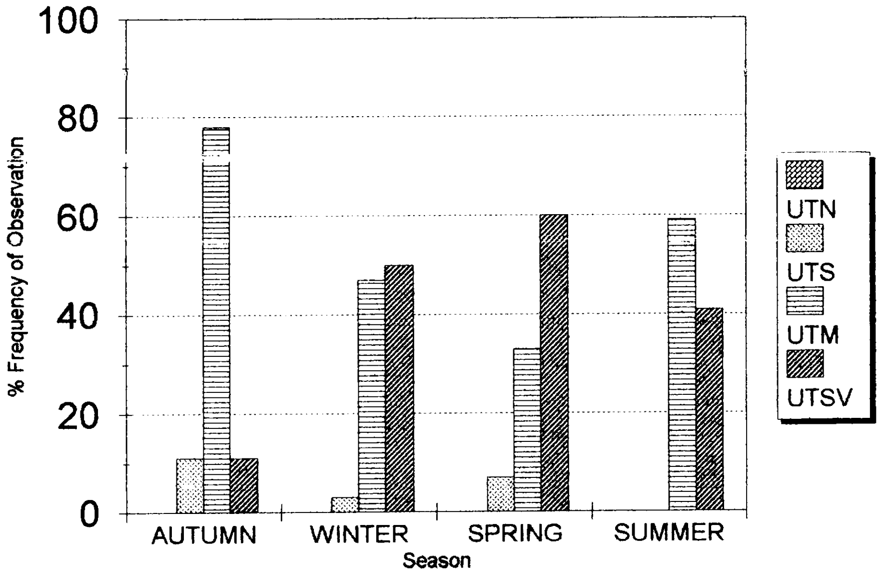


CON - cover: none
COS - cover: slight
COM - cover: medium
COD - cover: dense



TRS - tree stratum: sparse
TRO - tree stratum: open
TRM - tree stratum: medium
TRD - tree stratum: dense

FIGURE 31 Seasonal frequency distribution of red hartebeest in relation to a) vegetation: vertical structure; b) vertical herbaceous layer; c) grass canopy cover; and d) horizontal structure



UTN - Utilisation: none
UTS - Utilisation: slight
UTM - Utilisation: moderate
UTSV - Utilisation: severe

FIGURE 32 Seasonal frequency distribution of red hartebeest in relation to degree of utilisation

(ii)Correspondence Analysis

Correspondence Analysis is applied to an example of frequency measures in an ecological environment and the interaction between certain animal species and a number of habitat factors are examined. The data show frequency counts of 6 animal species (represented as rows) with 54 habitat factors (represented as columns) (Beardall, Joubert & Retief 1984).

Interpretation of correspondence analysis is based on the numerical output (Tables 2 & 4) together with the graphical display (Figure 31).

The total inertia(I) is calculated (Table 2) as the sum of the moments of inertia. In the column PERCENT each eigenvalue is expressed as a percentage of (I) and the cumulative percentages of inertia are listed in the column headed CUMUL PERC (Beardall, Joubert & Retief 1984).

TABLE 2 Moments of inertia and their percentage of the total inertia

Axe	Inertia(Eigenvalue)	Percent	Cumul percentage
1	0.074	53.8%	53.8%
2	0.038	27.6%	81.4%
3	0.012	8.9%	90.3%
4	0.007	5.3%	95.6%
TOTAL INERTIA (I) = 0.138			

For the purpose of the following discussion we look at the angle formed when joining two points to the origin, where a small angle indicates a high "correlation" (Beardall *et al.* 1984). The distance of the points from the origin plays an important role and points close to the origin have weak "correlations".

As the number of variables increased, interpretation of the graphical display became more complicated and variables were chosen subjectively based on chi-square values (Table 3).

TABLE 3 Symbols used in the Correspondence Analysis of data for the herbivores on the Roodeplaat Dam Nature Reserve

BWB - blue wildebeest
KUDU - kudu
IMPA - impala
RHB - red hartebeest
WB - waterbuck
ZEB - zebra
L1 - Berchemia zeyheri thicket
L2 - Acacia karroo closed woodland
L3 - Acacia caffra-Setaria sphacelata closed woodland
L4 - Acacia caffra-Combretum apiculatum closed woodland
L5 - Acacia caffra-Faurea saligna open woodland
L6 - Burkea africana closed woodland
L7 - Setaria sphacelata-Polygala hottentotta grassland
L8 - Melinis repens-Cynodon dactylon old land grassland
AGR - Activity: graze
ADR - Activity: drink
ARE - Activity: rest
AESC - Activity: escape
AMVV - Activity: moving
ASPE N - Aspect: north
ASPE NE - Aspect: north-east
ASPE E - Aspect: east
ASPE SE - Aspect: south-east
ASPE S - Aspect: south
ASPE SW - Aspect: south-west
ASPE W - Aspect: west
ASPE NW - Aspect: north-west
LPL - Landscape position: plains
LLS - low slope
LSS - steep slope
LPT - plateau
LSTR - stream
LDAM - dam
SLOP 1 - Slope: 0-3°
SLOP 2 - Slope: >3-8°
SLOP 3 - Slope: >8-16°
SLOP 4 - Slope: 16-25°
SLOP 5 - Slope: >25°
EROS N - Erosion: none
EROS S - Erosion: slight
EROS M - Erosion: moderate
EROS SV - Erosion: severe

HERB - grass stratum
BUSH - Shrub stratum
TREE - Tree stratum
TRS - Tree stratum: sparse
TRO - Tree stratum: open
TRM - Tree stratum: medium
TRD - Tree stratum: dense
GRS - Grass height: short
GRM - Grass height: medium
GRT - Grass height: tall

CON - Cover: none
COS - Cover: slight
COM - Cover: medium
COD - Cover: dense
UTN - Utilisation: none
UTS - Utilisation: slight
UTM - Utilisation: moderate
UTSV - Utilisation: severe

On interpreting Figure 33 it is important to realise that there is no interpretation of distances between objects and variables (Greenacre 1978, 1981). However, the angle formed when joining two elements to the origin with straight lines gives a fairly good indication of their "closeness". If the angle so formed is small, we say the elements are highly correlated with each other. The larger the angle the weaker the correlation. For example the angle formed when joining KUDU, L3 (*Acacia caffra-Setaria sphacelata* closed woodland) and TREE (Tree stratum) are all small, indicating a close association. If the angle between the lines approaches 180°, the elements are strongly negatively "correlated" with each other. However, if an element's position is very close to the origin, such interpretations become weaker, since the element probably does not "relate" highly with the subspace depicted.

Thus to illustrate the interpretation, the detailed results in Table 4 show objects kudu and waterbuck with absolute contributions of 0,8549 and 0,6791 respectively, largely dominating axis 1. Axis 2 is dominated by impala (high positive values).
Similarly axis 1 is dominated by variables L5 (ABS CON = 1.3), ADR (ABS CON = 2.3283), LPL (ABS CON = 1.1256), SLOP 4 (4.7064), SLOP 5 (ABS CON = 3.5468) and UTN (ABS CON = 2.4857).
The results in Table 4 provide the following information for each element i.e. object (species) and variable (habitat factor) and axis:

WEIGHT: This value is equal to the proportion of observations of that object/variable.
#1F: This gives the co-ordinate of the object/variable with respect to the 1st axis.
RELCON: This contains the relative contribution of the axis to the inertia of the element. It also represents the squared correlation of the element with the axis. That is to say it describes the importance of the axis to the element. (Species: Species tolerance - root mean squared deviation for species. Samples: Sample heterogeneity - root mean squared deviation for samples).

TABLE 4 Decomposition of the first two moments of inertia in terms of the habitat factors (variables) and the animal species (objects)

No.	Name	Weight	#1F	RELCON	ABSCON	#2F	RELCON	ABSCON
1	BWB	1103	-0.1423	0.946	0.3879	-0.044	0.9438	0.425
2	KUDU	1083	0.4391	1.0688	0.8549	0.0688	1.0176	0.8759
3	IMPA	1105	-0.1804	0.9349	0.1675	0.3975	1.0765	0.9808
4	RHB	1111	-0.2097	0.8589	0.4838	-0.139	0.9527	0.6962
5	WB	1103	0.3257	1.0236	0.6791	-0.1031	0.948	0.7472
6	ZEB	1091	-0.225	0.9295	0.4692	-0.1806	0.9386	0.7713
1	L1	8	1.6204	1.5288	0.6885	4.1179	3.9663	0.0443
2	L2	73	0.8735	0.8584	0.0419	-0.7897	0.7768	0.0182
3	L3	210	0.9278	0.9047	0.0404	0.8587	0.849	0.0124
4	L4	21	3.3914	3.1477	0.7428	-1.8468	1.7782	0.6132
5	L5	10	2.545	2.3765	1.3098	3.8587	3.7162	0.7442
6	L6	5	2.5669	2.3965	1.186	-0.0966	0.1355	1.1856
7	L7	263	-1.3101	1.2326	0.0303	-0.7186	0.7185	0.0107
8	L8	11	-1.8832	1.7536	0.2662	0.7185	0.7305	0.2466
9	AGR	497	-0.1626	0.3065	0.0016	0.0234	0.1986	0.0016
10	ADR	3	-0.5599	0.5799	2.3283	-4.0734	3.9189	1.6979
11	ARE	73	-0.535	0.554	0.1135	-0.0629	0.2134	0.1133
12	AESC	27	1.2028	1.151	0.0075	-0.2132	0.2644	0.0058
13	AMVV	63	0.1657	0.3176	0.021	0.0323	0.1925	0.0209
14	ASPE N	103	0.2646	0.3657	0.0704	0.3053	0.3597	0.0669
15	ASPE NE	36	0.1741	0.3153	0.1349	1.3591	1.3269	0.0647
16	ASPE E	58	0.933	0.9077	0.1478	-1.4823	1.432	0.0643
17	ASPE SE	28	0.4477	0.5052	0.2134	-2.1453	2.0657	0.0386
18	ASPE S	56	-0.0704	0.2893	0.4589	3.0769	2.9691	0.0993
19	ASPE SW	38	-0.3537	0.4185	0.0108	0.0334	0.2048	0.0107
20	ASPE W	153	-0.7009	0.694	0.0144	0.3329	0.3816	0.0102
21	ASPE NW	94	0.0863	0.2898	0.1797	-1.6893	0.6294	0.0713
22	LPL	29	-1.5021	1.4036	1.1256	5.0028	4.8193	0.1749
23	LLS	215	-0.1705	0.3082	0.115	1.6689	1.6212	0.0092
24	LSS	301	0.2715	0.3763	0.129	-1.7835	1.7199	0.0081
25	LPT	31	-1.0597	1.0096	0.1692	1.6935	1.647	0.0603
26	LSTR	19	2.1	1.9675	0.336	-1.0428	1.0083	0.2946
27	LDAM	4	2.934	2.7194	0.621	-2.0933	2.0158	0.4546
28	SLOP 1	408	-0.2421	0.3473	0.0008	-0.0926	0.216	0.0005
29	SLOP 2	147	0.5752	0.6028	0.0335	0.8672	0.8588	0.005
30	SLOP 3	12	-0.177	0.3094	0.4074	-2.7323	2.6294	0.1238
31	SLOP 4	2	-1.9229	1.7806	4.7064	-1.1583	1.1143	4.6554
32	SLOP 5	1	4.4006	4.0749	3.5468	-2.7149	2.6118	3.2668
33	EROS N	61	1.0734	1.0364	0.0665	-0.4641	0.4794	0.0583
34	EROS S	323	0.4559	0.5078	0.0254	-0.7887	0.7772	0.0017
35	EROS M	191	-0.8582	0.8296	0.0818	1.3253	1.2945	0.015
36	EROS SV	27	-1.3478	1.2646	0.0726	0.9232	0.916	0.0402
37	HERB	227	-1.7352	1.617	0.0466	-1.0775	1.0544	0.0025
38	BUSH	6	2.6863	2.5058	0.8264	-1.132	1.0951	0.7777
39	TREE	367	1.0565	1.0198	0.0189	0.6819	0.6835	0.0012
40	TRS	234	-1.5745	1.471	0.0353	-0.8038	0.7984	0.0108
41	TRO	159	0.0283	0.2711	0.0525	-0.0776	0.2123	0.0523
42	TRM	148	1.0633	1.0258	0.0522	0.9831	0.9649	0.0155
43	TRD	58	3.7769	3.5053	0.0978	1.2099	1.1738	0.0422
44	GRS	147	-1.2352	1.1637	0.0817	1.2042	1.1809	0.0266
45	GRM	326	-0.0141	0.2734	0.0105	-0.3651	0.3986	0.0054
46	GRT	125	1.6037	1.5131	0.0122	-0.5474	0.5479	0.0008
47	CON	4	-0.2384	0.3455	1.2493	-1.315	1.2681	1.1836
48	COS	108	-0.5944	0.6076	0.0732	0.8139	0.811	0.048
49	COM	423	-0.0796	0.2792	0.0015	-0.0463	0.2016	0.0014
50	COD	64	1.7408	1.6369	0.1251	-1.1492	1.1133	0.0749
51	UTN	1	5.9325	5.4934	2.4857	1.8094	1.7406	2.3613
52	UTS	72	2.7982	2.6053	0.0107	0.2832	0.3129	0.0077
53	UTM	296	0.447	0.5018	0.0153	-0.5969	0.5997	0.0017
54	UTSV	230	-1.4205	1.3306	0.0228	0.6874	0.699	0.0048

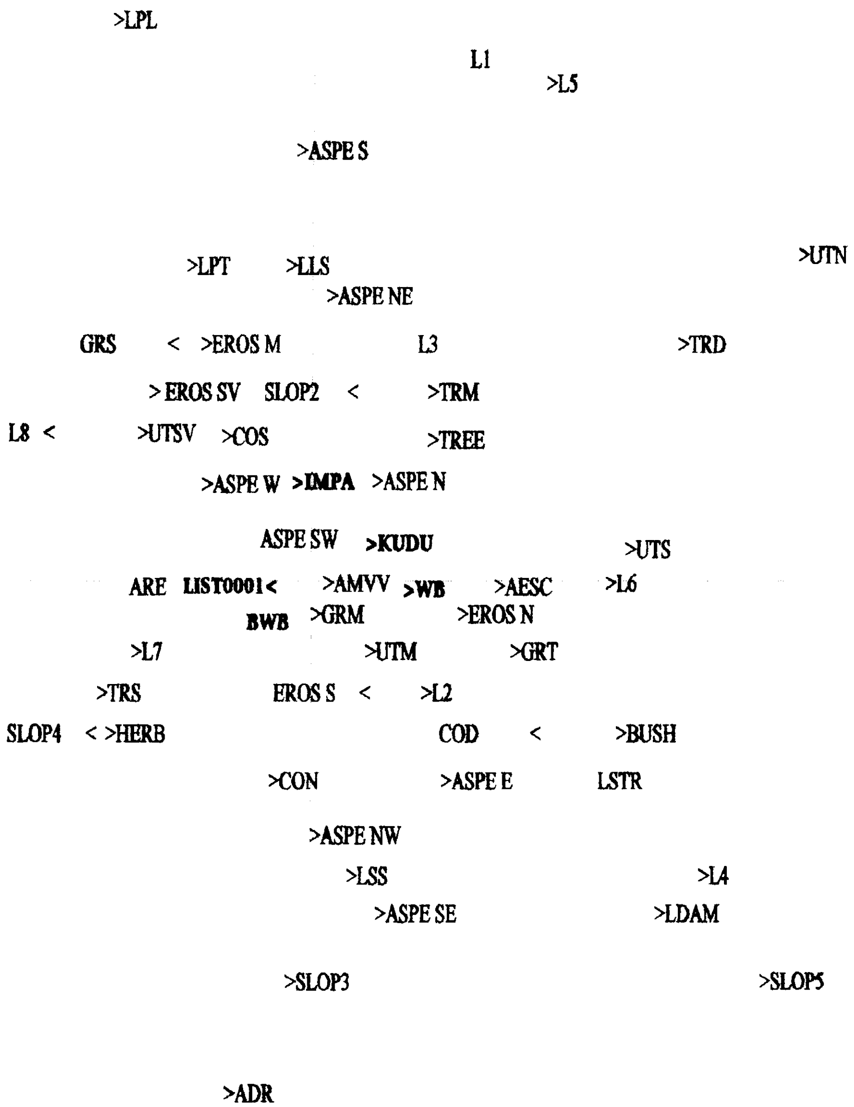


FIGURE 33 The graphical display of Correspondence Analysis for the selected herbivores on the Roodeplaat Dam Nature Reserve.
The following items are close together, so they are indicated as a list in the plot:
List of items 0001 - RHB ZEB

ABSCON: This contains the absolute contribution that the element makes to the inertia of the axis. It is thus a measure of the importance of this element to the axis. (Species: Cumulative fit for species as fraction of variance of species. Samples: Squared residual length per sample with 4 axis).

Objects and variables which correlate highly with this axis are indicated by large values in the column REL CON, and the sign of the "correlation" is indicated by the sign of the co-ordinate in the column 1F. Hence, kudu, waterbuck, L4, LDAM, SLOP5, BUSH, TRD, UTN and UTS are positively "correlated" with axis 1, and BWB, IMPA, RHB, ZEB, L7, LPL, SLOP4, TRS and UTSV are negatively correlated with the axis.

a) Axis 1

This axis, accounting for 53.8% of the total inertia, appears to contrast dense tree cover, slight utilisation, kudu and waterbuck versus zebra and red hartebeest, low plains and sparse tree cover.

On the other hand the denser, broad-leaf, long grass areas were the areas kudu and waterbuck associated with whereas the zebra and red hartebeest were found in the flatter short grass plains with sparse tree cover.

b) Axis 2

Axis 2, accounting for 27.6% of the total inertia, contrasts impala, L1 and L5 *(Berchemia zeyheri* thickets and *Acacia caffra - Faurea saligna* open woodland), plains (LPL) and slight utilisation versus blue wildebeest and red hartebeest, open grassland (HERB), steep slopes and sparse trees.

c) Interpretation of Figure 33

Figure 33 shows the projection of animal species and habitat factors into a common subspace of axis 1 and 2 of correspondence analysis.

In the top right quadrant, there is a close association between kudu, L3 (*Acacia caffra-Setaria* *sphacelata* closed woodland) and dense trees (TRD), indicated by the small angle that they make with each other on being joined to the origin by straight lines. A strong association is also indicated with the northern and north-eastern aspect (ASPE N & ASPE NE) and slight utilisation (UTS).

Figure 33 gives a picture of waterbuck and kudu in areas with dense trees at low slopes (slope >3-8°) where grass is long and slightly utilised. Quadrant II (bottom right) shows that there are close associations between waterbuck and L4 (*Acacia caffra-Combretum apiculatum* closed woodland), landscape position near the dam (LDAM), L2 *(Acacia karroo* closed woodland) with tall grass height (GRT).

Although red hartebeest and zebra are very close to the origin they are closely associated with each other and with L7 (*Setaria sphacelata-Polygala hottentotta* grassland), sparse tree cover (TRS), grass stratum (HERB), slight erosion (EROS S), blue wildebeest (BWB) and a medium slope of 8-10° (SL3).

It is clear that a great deal can be obtained from this graphical display, supporting the information obtained from the frequency histograms.

(iii) Redundancy analysis

Figure 34 displays the relationship between the animal species and environmental variables in the different range types. The environmental variables in every range type (expressed on a scale of 1-10) are slope, degree of erosion, percentage rock, soil, biomass, percentage cover, tree cover, utilisation and range condition.

The arrows for red hartebeest and zebra make small angles with the arrow for soil, erosion and biomass. These species are positively correlated with the soil type, degree of erosion and the biomass. Range condition and L4 (*Acacia caffra-Combretum apiculatum* closed woodland), are inferred to be negatively correlated with red hartebeest and zebra. The former animal species are then more abundant in L7 (*Setaria sphacelata-Polygala hottentotta* grassland) and are influenced by soil type, erosion and biomass.

Kudu and Waterbuck arrows point in the same direction and make a small angle, which indicates that these two species are positively correlated with each other and also with L2 and L3 (*Acacia karroo*-closed woodland and *Acacia caffra-Setaria sphacelata* closed woodland), slope, utilisation and rockiness.

L7 (*Setaria sphacelata-Polygala hottentotta* grassland), red hartebeest and zebra are negatively correlated with range condition and tree cover. Impala are negatively correlated with L1 (*Berchemia zeyheri* thicket) and to a lesser extent with range condition.

The abundance of blue wildebeest are affected by the degree of utilisation and slope and the blue wildebeest are also positively correlated with L7 and L2 (*Setaria sphacelata-Polygala hottentotta* grassland and *Acacia karroo* closed woodland), because the angle between the arrows drawn are small.

The angles between the lines gives an idea of the correlation between a species abundance in a certain range type. Blue wildebeest are abundant in L2, L3 and L4, as are kudu, waterbuck and impala. Red hartebeest and zebra are abundant in L7 (*Setaria sphacelata-Polygala hottentotta* grassland).

Redundancy analysis summarises and supports the tendencies shown in the interpretation of correspondence analysis and the frequency histograms.

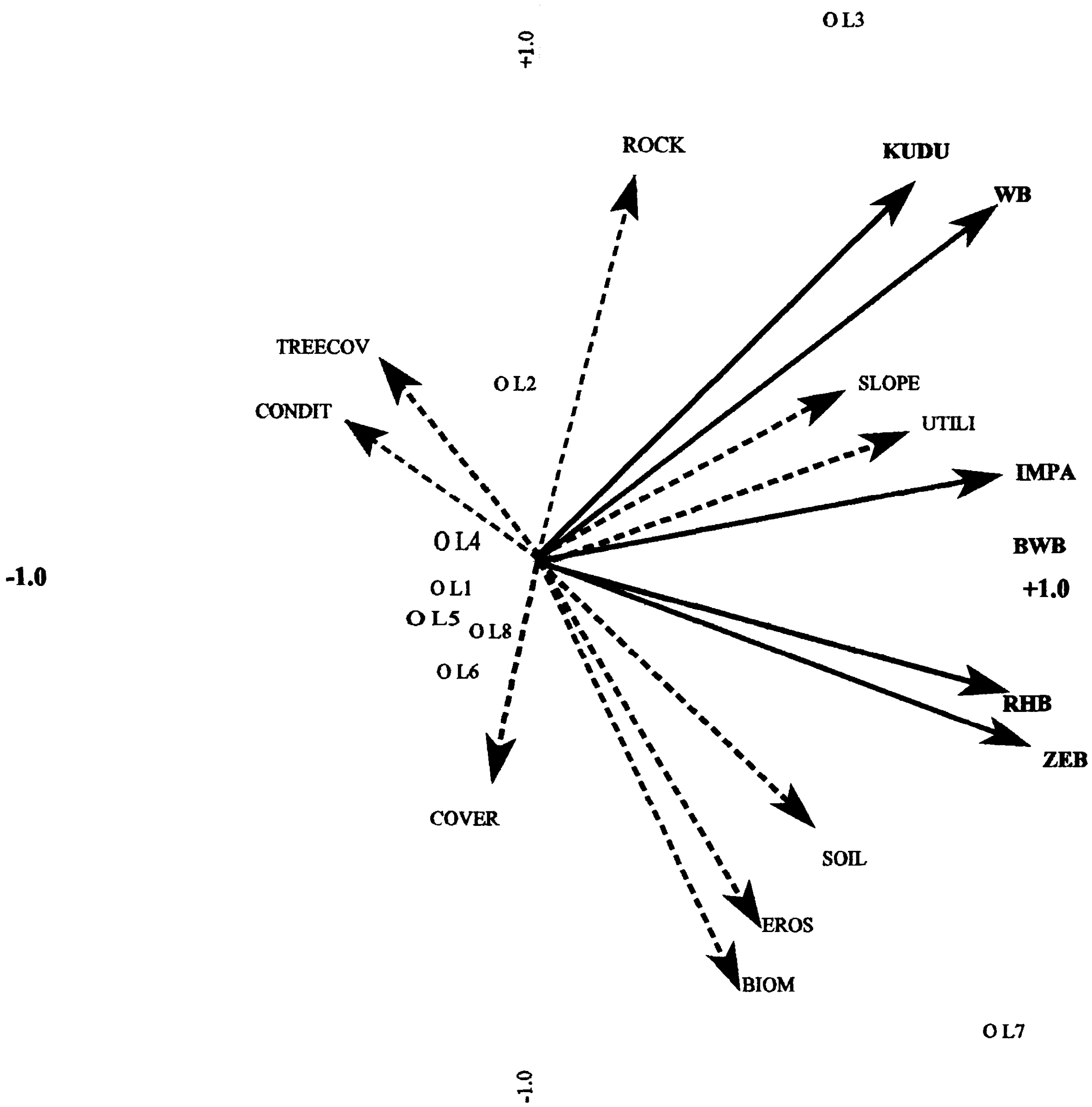


FIGURE 34 Biplot based on redundancy analysis of the Roodeplaat Dam Nature Reserve data with respect to environmental variables (arrows: slope, erosion, soil, rock, biomass, %cover, tree cover, utilisation and range condition). The arrows for animal species and environmental variables display the approximate (linear) correlation coefficients between animal species and the variables

3.2.4 Discussion

Certain valuable conclusions can be made from the results of the statistical analyses performed on the data. It should be noted that animals move around considerably on such a small area, and that the results are of their main habitat preferences. The references given provide confirmation of the results. It can be clearly seen that the methods support each others findings and can be summed up as follows:

(i) Kudu

- kudu were strongly associated with waterbuck, L3 and a dominant tree stratum
- *Acacia caffra - Setaria sphacelata* (L3) closed woodland was preferred throughout the year
- Medium and steep slope landscape positions, on a northern and north-eastern aspect
- browsing most of the times, otherwise moving and escaping
- preferred to move around medium to dense tree layer in range with a dominant tree layer
- Herbaceous layer: medium to long grass swards, slightly utilised, with a good canopy cover and slight erosion. Avoid utilised areas which were bare and severely eroded

Beardall *et al.*(1984) and Engelbrecht (1986) found that kudu preferred the upper and steeper slopes in the Kruger National Park. The findings of Hirst (1975) and Pienaar (1974) were confirmed with kudu preferring semi-deciduous woodland and thorn mixed woodland.

(ii) Blue wildebeest

- Associated with waterbuck and zebra
- Prefer L2 (*Acacia karroo* closed woodland), L3 (*Acacia caffra - Setaria sphacelata* closed woodland), L4 (*Acacia caffra - Combretum apiculatum* closed woodland) and L7 (*Setaria sphacelata - Polygala hottentotta* grassland). Of these L4 and L7 were favoured and L2 and L3 were less preferred.
- low and steep slopes, western aspect, negative association with plateaus
- they spend most of the time grazing during the day, moving and resting occasionally
- preferred the tree stratum and herbaceous stratum equally , but in winter showed a marked

preference for herbaceous stratum. If they were found associated with the tree stratum, it was where sparse cover occurred and they avoided dense tree cover.

- Selected short to medium grass lengths, moderate grass canopy cover which is utilised moderately. They were found regularly resting under trees where the area were severely over-utilised and erosion was high, but they grazed in areas which were not heavily utilised and only slightly eroded.

Gertenbach (1987) found a high degree of association between blue wildebeest and zebra in the Kruger National Park. Hirst (1975) and Beardall *et al.* (1984) also found that they selected short grass on high clay soils, and on slopes < 2° (Wentzel 1990). Grunow (1980) also found that they were often associated with burnt veld as was the case on the Roodeplaat Dam Nature Reserve.

Hirst (1975) concludes that they basically prefer open short grass savanna but readily make use of other habitats under certain conditions, and that good visibility is of great importance to their distribution.

(iii) Waterbuck

- Preferred L2 (*Acacia karroo* closed woodland) and L3(*Acacia caffra-Setaria sphacelata* closed woodland) most of the time near the dam. Other preferences included L4 (*Acacia caffra-Combretum apiculatum* closed woodland) and L7(*Setaria sphacelata-Polygala hottentotta* grassland).
- Strong relationship with kudu
- Positive relationship with steeper slopes but also utilised lower slopes.
- Never a strong relationship with any aspect, moved around most of the time grazing
- Preferred the dominant tree layer throughout the year, of which the trees were open, medium and sparsely covering the area.
- Preferred medium and longer grass sward lengths with a good canopy cover and moderate utilisation throughout the year

Pienaar(1974) found that waterbuck are waterloving antelope which prefer frequent broken, lightly wooded country near permanent water.

The results of Hirst (1975) and Engelbrecht (1986) imply a preference based on abundant vegetation, especially abundant tall grass within woodland and in dense evergreen vegetation along watercourses. They also show a preference for tall and abundant grasses under a high woodland canopy.

(iv) Burchell's Zebra

- Associated with blue wildebeest and red hartebeest and preferred L7 (*Setaria sphacelata-Polygala hottentotta* grassland) and L8 (*Melinis repens-Cynodon dactylon* oldland grassland) throughout the year. Preferred lower and steeper slopes alternatively on a western (mostly preferred), northern and north-western slope.
- grazing and resting most of the time during the day.
- The herbaceous layer (dominant basal layer) were sought after and the dominant tree layer was least preferred. They avoided dense tree layers and selected areas with a sparse tree stratum.
- Selected a medium grass height and in summer they preferred short grass lengths. They had a distinct preference for moderate canopy cover of grass. They also showed a positive relationship with taller grass lengths but it was not significant.
- Selected moderately to over-utilised areas and avoided under-utilised areas.

Hirst (1975) states that zebra are commonly associated with blue wildebeest over much of their common geographic range. They prefer savanna vegetation on clay soils, habitats with prominent grass components and habitats with short grass and bare soil patches. They avoid woodland vegetation on sandy soils, habitats with dense woody vegetation with small trees and tall grass habitats.

Theron (1991) found that Burchell's zebra selected areas in the northern Transvaal with low and mid slopes, slight to moderate erosion and medium grass height, but they selected sparse canopy cover of the herbaceous layer and a dominant tree stratum which was not the case on Roodeplaat Dam Nature Reserve.

(v) Impala

There were only 7 animals on the reserve at the time of the study and animals were not seen very often.

- They were associated with grazing and moving in L1 (*Berchemia zeyheri* thickets), L2 (*Acacia karroo* closed woodland), L3 (*Acacia caffra - Setaria sphacelata* closed woodland) and most often with L7 (*Setaria sphacelata-Polygala hottentotta* grassland)
- Strong relationships with lower slopes, plains and plateaus on western and south-western slopes
- Varied between tree layer (medium and open) and the herbaceous layer (sparse tree layer)
- Selected short and medium grass sward lengths with low to moderate herbaceous cover and slight utilisation. They also preferred areas where there were larger areas with exposed soils and low plant cover, but this was the area in range type 3 (*Acacia caffra-Setaria sphacelata* closed woodland) that was burnt and all the animals concentrated there.
- Avoided areas with dense grass cover which were under-utilised.

Pienaar (1974) stated that the impala is a highly adaptable species often particularly abundant in degraded *Acacia* woodlands or thickets along rivers, and this is probably due to their ability to switch ad lib from a grazing to a browsing diet.

Hirst (1975) indicated impala to be essentially animals of open savanna, generally clear of understorey, with tall clumped woody plants. They also seek out habitats with short grass with bare patches and low tree density, also occasionally dense grass cover areas which was not the case on the reserve.

They avoid tall grass and high tree densities or scanty vegetation with a bare substrate.

(vi) Red hartebeest

- Closely associated with zebra and L7 (*Setaria sphacelata - Polygala hottentotta* grassland).
- They utilised steep slopes most of the time with a western aspect and a north-western aspect in autumn and winter, grazing at daytime
- They avoided areas which were severely overgrazed and eroded and preferred areas which were slightly eroded.
- Preferred the herbaceous layer. Dominant tree layer also preferred but mostly sparse and open

tree distribution. Avoided dense tree layer.

- Selected short to medium grass lengths with a good canopy cover. Avoided areas which were sparsely or very densely covered.

- Preferred moderately utilised areas but not under-utilised areas

Kok & Opperman (1985) stated that red hartebeest preferred open grassy plains, alternating with open forests where small patches of bush and forest trees offer shelter. They are seldom found in dense plant vegetation and prefer open short grassland.

CHAPTER 4

HABITAT MANAGEMENT

4.1 Introduction

Range management refers to the management of natural vegetation for specific objectives related to different forms of land use (Trollope, Trollope & Bosch 1990). In the wildlife context a wide spectrum of different forms of land use are practised ranging from nature conservation through to game ranching with different combinations of both occurring throughout the spectrum. Consequently the products useable to society emanating from these areas vary greatly i.e. creating and maintaining plant and animal communities attractive to tourists through to trophy hunting and producing venison. Therefore the management of range stocked with wildlife is extremely complex and must be adapted to the particular form of land use that is being practised (Trollope 1990).

The smaller the area being used for wildlife, the more intensively it must be managed (Bothma 1989), because such areas are not self-regulating ecological units. Roodeplaat Dam Nature Reserve is such a small area and the most important factors to consider in the formulation of a range management program for such a small area are the assessment of range condition, setting of realistic stocking rates of suitable wildlife species, grazing and browsing management, range burning and monitoring range condition.

4.2 Determination of range condition of the herbaceous layer

The assessment of range condition is a prerequisite for the formulation of a sound range management program (Trollope 1990). The concept of range condition refers to the condition of the vegetation in relation to some functional characteristics, normally sustained forage production and resistance to soil erosion (Trollope, Trollope & Bosch 1990).

The first step in formulating a range management program, is the identification and the assessment of the condition of the vegetation in each habitat type on the reserve. This will involve demarcating the different range types in the area and identifying the various homogeneous vegetation units or habitats in each range type. The vegetation of the reserve was classified by means of the Braun-Blanquet method (Werger 1974), into eight homogeneous plant communities as mentioned in Chapter 2 (Van Rooyen 1984). Sample sites are then located in each homogeneous, vegetation unit to assess the condition of the vegetation in relation to some functional characteristics. There are obviously a wide range of functional characteristics that can influence the suitability of a habitat for different game species. However the most important functional characteristics are the potential of the vegetation to produce forage and the physiognomic structure of the vegetation.

A great deal of attention has in recent years been given to techniques for the quantification of the condition of the grassland, karoo and savanna vegetation of South Africa. The techniques are by no means unanimously accepted by all workers in this field, but they do provide a useful set of guidelines for immediate practical application (Tainton 1988b).

In South Africa research into methods of range condition assessment began in 1970 with the development of an ecologically based method for the climax grasslands of the Orange Free State by Roberts (1970). Further research and revision was done by Foran (1976); Tainton, Foran & Booysen (1978); Tainton, Edwards & Mentis (1980), Tainton (1981); Vorster (1982); Danckwerts (1982); Mentis (1983); Barnes, Rethman, Beukes & Kotze (1984); Teague & Danckwerts (1984); Trollope (1986); Willis & Trollope (1987); Peel, Grossman & Van Rooyen (1991).

An applicable method to use on the Roodeplaat Dam Nature Reserve had to be found that was both easy to use and quick. Four methods of processing has therefore been applied to the data collected.

4.2.1 Methods

Collection of data

The nearest plant method was used to provide data on botanical composition and species frequency. Mentis (1981) found that the step-point method yielded results which did not differ in precision or in absolute amount from those obtained using the wheel-point method. The step-point method is a relatively quick practical method, saves man power and renders the technique usable for extension officers and farmers. The observer makes a mark on the front of his shoe. Everytime the person takes a step, the mark on his shoe act as the descending sample point.

Five to eight sites per plant community was chosen randomly to cover all variations of plant growth forms. A 200-point step-point for plant observations, were conducted in two parallel lines spread 5 metres apart. Each transect was delineated in a north-south direction. The nearest plant (grasses & forbs) to every point was identified and the percentage species composition (frequency) was calculated. If there were no plants within 30 cm from the point, it is noted as bare ground (Mentis 1981).

Processing of the data

To determine the most appropriate way to process the data, four methods of processing were applied on the *Setaria sphacelata-Polygala-hottentotta* grassland, which covers the biggest surface area on the reserve (383 ha, 44% of total area). The methods will be discussed under the following headings:

a) To calculate ecological index and grazing capacity using the computer program GRAZE (Bredenkamp & Van Rooyen 1990)

b) The ecological index method (Vorster 1982, Danckwerts 1989)

c) Weighted palatability composition (Barnes 1988, 1990)

d) Rainfall-biomass correlation (Coe, Cumming & Phillipson 1976)

To use methods (a) and (b), the quantitive value of each species (% frequency) was calculated and the species categorized according to their reaction to grazing. Vorster (1982) and Tainton (1984) identified four ecological categories which were subsequently redefined and applied according to the method described by Danckwerts (1989). The following ecological categories were used, namely Decreasers, Increaser I(a), Increaser I(b), Increaser II(a), Increaser II(b) and Increaser II(c).Van Oudtshoorn (1991) and former monitoring reports of the reserve were used to decide on the category of a grass species.

Decreasers are those species which are dominant in veld that is managed well and decrease when the veld is either over- or under-utilized. Increaser I(a) are those species that occur naturally in the veld but increase with moderate under-utilization or selective grazing. Increaser I(b) are those species that occur naturally in the veld, but increase with excessive under-grazing or selective grazing. Increaser II(a) are species that occur naturally in the veld, but increase with moderate over-grazing. Increaser II(b) are species that occur naturally, but increase with excessive over-grazing. Increaser II(c) are those species which also occur naturally in the veld, but increase with very excessive over-grazing (Danckwerts 1989).

With the abovementioned categories, an ecological index is calculated for every plant community. Values of 10, 7, 4 and 1are allocated to multiply Decreasers, Increaser 1, Increaser 2a, 2b and Increaser 2c respectively for the calculation of the Ecological Index. If all the species were Decreasers in a survey, the maximum theoretical index value would be 1000. Range in a good condition with a high grazing capacity, has got a high percentage of Decreasers and Increaser 1's. With the calculation of grazing capacity for wildlife some factors were brought into consideration like habitat variables (koppies, valleys, rivers), selective feeding habits (habitat preference) of wildlife and the restrictions of a one-camp system. The grazing capacity for wildlife is for that reason some 30-50% lower than that for livestock (Peel, Grossman & Van Rooyen 1991).

Method (a): - GRAZE

GRAZE is based on the algorithm of Danckwerts (1989) and on the Ecological Index Method of

Vorster (1982), but adapted by Bredenkamp & Van Rooyen (1990) for savanna conditions. The algorithm in GRAZE incorporates the effect of bush (trees and shrubs separately) on the grazing capacity, as well as the total grass cover (canopy cover). The effect of burning and accessibility of terrain are also incorporated (Bredenkamp & Van Rooyen 1990).

The grazing capacity for game are given for good (average rainfall) and a bad rainfall year (approximately 20% lower than average).

Method (b): - The ecological index method

Danckwerts (1989) provides a grazing model for the False Thornveld (Acocks 1988) of the Eastern Cape, based on range condition and mean annual rainfall, for areas where *Acacia karroo* does not dominate the woody vegetation or where woody vegetation is absent.

To calculate range condition score, "forage factors" are allocated to each species. These factors represent the agronomic value of each species on a scale of 1 to 10 in terms of their potential to provide grazable forage.

After species at the sample site have been expressed in percentage composition and classified into various categories, these are listed in category in table form.

The relevant forage factor is then multiplied with the percentage composition of each species to give the individual species score. These are added up at each sample to give the total score of the site. The total score expressed as a percentage, gives the percentage range condition score of the site.

Method (c): Weighted palatability composition

The method was developed by Barnes, Rethman, Beukes & Kotze (1984) for two main reasons:

(a) To provide a model which would quantatively link carrying capacity with range condition.

(b) To overcome the subjectivity encountered in other methods. This method provides the operator with a formula for assessing the grazing value of range in terms of its palatability. Values ('weights') are allocated to grasses which differ in palatability and an average palatability value are calculated and called WPC - Weighted Palatability Composition.

Palatability values for every grass species are classified as palatable, intermediate and unpalatable

(Table 6). The percentage palatable grass is multiplied by three, intermediate by two and unpalatable grasses multiplied by one.

Method (d):Rainfall - biomass correlation

Coe, Cumming & Phillipson (1976) explored the relationships of standing crop biomass and their energy expenditure and production to mean annual precipitation and predicted above ground net primary production.

They tested the hypothesis that it is possible to predict the large herbivore biomass of semi-arid African savannas from annual rainfall data. They found, with linear regression analysis, a significant relationship ($r = 0.94$, $P < 0.001$) between annual rainfall (range: 165 to 650 mm) and large herbivore biomass (range: 405 to 4 848 kg/km^2) (Schmidt, Theron & Van Hoven 1995).

The above mentioned study by Coe *et al.* (1976) was based on aerial censuses i.e. the animals counted from the air. Fortunately aerial censuses on the Roodeplaat Dam Nature Reserve takes place every year and large herbivore numbers are available from this sensus.

In this context it is worth noting that Whittaker (1970) has shown an almost linear relationship between primary production and rainfall in a range of vegetation types growing in rainfall regimes of between 100 and 800 mm per year.

Standing crop biomass represents the sum of the live weights of individual animals occupying a given area. In practice this is computed by multiplying the density of each species by its average live weight and then summing the biomass of species making up the community. The accuracy of biomass estimates depends upon (i) the completeness and accuracy of initial sensus and (ii) the accuracy of the unit weight used for each species.

4.2.2 Results and Discussion

The grazing capacity of the range is the biomass (live mass) of game or stock that can live off it without causing deterioration, i.e. a decrease in basal cover or a change for the worse in the species composition of the veld plants. Carrying capacity is expressed as the number of hectares required to maintain one animal unit (= one large stock unit - LSU) (Rowe-Rowe 1987). The LSU is equivalent to a mammal of conventional quadruped shape which has a mass of 450 kg(i.e. the average size steer) and which has a growth rate of 500 g per day on grass pasture with a mean digestible energy (DE) concentration of 55% (Meissner 1982).

(a) GRAZE

The computer program GRAZE gives the following results:

GRAZING CAPACITY: *Setaria sphacelata-Polygala hottentotta* grassland

SIZE(HA): 383 hectare

		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	0	0	
	- SHRUB	0	0	
		1.0	1.0	
DECREASERS		28	28	
INCREASER 1		32	32	
INCREASER 2a&b		24	24	
INCREASER 2c		16	16	
		-----	-----	
TOTAL		100	100	
ECOLOGICAL INDEX (Range condition score)		616	616	
% GRASS COVER		65	52	
AVE RAINFALL (mm/year)		633	506.4	
ACCESSIBILITY(.9//1)		1	1	
FIRE (.8//1)		0.8	0.8	
GRAZING CAPACITY (CATTLE)		4.5	6.4	ha/LSU
GRAZING CAPACITY (GAME)		**8.0**	**11.4**	**ha/LSU**

(b) The Ecological Index Method

The most appropriate means of estimating grazing capacity is by using the relationship (Danckwerts 1989):

$$GC = -0.03+0.00289\ X1+[(X2-419.7) \times 0.000633]$$

where GC = grazing capacity expressed in large stock unit per hectare

X1 = percentage range condition score

X2 = mean annual rainfall in millimetres per year

The above model requires sample site range condition scores to be expressed as a percentage of a benchmark range condition score (Schmidt *et al.* 1995). The highest range condition score in the assessment on the Roodeplaat Dam Nature Reserve, was taken as the benchmark's range condition score. The results are given in Table 5.

TABLE 5 Calculation of range condition scores at sites in the Setaria-sphacelata-Polygala hottentotta grassland

Species category	Species	Factor	Site 1 %	Score	Site 2 %	Score	Site 3 %	Score	Site 4 %	Score	Site 5 %	Score
Decreaser	Brachiaria serrata	10	1	10							3	30
	Diheteropogon amplectens	10	15	150	5	50	4	40				
	Themeda triandra	10	3	30	3	30	1	10				
	Setaria sphacelata	10			15	150	19	190	31	310	24	240
	Digitaria eriantha	10					1	10				
	Panicum natalensis	10					2	20				
	Eustachys paspaloides	10			2	20					3	30
Decreaser total			**19**		**25**		**27**		**31**		**30**	
Increaser 1	Schizachyrium sanguineum	7	8	56	5	35	3	21	4	28		
	Hyparrhenia hirta	7							1	7	2	14
	Hyperthelia dissoluta	7	11	77								
	Trachypogon spicatus	7	3	21					1	7		
	Tristachya biseriata	7	10	70	3	21			9	63		
	Tristachya leucothrix	7	11	77	19	133	20	140	14	98	22	154
	Loudetia simplex	7	5	35	10	70	1	7			1	7
	Bewsia biflora	7	5	35			1	7	2	14		
	Urelytrum agropyroides	7	4	28	3	21	4	28	1	7	4	28
	Cymbopogon excavatus	7	3	21	3	21			3	21		
	C. plurinodis	7										
Increaser 1 total			**60**		**43**		**29**		**35**		**29**	
Increaser 2 a + b	Heteropogon contortus	4			2	8			3	12		
	Sporobolus stapfianus	4										
	Eragrostis chloromelas	4	2	8	6	24	20	80	7	28	18	72
	E. racemosa	4					1	4			1	4
	E. rigidior	4										
	E. superba	4										
	E. curvula	4					1	4	6	24		
	Cynodon dactylon	4										
	Enneapogon scoparius	4										
	Elionorus muticus	4			7	28	4	16	6	24	6	24
Increaser 2(a+b) total			**2**		**15**		**26**		**22**		**25**	
Increaser 2c	Melinis repens	1	5	5	10	10	6	6	3	3	4	4
	Aristida congesta	1	2	2	1	1			2	2	3	3
	Tragus berteronianus	1										
	Eragrostis gummiflua	1							6	6		
	Pogonarthria squarrosa	1	1	1	3	3	3	3	2	2	3	3
	Trichoneura glandiglumis	1	5	5	1	1	6	6				
	Aristida stipitata	1										
	Aristida congesta barb.	1									1	1
	Aristida canescens	1					1	1				
	Eragrostis nindensis	1	1	1	1	1						
Increaser 2c total			**14**		**16**		**16**		**13**		**11**	
Forbs total	Forbs				6		13				8	
Ecological Index (Total score out of 1000 - theoretical maximu				632		627		593		656		614
Percentage veld condition score				63.2		62.7		59.3		65.6		61.4
Average % veld condition score				62.44								
GRAZING CAPACITY		**0.285**	**LSU/ha**									
		3.503	**ha/LSU**									

(c) Weighted palatability composition

TABLE 6 Determination of weighted palatability composition (Barnes 1988) for obtaining grazing capacity in the Setaria sphacelata-Polygala hottentotta grassland

Species category	Species	Palatability factor	Site 1 %	Site 1 Score	Site 2 %	Site 2 Score	Site 3 %	Site 3 Score	Site 4 %	Site 4 Score	Site 5 %	Site 5 Score
Decreaser	Brachiaria serrata	2			1	2					3	6
	Diheteropogon amplectens	3			15	45	5	15	4	12		
	Themeda triandra	3			3	9	3	9	1	3		
	Setaria sphacelata	3	31	93			15	45	19	57	24	72
	Digitaria eriantha	3							1	3		
	Panicum natalense	3							2	6		
	Eustachys paspaloides	3					2	6			3	9
Decreaser total			**31**		**19**		**25**		**27**		**30**	
Increaser 1	Schizachyrium sanguineum	1	4	4	8	8	5	5	3	3		
	Hyparrhenia hirta	2	1	2							2	4
	Hyperthelia dissoluta	2			11	22						
	Trachypogon spicatus	1	1	1	3	3						
	Tristachya biseriata	2	9	18	10	20	3	6				
	Tristachya leucothrix	2	14	28	11	22	19	38	20	40	22	44
	Loudetia simplex	1			5	5	10	10	1	1	1	1
	Bewsia biflora	2	2	4	5	10			1	2		
	Urelytrum agropyroides	1	1	1	4	4	3	3	4	4	4	4
	Cymbopogon excavatus	1	3	3	3	3	3	3				
	C. plurinodes	1										
Increaser 1 total			**35**		**60**		**43**		**29**		**29**	
Increaser 2 a + b	Heteropogon contortus	2	3	6			2	4				
	Sporobolus stapfianus	2										
	Eragrostis chloromelas	2	7	14	2	4	6	12	20	40	18	36
	E. racemosa	2							1	2	1	2
	E. rigidior	1										
	E. superba	2										
	E. curvula	2	6	12					1	2		
	Cynodon dactylon	2										
	Enneapogon scoparius	2										
	Elionorus muticus	1	6	6			7	7	4	4	6	6
Increaser 2(a+b) total			**22**		**2**		**15**		**26**		**25**	
Increaser 2c	Melinis repens	1	3	3	5	5	10	10	6	6	4	4
	Aristida congesta	1	2	2	2	2	1	1			3	3
	Tragus berteronianus	1										
	Eragrostis gummiflua	1	6	6								
	Pogonarthria squarrosa	1	2	2	1	1	3	3	3	3	3	3
	Trichoneura glandiglumis	1			5	5	1	1	6	6		
	Aristida stipitata	1										
	Aristida congesta	1									1	1
	Aristida canescens	1							1	1		
	Eragrostis nindensis	1			1	1	1	1				
Increaser 2c total			**13**		**14**		**16**		**16**		**11**	
Invader total	Karroid-species						6		13		8	
Total score out of 300				205		171		179		195		195
% of maximum possible value ^				67.65		56.43		59.07		64.35		52.47
WPC value ^ ^				51.53		34.695		38.655		46.575		28.755
Average WPC value				40.05								
Relative grazing capacity ^ ^ ^				3.3 ha/LSU								
Actual grazing capacity ^ ^ ^ ^				23.1 ha/LSU								

^ 100% palatable grasses x 3 = 300
^ ^ WPC = 1.5(x - 33.3) were x is the percentage obtained at *
^ ^ ^ Relative grazing capacity(RGC) for a given WPC value determined using relation shown in Figure 35
^ ^ ^ ^ Actual grazing capacity = RGC x base value grazing capacity in ha/LSU (7 ha/LSU)
Base value grazing capacity is derived from the map of the Departement of Agriculture(1986) which gives the grazing capacity for the Transvaal region for cattle

The values are added to give a total. The following formula is used to work out a numeric value which is the WPC (weighted palatability composition).

$$Total/300 \times 100 = A\%(scale 33,3\text{-}100)$$
$$WPC = (A\% - 33,3) \times 1,5(scale\ 0\text{-}100)$$

There is a relationship between the WPC value and the relative grazing capacity of the range (Figure 35). The actual grazing capacity will depend on the potential production level of the specific area. The WPC value is used to read from the graph (Figure 35) the relative grazing capacity of the range. The real/realistic grazing capacity is determined by using the potential productivity level of the specific region.

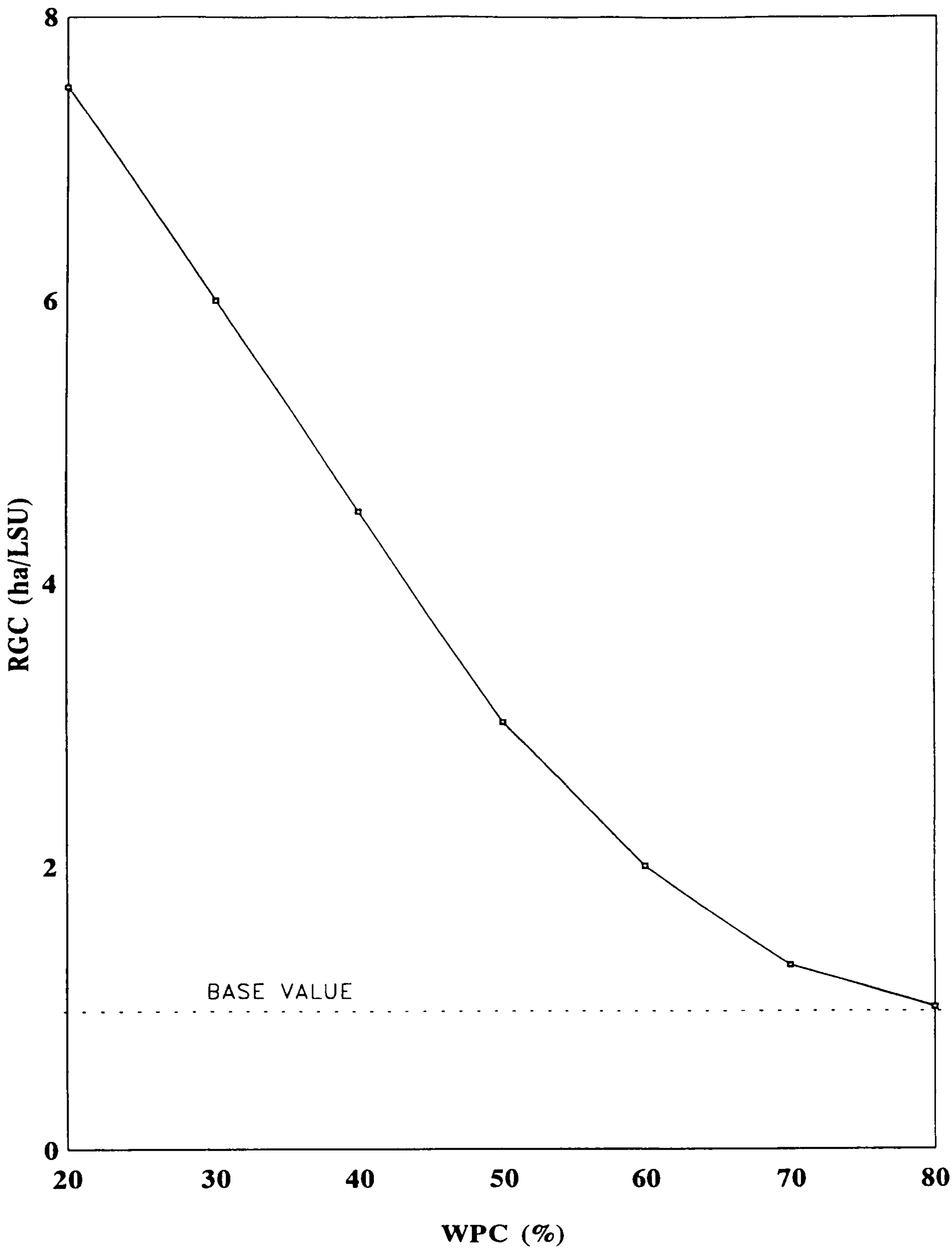


FIGURE 35 Relationship between weighted palatability composition (WPC in %) and relative grazing capacity (RGC in ha/LSU) in the south-eastern Transvaal grassveld

The weighted palatability composition (WPC) in the *Setaria sphacelata-Polygala hottentotta* grassland is 40.045, the relative grazing capacity (RGC) is read off the graph and the value given is 3,3 ha/LSU. The actual grazing capacity is calculated by multiplying RGC with the base value grazing capacity in ha/LSU. The base value grazing capacity is derived from the map of the Department of Agriculture (1986), which gives the grazing capacity for the area north-east of Pretoria as 7 ha/LSU. The actual grazing capacity will then amount to 23,1 ha/LSU (3,3 X 7).

(d) Rainfall-Biomass correlation

The regression equation calculated for wildlife ecosystems receiving less than 700 mm rainfall annually, is:

$$\text{Large herbivore biomass}(kg/km^2) = 8{,}684(\pm 2{,}28)AP - 1205{,}9(\pm 156{,}6)$$

where AP = mean annual rainfall

The average annual rainfall in the Roodeplaat Dam area is 633 mm per year. The use of the large stock unit LSU) was made for calculating carrying capacity. A LSU is defined as a steer of 450 kg gaining mass at a rate of 500 g a day on grass having a mean digestible energy of 55 % and to maintain this 75 MJ of metabolisable energy per day is required (Meissner 1982). The large herbivore biomass in kg per km^2 was divided by 450 to convert the biomass estimate into a metabolic mass estimate. The unit area was also changed from km^2 to ha. The carrying capacity estimate was therefore converted from kg live mass per km^2 to ha per LSU. The large herbivore biomass is calculated as 4403,964 kg/km^2. Converted to a more practical equation it gives the grazing capacity as 10 ha/LSU or 86 LSU on the 870 ha study area.

The grazing capacity calculated with this formula is 50% lower than for livestock and compensate for selective grazing methods of wildlife species as well as for the lack of intensive rotational grazing systems for wildlife. The results of the different methods used, are given in Table 7.

TABLE 7 Grazing capacity (ha/LSU) of Roodeplaat Dam Nature Reserve analysed with four different methods in the *Setaria sphacelata-Polygala hottentotta* grassland

Method		Grazing capacity(ha/LSU)
a) GRAZE method		8.0 (11.4 in bad year)
b) Ecological index method		3.51 (4.76 in bad year)
c) Palatability method		23.1
d) Rainfall-biomass correlation method		10
	Mean =	11

The estimates of the combined grazing and browsing capacity using the equation of Coe *et al.* (1976) were 10 ha/LSU. If 80% of the combined estimate were considered to represent a grazing capacity estimate and 20% a browsing capacity estimate, after the stocking rate rule of thumb of Mentis (1983) (ratio of 40% LSU bulk grazer to 40% LSU concentrate grazer to 20% LSU browser), then the carrying capacity estimate would be 12.5 ha/LSU. The equation of Coe *et al.* (1976) was, however, derived from a regression analysis of rainfall data and aerial game counts. According to Bothma, Peel, Pettit & Grossman (1990), most game and particularly browsers, tend to be under-counted rather than over-counted during aerial game counts. Under-counting may therefore partly account for the conservative estimate of grazing capacity (Schmidt *et al.* 1995).

The conservative grazing capacity given by using the weighted palatability composition method (Barnes *et al.* 1984) (23.1 ha/LSU), can be as a result of this method that has been developed for the south-eastern Transvaal - grassveld (Mpumalanga province) where the composition and palatability of species might differ greatly from that on the Roodeplaat Dam Nature Reserve.

In Table 7, the GRAZE and ecological index methods seems to be the most appropriate and reliable, and it gives the more acceptable answers. The methods was chosen above that of Coe *et al.* (1976) because monitoring of the herbaceous stratum is recommended for adaptive management and a record to determine trends in species frequency and range condition. The data obtained is used in the methods recommended for further analysis. However, the method of Coe *et al.* (1976) can be used as a reference after carrying capacity is determined. These two methods were then applied to the other range types of the reserve, and the results are shown in Tables 8 and 9. The range types are numbered as follows:

Range type number
1 = *Setaria sphacelata - Polygala hottentotta* grassland
2 = *Burkea africana* closed woodland
3 = *Acacia karroo* closed woodland
4 = *Acacia caffra - Setaria sphacelata* closed woodland
5 = *Acacia caffra - Combretum apiculatum* closed woodland
6 = *Acacia caffra - Faurea saligna* open woodland
7 = *Melinis repens - Cynodon dactylon* old land grassland
8 = *Berchemia zeyheri* thickets

TABLE 8 The total grazing capacity (ha /LSU), unit size and Ecological Index for the Roodeplaat Dam Nature Reserve. The grazing capacities (GC) for an average rainfall year (A) and below average (approximately 20% lower than the average) rainfall year (B) are given in the table.

Range type number	Unit size(ha)	GC(livestock)		GC(game)	
		A	B	A	B
1	383	4.5	6.4	8.0	11.4
2	8	3.9	5.7	5.5	8.1
3	117	4.2	6.2	5.5	8.2
4	234	4.1	6.3	6.3	9.5
5	26	4.5	7.3	6.6	10.7
6	10	3.7	5.4	5.5	8.0
7	55	4.1	6.2	6.6	10.0
8	37	4.8	6.7	6.0	8.4
Total	870 Average	3.81	5.48	6.80	10.02

The long term average rainfall was taken as 633 mm/year[1]. The ecological index and grazing capacity as determined by GRAZE, are fully printed in Appendix A.

[1]Agricultural Research Council; Institute for Soil, Climate and Water. Private Bag X79. Pretoria, 0001

TABLE 9 The range condition score of the Roodeplaat Dam Nature Reserve as determined by the Ecological Index Method (Vorster 1982, Danckwerts 1989)

Range type		Decreasers	Increasers 1	Increasers 2a & b	Increasers 2c
nr.		**10**	**7**	**4**	**1**
1	%	28	32	24	16
	Score	280	224	96	16
2	%	22	27	23	28
	Score	220	189	92	28
3	%	27	1	44	28
	Score	270	7	176	28
4	%	26	6	34	34
	Score	260	42	136	34
5	%	11	3	42	44
	Score	110	21	168	44
6	%	32	15	28	25
	Score	320	105	112	25
7	%	14	33	16	37
	Score	140	231	64	37
8	%	58	0	35	7
	Score	580	0	140	7

Total score and percentage score of range type numbers:

1	616	61.6%	5	343	34.3%
2	529	52.9%	6	562	56.2%
3	481	48.1%	7	472	47.2%
4	472	47.2%	8	727	72.7%

Average percentage score = 52.53%

*GRAZING CAPACITY = 0.26 LSU/ ha i.e. 3.85 ha/LSU (livestock)

** GAME = 5.75 ha/LSU

* Formula (Danckwerts 1989) used to determine Grazing capacity

GC = -0.03 + 0.00289X1+[(X2-419.7) x 0.000633)]: where X1 is percentage range condition score, X2 is average rainfall

** For game determined at 50% lower than that of livestock to adapt for selectice grazing habits of game as well as lack of an intensive rotational grazing system (Pauw 1988) on a game reserve.

From Table 8 and 9 it can be said that the method of Danckwerts (1989) gives a slight overestimation of the grazing capacity (5.75 ha/LSU) for game. GRAZE (Bredenkamp & Van Rooyen 1990) incorporates the effect of bush, total grass cover as well as burning and accessibility of the terrain and gives a grazing capacity in an average rainfall year of 6.80 hectares needed to support one LSU, and in a below average rainfall year as 10.02 ha/LSU. The maximum number of LSU that the reserve can support is 128 LSU. Therefore the results will be based on this program.

Range condition and grazing capacity

Range condition trend refers to the direction of change in range condition as influenced primarily by the intensity of utilisation of the grass sward by grazing animals (Trollope, Potgieter & Zambatis 1989). The relative dominance of the Decreaser and Increaser herbaceous species shows the trends in range condition and also indicates the reason for these trends. These data can be used for formulating strategies that will either maintain or alter the condition of the range depending on the management objectives. The trends and condition of the different range types (Figure 3) will be dealt with separately.

Setaria sphacelata - Polygala hottentotta grassland.

This plant community extends over 383 hectares of the reserve (44% of total area) and covers plains areas and slopes of up to 10°, on soils with a high clay fraction but that varies between loamy sand and sandy clay soils (Figure 3, 6).

Species found distinctively in this community are *Polygala hottentotta, Indigofera daleoides, Babiana hypogea, Chamaecrista mimosoides, Eriosema burkei, Hibiscus microcarpus, Microchloa caffra, Zornia milneana, Striga elegans, Bulbostylis burchellii and Hyparrhenia hirta*. Other herbaceous species with a high cover abundance are *Brachiaria serrata, Triumfetta sonderi, Diheteropogon amplectens, Setaria sphacelata, Bewsia biflora, Elionorus muticus and Tristachya biseriata.*

The grazing capacity for game in this community is calculated as 8.0 ha/LSU for an average rainfall year and as 11.4 ha/LSU in a below average rainfall year (20% lower than average).

The benchmark is an example of vegetation that is considered to provide the highest possible sustained profit from animal production for the range type under consideration (Danckwerts 1989).

The highest ecological index score (Ecological index = 643) of all the survey points in this community, was taken as the benchmark and the other sites in the community showed a very significant correlation (82 - 95%) with the benchmark, implying that the areas give a very good indication of the condition in this plant community. Increaser 1's has the highest score (31%) and this indicates under-grazing or selective grazing, and that the range has a moderate to low forage production potential but a very high fuel production potential. Fuel load (sufficient grass available to carry the fire), measured with a disc pasture meter (Bransby & Tainton 1977) and expressed in kg/ha, is regarded as one of the most important factors influencing fire behaviour because the total amount of heat energy available for release during a fire is related to the quantity of fuel (Luke & McArthur 1978). The forage production potential is the actual amount of acceptable grazable forage produced. It is generally accepted that the Decreaser species produce more acceptable forage than the Increaser species, and that, with few exceptions, there is a close relationship between the amount of acceptable forage produced and the ecological status of the community (Tainton 1984). But conversely the community also consists of a high percentage of Decreaser species (27%), due to a high percentage of *Setaria sphacelata*, and a lowest percentage (15%) of Increaser 2c species, resulting in a high range condition score.

An effective means of reversing the succession from Increaser 1 stage to the Decreaser stage and improving the forage potential of the range is to increase the frequency of burning to once every two to three years. This will improve the palatability of the grass sward and therefore its attractiveness for grazing animals (Trollope, Potgieter & Zambatis 1989). It has to be said that this type of vegetation is sourveld and rapidly becomes unpalatable to grazers on reaching maturity. Therefore it will never be heavily grazed under natural conditions and Increaser 1 species will always be an important component of the grass sward but need not be the dominant one.

Burkea africana closed woodland

This community is found on the eastern side of the dam in the southern corner of the reserve on sourish sandy soils on plains and on slopes of up to 5° (Figure 3, 6). This community is characterised by woody species such as *Burkea africana, Protea caffra, Ochna pulcra* and *Cryptolepis oblongifolia.* Other prominent species found in the community are *Ozoroa paniculosa, Vangueria infausta, Rhus zeyheri and R. leptodictya.*

Herbaceous species representative of the community are *Commelina africana, Cleome monophylla, Digitaria eriantha, Tristachya biseriata, Diheteropogon amplectens, Xerophyta retinervis, Aloe davyana, Loudetia simplex, Bewsia biflora, Helichrysum cephaloideum and Urelytrum agropyroides.*

The grazing capacity for game of this community is 5.5 ha/LSU in a good rainfall year and 8.1 ha/LSU in a bad (20% under average) rainfall year. The communities size is 8 ha and is the smallest on the reserve (1% of area).

The ecological index value of this community is 507 which indicates that the range condition is in a fairly good condition. The range is dominated by Increaser 2 (2a & b = 22%, 2c =27%) and Increaser 1 (26%) species showing that there are some overgrazing taking place. There are also areas present where the range is underutilised, a sign of patch grazing. The range is, however, not totally overutilised because the Decreaser species make up 21% of the frequency.

Decreaser grass species can be encouraged in the Increaser 2 dominant range by reducing the frequency of burning to once every five to six years (Trollope *et al.* 1989). It will have the effect of decreasing the grazing pressure, because the animals will be attracted to other areas that are more frequently burnt, and this area will have time to recover. The overutilization can be explained by the large number of zebras and blue wildebeest found frequently in this community throughout the year.

Acacia karroo closed woodland

This community covers an area of 117 hectares of the reserve (13.5%) on the eastern side of the dam and is found on low lying plains and on slopes of up to 5° (Figure 3 & 6). The soils have the highest clay percentage of all the plant communities.

The community is characterised by a high cover-abundance of *Acacia karroo*. Other species found in the area are *Grewia flava, Rhus lancea, Ziziphus mucronata* and *Euclea crispa*. The herbaceous stratum is characterised by species such as *Panicum coloratum, Digitaria argyrograpta, Setaria sphacelata, Corchorus asplenifolius, Eragrostis curvula, Themeda triandra* and *Heteropogon contortus*.

The oldland grassland community is found on the same geological formation and soils as the *Acacia karroo* closed woodland and is similar in high clay fraction, percentage rock cover, slope, aspect and pH of the soil, and it also has a similar floristic association. This indicates that the old lands must have been areas that could have been described as *Acacia karroo* closed woodlands in the past. In this study a tendency is noted that after 12 years, *Acacia karroo* is encroaching the old land communities (described by Van Rooyen 1984) and is increasing in cover-abundance, showing a trend in relation with the above mentioned (Figure 36).

The grazing capacity of the community is 5.5 ha/LSU in a good rainfall year and 8.2 ha/LSU in a bad rainfall year.

Five surveys were conducted in this community of which one survey resulted in an ecological index of 835 which is very good and could be explained by the high percentage of Decreaser species, especially *Setaria sphacelata*, and the low percentage of Increaser 2 species. The other surveys showed lower indexes (36-56% lower) and if the first survey are left out of the calculations, the result is an average ecological index of 389,5 (Grazing capacity = 5.9 ha/LSU in good year and 9.1 ha/LSU in bad year).

The results show that Increaser 2 species dominate the community (44% frequency) and for that reason showed moderate overutilisation, but that there are still a high percentage of Decreaser species (27%) in the community mainly due to the high frequency of *Setaria sphacelata*. This gives an ecological index of 481 which indicates an average to fairly good range condition.

The high degree of utilisation in this community might be as a result of the palatability of the grasses associated with the textured soils. To encourage the increase of Decreaser species, burning can be reduced to once every five years. But there are areas in this community with a very high fuel production that is not grazed because it most probably becomes too stemmy (Hurt 1992). This is commonly the case with *Themeda triandra*, the Decreaser species that dominates this area on the reserve. It is recommended that the areas with the highest forage production and with high cover abundance of *Acacia karroo*, should at least be burnt every two to three years.

Acacia caffra - Setaria sphacelata closed woodland

This variation occurs over the whole reserve on plains and especially on southern facing slopes of up to 20° and is characterised mainly by the presence of *Acacia caffra* (Figure 3). Other woody species that is commonly found are *Rhus leptodictya, Rhus lancea, Dombeya rotundifolia* and *Ehretia rigida*. Herbaceous species found are *Themeda triandra, Setaria sphacelata, Eragrostis curvula, Diheteropogon amplectens* and *Cymbopogon excavatus*. This community covers 234 hectares of the reserve (27% of the reserve).

The mean Ecological Index value is 479 and the grazing capacity in good and bad rainfall years is 6.2 and 9.4 ha/LSU respectively.

The community is dominated by a high percentage of Increaser 2 species (2a&b = 34% and 2c = 34%) indicating moderate to extensive overgrazing. This can be explained by the fact that there were recent fires (1995) in large parts of this community making the grass initially more palatable and acceptable for all the grazing species. As a result there were higher grazing pressure after a certain time and trampling occurred.

The fact that there were a fair amount of Decreasers (26%) indicates that the range is in a fairly good condition but care should be taken for overgrazing and fire must be prevented in this area for at least two years to allow recovery.

Acacia caffra - Combretum apiculatum closed woodland

The community is just in one area next to the dam on a northern slope of 5° (Figure 3). It covers an area of 26 hectares (3% of total area) and species characteristic of the community is *Combretum apiculatum*, dominating it, and other woody species such as *Acacia caffra, Combretum molle, Ozoroa paniculosa* and *Dombeya rotundifolia*. Herbaceous species found are *Hyperthelia dissoluta, Enneapogon scoparius, Setaria sphacelata, Loudetia flavida* and *Themeda triandra*.

This community has the lowest range condition scores (411 & 212) with an average of 319. Grazing capacity is 6.8 and 11.2 ha/LSU for good and bad rainfall years respectively. It also has a very high percentage Increaser 2 (2a&b = 39% and 2c = 42%) species, and a low percentage of Decreasers (10%), which indicates that there are a high degree of moderate and extensive overutilisation on this area. This can be explained by the fact that the bigger herds of blue wildebeest, zebra and waterbuck preferred this area to rest because it was in a sheltered part of the reserve, away from the busy dirt roads, warmer in winter and near the dam.

In this situation it was noted that the range, while being overutilised, still had a high fuel but a low forage production potential, especially the big area north of the road (Figure 3). This was also noted in the Kruger National Park by Trollope, Potgieter & Zambatis (1989), where they found that the *Sclerocarya birrea-Acacia nigrescens* Savanna landscape was overutilised with a low forage production potential, but that the range in that condition still had a very high fuel production potential.

According to the management records this area was burnt in 1983 and 1990 and it can be suggested that the area north of the road must be burnt at least every two to three years to improve range condition and forage production (Trollope *et al.* 1989). The rest of the area must be monitored and if necessary, be burnt in two years time (1998).

Acacia caffra- Faurea saligna open woodland

This community is only 10 ha (1.2% of total area) in size and is found in isolated areas on the eastern and southern side of the dam, on plains and on western slopes of up to 10°. *Faurea saligna* is a differentiating species and other woody species present are *Acacia caffra, Ozoroa paniculosa, Rhus zeyheri* and *R. leptodictya*. Herbaceous species which are noticeable are *Setaria sphacelata, Diheteropogon amplectens, Loudetia flava, Clerodendrum triphyllum* and *Chaetacanthus costatus.*

This community is in a very good range condition with an ecological index of 489 and a grazing capacity of 5.9 and 8.8 ha/LSU in good and bad rainfall years respectively. The dominant presence of Decreaser species (28%) shows that it is in good condition, but the fact that the Increaser 2 species are also noticeable shows that there are areas which are overgrazed with heavily eroded areas and exposed soils.

It can be suggested that burning should be avoided in this community for at least two years, for the range to recover and that the grazing pressure would naturally decrease.

Melinis repens - Cynodon dactylon old land grassland

This community is found distributed over the whole reserve on plains and on slopes of up to 5°, and especially where there were human disturbance like old lands, residences and camping areas (Figure 3). The herbaceous stratum are characterised by the occurrence of species like *Melinis repens, Cynodon dactylon, Aristida congesta subsp. barbicollis, Bothriocloa insculpta, Hermannia depressa, Eragrostis curvula, Heteropogon contortus, Eragrostis superba* and *Verbena bonariensis.* This community is 55 hectares in size (6% of area) and an ecological index value of 461 was calculated with a grazing capacity in normal rainfall years of 6.7 ha/LSU and 10.2 ha/LSU in below average rainfall years. There is a high percentage of both Increaser 1 (32%) and Increaser 2 (35%) species and indicates that it is in an average condition. This range can be improved to Decreaser dominant range by burning this grassland range type once every two years because the fuel load is very high and grasses become unpalatable very soon in the season (Trollope *et al.* 1989). It was noted that there were areas which were heavily utilised and areas which were completely underutilised, and that suggests that the burning programme should be applied according to the degree of utilisation. *Acacia karroo* is also beginning to encroach and the cover-abundance is higher than 10 years ago (Figure 36) .

Berchemia zeyheri - thickets

This community is found mainly in the grasslands on the eastern side of the dam in the central and southern parts of the reserve on plains and on slopes of up to 20° mostly on a western aspect (Figure 3, 6). This range type is 37 hectares (4% of the area) in size, and has four variations of which one is hydrophilic, and is found next to the dam while the other variations of the range type are found in small clumps of different sizes scattered in the *Setaria sphacelata - Polygala hottentotta* grassland. Along the dam shore species like *Combretum erythrophyllum, Melia azedarach, Achyranthus aspera* and *Sebaea leiostyla* are distinctive. In the grassland species like *Acacia robusta, Hibiscus calyphyllus, Pappea capensis, Berchemia zeyheri, Olea europaea, Justicia flava, Dovyalis zeyheri, Commelina benghalensis, Aloe marlothii, Delosperma herbeum, Rhynchosia caribaea, Scolopia zeyheri, Opuntia ficus-indica, Protasparagus setaceus* and *Solanum incanum* are common.

FIGURE 36 Aerial photographs (1979 and 1991 respectively) to illustrate *Acacia karroo* woodland invading the *Melinis repens*-*Cynodon dactylon* old land grasslands

FIGURE 36 (CONTINUED)

The quality of this range is very high and it was calculated that it had an ecological index of 539. Grazing capacity was calculated as 7.1 and 10.6 ha/LSU for good and under average rainfall years respectively. This is probably so high because the percentage frequency of Decreaser species is so high (43%). The presence of Increaser 2 a & b were also noticeable that show that certain areas were overgrazed and other areas were in very good condition. The Decreasers are in abundance especially under the dense tree canopy and where it is very moist and ideal especially for *Panicum maximum*, which is a very nutritional grass species. This range has a high forage and fuel production potential and is indicative of range that is being moderately utilized by grazing animals. This range can be maintained if so desired by applying the existing stocking rate of animals.

4.2.3 Interpretation of range condition assessment

Stocking rate is the area of land allotted to each specified animal unit. The difference between this and grazing capacity is primarily a function of vegetation when utilised to an optimum condition while stocking rate is the managers estimate of what land to animal relationship will provide the most beneficial return (Booysen 1967; Trollope, Trollope & Bosch 1990).The available quality of the habitat, the objectives planned for the game ranch and money available are amongst the most important aspects which influence purchase of game for a particular game ranch (Bothma 1989).

Roodeplaat Dam Nature Reserve is a small reserve and care should be taken if any new game species are to be reintroduced. Bothma (1989) states that the smaller the area, the more intensively it has to be managed and more certainty prevails about the type of management that has to be practised.

The current management plan states that management of the flora must be to conserve the natural plant communities and plant species and that the recommended stocking rate must be applied. All mammals, birds, reptiles, amphibians, fish and invertebrates which occurred naturally in the area must be protected, and with reference to the size of the reserve, only selected game species can be reintroduced.

The condition of the range over the whole reserve is very good with a grazing capacity of 6.80 ha/LSU, the grass cover is high and it is at present stocked at 60.48% of the maximum capacity of LSU calculated. Figure 37 gives a graphic analysis of the grazing capacity of each plant community.

Wentzel, Bothma & Van Rooyen (1991) found in a study in the Kruger National Park, that the herbaceous layer resembles a mosaic with under-utilised, lightly to heavily utilised and over-utilised areas. Wentzel *et al.* (1991) states that veld management is often geared towards improving veld condition and an increase in Increaser grass species which is widely regarded as indicative of veld in "good" condition. This premise conflicts with the study findings that not all herbivore species will benefit from veld in "good" condition, even if the herbaceous layer is dominated by Decreaser grass species such as *Themeda triandra.* Rather it is to the benefit of all herbivore species that veld in different stages of utilisation should be present. Management in large conservation areas should therefore aim to satisfy the habitat requirements of all organisms and attempt to safeguard all essential processes within such a system. Apart from the practical problems involving the "improvement" of over-utilised veld, it may well be that localised over-utilisation of the herbaceous layer within the grazing mosaic is desirable, within limits of resilience for the ecosystem concerned.

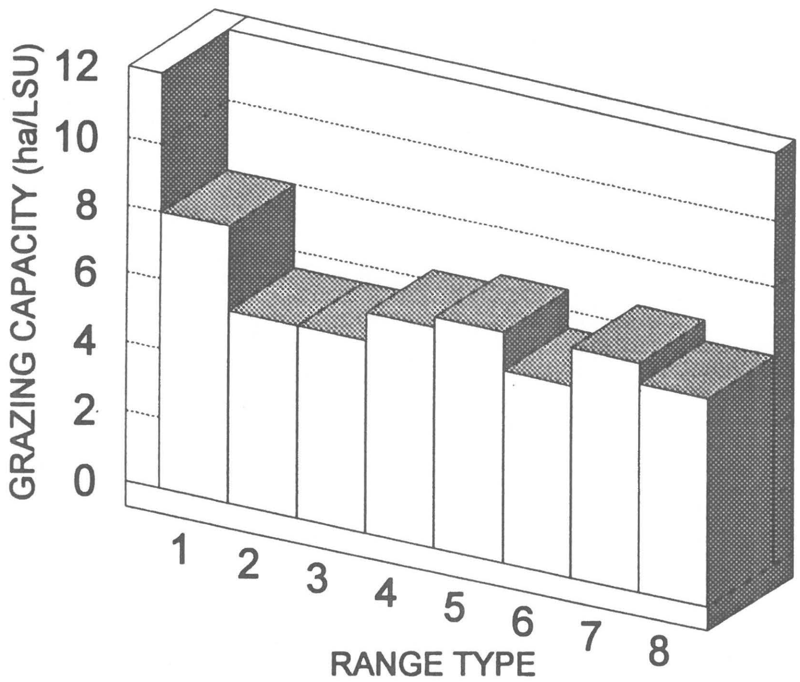
This statement of Wentzel *et al.* (1991) is relatively easy to manage in a large area like the Kruger National Park, but as mentioned, the smaller the area being used for wildlife the more intensively it must be managed (Bothma 1989). Therefore, the aim of management on the reserve should be to maximise range condition by applying adjustments to animal species, numbers and ratios of types of feeders and the application of a consistent and scientifically calculated burning programme.

In savanna areas Mentis (1981) recommends a ratio of 2AU bulk grazers: 2AU concentrate feeders: 1AU browsers. This recommendation takes into account that browsers and grazers utilise different and unrelated sources of forage and their numbers should therefore, be a function of the browsing and grazing capacity of the range (Trollope 1990). Since this section deals with grazing capacity, browsers are left out of the ratio, and this gives a ratio of 2:2, 50% for bulk grazers and 50% for concentrate feeders (selective feeders and mixed feeders).

In calculating the recommended number and composition of game species, the browsing capacity of the woody stratum (discussed in section 4.3) had to be considered. The grazing capacity was calculated for the herbaceous stratum and for that reason, the herbaceous component in the diet of impala (mixed feeder) and kudu (mainly browser) was calculated as 55% and 10% respectively (Pauw 1988).

This changed the LSU inversion of impala from 5.20 to 2.86 animals/LSU and for kudu from 1.84 to 0.184 animals/LSU (Bothma 1995). From the browsing capacity assessment (BECVOL: section 4.3.3), it was calculated that the reserve could support 2 impala and 11 kudu, which gives a total of 30 impala and 14 kudu if the results of GRAZE and Becvol are added.

The calculation is summarised in Table 10 and gives the current number of large herbivores and compositions, the recommended number of game species for average and below average rainfall years for 100% stocking rate and a 60% stocking rate.



1 - Setaria sphacelata-Polygala hottentotta grassland
2 - Burkea africana closed woodland
3 - Acacia karroo closed woodland
4 - Acacia caffra-Setaria sphacelata closed woodland
5 - Acacia caffra-Combretum apiculatum closed woodland
6 - Acacia caffra-Faurea saligna open woodland
7 - Melinis repens-Cynodon dactylon old land grassland
8 - Berchemia zeyheri thicket

FIGURE 37 - The grazing capacity (ha/LSU) in every range type on the Roodeplaat Dam Nature Reserve

TABLE 10 The present and recommended number and composition of game species for normal and below average rainfall years on the Roodeplaat Dam Nature Reserve as calculated by GRAZE (Bredenkamp & Van Rooyen 1990)

PRESENT NUMBER OF GAME SPECIES (1995)

ECOLOGICAL GROUP AND ANIMAL SPECIES	%MC	LSU equiv	LSU inv	NUMBE	SRATIO	MGS	Nr.males	Nr.female	Juveniles
A: GRAZERS NON-SELECTIVE FEEDERS									
Burchell's zebra	19.6	25.08	1.51	38	3:7	10	11	20	7
Waterbuck	14.5	18.5	1.99	37	3:5	8	14	16	7
Sub TOTAL	34.1								
SELECTIVE FEEDERS									
Blue wildebeest	11.7	15	1.99	30	1:4	15	7	18	5
Red hartebeest	3.17	4.1	2.69	11	3:5	8	7	4	0
Sub TOTAL	14.87								
MIXED FEEDERS									
Impala	2.23	2.85	5.2	15	1:4	25	10	5	0
Sub TOTAL	2.23								
B: BROWSERS									
Kudu	9.28	12	1.84	22	1:3	12	3	14	5
Sub TOTAL	9.28								
TOTAL	60.48	77.53		153			52	77	24

RECOMMENDED NR. OF GAME SPECIES IN A GOOD RAINFALL YEAR WITH MAXIMUM LSU = 128

	%MC	LSU equiv	LSU inv	Number	SRATIO	MGS	%INCR	Nr.males	Nr.females
Burchell's zebra	25	32	1.51	48	3:7	10	20	14	34
Waterbuck	25	32	1.99	64	3:5	8	20	24	40
Sub TOTAL	50								
Blue wildebeest	12.5	16	1.99	32	1:4	15	20	6	26
Red hartebeest	12.5	16	2.69	43	3:5	8	20	16	27
Sub TOTAL	25								
Impala (55% grass in diet)	12.5	16	2.86	46	1:4	25	37	9	37
Kudu (10% grass in diet)	12.5	16	0.184	3	1:3	12	20	1	2
Sub TOTAL	25								
TOTAL	100	128		236					

RECOMMENDED NR. OF GAME SPECIES IN A BAD RAINFALL YEAR WITH MAXIMUM LSU = 87

	%MC	LSU equiv	LSU inv	Number	SRATIO	MGS	%INCR	Nr.males	Nr.females
Burchell's zebra	25	21.75	1.51	32	3:7	10	20	10	22
Waterbuck	25	21.75	1.99	43	3:5	8	20	16	27
Sub TOTAL	50								
Blue wildebeest	12.5	10.8	1.99	22	1:4	15	20	4	18
Red hartebeest	12.5	10.8	2.69	29	3:5	8	20	11	18
Sub TOTAL	25								
Impala	12.5	10.8	2.86	31	1:4	25	37	6	25
Kudu	12.5	10.8	0.184	2	1:3	12	20	1	1
Sub TOTAL	25								
Total	100	86.7		159					

%MC = Percentage of maximum capacity
LSU inv = Large stock unit inversion (animals/LSU) from Bothma (1995)
LSU equiv = Large stock unit equivalent
SRATIO = Optimal sex ratio
MGS= Minimum group size of species
% INCR = Percentage increase per year

Table 10 (continued)

The present and recommended number and composition of game species for normal and abnormal rainfall years, for a 60% stocking rate on the Roodeplaat Dam Nature Reserve as calculated by GRAZE (Bredenkamp & Van Rooyen 1990)

RECOMMENDED NR. OF GAME SPECIES IN A GOOD RAINFALL YEAR WITH MAXIMUM LSU = 128

	%MC	LSU equiv	LSU inv	Number	SRATIO	MGS	%INCR	Nr. Males	Nr. Females
Burchell's zebra	15	19.2	1.51	30	3:7	10	20	9	21
Waterbuck	15	19.2	1.99	38	3:5	8	20	14	24
Sub TOTAL	30								
Blue wildebeest	7.5	9.6	1.99	19	1:4	15	20	4	15
Red hartebeest	7.5	9.6	2.69	26	3:5	8	20	10	16
Sub TOTAL	15								
Impala (55% grass in diet)	7.5	9.6	2.86	28	1:4	25	35	6	22
Kudu (10% grass in diet)	7.5	9.6	0.184	2	1:3	12	20	1	1
Sub TOTAL	15								
TOTAL	60	76.8		143					

RECOMMENDED NR. OF GAME SPECIES IN A BAD RAINFALL YEAR WITH MAXIMUM LSU = 87

	%MC	LSU equiv	LSU inv	Number	SRATIO	MGS	%INCR	Nr. Males	Nr. Females
Burchell's zebra	15	13.05	1.51	20	3:7	10	20	6	14
Waterbuck	15	13.05	1.99	26	3:5	8	20	10	16
Sub TOTAL	30								
Blue wildebeest	7.5	6.5	1.99	13	1:4	15	20	3	10
Red hartebeest	7.5	6.5	2.69	18	3:5	8	20	7	11
Sub TOTAL	15								
Impala	7.5	6.5	2.86	19	1:4	25	35	4	15
Kudu	7.5	6.5	0.184	1	1:3	12	20	1	0
Sub TOTAL	15								
Total	60	52.1		97					

%MC = Percentage of maximum capacity
LSU inv = Large stock unit inversion (animals/LSU) from Bothma (1995)
LSU equiv = Large stock unit equivalent
SRATIO = Optimal sex ratio
MGS= Minimum group size of species
% INCR = Percentage increase per year

Due to the high ratio of selective feeders and browsers, it is essential that the animal species numbers in this category be reduced as recommended, for maximum increase (offspring). Recommended percentage of maximum capacity is maintained at 60%, so that the ecological groups are divided as selective grazers (15%), non-selective grazers (30%), mixed feeders (7.5%) and browsers (7.5%).

A further recommendation is made for 100% stocking rate at selective grazers (25%), non-selective grazers (50%), mixed feeders (12.5%) and browsers at 12.5%. Trollope (1990) states that for maximum venison production it is recommended that the stocking rate should be equivalent to approximately 50% of the ecological carrying capacity, because at this level the rate of increase of an animal population is at a maximum. Conversely for sport hunting and game viewing, the stocking rate should be higher than 50% of ecological carrying capacity, because here the emphasis of management is on maximising animal numbers.

Populations of wild animals in nature have developed a social structure which results in the optimum production of progeny (Bothma 1989). One aspect of this structure, necessary to discuss for the management of this reserve, are sex ratio, in accordance with the type of reproductive system and the type of reproductive bond between the two sexes. An imbalance in the sex ratio of animals often leads to a poor serving frequency and leads to sub-optimal productivity. It is difficult to make recommendations out of hand about the optimal sex ratio. On the reserve the herd of male animals in particular can be limited in such a way that the territorial rams or bulls are still stimulated to mate as a result of the "threat" posed by other males, and that there are enough quality male animals in reserve to replace territorial animals if they become too old, deteriorate physically, or die. Knowledge of the social structure of each animal type will eventually determine what a population optimum sex ratio will be.

A population productivity can be increased by replacing a section of the male animals in the population with producing females (Bothma 1989). The manager has to monitor sex ratios from year to year.

* If the stocking rate be kept at 60% of maximum capacity, the recommended number of 30

Burchell's zebra (9 males: 21 females) are correct. If the stocking rate is 100%, the numbers can be increased to a total of 48 zebra of which 14 are male and 34 are female in an average rainfall year.

* Waterbuck is a bulk grazer (Trollope 1990) and at 60% stocking rate, is at the correct total but the ratio of male:female can be adapted to 14:24.

* The blue wildebeest, being a concentrate grazer (Trollope 1990), are in total too high for 60% stocking rate. It is suggested that the number be decreased and that the sex ratio of 1:4 be maintained so that there are 4 males and 15 females.

* The red hartebeest does not show significant progeny (increase) over the last few years, not because it does not adapt well on the reserve, but because it may be that the current sex ratio favours males. The recommended ratio is 3♂ :5♀ and currently it is approximately two males to one female. To ensure a high viability with good performance, it is suggested that 12 more females animals be introduced or that the number of males can be adapted to 10 (at 60% stocking rate). Minimum group size is recommended at eight individuals.

* The recommendation for kudu and impala are summarised in section 4.3.3 with the results of the browsing capacity of the woody stratum.

There are smaller antelope that also utilise the grazing and browsing component, but to a far lesser extent. There are approximately 5 warthogs, 5 common duiker and 27 steenbok on the reserve.

The warthog is a true savanna dweller that avoids dense cover and forest but depends on burrows to escape predators (Estes 1992). In general they are vegetarians, living on annual and perennial grasses which grow in lawn-like swards, and are partially to freshly sprouting grasses after a burn, and also to rooting on the underground rhizomes of grasses. They will also eat sedges, herbs, shrubs and wild fruit (Skinner & Smithers 1990).

The common duiker is almost exclusively a browser, only very rarely eating grass. Their diet consists of the leaves, twigs, flowers, fruit and seeds of a wide variety of trees and shrubs (Skinner & Smithers 1990).

The steenbok is a species which inhabits open country and they do not occur in forest or thick woodland. They both browse and graze, utilising in particular forbs growing in the grass stratum.

There are species which can be recommended which are both a financial and tourist benefit. These proposed animals are discussed.

Bushbuck

In the southern African sub region they do not occur in the arid areas and are found only in the southern savanna zone (Skinner & Smithers 1990), where there is water and cover. They occur widely in the Transvaal excluding the grassland areas.

Throughout their wide distributional range, Bushbuck are closely associated with riverine or other types of underbrush adjacent to permanent water supplies. Cover and the availability of water appear to be among the most important habitat requirements for Bushbuck. Bushbuck are predominantly browsers but also graze to a lesser extent. The habitat and range types along the shore of the dam are ideal habitat and cover for these animal species.

Ostrich

Ostriches used to inhabit large areas of southern Africa, but over the years their numbers have dwindled significantly. Their habitat ranges from bushveld to desert and they are adaptable to a variety of range types (Skinner & Smithers 1990). Ostriches may be included in the species mix on reserves, but, because they are mainly herbivorous, their numbers must be taken into account when the carrying capacity of the reserve is calculated.

Ostriches are in demand on game ranches not only because of their commercial value, but also because they are interesting animals and an attraction to tourists (Bothma 1989).

Giraffe

In historical times the limits of distribution of the giraffe have shrunk dramatically and the present picture shows that throughout their range from eastern South Africa to West Africa, their occurrence is patchy and discontinuous. With the establishment of reserves they nevertheless are not an endangered species and with the enlightened appreciation of wildlife, they have been widely reintroduced onto farms and game reserves with success in southern Africa. Giraffe occur in a wide variety of dry savanna associations ranging from scrub to woodland, providing that these include the particular range of plant species necessary to cover their seasonal requirements (Skinner & Smithers 1990).

Giraffe are predominantly browsers, utilising a wide range of food plants, but will graze occasionally on fresh sprouting seasonal grasses. They feed on various species according to the season (Hall-Martin 1974), which occur on the reserve like *Acacia* species (*A. caffra, A. karroo*), *Combretum* species (*C. apiculatum*), *Ziziphus* species, *Euclea* species and *Maytenus* species.

Various species of *Acacia* are the most important and preferred plants to giraffe. Giraffe can browse up to a height of five metres which is higher than can be reached by other browsing species. Giraffe has an aesthetic value and from a tourism point of view may be a very good consideration. According to Hall-Martin (1974) the recommended stocking rate is 0.09 to 2.6 giraffe per km^2 in different areas in Africa. The recommendation for giraffe is discussed in section 4.3.3.

The difference between the current and recommended animal numbers, and also the reintroduction and removal of species, will result in the reaching of the ideal total but this will only realise over time and with a few adjustments every year. Some populations will have to be reduced proportionally and others have to be left to increase naturally. It is important for the manager to monitor the range condition and population structures regularly to keep a finger on the pulse.

4.3 Determining browsing capacity of the woody stratum

4.3.1 Introduction

An agro-ecological quantification of woody plant communities is frequently necessary for research and as an aid in the management of such communities for animal production (Smit 1989). Statistics relating to carrying capacity and other quantitative criteria are meaningless unless a realistic assessment is made of the amount of accessible and usable leaf fodder available for browsers (Young 1992).

According to Rutherford (1979) it is important to have a clear understanding of what precisely is meant by the terms browse and available browse. Although many workers have viewed browse in different ways, the concept clearly remains inseparable from the type or types of animal being considered. A division based on stomach structure classes ruminants as bulk and roughage feeders, i.e. , grazers as opposed to concentrate feeders, i.e. browsers. This division results in herbaceous diet material also being considered as browse. However, techniques of measuring amounts of vegetation often depend strongly on the herbaceous or woody nature of the plants. For this reason the term browse is restricted to woody plant material.
Browse may be viewed as the sum total of that plant material on a woody species that is potentially edible to a specified set of animals. The lowest limit of edibility is thus a critical determinant of the total amount of browse material. Seasonal changes, for example in palatability and moisture content of plant material, may also affect a specific definition of browse. Standing browse is most commonly regarded as the current seasons growth of leaves and twigs.

Rutherford (1979) also states that available (accessible) browse is usually a more restricted quantity than browse. Availability of browse in most studies is simply determined on the basis of maximum height above ground to which the animal can utilize browse. The definition is more difficult to apply in very broken or uneven terrain. In special cases animals, like kudu or waterbuck may break down browse from their usual range of browse, making it available to themselves or to other smaller browsers. The amount of available browse also depends on seasonal activities of other animal groups, especially those of large scale insect defoliators. It is accepted that the available browse refers to leaves, young twig material, bark, flowers and pods within a reachable height.

Pellew (1983) defines browse production as the rate of change of edible biomass when protected from browsing over a specified period of time. In practice the available browse production is considered as the cumulative increment of new shoots (kg dry matter/ha) below 5,5 m (maximum browsing height for giraffe) over a given time (3 months or a year) when browsing is excluded (Pellew 1983). Because of the small mass of unused but available leaf production arising from lignified shoots, this measure of browse production is likely to be an under-estimate of the actual rate of forage production.

In an agricultural system, depending on the density of stock, plants would be subjected to varying rates of use (Teague 1989). To develop a predictive capability regarding optimal management strategies, it is important to predict consumption as a function of accessible plant material on offer (Teague 1989).

A technique was developed by Pauw (1988) to determine the available leaf material on different height levels. Direct measurements of the crown diameter were made on different height levels. This was supplemented with direct visual estimations of the available leaf material. The ratio between the dry mass of the leaves per standard volume unit was used to determine the total dry mass of the leaves per species, per height level and per soil surface unit. The total survey was done by one person and involved only a slight destruction of leaf material.

Another method was developed by Smit (1989) for quantitatively describing woody plant communities i.e. BECVOL. With this method it is also possible to determine the available leaf material on different height levels. Spatial volumes of each separate tree segment are calculated. The total survey was done by one person, involved no destruction of leaf material and is not labour intensive.

Taking into account the ecological implications of trees in bushveld areas, Smit (1989) lists the following three aspects as the most important from an agricultural point of view: (i) competition with herbaceous vegetation for moisture; (ii) food for browsers and (iii) creation of subhabitats suitable for desirable grasses. In bushveld, certain grass species occur in association with trees. An important association is that of *Panicum maximum* under trees, since this species can contribute significant amounts of forage (Bosch & Van Wyk 1970; Kennard & Walker 1973; Smit & Rethman 1989).

Teague, Trollope & Aucamp (1981) defined a Tree Equivalent (TE) as an *Acacia karroo* tree of 1,5 m height. To quantify browse material, Teague *et al.* (1981) defined a Browse Unit (BU) as an *Acacia karroo* tree with a height of 1,5 m. The difference between the BU and TE is that all unacceptable species are excluded in the calculation of the BU, as well as those individuals which have their lowest browseable material above 1,5 m.

Bearing in mind the three main ecological effects of trees, mentioned above, the following three quantitative descriptive units are proposed:
(a) Evapotranspiration Tree Equivalent (ETTE) - defined as the leaf volume equivalent of a 1,5 m single stemmed *Acacia karroo* tree.
(b) Browse Tree Equivalent (BTE) - defined as the leaf mass equivalent of a 1,5 m single stemmed *Acacia karroo* tree. BTE is a descriptive measure of potential production and as such, factors contributing to leaf loss must be considered. These factors will be discussed under method (4.3.2).
(c) Canopied Subhabitat Index (CSI) - defined as the canopy spread area of those trees in a transect under which associated grasses like *Panicum maximum* is most likely to occur, expressed as a percentage of the total transect area.
Acacia karroo is taken as a standard since it is the most widespread bushveld species. The calculation of the ETTE and BTE are based on the relationship between the spatial volume of a tree and its true leaf volume and true leaf mass respectively, taking into account differences in leaf densities (Smit 1989).

4.3.2 Method

The woody vegetation was surveyed using the belt transect method described by Smit (1989). The size of a transect which was surveyed in every plant community together with the step-point method, was a length of 100 metres and two metres in width, making up 200 m^2. A two-metre rod was used to define the boundaries. All the rooted woody species were identified and recorded. The spatial volume of the tree (dimensional measurements) were calculated from measurements consisting of the following :

(A) Tree height

(B) Height of maximum canopy diameter

(C) Height of first leaves or potential leaf bearing stems

(D1 & D2) Maximum canopy diameter

(E1 & E2) Base diameter of the foliage at the height of the first leaves or potential leaf bearing stems .

The tree height is taken as the height of the main tree crown, ignoring any small stems protruding from the crown (Figure 38).

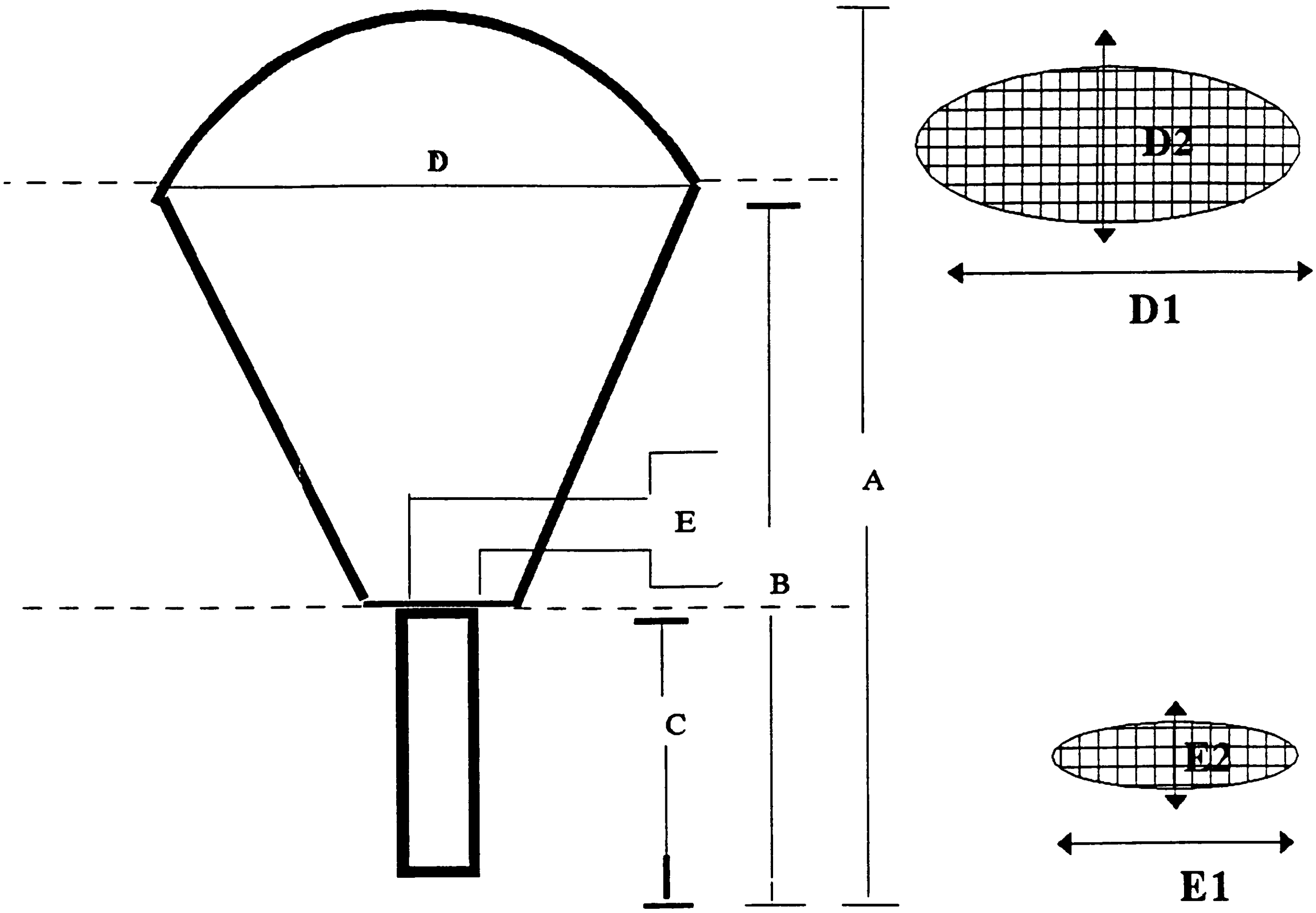


FIGURE 38 A schematised illustration of an ideal tree, its measurements and structure (Smit 1989)(see text p 113 for explanation of symbols)

Further analysis of the data was done using the BECVOL programme developed by Smit (1989). The name of the BECVOL-model is derived from "Biomass Estimate from Canopy VOLume". This program is a refined version of the Canopy Sub-habitat Index (CSI) program devised by Smit (1989). The BECVOL programme calculates the spatial volume of a tree using this value to determine the ETTE, BTE and dry leaf mass of a tree below a specified Maximum Browse Height (MBH). The calculation of the ETTE and the BTE are based on the relationship between the spatial volume of a tree and its true leaf mass respectively (Smit 1989).

From potential leaf production the following factors contributing to leaf loss can be listed. Fifty percent of the leaves are not available to browsers, 25 % may be discarded to prevent over utilisation and maintain vigour, and other species also utilise the woody vegetation like insects, and for that a further 12% are lost (Orban pers. comm.)[2]

4.3.3 Results and Discussion

Survey data was grouped and analysed to calculate the total LSU that the area could support for browsers. To sustain one mature goat for one year, it needs 1500-3000 BTE's (Danckwerts 1989). One large stock unit (LSU) is equal to 6 goats (Meissner *et al.* 1983). This amounts to 18 000 BTE's needed to sustain one LSU. From this, the browsing capacity is calculated.
Currently kudu and impala are the only browsers of importance and if the browsing capacity under the 2.0 meter height class is calculated, it gives a total biomass of 27 9764.32 kg for the whole reserve. If the abovementioned factors which influence actual browse availability are included, a browse biomass of 34 970.54 kg is available (Table 11).
According to Meissner, Hofmeyer, Van Rensburg & Pienaar (1983), 9-14 kg dry mass are needed for a 450 kg steer to gain 500 g per day. For a year it is calculated as 4 927.6 kg needed to sustain one LSU. If browse biomass of 34 970.54 kg is divided by 4 927.6 kg (needed to sustain one LSU), it adds up to 7.10 LSU in total which the study area can support (Table 11).

[2] Orban, B. Centre for Wildlife Management, University of Pretoria, Pretoria 0002

TABLE 11 The calculation of browsing capacity for the Roodeplaat Dam Nature Reserve using BECVOL (Smit 1989)

	IMPALA(10% of total LSU: 7.10, 45% leaves in diet)	KUDU (90% of total LSU: 7.10, 90% leaves in diet)	GIRAFFE
TOTAL LEAFMASS(kg) < 2m	34970.54	34970.54	---
TOTAL LEAFMASS (kg) 2-5m	---	---	108394.59
LSU	0.71	6.39	22.0
*ANIMALS/LSU	2.34	1.66	0.63
RECOMMENDED ANIMALS TOTAL	2	11	11

* Calculated at percentage of leaves utilised in the impala and kudu diet (45% and 90% respectively)

This was only calculated for browsers which can utilise browse under a height of two meters. One LSU inverted are 5.2 impalas but they utilise an average 45% of browse or leaves in their diet, making it 2.34 animals per LSU. If this is multiplied by 7.10 LSU it gives a total of 16 impala that can be sustained by the area. But kudu must also be included and therefore it can be calculated that 60 % of the total LSU can be made up by kudu and the other 40 % can be filled by the impala. If this is calculated it gives a total of 11 kudus and 2 impala (Table 11).

If the reserve needs to sustain giraffe, it must be calculated if there is enough browse above two meters to sustain giraffe. If one LSU is equal to 0.63 giraffe (Bothma 1995), then 22.0 LSU are equal to 14 giraffes. This implies a density of 1.6 giraffes per km². Hall-Martin (1974) supplies statistics on population densities varying from 0.09-2.6 giraffes per km² for areas in South Africa, Zaïre and Kenya. Skinner *et al.* (1990) states that in East Africa, their home range size has been estimated as 62 km² for males and 85 km² for females. In the eastern Transvaal Lowveld, with its dense population, it is 22.8 km² and 24.6 km² respectively. This indicates that their home range stretches over a large area which is the limiting factor in the study area. Therefore it is recommended that the number of giraffe should be 1:250 ha, which will be 3-4 giraffes.

GRAZE suggested a total of 2 kudus in Section 4.2.2. If BECVOL's recommendation (11) is added to that, it is recommended that the reserve can support a total of 14 kudus. The minimum group size for kudu is 12. The correct ratio would be 11 females to 3 males.
The reserve can support more than the current 15 impala and the recommended ratio is 1:4. The effect is that there cannot be significant increase per year to be economically sustainable, and if action should be taken the minimum group size is 25. Because the impala are mixed feeders, only 45 % (Pauw 1988) of their food is made up of browse. If BECVOL's suggestion and GRAZE (Chapter 4.2.2) is added, the total number of impala can be increased to 8 males and 22 females. If a smaller change is to be made, the ratio of one male to four females must be achieved.

The suggested bushbuck is a very selective feeder, and mainly browses herbs and foliage of shrubby legumes and to a lesser extent eats tender green grass (Estes 1992). For this reason it is not included in the calculation for suggested recommended of browsing species.

4.4 Burning management : Determining the pasture yield of plant communities

4.4.1 Introduction

Veld burning has for long been a controversial aspect of the management of South African vegetation, no doubt due in part to the differences in the reaction of different vegetation types to fire and to the interaction between burning and grazing. The fire climax grasslands and the savanna(bushveld) areas owe their very natures to their long history of fire which has apparently played such an important role in their development (Tainton 1981).

The study of fire in Africa shows there is a very close relationship between fire and man and lends support to the view of Komarek (1971) that Africa is the fire continent. This stems from the fact that fire is regarded as one of the oldest phenomena in the world and as a product of lightning, fire can be traced to the early development of terrestrial vegetation. Climatic factors are the driving force of fire ecology and all that is necessary for fire to occur anywhere on earth is to have lightning as the primary ignition source and climatic conditions that will permit burning and the spread of fires resulting from lightning strikes. Research on the effects of fire has been conducted throughout the grassland and savanna areas of Africa since the early period of the century (West 1965; Rose-Innes 1971; Scott 1971). An interesting feature about these early investigations and subsequent research , was that it focused on addressing the two key questions of what are the effects of season and frequency of burning on the forage production potential of the grass sward and the ratio of bush to grass in savanna areas.

Van Rooyen, Grunow & Theron (1989) listed six major objectives of using fire in grassland management:

- To remove moribund or unacceptable grass material that has accumulated from the previous seasons, before it suffocates the more acceptable grasses - this is a valid reason
- To stimulate growth during seasons, like autumn and winter, when there is little green grazable material available on the veld - this is an undesirable practice and autumn burning on sour veld areas is now illegal in South Africa.

- To destroy parasites, and particularly ticks - veld burning is seldom recommended for this purpose.
- To control the encroachment of undesirable plants (woody or herbaceous) which decreases the productivity of the grass layer - it is effective if applied correctly
- To make fire breaks for the protection of veld - a valid reason
- To burn parts of an area to encourage rotational grazing - effective where it concerns game, if applied correctly.

Any discussion of veld burning must take account of the practical objectives of including fire in management programmes in each vegetation type independently if its role is to be realistically assessed (Tainton 1981).

Fire ecology refers to the response of the biotic and abiotic components of the ecosystem to the fire regime i.e. type and intensity of fire and the season and frequency of burning (Trollope, Trollope & Bosch 1990). There are three broad types of fires based on the layers in which the vegetation burns, namely, ground, surface and crown fires (Brown & Davis 1972; Luke & McArthur 1978).
Surface fires are the most common type of fire and in tree and shrub vegetation, can develop into crown fires when the foliage ignites and carries the fire above the surface of the ground (Trollope 1989). Brown & Davis (1972) and Luke & McArthur (1978) define a surface fire as a fire that burns in the herbaceous surface vegetation and a crown fire as a fire that burns in the canopies of trees and shrubs.

Besides the aforementioned types of fires, a further subdivision can be made into fires burning with and against the wind. Trollope (1978) referred to these as head and back fires, respectively. Crown fires occur only as head fires but surface fires occur either in the form of head or back fires. Trollope (1978) reported on the effects of surface fires occurring as either head of back fires on the grass sward in the savanna areas of the Eastern Cape. Results showed that head fires had a significantly greater rate of spread, flame height and overall intensity than back fires. However at ground level back fires were more intense and had a significant depressive effect on recovery of the grass sward, resulting in lower yields. The results indicated that the critical threshold temperature was approximately 95 C° and that this temperature was maintained for 20 seconds longer during back fires than during head fires, thus explaining the depressive effect on the recovery of the grass sward.

However, the effect of **fire intensity** on the recovery of the grass sward was investigated in the arid savannas of the Eastern Cape by Trollope & Tainton (1986) and after a series of fires ranging in intensity from 925 to 3 326 kJ/s/m, there were no significant differences in the recovery of the grass sward at the end of the first or second growing seasons after the burns. Therefore it would appear that fire intensity has no significant effect on the recovery of the grass sward after a burn.

Season of burning is one of the most controversial questions concerning the use of fire in range management. West (1965) stressed the importance of burning when the grass is dormant and advocated burning just prior to the spring rains at the end of winter in order to obtain a high intensity fire necessary for controlling bush encroachment. Conversely Scott (1971) stated that burning in winter damages the grass sward and recommended burning after the first spring rains for all forms of controlled burning. However, more recent research has led to the conclusion that for all practical purposes burning when the grass sward is dormant in late winter or immediately after the first spring rains has very little difference in effect on the grass sward (Tainton, Groves & Nash 1977; Dillon 1980; Trollope 1987).

The effect of **frequency of burning** on forage production has not been intensively studied in South Africa and only limited quantative data are available. The general conclusion is that the immediate effect of burning on the grass sward is to significantly reduce the yield of grass during the first growing season after burning but the depressive effect disappears during the second season (Tainton & Mentis 1984; Trollope 1984)

According to Trollope (1989) no set rule can be laid down regarding the frequency of burning. When fire is used to remove moribund and /or unacceptable grass material, the frequency of burning will depend upon the rate at which excess litter accumulates. This in turn will be influenced by the degree of utilisation of the veld during the growing season and by the general conditions for plant growth. Therefore when grass utilisation is low and growth conditions are favourable, the frequency of burning would be high and *vice versa*. Sourveld areas generally require a much higher frequency of burning than sweetveld areas.

The effect of frequency of burning on the quality of forage is that generally frequent fires improve and maintain the nutritional quality of grassland, particularly sourveld (West 1965; Tainton *et al.* 1977).

4.4.2 Method

Herbaceous plant material was quantified by using a disc pasture metre (Bransby & Tainton 1977) which has the advantage of providing quick and accurate results.

The disc pasture meter is a simple, inexpensive instrument which may be used to make rapid but reliable estimates of the standing crop of herbaceous plant material. Linear regression relationships between the disc height and the standing crop are usually fairly good.

Estimation of the standing crop of grass using the disc pasture meter compares favourably with traditional methods of estimating yield and its attraction lies in the rapidity with which yield estimates can be made and the non-destructive nature of sampling. The disc pasture metre can be used to provide an objective basis on which to adapt animal numbers in a grazing system, to identify the critical level of pasture utilization, to estimate animal intake, to study animal selection patterns and to estimate grass fuel loads. It may also be useful to quantatively describe pasture-animal relationships and construct pasture growth curves (Trollope 1990).

A standard calibration for the disc pasture meter has been calculated for the Kruger National Park by Trollope & Potgieter (1985). Similar calibrations can be made for each specific ranch. However, according to Trollope (1990) previous veld experience indicates that the calibration made for the Kruger National Park can be applied with success to other areas within the Transvaal Bushveld. Thus one is able to obtain a precise estimation of grass fuel loads. These values and a range condition assessment can then be used to determine whether or not it is necessary to burn the area in question. Thus the frequency of burn should be based on the accretion matter, which in turn is related to rainfall and grazer concentration (Trollope 1990). These factors will usually result in a burning frequency of 2 to 4 years under sourveld and high rainfall conditions (Trollope 1990).

Disc pasture meter readings were calculated in every plant community on Roodeplaat Dam Nature Reserve on different areas which represents the standing crop of the particular plant community and thus to estimate the grass fuel load of the specific range type.

4.4.3 Results and discussion

In each range type the mean disc height is read in the standard calibration equation developed by Trollope & Potgieter (1985) from a standardised table and the standing grass crop (kg/ha) are calculated for each plant community (Table 12).

The standard regression equation is :

$$y = -3019 + 2260\sqrt{x}$$

where y = estimated fuel load (kg/ha)

x = mean disc height (cm)

TABLE 12 The standing grass crop (kg/ha) for every plant community on the Roodeplaat Dam Nature Reserve (1994).

Plant community	Standing grass crop (kg/ha)
Berchemia zeyheri - thickets	2831
Acacia karroo - closed woodland	5792
Acacia caffra - *Setaria sphacelata* - closed woodland	3685
Acacia caffra -*Combretum apiculatum* - closed woodland	5067
Acacia caffra - *Faurea saligna* - open woodland	3983
Burkea africana - closed woodland	4234
Setaria sphacelata - *Polygala hottentotta* - grassland	6569
Melinis repens - *Cynodon dactylon* - old land grassland	5734

Trollope (1989) states that when burning to remove moribund and unacceptable grass material, a cool fire is required to remove the material and do least damage to the vegetation. Such a fire would be obtained if it is applied when the air temperature is <20°C and the relative humidity >50%. These conditions generally prevail during the morning until approximately 11h00 and during the afternoon after 15h30. It is difficult to recommend what grass fuel loads should be except to state it should be as low as possible, but sufficient to carry a fire. Field experience indicates that the minimum fuel load required to carry a fire is approximately 1 500 kg/ha. It can however be less in the drier western areas of southern Africa (1 000 - 1 200 kg/ha).

When burning to eradicate and/or prevent the encroachment of undesirable plants, a hot fire is required. Tropical and sub-tropical trees and shrubs have non-flammable foliage and higher grass fuel loads are required. Research and experience indicate that a sufficiently intense fire will be obtained to destroy the aerial growth of bush to a height of 2 m with a grass fuel load of >4000kg/ha. For an intense fire the air temperature should be >25°C to 30°C and the relative humidity <30%. These conditions generally prevail between 11h00 and 15h30 during the day (Trollope 1989).

The basic management technique is to apply treatments to the veld on a rotational basis that will attract game to these areas thus providing a rest period to the vacated area (Trollope 1990).

Trollope (1990) further states that generally the most effective way of attracting game to a particular area is to burn the veld resulting in the production of highly palatable and nutritious forage. Suffice to say that the burning programme must be carefully planned, the most important factor being the size of the area being burnt. Care must be taken to ensure that the burnt area far exceeds the short term forage requirements of the game that will be attracted to it so that no over-utilisation of the veld occurs. Another important factor is the stocking rate of the game, particularly grazers which must be such that sufficient grass fuel will accumulate for the implementation of a burning program. Rotational resting can also be implemented by the strategic placing of licks to attract game to a new area (Young 1992).

Trollope's (1990) guidelines for management decision can be applied to the reserve (see Van Heerden 1992), and these following questions with the answer to what number must be consulted next, is given:

1) Is bush encroachment a problem?

   Yes → 2

   No → 5

2) Are the accumulated burnable grassmaterial > 4 000kg/ha?

   Yes → 3

   No → 4

3) Burn the veld under the following circumstances:

   Air temperature > 25°C

   Relative humidity < 30%

4) Wait till accumulated grassmaterial exceeds 4 000kg/ha before burning the veld

5) Are there a lot of moribund material building up in the grass sward that can cause suffocation of the new grass shoots ?

   Yes → 6

   No → 9

6) Are the burnable grassmaterial (fuel load) between 2 000 and 4 000 kg/ha ?

   Yes → 7

   No→ 8

7) Burn the veld under the following conditions:

   Air temperature < 20°C

   Relative humidity > 50%

8) Wait till the grassmaterial increase to 2 000 kg/ha before it is burnt

9) It is not necessary to burn the veld

As the ecosystem is a dynamic system, decisions can not only be based on theory alone. The regional officer plays an important role in this decision. The decision rests upon quantitative data as measured by plant surveys (veld condition assessment) and the dry phytomass using the disc pasture meter (kg/ha), but a subjective judgement forms a very important part and depends upon certain factors.

If an accidental fire breaks out and burns down a part of a burning block, the rest of the block should be burnt manually. If animals concentrate on a specific area overutilising it, the area surrounding the latter should be burnt to entice the animals. Another important factor is the reason for burning, either for removing moribund material or preventing bush encroachment. All these factors taken into consideration influence the decision.

Roodeplaat Dam Nature Reserve is divided up in burning blocks (Figure 39) and is burnt accordingly. A complete record is held since 1972. The following conclusions could be made following the range condition assessment (Chapter 4.2.2), the disc pasture meter results and visual observations. Further recommendations are made following this discussion of the existing burning block system, concerning an ecologically acceptable burning programme.

The block burn approach is where a block of vegetation is defined by fire breaks, and the entire block receives more-or-less the same impact from the fire (Hurt 1992).

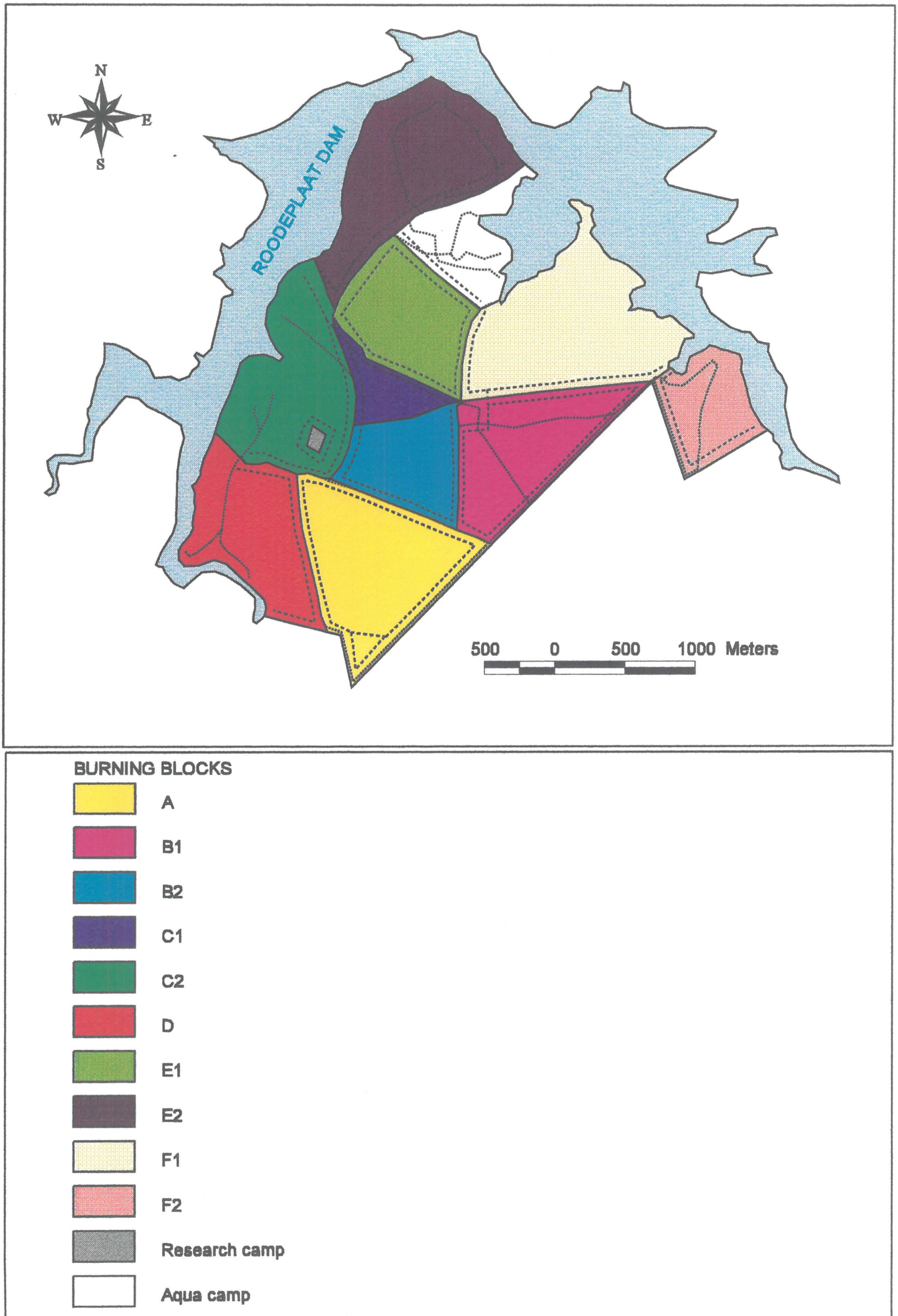


FIGURE 39 The burning blocks on the Roodeplaat Dam Nature Reserve

BLOCK A:

The biggest area of the block (105.1 ha) is covered by *Setaria sphacelata-Polygala hottentotta* grassland and *Acacia caffra-Setaria sphacelata* closed woodland, while small areas of *A. caffra-Faurea saligna* open woodland, *Burkea africana* closed woodland and *Berchemia zeyheri* thickets cover the rest of the block. The calculated dry phytomass of the grassland range type is 6 569 kg per hectare. After another fuel load assessment in 1995, is was calculated between 7 600 and 9 300 kg/ha. The block was burnt in 1996 and it is suggested that the veld should rest for 2-4 years.

BLOCK B1:

This block (82.6 ha) include the range types *Melinis repens-Cynodon dactylon* old land grassland, *Acacia karroo* closed woodland, *Setaria sphacelata-Polygala hottenttotta* grassland and a small area of *Acacia caffra-Setaria sphacelata* closed woodland. Besides the visual conformation of plenty of moribund vegetation which is underutilised by game, the data obtained from the disc pasture meter also gives a clear picture that this block needs burning. The dry phytomass was calculated as 5 734 kg/ha in the old lands and 5 792 kg/ha in the *Acacia karroo* closed woodland. In 1995 the phytomass was calculated as 4 200-6 000 kg/ha. The old lands was burnt in 1983, and the last time the *Acacia karroo* community was burnt, was in 1983 and 1986. The whole block was burnt as a result of the high phytomass in 1995 and the veld should rest for 2-4 years.

BLOCK B2:

Setaria sphacelata-Polygala hottentotta grassland and *Acacia caffra-Setaria sphacelata* closed woodland cover this block (51.9 ha). The phytomass was measured as from 3 700 to 7 300 kg/ha. This block was previously burnt in 1987 and 1995. According to the veld condition assessment, this type of veld needs increased frequency of burning to once every two to three years to improve the forage potential of the veld (Trollope *et al.* 1989).

BLOCK C1:

A large part of this block (23.4 ha) burnt accidentally in 1994, and the game completely overutilised it after the first rains fell. It includes *Acacia caffra-Setaria sphacelata* closed woodland and *Berchemia zeyheri* thickets. This veld has to be given the chance to recover and burning should not be applied here for the next four years (until 1999).

BLOCK C2:

It includes parts of five different range types scattered in the block (93.3 ha). The two camping areas are also included resulting in a smaller burning area between the road and the dam. The range types are *Acacia karroo* closed woodland, *Berchemia zeyheri* thicket, *Setaria sphacelata-Polygala hottentotta* grassland, *Acacia caffra-Setaria sphacelata* closed woodland and the camping areas situated in the *Melinis repens-Cynodon dactylon* old land grassland . Most of these range types does not require a high frequency of burning, except for the old lands and the grassland which in turn does not cover a large area of the block. This block was burnt in 1988, 1992 and 1994 and it is recommended that the block be allowed to rest for at least two years before it is burnt again.

BLOCK D:

The biggest part of this block (77.3 ha) is covered by the *Setaria sphacelata-Polygala hottentotta* grassland and smaller, broken areas of hydrophilic *Berchemia zeyheri* thickets, *Melinis repens-Cynodon dactylon* old land grassland, *Acacia caffra-Setaria sphacelata* closed woodland and *Acacia caffra-Faurea saligna* open woodland. The phytomass was calculated as 8 500-8 900 kg/ha. Just the old land next to the dam burnt in 1994 and the grassland was previously burnt in 1988. As a result of the high phytomass, the block was burnt again in 1995.

BLOCK E1:

This block was burnt previously in 1987. Range types included in this block (69.2 ha) are *Melinis repens-Cynodon dactylon* old land grassland, *Setaria sphacelata-Polygala hottentotta* grassland and patches of *Acacia karroo* closed woodland, *Acacia caffra-Setaria sphacelata* closed woodland and *Berchemia zeyheri* thickets. The area of the *Acacia karroo* closed woodland, has very dense stands of *Themeda triandra* and *Hyparrhenia hirta* grasses and is totally underutilised and furthermore, the grassland are very dense. *Acacia karroo* is invading the old land grassland and if an open veld is required to improve visibility , a hot fire is suggested to control the bush/*Acacia* invasion as well as the dense grass cover. A block burn is suggested in 1996.

BLOCK E2:

The biggest area of the block (104.1 ha) is covered by the *Acacia caffra-Combretum apiculatum* closed woodland on the northern side of the hill. The phytomass in this range type are 5 067 kg/ha which is high. This veld has a high forage production potential and since it has been burnt in 1990, it is suggested that this specific range type has to be burnt at least every two to three years to improve veld condition.

The other areas are comprised of *Acacia karroo* closed woodland, *Setaria sphacelata-Polygala hottentotta* grassland and *Acacia caffra-Setaria sphacelata* closed woodland. These areas need no burning for at least a year.

BLOCK F1:

This block (119.6 ha) consist of two major range types, *Acacia caffra-Setaria sphacelata* closed woodland and *Setaria sphacelata-Polygala hottentotta* grassland. Some areas in this block are severely overutilised because this area are not near any roads or human structures, and it seems that the animals find refuge in this area. The woodland areas does not need any burning, as shown from the pasture meter data (3 685 kg/ha), and the grassland needs a rest. For this reason, no burning in this block is recommended.

BLOCK F2:

This block is the smallest of all the burning blocks (44.8 ha) and include areas of *Acacia karroo* closed woodland, *Setaria sphacelata-Polygala hottentotta* grassland, a small area of *Melinis repens-Cynodon dactylon* old land grassland and a strip of *Acacia caffra-Setaria sphacelata* closed woodland next to the dam. This block has to be considered for burning in 1996 since it has been burnt the last time in 1987.

In the existing system, it seems as if the blocks were chosen according to the road system, which is practical but not ecologically correct. To plan an ecological burning programme, the following are some important guidelines:

- The border of a burning block must follow a plant community border or ecotone and has to take into account plant species composition, range condition, species diversity and contours. Maximum biodiversity will result from fires burning under varying conditions as well as fires which are implemented at different stages of the growing cycle of all plants (Hurt 1992).

- A mosaic pattern of veld burning is recommended to maintain species diversity of the vegetation, to remove moribund material, to keep grazing short for grazers or as fire breaks. A mosaic pattern of veld burning is used to encourage rotational grazing but due to the fact that game animals tend to graze these burnt areas soon after the fire, this practice can be extremely harmful if the burnt areas are not large enough or if stocking rates are not kept low (Van Rooyen, Bredenkamp & Theron 1995).

- In sourveld areas, burning once every 2-4 years will be adequate to remove moribund and/or unacceptable grass material (Trollope 1990).

- A total of 25% of the reserve should be burnt every year.

A proposed burning block system will therefore be discussed as illustrated in Figure 40.

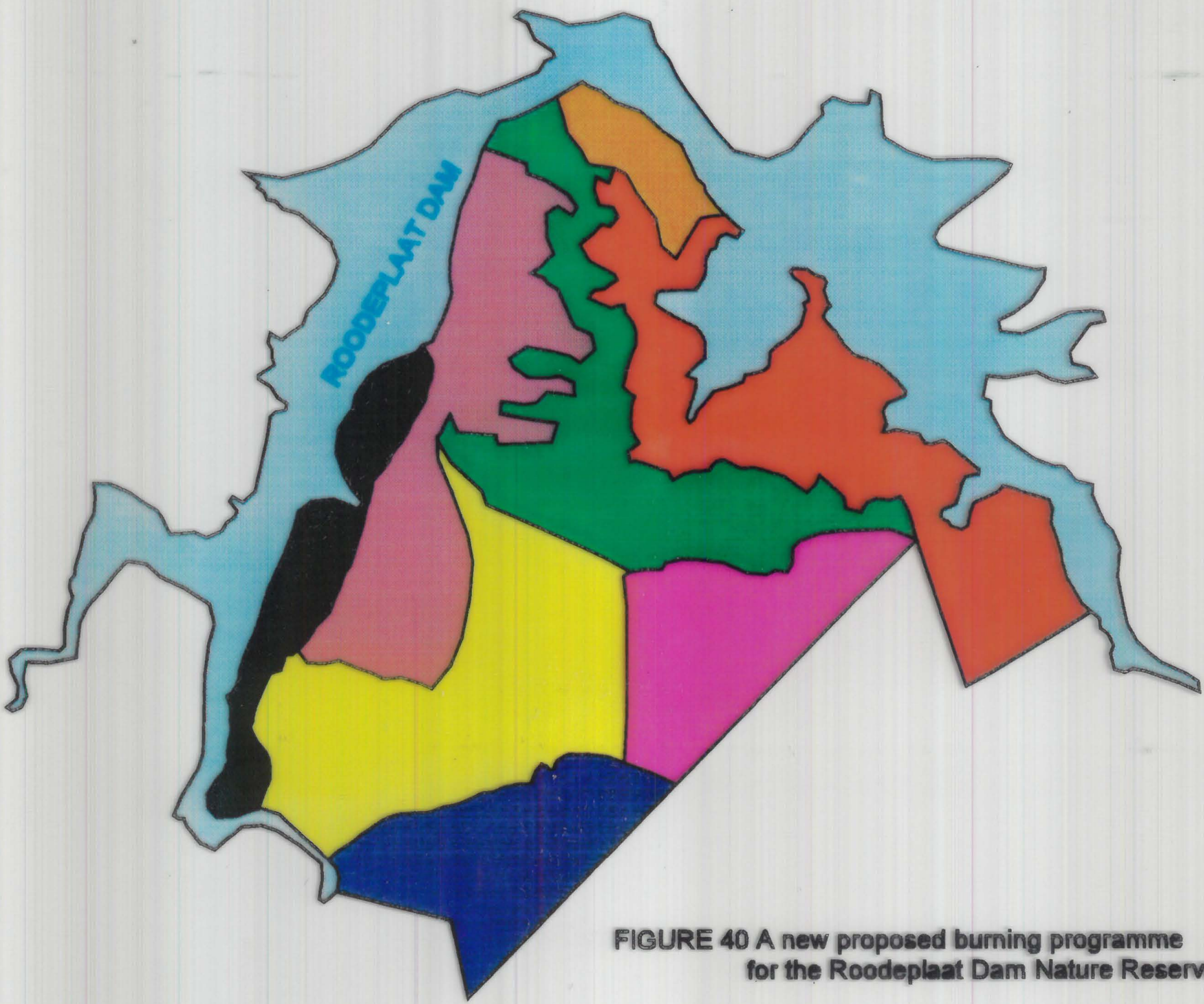
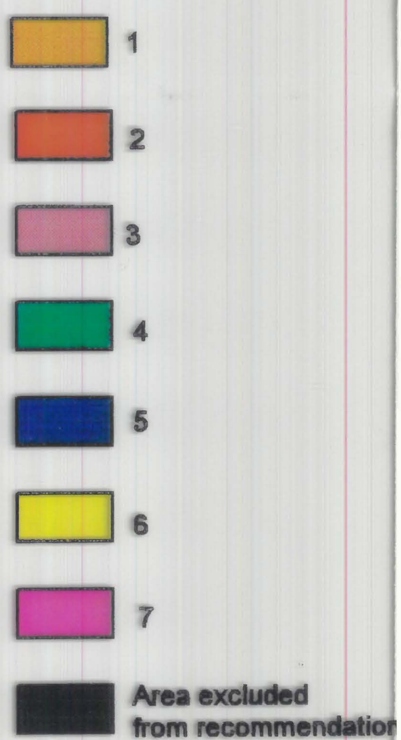
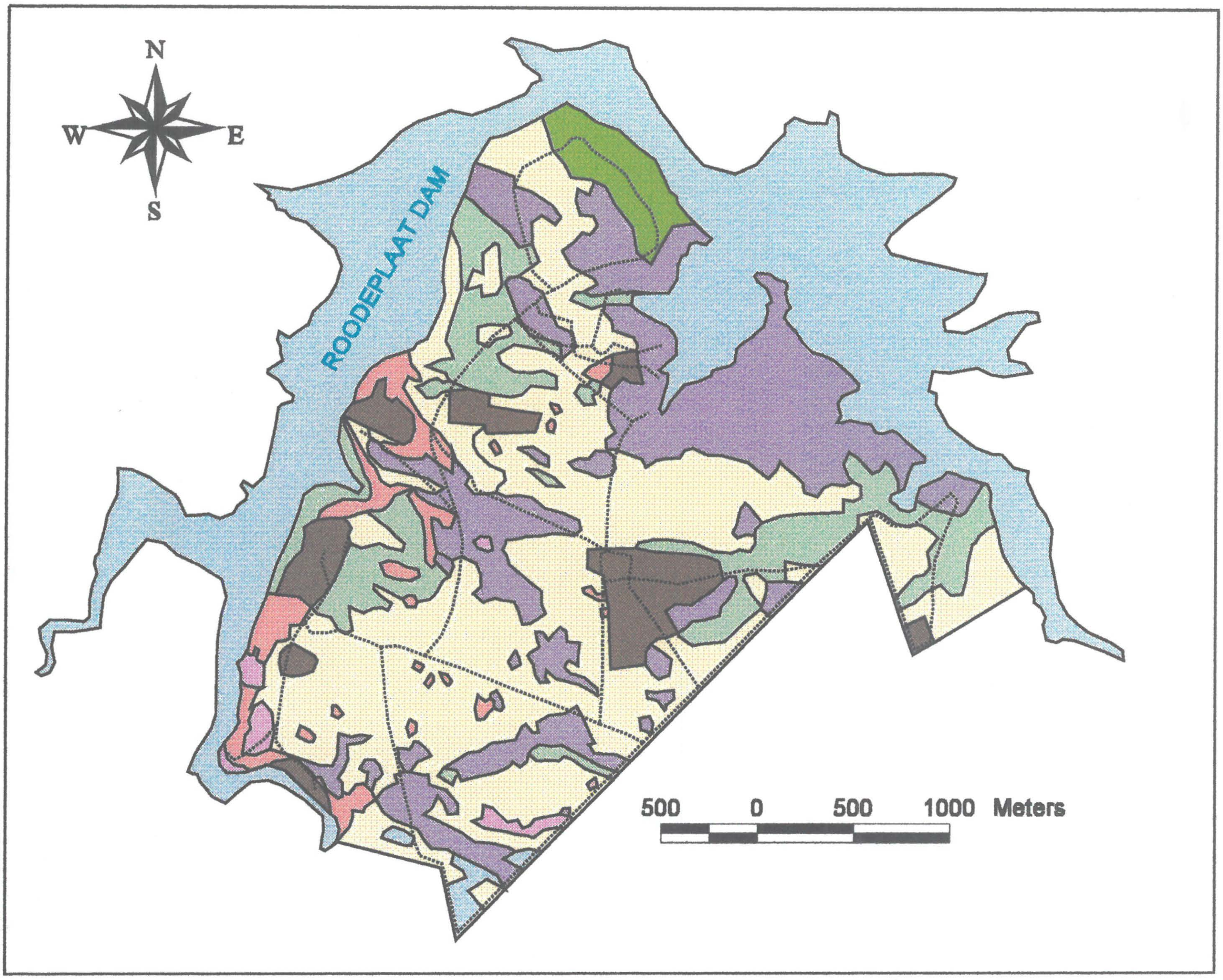


FIGURE 40 A new proposed burning programme for the Roodeplaat Dam Nature Reserve





Berchemia zeyheri thickets

Acacia karroo closed woodland

Acacia caffra-Setaria sphacelata closed woodland

Acacia caffra-Combretum apiculatum closed woodland

Acacia caffra-Faurea saligna open woodland

Burkea africana closed woodland

Setaria sphacelata-Polygala hottentotta grassland

Melinis repens-Cynodon dactylon old land grassland

Block 1 is the *Acacia caffra-Combretum apiculatum* closed woodland community which is accounted for as a separate burning block, regarding its species composition, morphology and aspect.

Block 2 is mostly *Acacia caffra-Setaria sphacelata* closed woodland also including the south-eastern corner of the reserve.

Block 3 is selected as a whole unit/block because it is difficult to separate the different range types which are very diverse and scattered. The youth camps also cover a large area, and is not considered for burning the way the rest of the reserved is burnt. A part of the *Acacia karroo* closed woodland and the old land grassland stretches over the road and should be included if block 3 is burnt.

Block 4 is mainly the grassland that is clearly separated from the woodland areas and must be burnt accordingly.

Block 5 includes the grassland and the *Acacia karroo* closed woodland and the border is along the drainage line to the main road.

Block 6 is mainly grassland stretching from the dam to the offices area in the old land grassland.

Block 7 is mainly the old land and *Acacia karroo* closed woodland and should be burnt as a unit.

The area from the Zeekoegat camp area, in the south-western corner, along the dam shore to the camping areas is *Berchemia zeyheri* thickets and it is recommended that this area not be burnt for the safety of the campsites and the unique and hygrophyllic character of the plant species.

This proposal can be considered for being ecologically more acceptable and for keeping the vegetation in mind, to enhance biodiversity and maintaining a variety of different habitat and feeding requirement for the animal species on the reserve.

However, if the old system is used, then the following burning block system is recommended until the year 2000.

1996 - Blocks C2, E1, E2 and F2
1997 - Blocks B2, D and F1
1998 - Blocks A and E2
1999 - Blocks B1, C1 and C2
2000 - Blocks B2, D and E1

It must be stressed that this recommendation is a guideline and that a burning programme in any situation, should not follow a rigid burning policy (e.g. once every four year irrespective of conditions). The decision for burn should be made opportunistically after assessing the objectives for burning, the availability of fuel immediately prior to the burn and fodder during the post-burn period, and the prevailing climatic conditions (particularly rainfall) (Hurt 1992).

CHAPTER 5

NUTRITIONAL MANAGEMENT

5.1 Introduction

During the season of active vegetation growth, large mammalian herbivores may be surrounded by an abundance of potential food in the form of plant foliage. However, during the dry or cold season when many plants become dormant, food availability decreases drastically in both quantity and quality. While protein concentrations in the leaves of woody plants tend to be somewhat higher than those in grass leaves, and less variable seasonally, the fibre content is more lignified and hence less digestable. Woody plant leaves also commonly contain high concentrations of secondary plant metabolites such as tannins which may restrict the nutritional availability of protein and interfere with fibre digestion (Owen-Smith & Cooper 1989).

Feeding behaviour is determined by factors such as availability, acceptability, digestibility and chemical composition of plants utilized. Chemical factors fall into three categories : (a) nutrients, including proteins and various mineral elements; (b) fibre, including cellulose, hemicelluloses and lignin, which influences physical toughness and digestibility and (c) plant secondary metabolites, which may function as toxins, or to reduce the digestive availability of nutrients (Cooper, Owen-Smith & Bryant 1988).

Energy is the most important measurement to indicate nutritive quality, but is the most difficult constituent in a ration to determine appropriately. This is mainly due to the fact that the rumen organisms change this energy that is captured in the plant material to substances that can be used to produce more organisms or may be utilised by the animal (Grant 1992).

Much of the gross energy available in the plant material is lost to the animal and when all the energy that is lost via these pathways is accounted for, the energy available for metabolism by the animal tissues is called metabolisable energy (Grant 1992).

The only accurate method to determine metabolisable energy is by utilising metabolic crates. This is however not practical for natural grazing and other methods have been investigated.

The aim of this part of the study, all of which is directly applicable to nutritional management on small reserves, is to determine seasonal changes in the chemical composition of the plant parts of the species preferred. From this information it could be estimated what are the seasonal changes in the nutritional intake of the animals relative to maintenance requirements. Tannin levels will also be related to browse availibility and browse capacity of the trees with regard to kudu and impala (the browsers presently found on the reserve).

5.2 Methods

Direct observations of food selection were done throughout the study period while collecting habitat preference data. A binocular was used to locate the exact position of the feeding herbivore. After the animals left the location, inspection was done at the feeding site and the following was recorded on a field form:
date, grid unit and time; species composition; subjective assessment of stalk/leaf ratio; plant parts eaten (Theron 1991).

The purpose of this feeding trial was to establish what food is utilized and when, how and where such foods were obtained. This information is useful for the management of particular game species. An understanding of the principles underlying seasonal changes in habitat use is of value to the successful management of wild ungulates in small reserves where inadequate diversity exists (Novellie, Fourie, Kok & Van der Westhuizen 1988).

Data was collected for kudu and Burchell's zebra. The reason for selecting these herbivores is, according to Van Hoven & Ebedes (1986), the kudu is an exclusive browser and the zebra is an exclusive grazer (impalas' numbers were too low to be included).

The time of collection of plant material for analysis were:

August - Winter, a critical time-dry season period
November - Spring/Summer-young leaf phase
April - Autumn-mature leaf phase

5.2.1 Crude protein and crude fibre

To determine the chemical composition of the most favoured plant species of the selected animals, samples were taken three times during the year to detect possible seasonal variation in feeding behaviour. The aim of determining chemical composition of the species, was to establish the nutritional value.

Crude protein and crude fibre of important food plants were determined in order to establish differences between species for preference.

Most of the nitrogen needed by animals are used for protein synthesis. The crude protein content is calculated from the nitrogen content of the food, determined by a modification of a technique originally devised by Kjeldahl over 100 years ago. In this method the food is digested with sulphuric acid, which converts to ammonia all nitrogen present except that in the form of nitrate and nitrite. This ammonia is liberated by adding sodium hydroxide to the digest, distilled off and collected in standard acid, the quantity being determined by titration or by automated colorimetric method. It is assumed that the nitrogen is derived from protein containing 16 percent nitrogen, and by multiplying the nitrogen figure by 6.25 (100/16), an approximate protein value is obtained. This is not true protein since the method determines nitrogen from sources other than protein, and the fraction is therefore designated crude protein (McDonald, Edwards & Greenhalgh 1988).

The fibre fraction of a food has the greatest influence on its digestibility, and both the amount and chemical composition of the fibre are important (McDonald *et al.* 1988). Although digestible cellulose make up 95% of the crude fibre fraction, crude fibre content still has a negative correlation with digestibility (Van der Merwe 1988). As a result of this fact, it is possible to derive digestibility from fibre content.

About 100 grams of plant material was collected, dried to a constant weight in a forcedraught oven at 70°C for 48 hours, determining moisture content and grounded through a 1 mm sieve. The chemical assay included crude protein (Kjeldahl nitrogen determination X 6.25) and crude fibre (Wijkström method) by standard AOAC (1984) procedures for animal feeds.

5.2.2 Tannin-related analysis (condensed tannins)

Plant parts of selected species for condensed tannin analysis was collected to make up a representative sample. Approximately ten grams of plant material was collected in a plastic bag and immediately placed in liquid nitrogen to fixate the tannins. The material was kept frozen until laboratory analysis. Condensed tannin was analysed by P. Awenand, Range and Forage Institute[3] using the acid butanol assay modified with polyvinylpyrrolidone (Watterson & Butler 1983) with quebracco as a standard.

5.2.3 Statistical analysis

Frequency histograms were drawn up for each period to establish differences in crude protein, crude fibre, moisture content and condensed tannins for different animals.

Line graphs demonstrate the change in crude protein, crude fibre, moisture and tannins for different periods in the year in order to determine trends.

5.3 Results and Discussion

The results of all analyses on the seasonally compounded samples are presented in Table 13.

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[3]Range and Forage Institute, Private Bag X05, Lynn East, Pretoria 0039

TABLE 13 Results from chemical analysis of preferred plant species on the Roodeplaat Dam Nature Reserve

Species	Abbre	% Moisture	% N	% CP	% CF	CT(% of dry matter)
WINTER						
Setaria sphacelata	SS	11.63	0.42	2.6	35.79	0
Themeda triandra	TT	12.5	0.4	2.5	34.95	0
Eragrostis chloromelas	EC	7.69	0.46	2.85	36.88	0
Cynodon dactylon	CD	14.29	0.54	3.36	32.19	0
AVERAGE		11.53	0.46	2.83	34.95	0.00
Acacia tortilis	AT	18.18	2.23	13.93	23.18	0.54
Rhus leptodictea	RL	30.43	1.16	7.21	13.22	0.203
Maytenus heterophylla	MH	48.21	1.22	7.62	15.92	0.475
Olea europaea	OE	29.73	1.41	8.81	16.92	0.135
Ziziphus mucronata	ZM	37.04	1.26	7.87	10.07	0.235
AVERAGE		32.72	1.46	9.09	15.86	0.32
SPRING/SUMMER - Young leaf phase						
Tristachya leucothrix	TL	74.77	1.15	7.19	36.64	0
Eragrostis chloromelas	EC	67.14	1.39	8.66	32.09	0
Setaria sphacelata	SS	74.12	1.36	8.49	32.98	0
Themeda triandra	TT	70.18	1.96	12.25	27.72	0
Panicum natalensis	PN	65.45	1.12	6.98	30.74	0
AVERAGE		70.33	1.40	8.71	32.03	0.00
Acacia caffra	AC	64.44	2.85	17.81	15.12	0.169
Acacia karroo	AK	63.08	1.81	11.28	13.12	2.23
Maytenus heterophylla	MH	68.25	1.73	10.76	18.01	0.272
Dombeya rotundifolia	DR	67.21	2.12	13.39	20.39	0.109
Rhus leptodictea	RL	69.32	2.25	14.04	11.68	0.226
Olea europaea	OE	56.67	1.68	10.53	15.72	0.122
Acacia tortilis	AT	52.73	2	12.5	21.96	0.702
Ziziphus mucronata	ZM	57.89	2.19	13.67	13.17	0.144
AVERAGE		62.45	2.08	13.00	16.15	0.50
SUMMER - Mature leaf phase						
Setaria sphacelata	SS	26.79	0.44	2.71	37.59	0
Tristachya leucothrix	TL	53.52	0.45	2.79	36.44	0
Melinis repens	MR	30.43	0.45	2.81	40.07	0
Themeda triandra	TT	34.04	0.43	2.66	33.58	0
Cynodon dactylon	CD	39.02	0.81	5.06	30.19	0
Eragrostis chloromelas	EC	29.63	0.77	4.81	35.64	0
AVERAGE		35.57	0.56	3.47	35.59	0.00
Acacia caffra	AC	46.00	1.75	10.94	23.75	0.92
Acacia karroo	AK	52.50	1.66	10.38	14.56	1.102
Acacia nilotica	AN	50.00	1.6	10	10.83	0.414
Acacia robusta	AR	51.52	1.3	8.13	24.53	0.581
Acacia tortilis	AT	62.86	2.07	12.93	21.78	0.79
Maytenus heterophylla	MH	58.62	1.16	7.25	16.35	0.963
Olea europaea	OE	45.65	1.33	8.34	17.91	0.095
Rhus leptodictea	RL	51.52	1.43	8.91	12.77	0.179
Grewia flawa	GF	39.13	1.83	11.47	22.8	0.144
Ziziphus mucronata	ZM	54.05	1.49	9.31	13.57	0.276
AVERAGE		51.18	1.56	9.77	17.89	0.55

5.3.1 Condensed Tannins

Tannin, a digestibility-reducing compound, forms complexes with protein by either phenolic hydroxyl bonding or covalent bonding. This inhibits the digestive action of fermentative enzymes (Owen-Smith 1982).

Kudu avoid dietary plants with a condensed tannin value higher than 5% of the leaf dry weight (Cooper & Owen-Smith 1985). They can taste this astringency in the mouth due to tannin precipitation with mucoprotein inside the mouth. In giraffe 83% of the diet in the Kruger National Park consisted of leaves with a condensed tannin content lower that 6% (Van Hoven 1991).

Browsers in free ranging areas can select for low tannin. However, kudu on ranches that have been fenced-in cannot always avoid plants with high tannin values. On the ranches where the average condensed tannin for the nine dietary plants tested was less than 5%, no mortalities occurred and these areas were mostly not fenced in and did not exceed a density of 4 kudu/100 ha. The highest mortality rate recorded was on a fenced ranch with 39% mortalities occurring with a density of 12 kudu/100 ha (Van Hoven 1991).

With the work of Furstenburg & Van Hoven (1994), they categorised the species preferred by giraffe in the Kruger National Park in three tannin content levels: (a) low tannin content, >0-4% of the dried leaf weight; (b) high tannin content, >4-15% and (c) extremely high tannin content, >15%.

The tannin content of the selected species did not significantly rise above 3% during the study period and only varied slightly within the seasons. Figure 41 shows a line graph displaying the differences in tannin content for the four species collected throughout the whole year. In general *Acacia tortilis* showed the highest value.

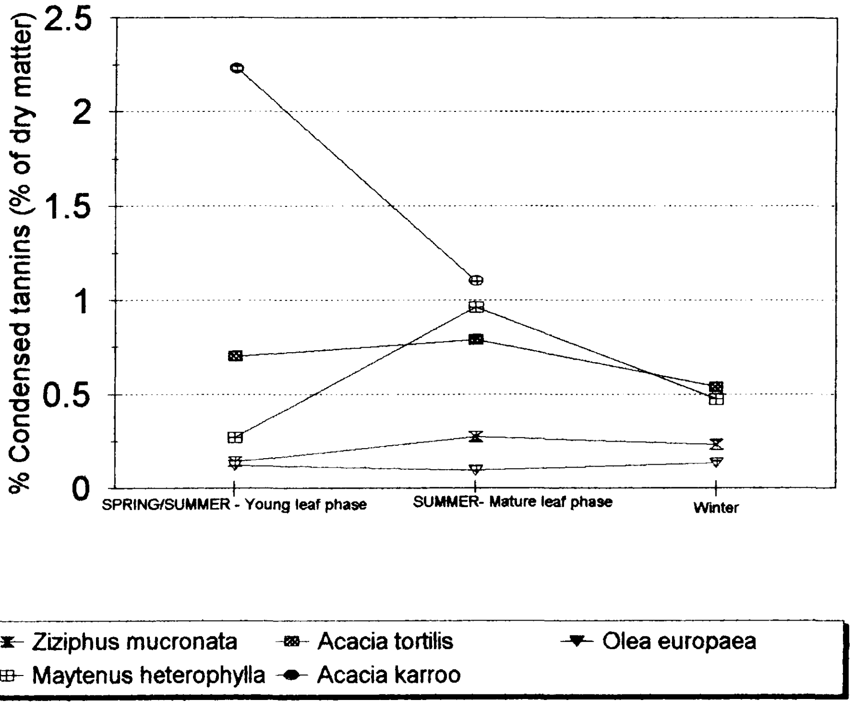

FIGURE 41 The difference in percentage condensed tannin content for four different species selected

Acacia karroo had the highest overall value for condensed tannins of 2.23% in the spring/summer period, and decreased to 1.10% in late summer.

The low overall tannin content can be explained by the relatively low stocking rate of browsers that does not influence the phenology of the tree species.

5.3.2 Crude protein & Crude fibre

Protein is probably the most common chemical component that limits animal performance. Protein requirements are determined by the species and class of animal and on the level of production. A minimum value of 5% CP in natural pastures is generally applied to ungulates on African veld. For levels below this, protein supplementation will usually be necessary. During the autumn and winter months the protein content of veld is virtually always inadequate and this makes protein supplementation essential during these periods (Tainton 1981).

Van Rooyen, Grunow & Theron (1989) states that the crude protein content of the leaves of trees and shrubs is higher than that of grasses, especially towards the end of the growing season. New growth has a crude protein content of 12-20%, while towards the end of the season it drops to 7-14%. Grasses have a crude protein content of 12-15% in the beginning of the growing season, and decline to 3-6% at the end of the growing season. The same trend of results was found at Roodeplaat Dam Nature Reserve.

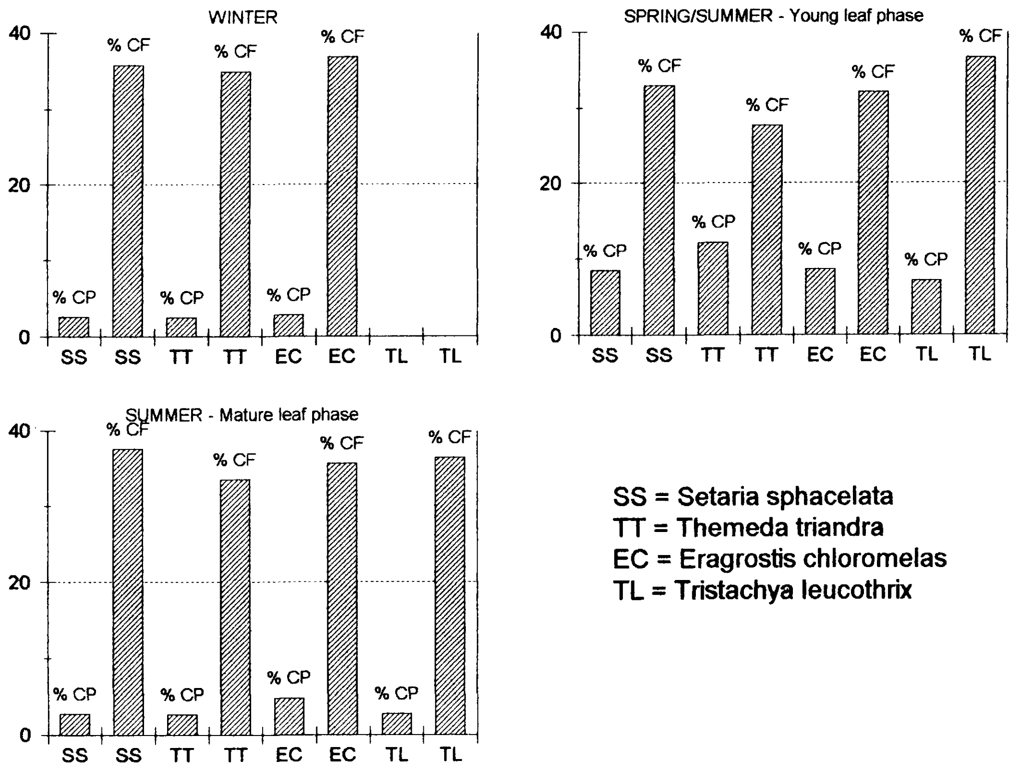

FIGURE 42 Percentage crude protein and crude fibre of species selected by zebra throughout the year

Figure 42 shows the crude protein and fibre percentages of species selected by zebra. Over the study period the zebra selected *Tristachya leucothrix* (64%), *Eragrostis chloromelas* (61%), *Setaria sphacelata* (51%), *Themeda triandra* (29%) and *Cynodon dactylon* (16%). The mean protein and fibre content of the grasses consumed by zebra for all three seasons were:

(i) Winter - 2.82% (CP), 34.95% (CF)
(ii) Spring/Summer - 8.71% (CP), 32.1% (CF)
(iii) Summer - 3.47% (CP), 35.6% (CF)

In winter the highest protein content was recorded in *Cynodon dactylon* (3.36%), in spring *Themeda triandra* (12.25) and summer *Cynodon dactylon* (5.06%). The fibre content in winter, was, as expected, much higher in *Eragrostis chloromelas* (36.88%), *Tristachya leucothrix* (36.64%) in spring and *Melinis repens* (40.07%) in summer.
The crude fibre content did not differ significantly throughout the year and did not rise to indigestible levels. Van der Merwe (1988) states that lucerne hay has a mean crude fibre content of 35.1%, while Boomker (1987) considered a medium fibre diet as approximately 18.7%. The results show that the fibre content throughout the year is normal within limits and that attention should be given to crude protein content.

The difference between crude protein and fibre content (Figure 43) was less conspicuous in the kudus' diet:

(i) winter - 7,8% (CP), 15.8% (CF)
(ii) spring - 12.9% (CP), 16.1% (CF)
(iii) summer - 9.8% (CP), 18% (CF)

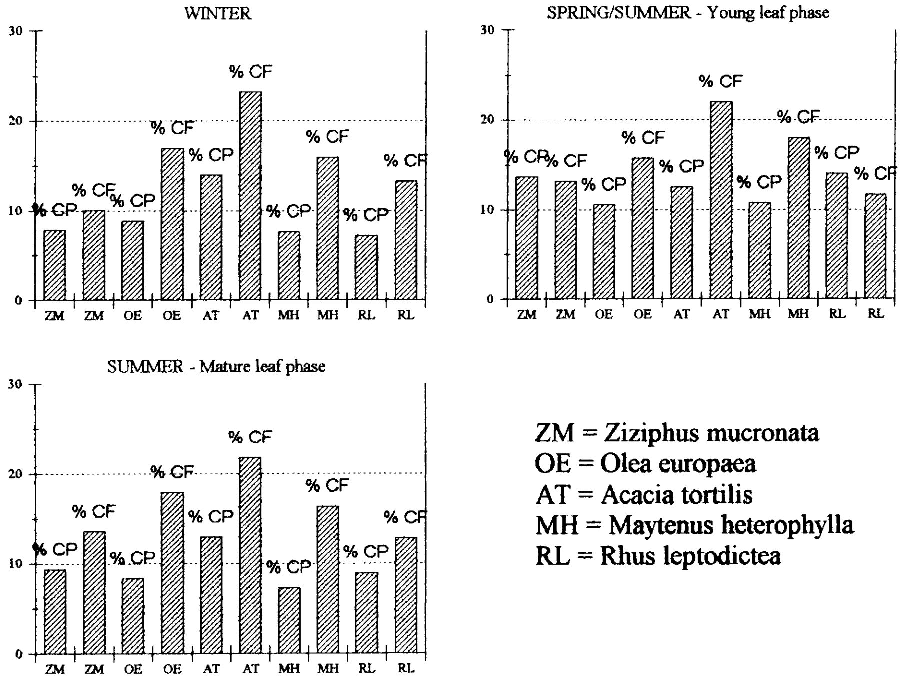

FIGURE 43 Percentage crude protein and crude fibre of woody plant species selected by kudu throughout the year

The *Acacia* species gave high crude protein values (mean = 10%) throughout the year, seeing that these species made up 95% of the kudus' diet preference. The main species selected by kudu other than *Acacia* species, were *Rhus leptodictya* (30%), *Olea europaea* (24%), *Maytenus heterophylla* (19%), *Grewia flava* (17%) and *Ziziphus mucronata* (13%) and this correspond with studies done elsewhere (Boomker & Van Hoven 1983, Cooper & Owen-Smith 1985, Du Plessis & Skinner 1987; Cooper, Owen-Smith & Bryant 1988).

Owen-Smith (1982) stated that grass leaves offer high crude protein levels, exceeding 15 to 20% of dry matter when young, declining rapidly in their protein content as growth occurs. Trees such as *Acacia* species, generally yield higher protein contents than other plant families, presumably as a result of nitrogen fixation by root nodule bacteria. According to Owen-Smith (1982) the crude protein content of tropical grasses commonly falls below 5%, which is regarded as the critical level necessary for maintenance of cattle during the dry season. The crude protein content of woody plant foliage remains considerably higher , generally above 10%, even during the dry season.

The grazers are usually able to satisfy their quantitative food requirements year-round, but are subjected to seasonal deficiencies in the nutritional quality of the available herbage. Browsers, in contrast, experience a much greater decrease in quantitative food abundance during the dry season, but less change in its quality (except possibly in terms of non-nutrient chemicals).

Knowledge of the nutritional value of the veld and the seasonal changes therein is extremely important to determine the grazing capacity of a specific area and therefore its suitability for game ranching (Van Rooyen *et al*. 1989).

In the study area, which is considered as sourveld (Tainton 1981), the most important grass species become unpalatable and lose their nutritional value at maturity. Translocation of mineral nutrients to the root system takes place towards the end of the growing season. Sourveld is therefore palatable and nutritious only during the growing season, that is in spring and summer, and it can support animals in a good reproductive condition between six and eight months per year. For at least three months nutritional deficiencies occur, e.g. phosphate and protein. It appears that game are less sensitive to phosphate deficiencies than livestock probably due to the fact that game species utilise "natural licks" better and are able to select plant material with a high nutritional value (Van Rooyen *et al.* 1989).

This drop in nutritional value causes a deterioration in the condition of the animal. Supplementary feeding is necessary for the main objective of supplementing the nutritional deficiencies in the natural veld. The animal will remain able to sustain its genetic potential by maintaining its ideal mass, condition and productivity (Groenewald & Heyns 1985). Another important objective of supplementary winter feeding is to stimulate appetite and to improve vegetation utilisation. Appetite-stimulating licks with a ureum or protein base are to be preferred above energy-rich feeds as supplements to natural grazing (Van Rooyen *et al.* 1989).

Pauw (1995b) states that there are commercial licks available (Lumol and Voermol energy blocks) or managers can mix their own licks at a lower cost as follows, keeping in mind that no provision is made for minerals as in the commercial blocks.

Suggested winter lick for game in sour veld:
Mix: 50% salt, 25% bone meal or dicalciumphosphate, 20% Calorie 3000 (molasses), 5% Urea. Licks must be placed early in winter to avoid the possibility that animals develop a lick or salt hunger driving them to overconsumption (Pauw 1995b). Ureum, however, can be harmful to animals, if overused (Van Rooyen *et al.* 1989). Therefore this type of lick must be protected from rain because if the ureum dissolves, the animals can get nitrate poisoning. Nitrate poisoning takes place when there is more nitrate in the diet that can be absorbed by the rumen microbes. Nitrate reacts with haemoglobin in the blood. As a result the haemoglobin is unable to convey oxygen and the animal suffocates (Van Hoven 1989). For this reason this lick is only placed out in winter and must be protected from getting wet.

Another recipe was used successfully on the Atherston Nature Reserve near Thabazimbi which includes the following:

2 bags of coarse salt (grade 1) mixed with 500 g of ground alum which has been boiled in 10 litres of water until dissolved. One bag of deloamed bonemeal and one bag of K-3000 molasses each are added and the mixture is placed in suitable containers (Van Rooyen *et al.* 1989).

From the results in Table 13 it can be seen that there is a protein deficiency in the dry months (mean crude protein content : 2.82% for grasses) on the reserve and therefore it may be necessary to consider supplementation for this nutrient deficiency by means of a lick in the dry season (winter months and early spring).

CHAPTER 6

MANAGEMENT GUIDELINES

Conservation management - the 'wise use' of wild animal populations- can and should, wherever it is possible, be applied to all those wild animal populations which can be assigned the status 'safe'. The term 'wise use' essentially means a controlled sustainable harvest of some description, such as a game culling programme which can produce meat, skins and other products, the capture of wild animals for live sales, and hunting on an organised basis. These are all activities referred to as consumptive uses of wildlife, as opposed to game viewing, tourism, photography, schools' environmental education courses, and the like, which are all non-consumptive uses (Thomson 1992).

The use of any wildlife resource, however, should normally only be implemented according to sound rationale: that is according to a management plan that is based upon the results of properly conducted ecological studies; and, in the case of state or corporate land, also according to approved methods and the dictates of official policy (Thomson 1992)

National Parks and reserves are important as instruments of conservation. In these areas alone the conservation of species supposedly takes precedence over all other uses of the land (Caughly & Sinclair 1994). Frankel & Soulé (1981) define the following: the purpose of a nature reserve is to hopefully maintain in perpetuity, a highly complex set of ecological, genetic, behavioural, evolutionary and physical processes for the compatible populations which participate in these processes. More plainly stated - The resource is wildness.

Management guidelines are therefore summarised under the following headings: veld management, wildlife management, tourist management and general management.

6.1 Range management

According to Bothma (1989) there are 2 basic kinds of wildlife management : active and passive management. Active management involves manipulation of game and their habitat. Passive management involves the prevention of any human influence. On the game reserve as a fenced-off, small area only active management is justifiable. Key aspects of the game and their habitat should therefore be monitored consistently so that trends will be noticed in time and management adjustments can be made accordingly.

Game ranch/reserve management demands a multifaceted approach and should be geared to reaching specific goals. The objectives should be clearly defined before any management planning or actual management can take place.

Adaptive management is suggested as the underlying philosophy for active management of a game reserve. Adaptive management, in contrast to a rigid management philosophy is flexible, can accommodate sudden environmental changes and sometimes even benefit from them.

The aim of adaptive management is rather to maintain biotic diversity and resilience in a system, than the creation of maximum stability. According to Walters & Hilborn (1978) passive adaptive management is the most ideal for systems with a high degree of natural variation such as in most ecosystems.

Adaptive management is a system of making management decisions by learning from past mistakes and successes. This is the ideal technique where a few facts are known and management cannot be delayed while research is being conducted (Stuart-Hill 1989).

A monitoring programme is geared as an early warning system to detect changes or trends as a result of management or natural events with the object of adapting management strategies where necessary. Ecological effects detection or ecological monitoring is the purposeful and repeated examination of the state or condition of specifically defined biotic groups in relation to external stress. Therefore monitoring is the frequent testing of the differences between baseline or initial surveys and follow-up studies.

The primary purpose is to monitor vegetation changes as reflected by:

- species composition
- species ratio/composition such as frequency, density and cover
- indicator species
- plant structure
- range condition
- rare and endangered species

Monitoring is a continuous process and should be done whenever management is applied, but any change as a result of natural changes, for example climate, should also be monitored. Many approaches are possible in ecological monitoring and in many cases ecological science cannot predict the long-term usefulness of the many possible approaches without more experience. Variety in approach and design is to be expected and encouraged. Wherever possible the endeavour in the future must however lie in standardizing with a specific goal as objective (Theron, Bredenkamp & Van Rooyen, unpubl.).

The following factors as minimum prerequisites should be monitored in terms of adaptive management:

- monitoring components of vegetation and veld condition
- monitoring animal components
- recording environmental conditions (rainfall)

The analysis of rainfall data (frequency and amount) at the end of the growing season (April/May), would give an indication of vegetational growth in the veld , as rainfall is positively correlated with primary production (Coe, Cumming & Phillipson 1976; Rutherford 1980; East 1984).

A system of rain-gauges can be introduced which must evenly cover the area, and must be easily accessible by road. Bothma (1986) suggested that on smaller game reserves, gauges should be erected every 4 km². On the Roodeplaat Dam Nature Reserve it is proposed putting up a total of two or three rain-gauges. One at the offices, one at the entrance gate and one on the koppie behind the offices in the *Setaria sphacelata-Polygala hottentotta* grassland.

The monitoring of vegetation composition in the growing season is of great importance and gives an indication of the reaction of the veld to factors such as rainfall, burning and grazer/browser impact. Monitoring of vegetation components should be done as a reference point in the future. In every range type two to three steppoint surveys would be adequate to determine veld condition, trends of veld condition and grazing capacity. Fixed plots have been constructed on the reserve (Figure 44).

The methods of monitoring veld condition are described in Chapter 4.1. A 200 point steppoint survey analysed by the Ecological Index Method (see Chapter 4.2.1, GRAZE), which is effective, fast and gives a lot of information, is recommended. The results of the programme gives a comparison of the veld condition between plant communities and good (average rainfall year) and bad rainfall years (approximately 20% lower rainfall than average).

The grazing capacity on the reserve is high and was calculated as 6.80 ha/LSU and is presently stocked at 52.47% of the maximum capacity of LSU calculated, which is 128. Recommendations were made to adapt numbers of animals and sex ratios at 60% and 100% of maximum capacity, respectively. If the aim of management for the reserve is conservation and game viewing, recommended stocking rate must preferably be more than 60% of maximum capacity..

Fire plays an important role on the reserve in removing moribund and unacceptable grass material from the previous season, stimulating new growth and making fire-breaks. A burning programme should be an important part of the management plan, and the burning programme is discussed in detail in Chapter 4.4.3.

Rainfall and stocking rate act synergistically as the most important determinants of veld composition score (Peel 1990). Rainfall cannot be manipulated and management should therefore aim at improving or at least maintaining the present range composition. It is therefore recommended that monitoring of the range, animal numbers (annually), rainfall (annually) and the woody-herbaceous relationship be undertaken.

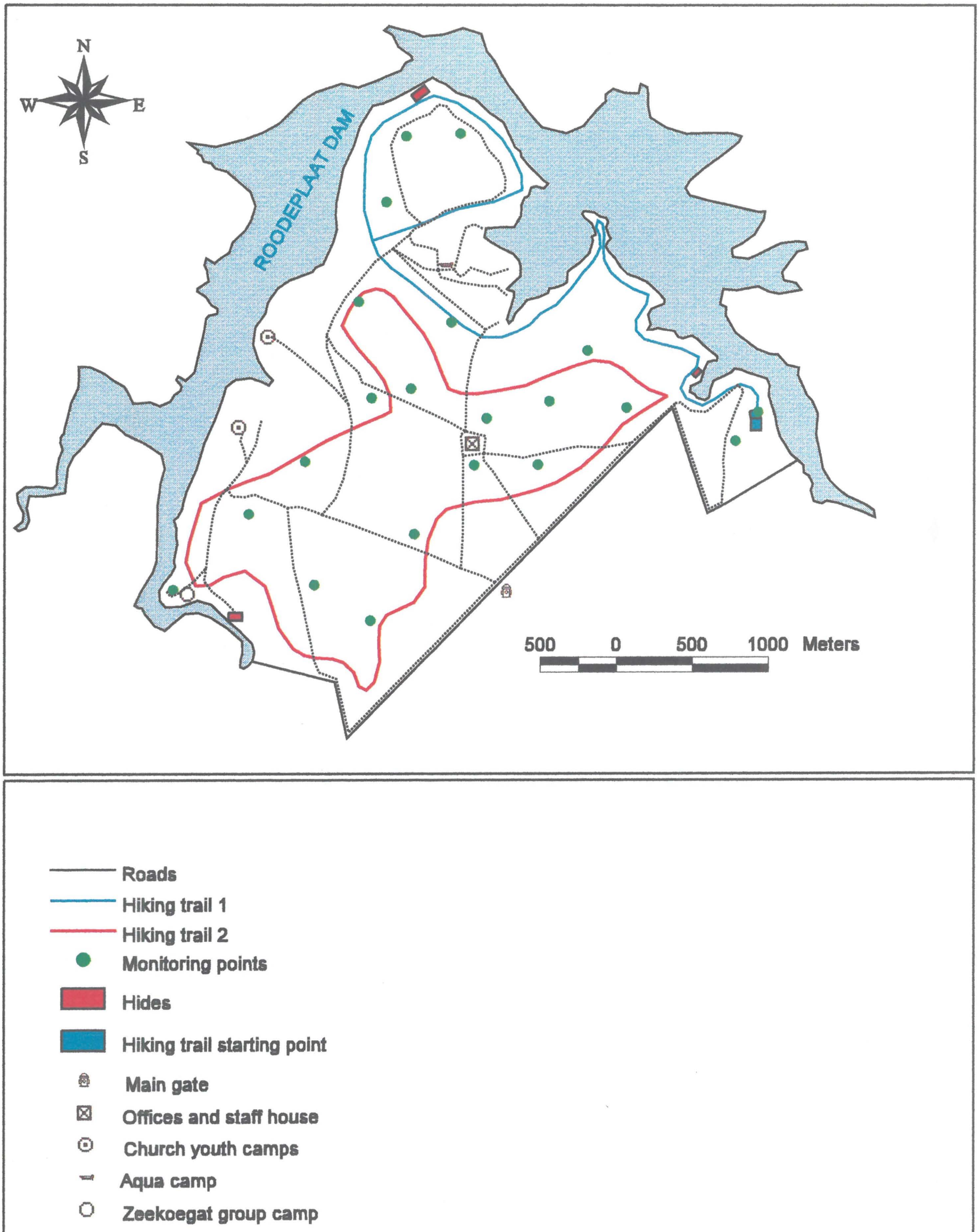

FIGURE 44 Monitoring points, proposed hiking trails and hides on the Roodeplaat Dam Nature Reserve

6.2 Wildlife Management

The study done on the habitat utilisation of ungulates, presents a wide basis for future management. The surveys done act as reference point and could with continued monitoring explain and predict changes in animal populations.

An increasing understanding of habitat requirements forms an integral part of any wildlife research or management activity. The aim of the study was to examine the habitat requirements of the six selected herbivores on the basis of plant community preference. The methods used to analyse the data gave the same results basically and confirm the findings of other researchers.

The population size of a species are determined by the capacity of the area to support individuals and enable reproduction. The Roodeplaat Dam Nature Reserve is currently stocked at 60.45% of maximum capacity of large stock units calculated. The recommended changes in sex ratio and numbers of animals are discussed.

Ecological groups of game should function as a unit for the management of species. Ecological groups according to Bothma & Van Rooyen (1989) and Skinner & Smithers (1990) are:

- selective grazers
- non-selective grazers
- mixed feeders
- browsers

Recommendations regarding the ratio of grazers to browsers to mixed feeders were considered.

The blue wildebeest and the red hartebeest are both closely associated with the Burchell's zebra and the *Setaria sphacelata-Polygala hottentotta* grassland and both select medium to short grass lengths. The blue wildebeest is also associated with burnt veld. An amount of blue wildebeest should be removed. The blue wildebeest is a concentrate grazer and would have a substantial impact on the range condition if its numbers are not controlled.

It was thought by management that the red hartebeest did not adapt well to the habitat, but red hartebeest prefer open grassy plains alternating with open forests where small patches of bush and forest trees offer shelter (Kok & Opperman 1985). There are however the wrong sex ratio to significantly show progeny. Currently they are present at a ratio of two males to one female. The minimum group size is eight. The recommended number and ratio may improve the increase over the next two years.

Bushbuck, ostrich and giraffe are recommended to be introduced on the reserve because they will be of tourist and financial benefit. They historically occurred in the area.

All the large herbivores on the reserve can adapt well because the vegetation covers all of their preferences. Open grassland, closed woodlands, riverine thickets and tall open woodlands are present in the study area and there are adequate water supply year round.

Wildlife management is impossible without information on game numbers when evaluating the stocking rate and animal performance (Peel 1990). A census should be taken once a year after capturing or hunting animals. The simplest way of monitoring numbers is to have a standardised veld form on which are indicated the animal species, date, time of day, sex ratio, herd size, aspects of behaviour and major rangetype. The ranger must complete the form while doing patrol.

On the Roodeplaat Dam Nature Reserve an aerial count is recommended. The major disadvantage of locating animals from the air is that when operating in moderately to densely wooded country, a high proportion of animals escape detection and that the purchase and running costs of an aircraft are often high.
However the advantages of operating from the air is that a given area of land can be covered in a shorter period of time and that the cost per unit area surveyed can be reasonable and often less expensive than ground methods using vehicles (Collinson 1985). A repeatable game count should be considered every year to obtain a reliable foundation for population management.

The seasonal distribution and numbers of game must be continually recorded. The age and sex ratios of the population must be monitored annually for the determination of trends. In the management of population numbers, it is important to know how a population functions and how its dynamics are applied on a game reserve. This knowledge is important if one considers how much suitable habitat is available, the condition of the habitat and how much money is available for the purchasing of the game (Bothma 1989). Distribution of animals show the total annual and seasonal distribution ranges and whether they are changing with time (Theron 1991).

A simple decision model has been drawn up by Pauw (1988) in terms of management of animal numbers (Figure 45). The model was based on eight possible combinations of tendencies in the three parameters, rainfall, veld condition and animal numbers.

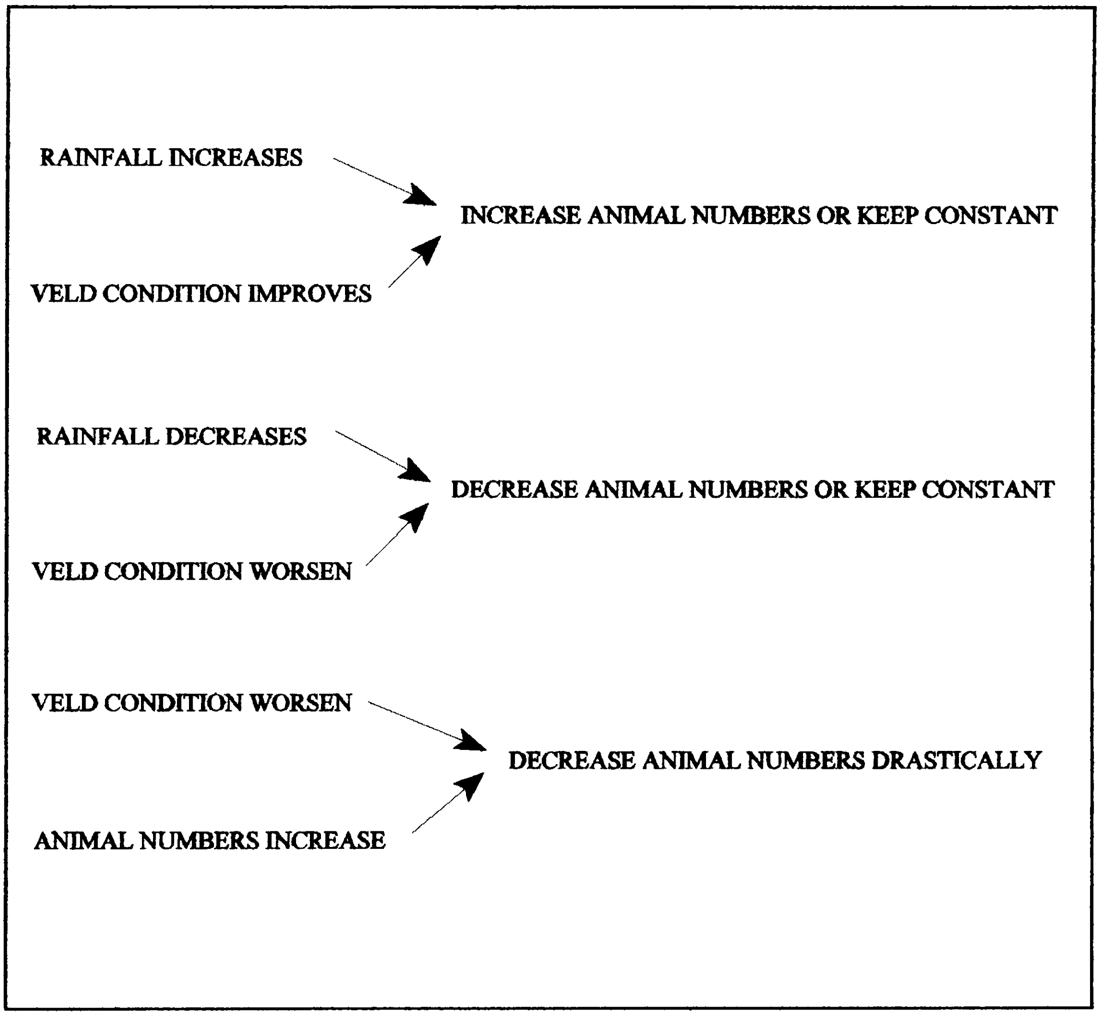

FIGURE 45 A simple model to decide on animal numbers and the management thereof on the Roodeplaat Dam Nature Reserve (Pauw 1988).

Single tendencies and combinations of tendencies observed, motivate the three management decisions in terms of animal numbers (Pauw 1988).

According to Pauw (1995a), the most important single management tool for the manager of the reserve who wants optimum production and a dense vigorous herbaceous cover, is control of the stocking rate. To control the stocking rate, one must first of all have reliable knowledge about the tendencies of game numbers on the reserve. Secondly, the effect of stocking rate to a healthy herbaceous composition must be known. Therefore herbaceous composition must also be measured. But conclusions about the effect of stocking rate on herbaceous cover are meaningless in the absence of knowledge of rainfall. Rainfall data must be gathered not only over time but also spatially over the extent of the reserve.

The combination of information on these three parameters allows for a decision on stocking rate to be taken at the end of the rainy season and before the onset of the dry season. How the information should be interpreted qualitatively is shown in Figure 45. The model is based on the objective of a healthy herbaceous composition, the role of rainfall as primary driving force and the modifying role of stocking rate.

Game farmers have come to realise that game cannot thrive on small enclosed units, without the supplementation of certain nutrients. It is common knowledge that most South African soils have a mineral deficiency. Phosphorus is the most common mineral known to be deficient. In the past, game was dispersed over a vast range of soil types, due to their annual movements, and could therefore compensate for a mineral shortage which would occur in one area, by getting it in another area. However, on the modern game ranch or reserve, these minerals need to be supplemented. The most common method used, is by placing mineral blocks at areas carefully chosen. During the winter months, protein shortages are of primary importance and together with mineral shortages, cause a drop in condition in game (Taylor 1994). These licks can serve as a form of rotational grazing by moving the licks around throughout the winter.

There are, however, some important points listed by Van Hoven (Unpubl) that must be remembered when placing out a lick:

- A lick has to be protected from rain, especially if it contains ureum
- A lick must not be placed at or near a watering place
- Licks must not be placed in over-utilised veld, it can lead to major degeneration of range condition
- Licks must be strategically placed over the reserve, so that game cannot concentrate in certain areas

A commercial lick can be used or the licks recommended as described in Chapter 5.3.

6.3 Tourist Management

6.3.1 Ecotourism and Environmental Education

Environmental education not only concerns nature conservation, but also the optimal development of the potential of individuals and society. The development of human resources is just as important to the environmental educator as is the conservation of nature's resources (Poalses 1994).

One of the keys to effective environmental management is knowledge (Van Wijk 1994). Most South Africans see the environment simply as something to be utilised for the sake of survival. The sustainable utilisation of the earth and its resources, and thus the survival of the human species, depend on this generation, who are uninformed about sound environmental practices (Poalses 1994).

In 1991 at the World Environment Day, the Deputy Minister of Education, Mr J.M. Ntsime, stated that it must surely be one of the most satisfying sights when one sees the young of our nation being appropriately educated by competent teachers. It is even more satisfying to see such young people being taught about ways of treating their environment responsibly, and in such a manner as to secure their future with sustainable development (Sehume 1992).

Sehume (1992) also states that the very principles of environmental education is aimed at influencing society to adopt those values and behaviours which minimise adverse effects upon our environment and encourage those values that increase the quality of life of all human beings. Environmental education highlights the relationship between mankind, his culture and his bio-physical surroundings and it is essential that we teach our children such positive values and behaviour.

Therefore, the attitude of the youth towards their environment and the role that environmental education can play in it, must receive urgent attention and the Roodeplaat Dam Nature Reserve is ideal for such projects. The need for projects involving children, learning about the environment on the reserve, its plant ecology, the dams ecology and animal ecology is large and it can benefit education and the reserves management equally. The education centre on the western shore of the dam can be utilised accordingly.

Ecotourism is not only a popular buzz-word, internationally it has become an issue of major interest among tourism marketers, planners, environmentalists and tourists. The Ecotourism Society defines ecotourism as " ...purposeful travel to natural areas, understanding the cultural and natural history of the environment and taking care not to alter the integrity of the ecosystem, while producing economic opportunities that make the conservation of natural resources beneficial to local people" (Van Niekerk 1995).

In South Africa the future comprehensive use of land will depend upon its productivity. Such productivity must be maintained and the role of natural areas in this regard must be accepted. This must include the right for natural areas to exist to the benefit of their biota and to the benefit of human beings through optimal sustained use. Future land use policies must also prevent human beings from plundering all natural areas without taking the ultimate consequences into consideration. A poor environment can only produce low quality of life at all levels (De Graaff 1971).

SATOUR lists the benefits of tourism (SATOUR fact sheet no. 6) as follows:

- creates jobs: every 30 new tourists create one direct and two indirect job opportunities;
- develops infrastructural services such as roads, water and electricity;
- generates investment;
- promotes mutual understanding and goodwill; and
- provides valuable funds for conservation and the balanced utilisation of resources.

To help ensure the future existence of the reserve as a regionally managed area, ecotourism on the Roodeplaat Dam Nature Reserve must focus on 2 major concepts:

- Implementing a sound management plan for the fauna and flora of this environment to ensure sustainability
- Promoting and enhancing the natural and cultural environments as a USF (unique selling feature).

This can be achieved by implementing and allowing recreational activities like walking/hiking trails, mountain bike riding, horseback riding and birding safari's to lookout points on the damshore.

Figure 44 shows a map suggesting routes for hiking and mountain bike riding on the reserve as well as proposed lookout points.

There are, however, existing facilities on the reserve namely three camps, Water Affairs' campsite, two staff houses and offices. Two camps are church youth camps, used by the Dutch Reformed and Reformed Church respectively. The Zeekoegat groupcamp is controlled by the Director of Nature Conservation and it offers conference facilities for Directors and personnel and also educational programme facilities. There is a social club area, Aqua club, used by personnel of Water Affairs, which was fenced off but the fence was taken down partially in 1994/1995. The western and northern side of the dam is public area, which includes the fishing, camping and motor boat launching area, indian and coloured recreational area and facilities for sailing and rowing (Figure 44).

6.3.2 Hiking

Hiking has become a very popular outdoor activity. In recent years we have seen the development of many trails and the trend is likely to continue. The planning of hiking trails is only one type of land use and for the sound placement thereof, within a sustainable resource base, requires careful planning (Hugo 1993). The basic principle underlying planning of hiking trails, is therefore the concept of "design with nature" which means that nature functions in the ideal way. Should one want to plan a trail sustainable over a long period of time, would have to be in harmony with nature. This includes the investigation of natural processes at work in the ecosystems through which the trail will run and the planning thereof according to these directives.

Guidelines for the planning of a walking/hiking trail on the reserve can be listed as follows: (Adapted from Stone 1993)

- Plan a trail which has minimal impact on the environment.
- As far as possible use "natural" pathways, with widening only where necessary. The trail must be compatible with the environment.
- Physical digging, pick work and cutting away unwanted vegetation constitutes a deliberate invasion of the environment and is a damaging activity. Extreme care must therefore be taken with this activity as you want to create a non-maintenance footpath, no watercourses which could lead to erosion, a footpath which appears natural in appearance and gradient, and which causes the least visual and environmental damage.
- The route markers must be clear, easily visible and consistent.
- Specialist groups must be consulted to expand the ideas and add value to the trail, i.e. bird, tree and animal specialists.
- An informative new brochure must be planned.
- Different vegetation types on the route must be indicated by means of maps placed on suitable structures.

As there are no dangerous animals on the reserve, it is an ideal area with a fairly good road system and routes, which makes mountain biking a fair consideration. Mountain biking and horse trails can therefore be considered to create additional revenue but will require adequate planning before the implementation thereof.

More than half of the study area is bordered by the dam creating an ideal habitat for waterfowl and land breeding birds. With this added bonus a bird lookout point can be constructed (Figure 44). This area is the most secluded spot on the reserve where boats will not be likely to disturb bird watchers. Motorised boats are not allowed at inlets to the dam and near the groupcamp in the southern part of the dam. Figure 46 gives an example of a "dock" that can be constructed as a hiker or birdwatching lookout point, seeing that the level of the dam does not drop and rise extensively.

If such adjustments towards tourism are going to take place, very strict gate control has to be implemented. The advantages obtained from such investments will always be more than the disadvantages as long as the management thereof is correctly planned and executed.

FIGURE 46 An example of a 'dock' constructed near a bird hide or as a bird watching lookout (Taken from Texas Parks and Wildlife, April 1994).

6.4 General Management

6.4.1 Roads and fencing

The roads on the Roodeplaat Dam Nature Reserve are currently being used by tourists, management and for fire breaks. The necessity of a road network in nature reserves for the purpose of developing tourism, or for controlling the detrimental effect of fires, is universally accepted (Pienaar 1968). The mere presence of a road may have a significant influence on the adjoining vegetation in view of its ability to curb accidental fires. Heavy tourist traffic along roads is a definite limiting factor to the movement and daily routine of timid species as well as breeding herds of other species (Pienaar 1968).

Bothma (1989) states that roads disturb the natural environment and should be placed discretely, taking the object of the road into consideration. There are two kinds of roads on the reserve, tourist roads and fire-breaks. The ideal tourist road should follow a contour or vegetation boundary, go through as many range types as possible and it should traverse the more open areas of the ranch for game viewing. Fire breaks should be at least 8 m wide to prevent fires from crossing them (Bothma 1989).

The tourist roads on the reserve are not necessarily for game viewing, but are primarily used to get to the different camps. They are also built in a straight line and this has the result of people tending to speed, creating a danger to animals. Speedbumps from the gate in the main road can therefore be suggested to limit excessive speeding.

Approximately half of the study area is fenced with a standard game fence and the rest is bordered by the dam. The problem with the existing fence is that animals move freely through it, such as warthog and jackal, giving free access to domesticated dogs. Bothma (1989) suggests a wire mesh fence (diamond, pig-, or jackal proof mesh), attached to the bottom half of the fence. Such a wire mesh can prevent certain predators or feral dogs from entering. It is also necessary to patrol fences on a regular basis to combat any poaching, to ensure that no game, dogs or predators have moved in or out of the reserve, and to repair breaks in the fence as soon as possible.

6.4.2 Problem areas

As a result of all the visitors, especially over weekends, there is a lot of litter (plastic bags, bottles, paper, tins etc.) that is dumped along the roads. This is not aesthetically acceptable and also is dangerous to the wildlife. Groups of campers can be used to clean up the reserve as a nature project which will benefit them as well as the reserves' wildlife.

The fence around the Aqua camp of the Department of Water Affairs has been taken down partially, and the rest of the poles remaining pose a danger to the wildlife and should be removed. There are also remains of a dump along the road with broken glass and litter lying around which should be removed.

6.4.3 Alien vegetation

Alien species do occur on the reserve and the current policy is to eradicate the plants when they get out of hand. Mechanical and chemical methods are used to control the invader plants.

Table 14 shows the main species present on the reserve and the current and recommended (Bromilow 1995) method to control the invader plant.

There are water weeds present in the dam and no method of control (chemical or mechanical) are implemented at this stage. If the weeds pose a definite threat to the ecology and health of the dam fauna and flora, then action will be taken to eradicate it. The weeds present are *Azolla filiculoides* (water fern), *Myriophyllum aquaticum* (parrot's feather) and *Lemna gibba* (duckweed).

TABLE 14 The present and recommended methods to control invader plants on the Roodeplaat Dam Nature Reserve

Invader species	Current control method	Recommended control method
Sesbania punicea (Red sesbania)	Mechanical: cut out, fell	Soil, foliar or cut-stump herbicides
Pinus pinaster (Cluster pine)	Mechanical: fell	Large plants: ring-bark/fell/soil acting herbicide Seedlings: uprooted/treated with herbicide
Lantana camara (Common lantana)	Mechanical: cut out	Chop dense bushes-paint stumps with herbicide
Opuntia ficus-indica (Prickly pear)	Chemical: MSMA (glyphosate)	Biological: cactoblastis/cochineal Chemical: MSMA
Opuntia imbricata (Imbricate prickly pear)	Chemical: MSMA	Chemical and biological control
Cereus peruvianus (Queen of the night)	Chemical: MSMA	Chemical: MSMA

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THE ECOLOGY AND MANAGEMENT OF WILDLIFE ON THE ROODEPLAAT DAM NATURE RESERVE

by

RENÉE VERMAAK

Supervisor: Prof. Dr. W. van Hoven
Centre for Wildlife Management
University of Pretoria
Pretoria, 0002

Co-supervisor: Prof. Dr. N. Van Rooyen
Department of Botany
University of Pretoria
Pretoria, 0002

MAGISTER SCIENTIAE (WILDLIFE MANAGEMENT)

SUMMARY

The ecology of the Roodeplaat Dam Nature Reserve was studied with the aim of compiling a feasible wildlife management plan or by improving the existing one.

Habitat preferences of large herbivores were investigated to determine habitat use and its reaction to seasonal changes. Three different methods of statistical analysis were applied to the data and all three support the general tendencies. The range condition was determined and four different methods of data analysis were compared to determine which one would be most suitable for the reserve. The GRAZE-method is recommended. A quantified description of the woody plant community (browse capacity) was determined using the BECVOL method.

The pasture yield of the plant communities was determined using the disc-pasture meter. A burning programme implementing the existing burning block system is proposed. Nutritional composition (crude protein, crude fibre and condensed tannin) of preferred plant species of zebra and kudu was evaluated to detect seasonal variation in food preference.

The condition of the veld over the whole reserve is good and the carrying capacity was determined as 6.80 ha/LSU, the grass cover is high and it is at present stocked at 60.48% of the maximum capacity of LSU. The aim should therefore be to maximise range condition by applying adjustments to animal numbers and ratios, as well as fire management. The management decision for a burning programme rests upon quantitative data as measured by plant surveys and the dry phytomass (kg/ha) and range condition, as well as an important subjective judgement. An overall protein deficiency was found in the dry months and it will be necessary to supplement it by means of licks placed at carefully chosen sites.

Ecological education and ecotourism possibilities were investigated with the object of obtaining sustainable use of this natural resource. Tourism is a very important part of income and there are great possibilities on the reserve for developing walking trails, bird hides and camping opportunities. Although it does not strictly adhere to ecological management principles, tourism can sustain management in terms of financial support and utilisation of the reserves resources. The smaller the area, the more intensively it has to be managed and more certainty prevails about the type of management that has to be practised. Guidelines and recommendations are provided for future purchasing and sales of game, monitoring of range condition and game populations, and general management of the reserve.

DIE EKOLOGIE EN BESTUUR VAN DIE ROODEPLAATDAM NATUURRESERVAAT

deur

RENÉE VERMAAK

Studieleier: Prof. Dr. W van Hoven
Sentrum vir Natuurlewebestuur
Universiteit van Pretoria
Pretoria, 0002

Mede-studieleier: Prof. Dr. N van Rooyen
Departement Plantkunde
Universiteit van Pretoria
Pretoria, 0002

MAGISTER SCIENTIAE (NATUURLEWEBESTUUR)

OPSOMMING

Die ekologie van die Roodeplaat Dam Natuurreservaat is bestudeer om 'n toepaslike bestuurspogram op te stel (òf ter verbetering van die bestaande program).

Die habitatvoorkeure van die groter herbivore is ondersoek om habitatgebruik en die reaksie op seisoenale veranderinge vas te stel. Drie verskillende metodes van statistiese ontleding is op die

data getoets en al drie gee dieselfde tendense. Die veldtoestand is bepaal en vier verskillende metodes van ontleding is daarop toegepas om vas te stel watter metode die beste op die reservaat toegepas kan word. Die GRAZE metode word voorgestel. 'n Gekwantifiseerde beskrywing van die blaarvreetkapasiteit is bepaal met behulp van die BECVOL metode.

Die brandbare grasproduksie (fitomassa) is bepaal om 'n brandprogram op te stel. 'n Nuwe ekologies aanvaarbare program is voorgestel. Die voedingswaarde (ru-proteïen, ruvesel en gekondenseerde tanniene) van voorkeurplantspesies van sebra en koedoe is evalueer om seisoenale variasie in voedingsvoorkeur te bepaal.

Die toestand van die veld is redelik goed oor die hele reservaat en die drakrag is vasgestel as 6.80 hektaar/grootvee-eenheid, grasbedekking is hoog en tans is die reservaat op 60.48% van die maksimum kapasiteit van grootvee-eenhede (128). Die doel is dus om te mik na maksimum veldtoestand deur dieregetalle en verhoudings aan te pas, asook deur brandbestuur. Die bestuur van brand berus op kwantitatiewe data-insameling (plantopnames), veld toestand en fitomassa (kg/ha) bepaling en 'n subjektiewe oordeel. Daar is 'n proteïentekort oor die hele reservaat in die droë maande en dit sal noodsaaklik wees om byvoeding te oorweeg met die uitplaas van lekke op geselekteerde plekke op die reservaat.

Moontlike ekologiese opvoeding en ekotoerisme is ondersoek om die reservaat as natuurlike hulpbron te bewaar. Toerisme is 'n belangrike deel van die jaarlikse inkomste en daar is groot moontlike om dit te bevorder op die reservaat soos byvoorbeeld staproetes, bergfietsroetes, uitkykpunte en kampering.

Hoe kleiner die area, hoe meer intensief moet dit bestuur word en hoe belangriker raak spesifieke bestuursbesluite. Riglyne en voorstelle word gemaak vir algemene bestuur, aankoop van wild, monitering van die veld en dierepopulasie en toerisme op die reservaat.

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APPENDIX A

GRAZING CAPACITY		UNIT	1	
SIZE (ha)			383	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	0	0	
	- SHRUB	0	0	
		1.0	1.0	
DECREASERS	:	28	28	
INCREASERS 1	:	32	32	
INCREASERS 2a + 2b	:	24	24	
INCREASERS 2c	:	16	16	
TOTAL		100	100	
ECOLOGICAL INDEX		616	616	
% GRASS COVER		65	52	
AVE. RAINFALL(mm/yr)		633	506	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		4.5	6.4 ha/LSU	
DANCKWERTS		3.533033	4.928412 ha/LSU	
GRAZING CAP. (GAME)		8.0	11.4 ha/LSU	

GRAZING CAPACITY		UNIT	2	
SIZE (ha)			8	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	40	40	
	- SHRUB	0.4	0.4	
		0.7	0.7	
DECREASERS	:	22	22	
INCREASERS 1	:	27	27	
INCREASERS 2a + 2b	:	23	23	
INCREASERS 2c	:	28	28	
TOTAL		100	100	
ECOLOGICAL INDEX		529	529	
% GRASS COVER		60	48	
AVE. RAINFALL(mm/yr)		633	506.4	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		3.9	5.7 ha/LSU	
DANCKWERTS		3.877473	5.625496 ha/LSU	
GRAZING CAP. (GAME)		5.5	8.1 ha/LSU	

GRAZING CAPACITY		UNIT	3	
SIZE (ha)			117	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	55	55	
	- SHRUB	5	5	
		0.6	0.6	
DECREASERS	:	27	27	
INCREASERS 1	:	1	1	
INCREASERS 2a + 2b	:	44	44	
INCREASERS 2c	:	28	28	
TOTAL		100	100	
ECOLOGICAL INDEX		481	481	
% GRASS COVER		75	60	
AVE. RAINFALL(mm/yr)		633	506	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		4.2	6.2 ha/LSU	
DANCKWERTS		4.097892	6.101650 ha/LSU	
GRAZING CAP. (GAME)		5.5	8.2 ha/LSU	

GRAZING CAPACITY		UNIT	4	
SIZE (ha)			234	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	25	25	
	- SHRUB	5	5	
		0.8	0.8	
DECREASERS	:	26	26	
INCREASERS 1	:	6	6	
INCREASERS 2a + 2b	:	34	34	
INCREASERS 2c	:	34	34	
TOTAL		100	100	
ECOLOGICAL INDEX		472	472	
% GRASS COVER		55	44	
AVE. RAINFALL(mm/yr)		633	506	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		4.1	6.3 ha/LSU	
DANCKWERTS		4.142041	6.200047 ha/LSU	
GRAZING CAP. (GAME)		6.3	9.5 ha/LSU	

GRAZING CAPACITY		UNIT	5	
SIZE (ha)			26	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	30	30	
	- SHRUB	10	10	
		----------------	--------------	
		0.8	0.8	
DECREASERS	:	11	11	
INCREASERS 1	:	3	3	
INCREASERS 2a + 2b	:	42	42	
INCREASERS 2c	:	44	44	
		-----------------	-----------------	
TOTAL		100	100	
ECOLOGICAL INDEX		343	343	
% GRASS COVER		70	56	
AVE. RAINFALL(mm/yr)		633	506	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		4.5	7.3 ha/LSU	
DANCKWERTS		4.898457	8.063989 ha/LSU	
GRAZING CAP. (GAME)		6.6	10.7 ha/LSU	

GRAZING CAPACITY		UNIT	6	
SIZE (ha)			10	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	30	30	
	- SHRUB	5	5	
		----------------	--------------	
		0.8	0.8	
DECREASERS	:	32	32	
INCREASERS 1	:	15	15	
INCREASERS 2a + 2b	:	28	28	
INCREASERS 2c	:	25	25	
		-----------------	-----------------	
TOTAL		100	100	
ECOLOGICAL INDEX		562	562	
% GRASS COVER		60	48	
AVE. RAINFALL(mm/yr)		633	506	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		3.7	5.4 ha/LSU	
DANCKWERTS		3.739200	5.339054 ha/LSU	
GRAZING CAP. (GAME)		5.5	8.0 ha/LSU	

GRAZING CAPACITY		UNIT	7	
SIZE (ha)			55	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	15	15	
	- SHRUB	2	2	
		----------------	----------------	
		0.9	0.9	
DECREASERS	:	14	14	
INCREASERS 1	:	33	33	
INCREASERS 2a + 2b	:	16	16	
INCREASERS 2c	:	37	37	
		----------------	----------------	
TOTAL		100	100	
ECOLOGICAL INDEX		472	472	
% GRASS COVER		70	56	
AVE. RAINFALL(mm/yr)		633	506	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		4.1	6.2 ha/LSU	
DANCKWERTS		4.142041	6.200047 ha/LSU	
GRAZING CAP. (GAME)		6.6	10.0 ha/LSU	

GRAZING CAPACITY		UNIT	8	
SIZE (ha)			37	
		GOOD YEAR	BAD YEAR	
% BUSH	- TREE	80	80	
	- SHRUB	40	40	
		----------------	----------------	
		0.3	0.3	
DECREASERS	:	58	58	
INCREASERS 1	:	0	0	
INCREASERS 2a + 2b	:	35	35	
INCREASERS 2c	:	7	7	
		----------------	----------------	
TOTAL		100	100	
ECOLOGICAL INDEX		727	727	
% GRASS COVER		50	40	
AVE. RAINFALL(mm/yr)		633	506	
ACCESSIBILITY(.9/1)		1	1	hill=0.9,plain=1
FIRE FACTOR (.8/1)		0.8	0.8	never=1,freq=0.8
GRAZING CAP(cattle).		4.8	6.7 ha/LSU	
DANCKWERTS		3.173375	4.255607 ha/LSU	
GRAZING CAP. (GAME)		6.0	8.4 ha/LSU	