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Evaluating ecological monitoring systems on Mabula Game Reserve, Limpopo, South Africa.

by

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Submitted in partial fulfilment of the requirements for the degree

MAGISTER SCIENTIAE (WILDLIFE MANAGEMENT)

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Department of Animal and Wildlife Sciences

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Supervisor: Prof. M.W. van Rooyen

Co-supervisor: Prof. J du P Bothma

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ABSTRACT

Evaluating ecological monitoring systems on Mabula Game Reserve, Limpopo, South Africa

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Ecological monitoring is an integral part of the ecological active adaptive management of wildlife reserves. The present study was conducted as an initial trial of a holistic ecological monitoring programme for Mabula Game Reserve using three existing survey methods. The information gained after each monitoring period and relevant management decisions are:

- Large herbivore monitoring: This monitoring system gave specific information on which vegetation community each of the types of large herbivores are utilising and selecting. This information was used in conjunction with the two vegetation monitoring systems and the wildlife count data to determine the stocking rate for each large herbivores on the reserve. If required, the populations can be increase or decreased, which was found to be necessary for browsers on Mabula Game Reserve.

- Herbaceous monitoring: This monitoring system provides information on the economic and ecological grazing capacity of the individual vegetation communities in terms of Grazing Units. The herbivore monitoring provides an estimation of the actual Grazing Units occurring in a vegetation community. The total stocking rate should be less than the economic grazing capacity (70% of the ecological grazing capacity).

- Woody monitoring: This monitoring system provides information on the economic and ecological browsing capacity of the individual vegetation communities in terms of Browser Units. The herbivore monitoring provides an estimation of the stocking rate of browsers occurring in a vegetation community, which should be less than the economic grazing capacity (70% of the ecological grazing capacity).

The combination of all the results from the three survey methods provided information on the stocking rates for the different types of herbivores, which will ensure optimal wildlife production without diminishing the condition of the vegetation on the reserve. Long-term monitoring will enable the establishment of a large database which can be used to assess the ecological dynamics of the components covered in the holistic monitoring system over time. Changes in habitat selection of the large herbivore can be observed and patterns can be determined in relation to environmental variables such as rainfall. The long-term monitoring of the vegetations layers will provide information on changes in the plant species composition and the structure of the vegetation communities. This information can then be compared to the habitat selection of the large herbivore species and other environmental influence to gain information to help in the determining the cause of any observed changes.

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Chapter 1

INTRODUCTION

Traditionally wildlife areas were managed by using practical knowledge gained by game rangers and park wardens through years of observation and experience. They turned the practice of wildlife management into an art form, but with no scientific basis (Walker 1998). The management of wildlife areas has progressed towards the integration of scientific research and management practices. Research ecologists have become involved in designing experiments, which mutually benefit scientists and managers (Walters & Holling 1990). According to Walker (1998), a simple formula for wildlife management is to try different things, monitor the outcomes, adjust the management actions and then repeat the process. The monitoring of the outcomes is an important step in the process and essential for an active adaptive management approach.

According to Bosch *et al.* (1996) monitoring can be defined as the periodic re-measurement of appropriate parameters to determine the effects of particular management strategies or policies, and the response of systems to change in the wider environment. The results of these assessments can be quantified in the form of data and information. Ecological monitoring is an important aspect of active adaptive management strategies for conservation areas and wildlife reserves. It is now recognised that good management goes beyond implementation and that effective management is integrally linked to well-designed monitoring of evaluation systems (Stem *et al.* 2005). Monitoring enables managers to periodically assess the state of the system so as to help in decision making at that point in the management process. Monitoring also allows managers to develop knowledge over time, which helps to predict how the system will respond to various possible management alternatives (Pollock *et al.* 2002). Despite the importance of ecological monitoring, few guidelines exist for designing monitoring programmes (Kremen *et al.* 1998).

In scientific practice, monitoring methods are precise and easily measured in an objective and repeatable manner. However, conventional scientific research and monitoring can be expensive, often requiring specialised skills or technology (Moller *et*

al. 2004). For the current study to develop an ecological monitoring programme for the Mabula Game Reserve the monitoring methods had to be scientifically valid, easily implemented and inexpensive to conduct. The measuring techniques were conducted by the reserve staff, who generally come from a lower level of education as they seldom have an education above a high school level. Therefore, the measuring techniques had to be simplistic, but still provide valid scientific data for analysis. Once the data are collected reliably the analysis can be conducted by academic institutes or by trained managers. The monitoring methods also had to be inexpensive regarding equipment and the duration of the monitoring surveys, as many wildlife reserves have small budgets for management purposes.

Mabula Game Reserve was established on old cattle ranches, which had degraded the veld through poor agricultural practices. As tourism-based wildlife reserves tend to overstock wildlife, it is essential that monitoring of the veld and the wildlife is conducted. Also, wildlife have been introduced which did not originally occur in this area and therefore monitoring will provide valuable information on these introduced animals with regard to their adaptation to and effect on the altered environment.

The objective of this study was therefore to develop a holistic monitoring programme covering three interrelated components of ecological management on Mabula Game Reserve. The first component involves the large herbivores on the reserve, which are essential for the tourism-based industry of Mabula Game Reserve. Revenue is also gained from the selling of these wildlife live. The other two ecological components are the herbaceous plants and the woody plants, which are utilised by the large herbivores. Reserve managers have been conducting monitoring of the herbaceous layer on Mabula Game Reserve, which is used to determine the ecological grazing capacity and assess the condition of the herbaceous plants of the vegetation communities on the reserve. There has been no monitoring of the woody layer prior to this study on Mabula Game Reserve. Monitoring the woody layer provides information on the ecological browsing capacity, plant species composition and structure of the woody layer for the different vegetation communities. Both the herbaceous and woody plants have a direct influence on the large herbivores on the reserve and vice versa. The monitoring of the large herbivores focused on the selection of the different vegetation communities on the reserve, which represent the different available habitats.

Chapter 2

THE STUDY AREA

2.1 GEOGRAPHICAL LOCATION AND INFRASTRUCTURE

Mabula Game Reserve is located in the Limpopo province of South Africa. It is situated in the Bela-Bela (Warmbaths) district, approximately 50 km west of Bela-Bela at longitude 27°54' S and latitude 24°46' E (Figure 2.1).

The Reserve is separated into two sections by the Renosterhoekspruit provincial road. Mabula Game Reserve, on the western side, covers an area of approximately 8500 ha. Madjuma Lion Reserve, on the eastern side, covers an area of approximately 1500 ha. No research was conducted in the lion reserve. Therefore is not discussed in this report. Both sections of the reserve are completely fenced with wildlife proof fencing. Roads traverse the reserve to facilitate tourist access and game drives. Buildings for the lodge, time-share and subdivision owners are scattered throughout the western and northern section of Mabula Game Reserve. Staff accommodation on Mabula Game Reserve can be found on the western and southern perimeter.

2.2 TOPOGRAPHY

The altitude of Mabula Game Reserve ranges from 1140 to 1432 m above sea level (Muller, 1998). The area is composed of mountainous terrain, covering 12 % of the surface area; plains, constituting 67 % of the surface area; and drainage areas, covering 21 % of the surface area (Bredenkamp & Van Rooyen 1990). The mountainous terrain runs along the western side of Mabula Game Reserve from north to south (Figure 2.1).

2.3 HYDROLOGY

Northwest of the mountainous terrain the drainage lines flow in a northerly direction, whereas they flow in a southerly direction in the central section of the reserve.

Waterways are generally perennial, with dams constructed for year-round water provision for wildlife.

2.4 GEOLOGY

Mabula Game Reserve is situated on the northeastern edge of the Cape-vaal craton. The largest portion of the reserve is underlain by igneous rocks consisting mainly of granite and pegmatitic granite of the Bushveld Igneous Complex. A prominent feature of the reserve is the fault line that displaces a band of granophyre of the Rashoop Suite of the Bushveld Igneous Complex. The northwestern and southwestern sections of the reserve are underlain by sedimentary rocks consisting mainly of arenite and shale of the Transvaal Supergroup while to the southwest, an andesitic band of the Smelterskop Formation and arenilitic shales of the Blaauwbank Member, are found (McCourt and Armstrong, 2001) (Figure 2.2).

2.5 SOILS

The dominant geological substrates of the area are weather resistant and take a relatively long time to weather in comparison to other substrates, such as dolerite. This results in less fertile soils. The soils of the region are therefore acidic, sandy, loamy to gravelly soils that were derived from sandstone, quartzite or shale. Soil fertility is one of the main factors that determines the vegetation composition of the area. The dominant soil types of the plains and drainage areas consist of Clovelly (Orthic A horizon on a yellow-brown apedal B horizon), Valsrivier (orthic A horizon on a pedocutanic B horizon over unconsolidated material without signs of wetness), Dundee (Orthic A horizon on stratified alluvium) and Hutton (Orthic A horizon on a red apedal B horizon) forms. The Mispah (Orthic A horizon on hard rock) soil type dominates the mountainous terrain and middle slopes. Valleys are characterised by the Hutton and Oakleaf (Orthic A horizon on a neocutanic B horizon) soil types (Macvicar 1991, Muller 1998). The soil types occurring in Mabula Game Reserve appear in Figure 2.3.

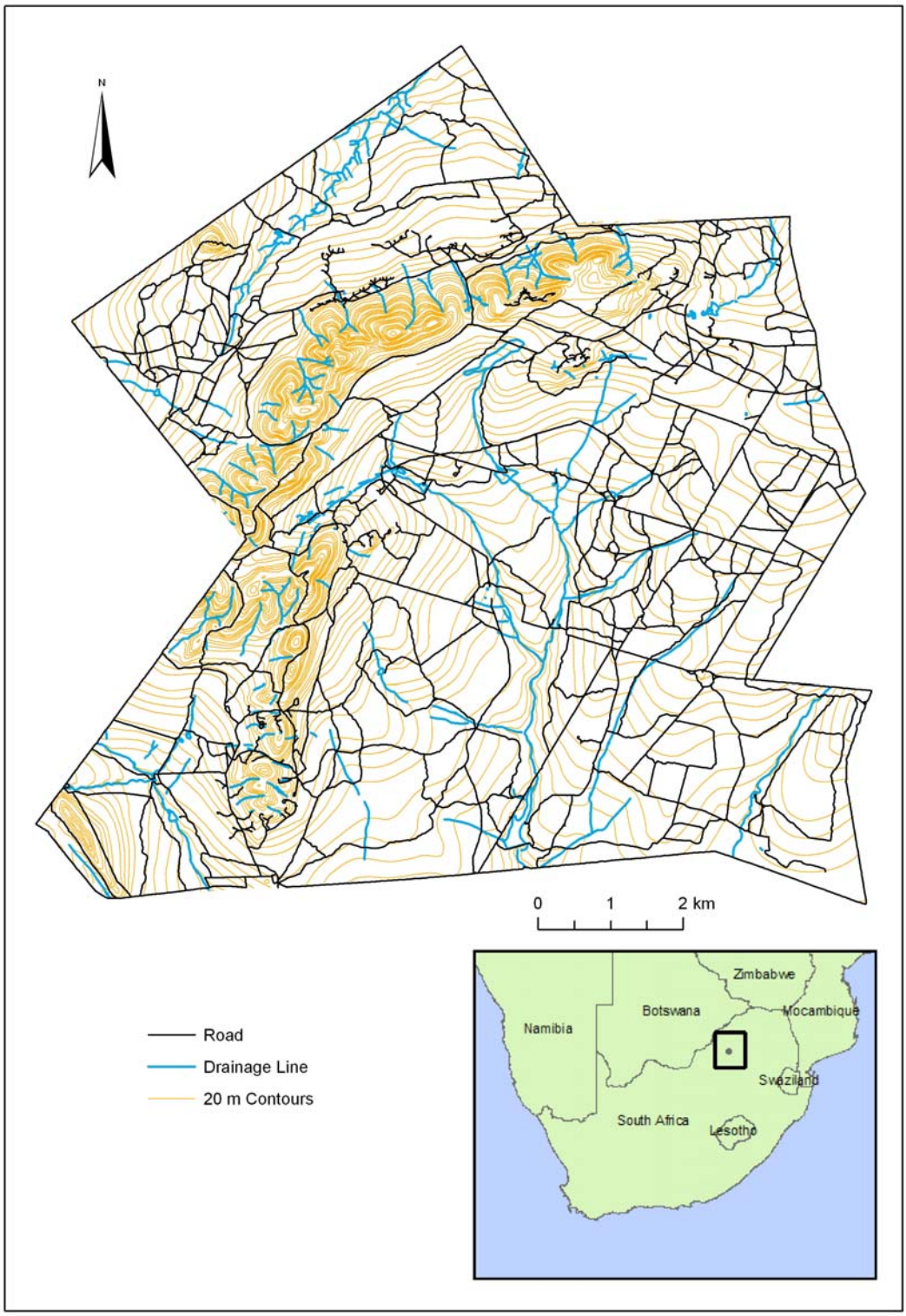

Figure 2.1. Mabula Game Reserve (excluding the Madjuma Lion Reserve) and its general location in South Africa.

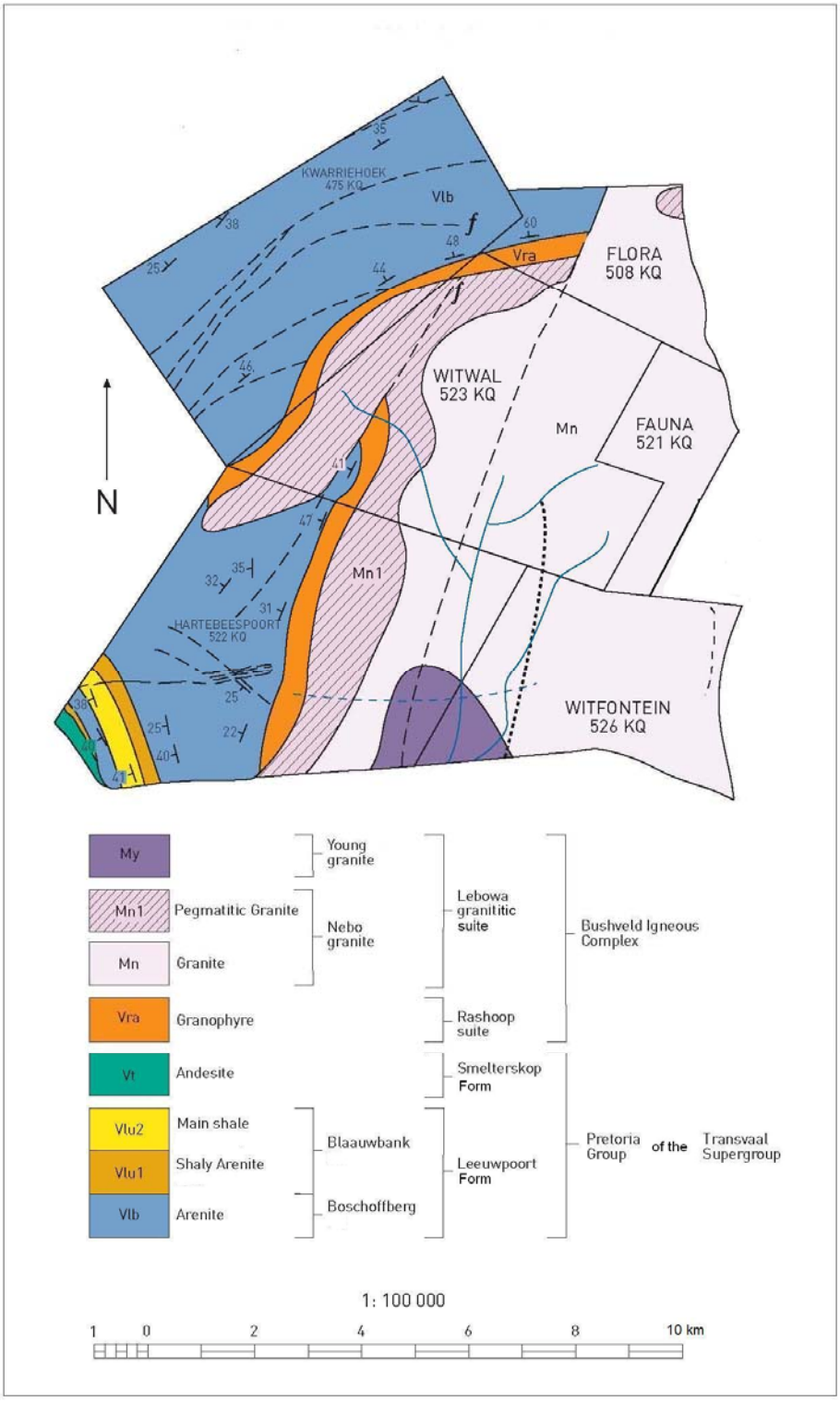

Figure 2.2. Geology map of Mabula Game Reserve (after Hartzer, 2000).

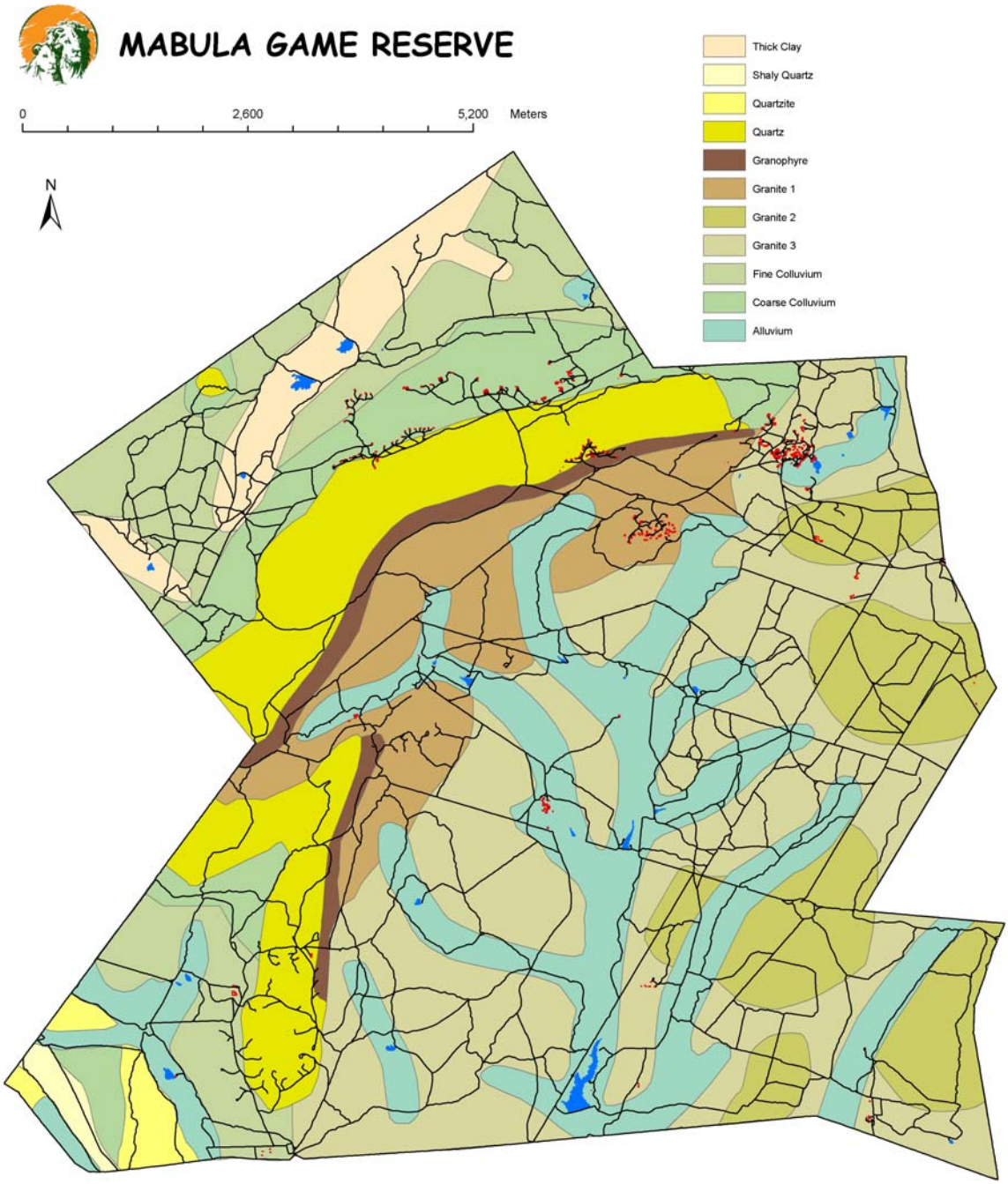

Figure 2.3. The soil on Mabula Game Reserve (Source: Mabula Reserve Management 2006).

2.6 CLIMATE

Mabula Game Reserve occurs in the Savanna Biome, with an unimodal, subtropical savanna climate (Low & Rebelo 1998). Mabula Game Reserve has been conducting its own weather monitoring since 1998 (Figure 2.4). Rainfall is recorded at four different sites on Mabula, and temperatures are recorded at one site. The mean yearly rainfall for Mabula game Reserve is 611.3 mm. The coolest month is June with a mean monthly maximum temperature of 12.7°C. The warmest month is January with a mean monthly high temperature of 23.3°C. The absolute minimum recorded temperature was 0.0°C and the absolute maximum recorded temperature was 38.5°C.

Climatic data form 1950 to 2006 (Figure 2.5) obtained from the Towoomba Meteorological Station (AgroMet No. 0589/594; Latitude 24° 54'S; Longitude 28°20'E; Altitude 1143 m above sea level), shows a mean rainfall of 631.90 mm per annum for Bela-Bela. The coolest month there is July with a mean monthly temperature of 12.2°C. The warmest month there is January with a mean monthly temperature of 23.5°C. The rain fall in this region is seasonal, with the majority of precipitation occurring during the warmer months from September to April.

2.7 VEGETATION

According to Low and Rebelo's (1995) classification the southern portion of Mabula Game Reserve is part of the Mixed Bushveld, whereas the northern portion is classified as part of the Waterberg Moist Mountain Bushveld. Both vegetation types are part of the Savanna Biome. In a comprehensive vegetation mapping atlas of South Africa, Mucina and Rutherford (2006) incorporated Mabula Game Reserve into the Central Sandy Bushveld (SVcb 12) of the Central Bushveld Bioregion within the Savanna Biome, which borders on to the Western Sandy Bushveld (SVcb 16) in the west (Figure 2.6).

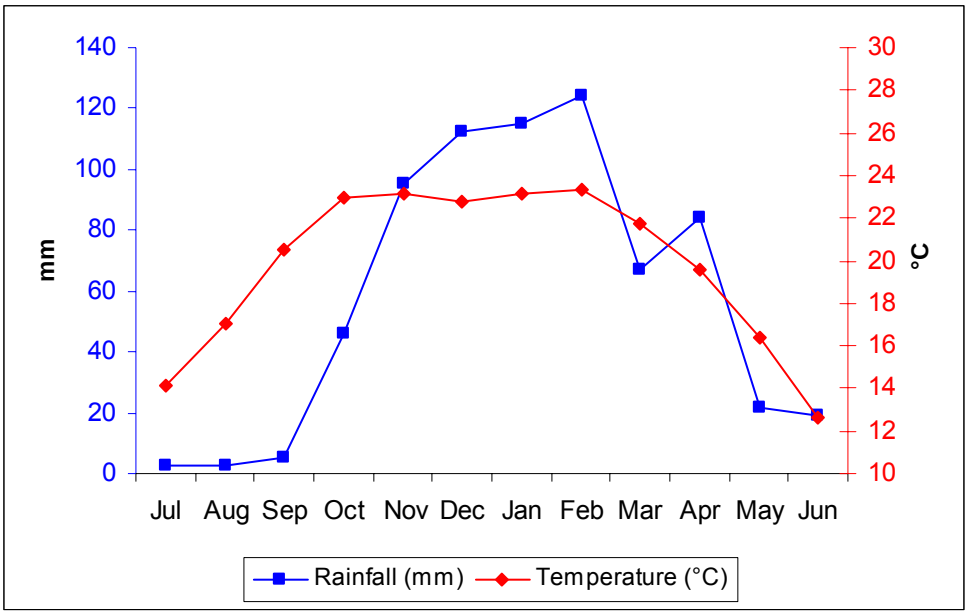

Figure 2.4. Climatogramme for Mabula game Reserve in the Limpopo province of South Africa to show the mean monthly rainfall and temperature observations over the past nine years. Source: Mabula weather observations, (1998 to 2007).

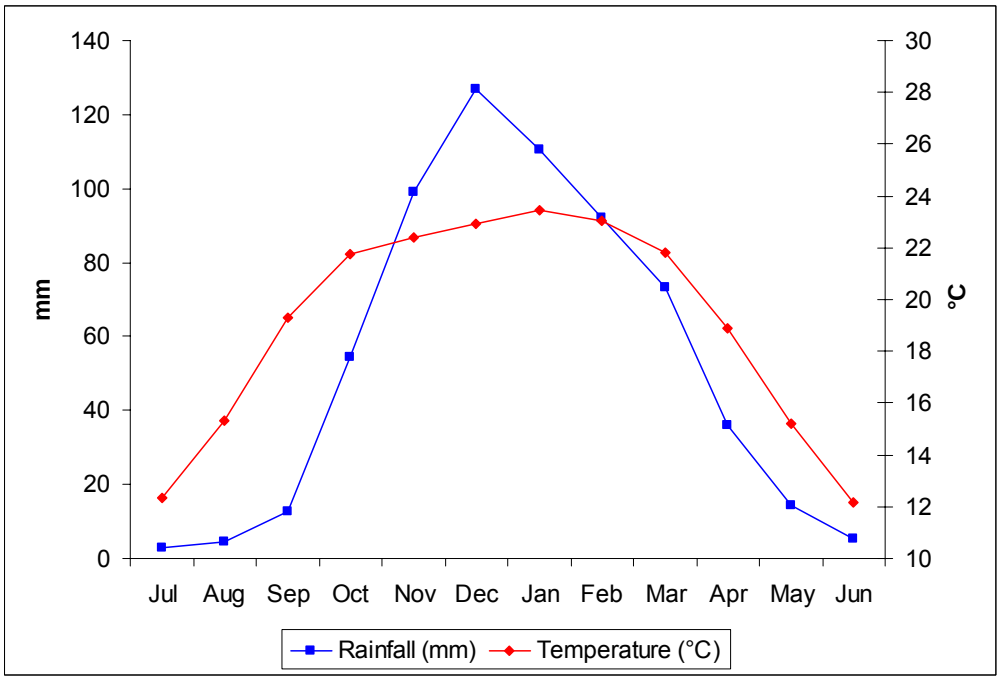

Figure 2.5. Climatogram for Toowoomba meteorological station in the Bela-Bela district to show the mean monthly rainfall and temperature from 1950 to 2006.

2.7.1 Vegetation communities

The vegetation map that was used for this study was compiled from two former vegetation surveys. Bredenkamp and Van Rooyen (1990) surveyed and identified Mabula Game Reserve's vegetation communities. However, the area that was surveyed excluded the farm Hartbeestpoort 522 KQ in the southwest corner of the reserve. This section of the reserve was surveyed by Du Toit in 1989. The vegetation communities based on these surveys were digitised by using ArcView and were then compared and integrated (Figure 2.7). As the communities associated with drainage areas and wet grasslands were more comprehensively assessed by Du Toit (1989), these community descriptions were used in the present study.

2.7.2 Description of the vegetation communities

The major vegetation communities on Mabula Game Reserve consist of the following:

Acacia caffra - Faurea saligna Short Open Woodland

This vegetation community covers 23.7% of the surface area of Mabula Game Reserve and is found in the eastern and central portions of the reserve. It occurs on sandy loam soils on undulating plains and slopes that do not exceed two degrees (Bredenkamp & Van Rooyen 1990).

The main woody plant species that were found in this community are:

Acacia caffra	*Acacia karroo*
Burkea africana	*Combretum apiculatum*
Combretum zeyheri	*Combretum molle*
Dichrostachys cinerea	*Dombeya rotundifolia*
Euclea crispa	*Faurea saligna*
Ozoroa paniculosa	*Peltophorum africanum*
Searsia lancea	*Searsia leptodictya*
Tarchonanthus camphoratus	*Terminalia sericea*
Vitex rehmannii	*Xerophyta retinervis*

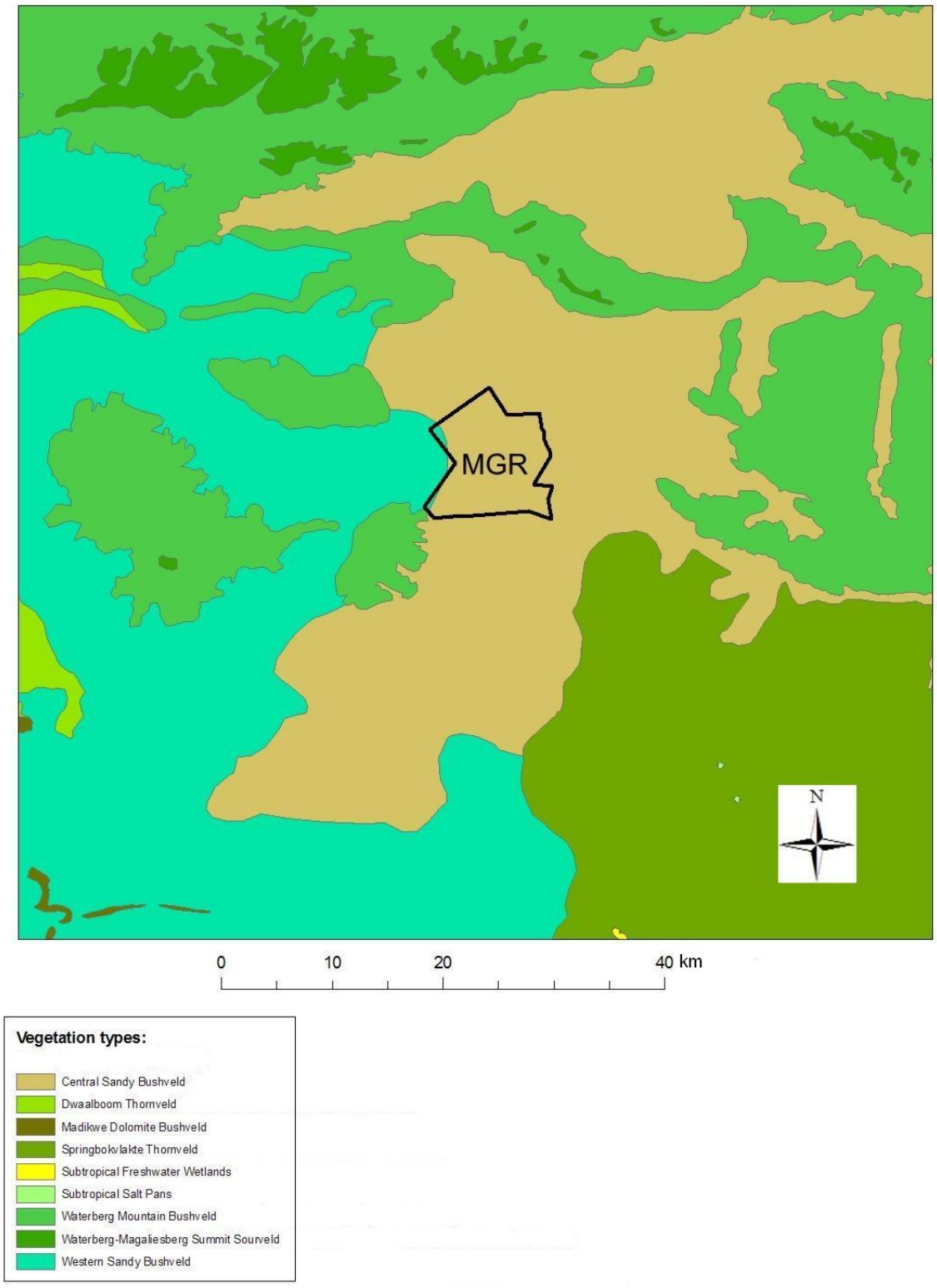

Figure 2.6. The bioregions of Mabula Game Reserve and its environs based on Mucina & Rutherford (2006).

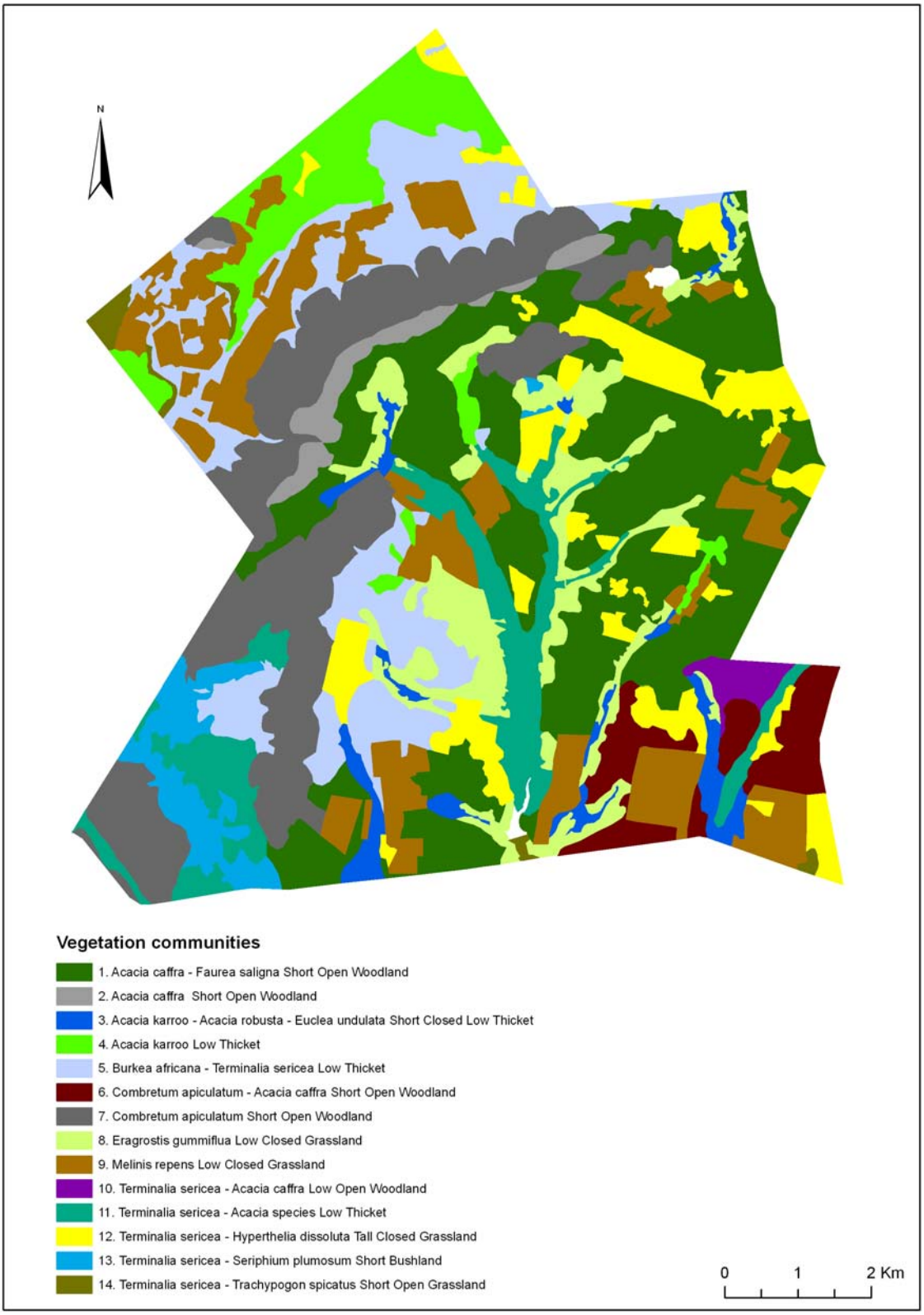

Figure 2.7. A map showing the vegetation communities on Mabula Game Reserve based on Bredenkamp & Van Rooyen (1990) and Du Toit (1989).

The main grass species that were found in this vegetation community are:

Digitaria eriantha
Elionurus muticus
Heteropogon contortus
Hyperthelia dissoluta
Setaria sphacelata
Themeda triandra

Acacia caffra Short Open Woodland

This vegetation community covers 1.8% of the surface area of Mabula Game Reserve and is found on the east-facing slopes of the mountainous area running through the northwestern part of the reserve.

The main woody plant species that were found in this community are:

Acacia caffra
Combretum molle
Combretum zeyheri
Cryptolepis oblongifolia
Diplorrhynchus condylocarpon
Faurea saligna
Grewia monticola
Lannea discolor
Ozoroa paniculosa
Protea caffra
Searsia lancea
Strychnos madagascariensis
Vitex rehmannii
Xerophyta retinervis
Ximenia caffra

The main grass species that were found in this community are:

Cymbopogon excavatus
Eragrostis racemosa
Melinis nerviglumis
Schizachyrium sanguineum
Themeda triandra
Trachypogon spicatus

Acacia karroo - Acacia robusta - Euclea undulata Short Low Closed Thicket

This vegetation community covers 2.6% of the surface area of Mabula Game Reserve and extends across the central and southern areas of the reserve. It represents riparian vegetation and vegetation in proximity to drainage courses (Du Toit 1989).
The main woody plant species that were found in this community are:

Acacia erubescens	*Acacia hebeclada*
Acacia karroo	*Acacia robusta*
Acacia tortilis	*Combretum hereroense*
Dombeya rotundifolia	*Euclea crispa*
Euclea undulata	*Grewia flava*
Ozoroa paniculosa	*Pappea capensis*
Peltophorum africanum	*Spirostachys africana*
Terminalia sericea	*Ziziphus mucronata*

The main grass species that were found in this community are:

Cynodon dactylon	*Digitaria eriantha*
Eragrostis gummiflua	*Heteropogon contortus*
Melinis repens	*Sporobolus ioclados*

Acacia karroo Low Thicket

This vegetation community covers 5.6% of the surface area of Mabula Game Reserve. It is associated with low-lying areas, drainage courses, and floodplains in the northwest of the reserve (Bredenkamp & Van Rooyen 1990).

The main woody plant species that were found in this community are:

Acacia caffra	*Acacia karroo*
Acacia hebeclada	*Acacia tortilis*
Berchemia zeyheri	*Elaeodendron transvaalense*
Combretum hereroense	*Combretum zeyheri*
Cussonia transvaalensis	*Euphorbia ingens*
Faurea saligna	*Ficus thonningii*

Gardenia volkensii
Pappea capensis
Peltophorum africanum
Searsia lancea
Searsia leptodictya
Spirostachys africana
Terminalia sericea
Vitex rehmannii
Ziziphus mucronata

The main grass species that were found in this vegetation community are:

Digitaria eriantha
Heteropogon contortus
Melinis repens
Setaria sphacelata

Burkea africana - Terminalia sericea Low Thicket

This vegetation community covers 11.1% of the surface area of Mabula Game Reserve and is found in deep sandy soils originating from quartzitic rocks (Bredenkamp & Van Rooyen 1990). It is found in the central and nothwestern section of the reserve.

The main woody plant species that were found in this vegetation community are:

Acacia burkei
Acacia caffra
Acacia erubescens
Acacia karroo
Acacia mellifera
Burkea africana
Clerodendrum glabrum
Combretum zeyheri
Dichrostachys cinerea
Dombeya rotundifolia
Elephantorrhiza burkei
Euclea crispa
Grewia flava
Grewia flavescens
Gymnosporia buxifolia
Lannea edulis
Ochna pulchra
Ozoroa paniculosa
Searsia lancea
Searsia leptodictya
Searsia pyroides
Sclerocarya birrea
Terminalia brachystemma
Terminalia sericea

The main grass species that were found in this vegetation community are:

Cynodon dactylon	*Digitaria eriantha*
Eragrostis rigidior	*Melinis repens*
Panicum maximum	*Perotis patens*
Pogonarthria squarrosa	*Setaria sphacelata*

Combretum apiculatum - Acacia caffra Short Open Woodland

This vegetation community covers 3.5% of the surface area of Mabula Game Reserve. It is found in the southeastern section of the reserve in drainage courses and alluvial fans on sandy loam soils originating from granitic rocks (Bredenkamp & Van Rooyen 1990).

The main woody plant species that were found in this vegetation community are:

Acacia caffra	*Acacia karroo*
Acacia tortilis	*Aloe davyana*
Burkea africana	*Combretum apiculatum*
Combretum zeyheri	*Dichrostachys cinerea*
Dombeya rotundifolia	*Euclea crispa*
Euphorbia schinzii	*Faurea saligna*
Lannea discolor	*Lippia javanica*
Ochna pulchra	*Pappea capensis*
Pterocarpus rotundifolius	*Searsia lancea*
Searsia leptodictya	*Vitex rehmannii*

The main grass species and sub-species that were found in this vegetation community are:

Aristida congesta subsp*. congesta*	*Digitaria eriantha*
Elionorus muticus	*Eragrostis chloromelas*
Heteropogon contortus	*Melinis repens*
Setaria sphacelata	*Themeda triandra*

Combretum apiculatum Short Open Woodland

This vegetation community covers 15.3% of Mabula Game Reserve and is found on the mountain range running through the western part of the reserve (Bredenkamp & Van Rooyen 1990).

The main woody plant species that were found in this vegetation community are:

Acacia caffra
Acacia erubescens
Acacia karroo
Acacia robusta
Aloe marlothii
Burkea africana
Combretum apiculatum
Combretum imberbe
Combretum molle
Combretum hereroense
Combretum zeyheri
Croton gratissimus
Cussonia transvaalensis
Dombeya rotundifolia
Elephantorrhiza burkei
Euphorbia ingens
Euphorbia schinzii
Euclea crispa
Euclea undulata
Faurea saligna
Ficus glumosa
Grewia monticola
Heteropyxis natalensis
Lannea discolor
Myrothamnus flabellifolia
Ochna pulchra
Ozoroa paniculosa
Asparagus africanus
Psiadia punctata
Searsia lancea
Searsia leptodictya
Tarchonanthus camphoratus
Terminalia sericea
Vitex rehmannii
Xerophyta retinervis
Ximenia caffra
Ziziphus mucronata

The main grass species that were found in this vegetation community are:

Cynodon dactylon
Digitaria eriantha
Eragrostis gummiflua
Eragrostis rigidior
Eragrostis trichophora
Heteropogon contortus

Eragrostis gummiflua Low Closed Grassland

This vegetation community covers 7% of the surface area of Mabula Game Reserve and is found through the central part of the reserve. The vegetation community grows in semi-swampy areas and is characterised by grassland with sparsely scattered trees (Du Toit 1989, Serfontein 2007).
The main woody plant species that were found in this vegetation community are:

Acacia tortilis
Dichrostachys cinerea
Pelthophorum africanum
Searsia pyroides
Terminalia sericea

The main grass species that were found in this vegetation community are:

Cynodon dactylon
Digitaria eriantha
Eragrostis gummiflua
Eragrostis trichophora
Melinis repens
Setaria sphacelata

Melinis repens Low Closed Grassland

This vegetation community covers 11.7% of the surface area of Mabula Game Reserve and is scattered throughout the reserve on abandoned cultivated land (Bredenkamp & Van Rooyen 1990).

The main woody plant species that were found in this vegetation community are:

Acacia caffra
Acacia karroo
Acacia tortilis
Acacia hebeclada
Burkea africana
Combretum zeyheri
Dichrostachys cinerea
Euclea crispa
Faurea saligna
Ficus thonningii
Lannea discolor
Peltophorum africanum
Terminalia sericea

The main grass species and sub-species that were found in this vegetation community are:

Aristida congesta subsp. *barbicollis*	*Cynodon dactylon*
Digitaria eriantha	*Eragrostis rigidior*
Melinis repens	*Pogonarthria squarrosa*

Terminalia sericea - Acacia caffra Low Open Woodland

This community covers 0.7% of the surface area of Mabula Game Reserve and is found in the southeastern section.

The main woody plant species that were found in this vegetation community are:

Acacia burkei	*Acacia caffra*
Acacia erubescens	*Acacia karroo*
Acacia mellifera	*Acacia robusta*
Burkea africana	*Clerodendrum glabrum*
Combretum zeyheri	*Dichrostachys cinerea*
Dombeya rotundifolia	*Euclea crispa*
Faurea saligna	*Grewia flava*
Grewia flavescens	*Lannea edulis*
Ochna pulchra	*Ozoroa paniculosa*
Gymnosporia polyacantha	*Searsia lancea*
Searsia leptodictya	*Searsia pyroides*
Sclerocarya birrea	

The main grass species that were found in this vegetation community are:

Cynodon dactylon	*Digitaria eriantha*
Eragrostis gummiflua	*Eragrostis trichophora*
Heteropogon contortus	*Perotis patens*

Terminalia sericea - Acacia species Low Thicket

This vegetation community covers 6.4% of the surface area of Mabula Game Reserve and is found in the southwestern, southeastern, and central areas of the reserve. It occurs close to streams and in gently sloping valleys (Du Toit 1989).

The main woody plant species that were found in this vegetation community are:

Acacia caffra
Acacia robusta
Burkea africana
Combretum zeyheri
Euclea crispa
Faurea saligna
Searsia leptodictya
Ziziphus mucronata
Acacia tortilis
Acacia nilotica
Clerodendrum glabrum
Dichrostachys cinerea
Euclea undulata
Grewia flava
Terminalia sericea

The main grass species that were found in this vegetation community are:

Cynodon dactylon
Eragrostis trichophora
Heteropogon contortus
Digitaria eriantha
Eragrostis gummiflua
Perotis patens

Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland

This vegetation community covers 7.5% of the surface area of Mabula Game Reserve and occurs on old cultivated lands (Bredenkamp & Van Rooyen 1990).

The main woody plant species that were found in this vegetation community are:

Acacia caffra
Acacia robusta
Dichrostachys cinerea
Terminalia sericea
Acacia karroo
Burkea africana
Faurea saligna

The main grass species that were found in this vegetation community are:

Cynodon dactylon
Eragrostis gummiflua
Eragrostis rigidior
Heteropogon contortus
Hyparrhenia filipendula
Hyperthelia dissoluta

Terminalia sericea – Seriphium plumosum Short Bushland

This vegetation community covers 2.5% of the surface area of Mabula Game Reserve and is found on sandy to loamy soils alongside waterways in the southwestern section of the reserve (Du Toit 1989).

The main woody plant species that were found in this community are:

Acacia caffra
Acacia hebeclada
Acacia karroo
Acacia tortilis
Dichrostachys cinerea
Euclea crispa
Searsia pyroides
Terminalia sericea

The main grass species that were found in this vegetation community are:

Brachiaria nigropedata
Dactyloctenium aegyptium
Chloris virgata
Eragrostis trichophora
Microcloa caffra
Sporobolus nitens
Urochloa mosambicensis

Terminalia sericea - Trachypogon spicatus Short Open Grassland

This vegetation community covers 0.6% of the surface area of Mabula Game Reserve and is located in the northwest of the reserve. It occurs on wetlands and has a sparse cover of woody species (Bredenkamp & Van Rooyen 1990).

The woody plant species that were found in this vegetation community are:

Acacia caffra	*Acacia hebeclada*
Acacia karroo	*Acacia tortilis*
Burkea africana	*Combretum imberbe*
Combretum zeyheri	*Dichrostachys cinerea*
Dombeya rotundifolia	*Elephantorrhiza elephantina*
Euclea crispa	*Faurea saligna*
Pappea capensis	*Peltophorum africanum*
Searsia lancea	*Searsia leptodictya*
Sclerocarya birrea	*Stoebe vulgaris*
Terminalia sericea	*Vitex rehmannii*

The main grass species that were found in this vegetation community are:

Aristida junciformis	*Digitaria eriantha*
Hyparrhenia hirta	*Hyperthelia dissoluta*
Pogonarthia squarrosa	*Setaria sphacelata*
Sporobolus ioclados	*Trachypogon spicatus*

Chapter 3

MONITORING OF THE LARGE HERBIVORES

3.1 INTRODUCTION

Monitoring of herbivore populations is an important aspect of wildlife reserve management, as proper management of wildlife requires a thorough understanding of habitat requirements and the potential for competitive interactions among species and sub-species (Wydeven & Dahlgren 1985). Monitoring of wildlife populations provides information that can be used for assessment of management strategies and decisions in relation to wildlife stocking densities or harvesting rates and vegetation management (Walker 1976, Pollock *et al.* 2002). It is important to note that Mabula Game Reserve had to re-establish wildlife populations because it was previously livestock and grain production. No long-term studies have been conducted on how the animals have dispersed across the reserve after this and the effect that the reintroduced large herbivores have had on the altered environment. Also, several types of wildlife which do not naturally occur in this region have been released on to Mabula Game Reserve. The relationship among naturally occurring herbivores and the introduced herbivores is unknown. Therefore proper assessment and monitoring of wildlife is required.

A monitoring programme for large herbivores should aim to determine their population size, sex ratios, age ratios and habitat selection. Mabula Game Reserve has conducted aerial counts and road strip counts since 1997. These counts focused on population size, sex ratios and age ratios. This chapter aims to develop an additional monitoring programme which determines the preference of the large herbivores for the different vegetation communities on Mabula Game Reserve. According to Arthur *et al.* (1996),

when habitats are classified into discrete categories from which an animal chooses, then habitat use can be studied. Therefore vegetation communities were used to classify the different habitats available to the different wildlife. Large herbivores are dependent on vegetation communities and have strong direct and indirect impacts on the composition and structure of plants in a vegetation community (Augustine & McNaughton 2007). The determination of habitat selection by wildlife can be used to assess the biological requirements of individual types of wildlife, predict the effects of habitat change, identify key areas for protection, and/or test management strategies (Arthur *et al*. 1996).

This study focused on the selection of vegetation communities by large herbivores, which was then compared to the current browsing and grazing capacities of these vegetation communities as outlined in chapters 4 and 5. Wildlife are generally not evenly distributed across vegetation communities on a reserve when foraging. However, the distribution of the different herbivores can be simplified as most are linked to specific vegetation forms. (Pienaar 1974, Dekker *et al*. 1996). According to Senft *et al.* (1987) a herbivores' relative preference for a vegetation community is generally a linear function of the relative abundance and/or nutritive quantity of the preferred plants in a community. The habitat selection is also related to influences such as: size of the available habitat; availability of water; availability of shelter from the elements and predation; competition; and reproductive suitability (Pienaar 1974). These influences were not addressed in this study, but can be addressed in the future when substantial data have been collected from the proposed monitoring programme.

Two methods have been used to determine habitat selection. The first method was initially developed by Jacobs (1974) for the determination of food selection. Forage ratio and Ivlev's electivity index were used to quantify food selection where the extent of selection and relative abundance of the food types were studied. Van Eeden (2006) has adapted this method to the selection of habitat or vegetation communities for wildlife to provide a ratio of use. The second method, using Chi-square goodness-of-fit test and the Bonferroni Z-statistic, was adapted by Van Eeden (2006) for determining the selection of vegetation communities by the large herbivores. The Bonferroni Z-statistic was assessed initially by Allredge & Ratti (1992) and provides a sound statistical method for determining habitat selection. The results from this chapter are further used in Chapters

4 and 5, where the browsing and grazing capacities are determined for the reserve and its different vegetation communities.

3.2 METHODS

3.2.1 Wildlife counts

Wildlife counts, which give information on the population size and sex ratios of different herbivores, are conducted on Mabula Game Reserve on a yearly basis. The aerial counts are conducted by a helicopter flying across the reserve during September. Road counts are conducted by dividing the reserve into areas depending upon the number of vehicles available and the vehicles traverse the entire section simultaneously. Both methods are conducted once a day for three days from 07:00 to 11:00.

3.2.2 Habitat selection

For the determination of habitat preference, four transects were chosen by using the existing roads on Mabula Game Reserve, with a buffer of 100 m on each side of the roads. The transects were situated in the northeastern, northwestern, southeastern and southwestern sections of the game reserve (Figure 3.1). The transects were carefully chosen so that the surface area of each vegetation community represented in the transect area was similar to the proportion of surface area which the vegetation communities covered in relation to the entire reserve (Table 3.1).

Each transect was traversed four times a month. Firstly, the transect was travelled in one direction at sunrise and then travelled in the same direction two hours prior to sunset. This was repeated the following day in the opposite direction. The sampling was conducted for eight days each month for one year.

The surveys were conducted using an Ipac handheld computer (produced by Hewlett-Packard), Esri's ArcPad was used to mark the location of large herbivore herds. This was downloaded to ArcView 8.2. An alternative method is to record the GPS co-ordinate of the viewing position, then record the distance to and compass bearing of the herd. This can then be manually entered into ArcView or other GIS programs. The alternative method was not used in this study.

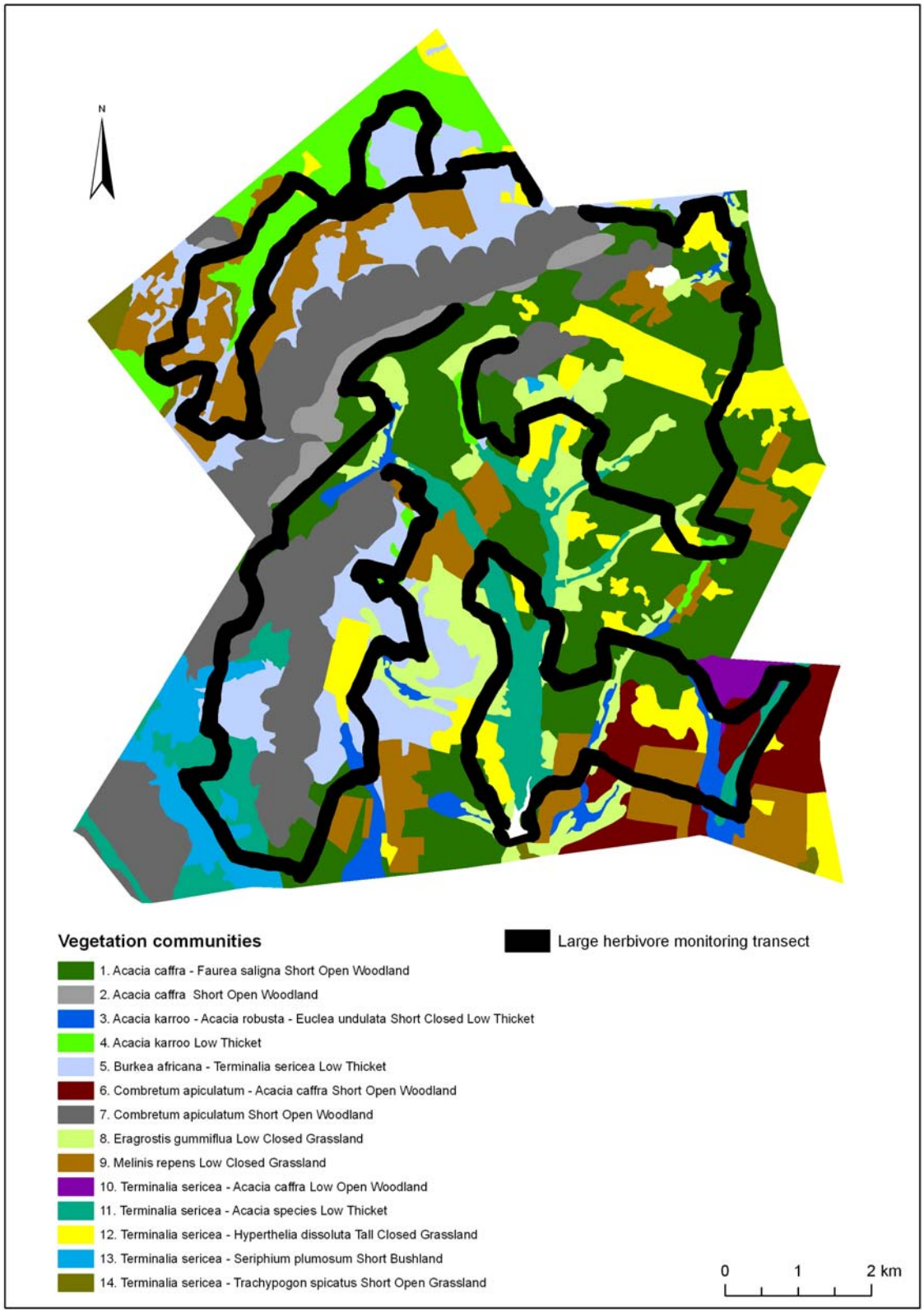

Figure 3.1. The large herbivore monitoring transects in relation to the roads and vegetation communities on Mabula Game Reserve.

Table 3.1. The proportional surface areas of the vegetation communities for the whole Mabula Game Reserve and that of the wildlife count transects

Vegetation community	Actual size (ha)	Percent of total area	Transect size (ha)	Percent of transect area
Acacia caffra - Faurea saligna Short Open Woodland	1979.0	23.7	350.5	24.9
Acacia caffra Short Open Woodland	150.3	1.8	18.3	1.3
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	214.5	2.6	38.5	2.7
Acacia karroo Low Thicket	471.2	5.6	131.7	9.4
Burkea africana - Terminalia sericea Low Thicket	927.8	11.1	227.6	16.2
Combretum apiculatum Short Open Woodland	1280.0	15.3	55.9	4.0
Combretum apiculatum - Acacia caffra Short Open Woodland	291.9	3.5	55.9	4.0
Eragrostis gummiflua Low Closed Grassland	589.0	7.0	109.1	7.8
Melinis repens Low Closed Grassland	978.7	11.7	175.3	12.5
Terminalia sericea - Acacia caffra Low Open Woodland	60.8	0.7	17.1	1.2
Terminalia sericea - Acacia species Low Thicket	534.4	6.4	85.6	6.1
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	625.1	7.5	99.5	7.1
Terminalia sericea – Seriphium plumosum Short Bushland	210.3	2.5	35.3	2.0
Terminalia sericea - Trachypogon spicatus Short Open Grassland	49.4	0.6	3.9	0.3
Total	8362.4	100.0	1404.1	100.0

The following data were recorded into Excel on the Ipac:

- Herd size
- Number of males
- Number of females
- Number of juveniles
- Activity:
    - Feeding
    - Resting
    - Moving
    - Drinking

The data were then linked as an attribute table to the location points in ArcView. The data were split according to the different herbivores and separated for the different vegetation communities by using ArcView. Only the recordings where feeding was observed were used, which enabled the determination of the preferred vegetation communities for utilisation. Additionally, the data were analysed separately for the dry season where utilisation has the most impact. The data on sex and age were not used as the total game counts give more reliable results. As the aim of this study was to develop a monitoring system, additional data, such as resting, moving and drinking, were recorded for potential future use.

Chi-square goodness-of-fit test

The Chi-square goodness-of-fit test was applied to the proportion of individuals for each type of herbivore that was found feeding in a vegetation community and the percent of the total surface area which each vegetation community covered. The calculated Chi-square values were compared to a tabled Chi-square with 13 degrees of freedom to give a *P*-value. The null hypothesis was that utilisation occurred in proportion to the availability of habitat (vegetation communities). If *P* was less than or equal to 0.05, the null hypothesis was rejected, showing that utilisation did not occur in proportion to the availability of habitat, therefore herbivores were selecting specific vegetation communities when foraging.

Jacobs' (1974) index (in Van Eeden 2006)

The index of Jacobs (1974) was used to determine the preference index of use (*PI*) of a particular herbivore for each vegetation community. This gave an indication of whether a vegetation community was preferred (where $PI > 0$, maximum +1) or not often used (where $PI < 0$, minimum -1). If $PI = 0$ then the vegetation community was used in the same ratio as its proportional occurrence.

The equations used were:

Equation 1: when $U > A$ then $PI_{(x)} = (-1 \div U) \times (A - U)$

Equation 2: when $U < A$ then $PI_{(x)} = (1 \div A) \times (U - A)$

Where: PI = preference for vegetation community x,

U = proportion of use of vegetation community x,

A = proportion of vegetation community x available in study area.

Bonferroni Z-statistic

The Bonferroni Z-statistic was used to determine the degree of preference of a vegetation community by the different herbivores, within a constructed 95% confidence interval (Allredge & Ratti 1992, Samuels & Witmer 1999).

The equation used was:

$$U \pm Z_{1-\alpha/2k} [U (1-U) / n]^{½}$$

Where: U = the proportion of use,

$Z_{1-\alpha/2k}$ = the upper standard normal table value corresponding to a probability tail area of $\alpha/2k$,

k = the number of vegetation communities,

n = the total number of individuals of observed.

The confidence intervals were constructed at 95%, with α = 0.05. There are 14 vegetation communities, therefore k = 14 and 1-α/2k = 0.9979. The relating *Z*-value of a normal curve for 0.9979 is 2.86, hence $Z_{1-\alpha/2k}$ = 2.86 (Samuels & Witmer 1999).

Where the proportion of the available habitat (percent surface area covered by a vegetation community) was less than the lower confidence interval, this habitat was preferred by the different herbivores. If the proportion was higher than the confidence interval, the habitat was not used. Where the proportion of the available habitat fell within the confidence intervals, no pattern was observed between availability and use. Therefore the habitat was utilised but not preferred.

If a herbivore showed no pattern of use for a vegetation community and a negative value for the preference index, then it was assumed that minimal utilisation of the particular habitat occurred. Therefore those herbivores are not included in the results. Importance values <0.10 were considered to be insignificant, and therefore were not included in the results.

3.3 RESULTS

3.3.1 Population size and sex ratio

Table 3.2 shows the species used for the determination of habitat selection and the corresponding population size and sex ratios determined by the game counts from 2003 to 2006. Some herbivores were not included as the numbers of observations were not large enough to establish accurate results for habitat selection. The excluded herbivores were:

African savanna buffalo *Syncerus caffer caffer*
bushbuck *Tragelaphus scriptus*
bushpig *Potamochoerus larvatus*
gray duiker *Sylvicapra grimmia*
southern reedbuck *Redunca arundium*
elephant *Loxodonta africana*
hippopotamus *Hippopotamus amphibius*

klipspringer *Oreotragus oreotragus*
mountain reedbuck *Redunca fulvorufula*
nyala *Tragelaphus angasii*
ostrich *Struthio camelus*
springbok *Antidorcas marsupialis*
steenbok *Raphicerus campestris*

3.3.2 Browsing and Grazing Units

Table 3.3 shows the number of Browsing and Grazing Units for each herbivore represented in the habitat selection monitoring. Table 3.4 shows the number of Browsing and Grazing Units for the excluded herbivores. One Browser Unit is equivalent to a 140 kg greater kudu and one Grazer Unit is equivalent to a 180 kg blue wildebeest (Bothma *et al.* 2004). The most important browsers on Mabula Game Reserve are Giraffe *Giraffa camelopardalis* and the most important grazers are Burchell's zebra *Equus burchelii*.

3.3.3 Chi-square goodness-of-fit test

The associated *P*-values for the Chi-square goodness-of-fit test were ≤0.05 for all herbivores except the giraffe; therefore the null hypothesis was rejected for all herbivores (Table 3.5), and habitat utilisation did not occur in proportion to the availability of habitat. However, the *P*-value for the giraffe over the whole year and the critical dry season was >0.05; therefore the null hypothesis was accepted, and the utilisation occurred in proportion to the availability of habitat.

Table 3.2. The wildlife numbers and their sex ratios (males per female) from the 2003 to 2006 wildlife count data for the wildlife used to determine habitat selection

	2003		2004		2005		2006	
	Road count		Road & aerial count		Road count		Aerial count	
Herbivores	Count	Sex ratio	Count	Sex ratio	Count	Sex ratio	Count	Sex ratio
Blesbok *Damaliscus pygargus phillipsi*	110	1.0:2.3	115	1.0:0.9	146	1.0:17.25	60	1.0:6.5
Blue wildebeest *Connochaetes taurinus taurinus*	56	1.0:2.1	74	1.0:1.3	130	1.0:1.0	165	1.0:2.0
Burchell's zebra *Equus burchelii*	276	1.0:1.1	346	1.0:2.4	380	1.0:0.7	375	1.0:1.5
Eland *Taurotragus oryx*	93	1.0:0.7	102	1.0:1.6	118	1.0:1.0	67	1.0:3.8
Gemsbok *Oryx gazella*	40	1.0:0.8	51	1.0:1.8	51	1.0:1.2	50	1.0:1.6
Giraffe *Giraffa camelopardalis*	60	1.0:1.2	86	1.0:1.1	99	1.0:0.7	70	1.0:1.3
Greater kudu *Tragelaphus strepsiceros*	140	1.0:1.8	180	1.0:2.6	200	1.0:0.6	196	1.0:2.6
Impala *Aepyceros melampus*	468	1.0:1.3	559	1.0:1.7	601	1.0:0.8	500	1.0:2.2
Red hartebeest *Alcelaphus caama*	145	1.0:0.7	161	1.0:1.4	165	1.0:1.6	110	1.0:1.8
Tsessebe *Damaliscus lunatus*	38	1.0:1.0	36	1.0:1.1	30	1.0:0.8	40	1.0:1.5
Warthog *Phacochoerus africanus*	450	1.0:1.2	396	1.0:1.3	534	1.0:0.3	545	1.0:1.3
Waterbuck *Kobus ellipsiprymnus*	60	1.0:1.5	74	1.0:2.5	81	1.0:0.7	75	1.0:1.6
White rhinoceros *Ceratotherium simum*	17	1.0:4.7	19	1.0:8.5	21	1.0:9.5	18	1.0:17.0
Total	2258		2521		2868		2607	

Table 3.3. Representative Browser and Grazing Units from the 2004 wildlife counts for the herbivores represented in the monitoring surveys

Herbivores	Browser Units	Percent of total Browser Units	Grazing Units	Percent of total Grazing Units
Blesbok *Damaliscus pygargus phillipsi*	6.9	0.8	51.8	4.5
Blue wildebeest *Connochaetes taurinus taurinus*	11.5	1.3	64.4	5.6
Burchell's zebra *Equus burchelii*	38.8	4.3	424.8	37.0
Eland *Taurotragus oryx*	122.4	13.6	102.0	8.9
Gemsbok *Oryx gazella*	10.7	1.2	42.1	3.7
Giraffe *Giraffa camelopardalis*	323.5	35.8	2.8	0.2
Greater kudu *Tragelaphus strepsiceros*	153.0	17.0	21.6	1.9
Impala *Aepyceros melampus*	123.0	13.6	75.5	6.6
Red hartebeest *Alcelaphus caama*	36.2	4.0	84.5	7.4
Tsessebe *Damaliscus lunatus*	1.6	0.2	23.9	2.1
Warthog *Phacochoerus africanus*	59.4	6.6	83.2	7.2
Waterbuck *Kobus ellipsiprymnus*	15.4	1.7	68.4	6.0
White rhinoceros *Ceratotherium simum*	0.0	0.0	104.5	9.1
Total	902.4	100.0	1149.5	100.0

Table 3.4. Representative Browser and Grazing Units from the 2004 game counts for wildlife which were not represented in the monitoring surveys

Herbivores	Browser Units	Grazing Units
African savanna buffalo *Syncerus caffer caffer*	28.5	82.4
Bushbuck *Tragelaphus scriptus*	1.4	0.2
Bushpig *Potamochoerus larvatus*	4.0	12.8
Grey duiker *Sylvicapra grimmia*	5.3	0.7
Southern reedbuck *Redunca arundium*	0.5	7.6
Elephant *Loxodonta africana*	85.0	27.4
Hippopotamus *Hippopotamus amphibius*	0.4	35.6
Klipspringer *Oreotragus oreotragus*	1.6	0.2
Mountain reedbuck *Redunca fulvorufula*	1.0	15.2
Nyala *Tragelaphus angasii*	2.9	0.6
Ostrich *Struthio camelus*	5.4	18.0
Springbok *Antidorcas marsupialis*	1.1	0.4
Steenbok *Raphicerus campestris*	2.6	2.7
Total	139.7	203.8

Table 3.5. The Chi-square values and associated *P*-values determining whether utilisation occurred in proportion to the availability of habitat

	Full Year		Dry Season	
Herbivores	Chi-square Value	*P*- value	Chi-square Value	*P*- value
Blesbok *Damaliscus pygargus phillipsi*	135.86	< 0.05	396.55	< 0.05
Blue wildebeest *Connochaetes taurinus taurinus*	45.06	< 0.05	70.08	< 0.05
Burchell's zebra *Equus burchelii*	20.40	< 0.05	26.34	< 0.05
Eland *Taurotragus oryx*	111.76	< 0.05	285.75	< 0.05
Gemsbok *Oryx gazella*	121.32	< 0.05	726.91	< 0.05
Giraffe *Giraffa camelopardalis*	12.80	> 0.05	18.23	> 0.05
Greater kudu *Tragelaphus strepsiceros*	46.69	< 0.05	47.15	< 0.05
Impala *Aepyceros melampus*	41.91	< 0.05	32.23	< 0.05
Red hartebeest *Alcelaphus caama*	88.55	< 0.05	97.44	< 0.05
Tsessebe *Damaliscus lunatus*	144.07	< 0.05	208.06	< 0.05
Warthog *Phacochoerus africanus*	62.49	< 0.05	94.94	< 0.05
Waterbuck *Kobus ellipsiprymnus*	24.13	< 0.05	85.95	< 0.05
White rhinoceros *Ceratotherium simum*	130.97	< 0.05	368.28	< 0.05

3.3.4 Habitat preference

The *Acacia caffra - Faurea saligna* Short Open Woodland (Table 3.6)

According to the preference index, the types of herbivores which showed a preference for the *Acacia caffra - Faurea saligna* Short Open Woodland over the whole year were blue wildebeest (*PI* = 0.13), eland (*PI* = 0.47) gemsbok (*PI* = 0.33) and greater kudu (*PI* = 0.31).

The types of herbivores which showed a preference during the dry season were blue wildebeest (*PI* = 0.33), Burchell's zebra (*PI* = 0.31), greater kudu (*PI* = 0.17) and white rhinoceros (*PI* = 0.19).

The *Acacia caffra – Faurea saligna* Short Open Woodland was preferred by common eland and greater kudu over the whole year according to the Bonferroni Z-statistic. This was the only vegetation community that these two species showed a preference for during this time period. Combined these wildlife species accounted for 30.51% (183.58 Browser Units) of the total Browser Units for the species represented in this study. They accounted for 15.59% (275.40 Grazing Units) of the total grazer units. The *Acacia caffra – Faurea saligna* Short Open Woodland was preferred by Burchell's zebra during the dry season. This was the only vegetation community Burchell's zebra selected and this wildlife species accounted for 4.29% (38.75 Browser Units) of the total Browser Units and 36.96% (424.75 Grazing Units) of the total Grazing Units.

Table 3.6. Preference Index and Bonferroni Z-statistic results for the selection of the *Acacia caffra* - *Faurea saligna* Short Open Woodland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok *Damaliscus pygargus phillipsi*	25.00	16.60	-0.35	0.08	-0.70	0.250	0.102≤*p*≤0.230	Not Used	-0.005≤*p*≤0.155	Not Used
Blue wildebeest *Connochaetes taurinus taurinus*	25.00	29.17	0.13	37.74	0.33	0.250	0.171≤p≤0.413	No Pattern	0.183≤p≤0.572	No Pattern
Burchell's zebra *Equus burchelii*	25.00	23.34	-0.08	37.05	0.31	0.250	0.185≤*p*≤0.281	No Pattern	0.276≤*p*≤0.465	Preferred
Eland *Taurotragus oryx*	25.00	47.73	0.47	3.33	-0.87	0.250	0.322≤*p*≤0.633	Preferred	-0.062≤*p*≤0.130	Not used
Gemsbok *Oryx gazella*	25.00	37.76	0.33	15.00	-0.41	0.250	0.235≤*p*≤0.521	No Pattern	-0.015≤*p*≤0.315	No Pattern
Giraffe *Giraffa camelopardalis*	25.00	21.86	-0.14	24.51	-0.04	0.250	0.129≤*p*≤0.308	No Pattern	0.121≤*p*≤0.370	No Pattern
Greater kudu *Tragelaphus strepsiceros*	25.00	36.84	0.31	30.67	0.17	0.250	0.261≤*p*≤0.476	Preferred	0.151≤*p*≤0.462	No Pattern
Impala *Aepyceros melampus*	25.00	18.20	-0.28	18.24	-0.28	0.250	0.151≤*p*≤0.214	Not Used	0.128≤*p*≤0.237	Not Used
Red hartebeest *Alcelaphus caama*	25.00	14.53	-0.43	19.25	-0.24	0.250	0.094≤*p*≤0.196	Not Used	0.102≤*p*≤0.283	No Pattern
Tsessebe *Damaliscus lunatus*	25.00	19.05	-0.25	11.54	-0.55	0.250	0.079≤p≤0.302	No Pattern	-0.014≤p≤0.245	Not Used
Warthog *Phacochoerus africanus*)	25.00	15.29	-0.40	11.80	-0.53	0.250	0.111≤p≤0.194	Not Used	0.068≤p≤0.168	Not Used
Waterbuck *Kobus ellipsiprymnus*	25.00	23.91	-0.06	21.67	-0.15	0.250	0.109≤p≤0.369	No Pattern	0.061≤p≤0.372	No Pattern
White rhinoceros *Ceratotherium simum*	25.00	20.90	-0.18	31.25	0.19	0.250	0.064≤p≤0.354	No Pattern	0.073≤p≤0.552	No Pattern

The *Acacia caffra* Short Open Woodland (Table 3.7)

According to the preference index, the types of herbivores which showed a preference for the *Acacia caffra* Short Open Woodland over the whole year were the eland (*PI* = 0.81) and greater kudu (*PI* = 0.43).

No herbivores showed any preference during the dry season.

The Bonferroni Z-statistic showed that no herbivores preferred the *Acacia caffra* Short Open Woodland over the whole year or during the dry season.

The *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket (Table 3.8)

According to the preference index the types of herbivores which showed a preference for the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket over the whole year were the eland (*PI* = 0.69), impala (*PI* = 0.76), gemsbok (*PI* = 0.32), , giraffe (*PI* = 0.15), greater kudu (*PI* = 0.63), tsessebe (*PI* = 0.63), warthog (*PI* = 0.40) and white rhinoceros (*PI* = 0.63).

The types of herbivores which showed preference during the dry season were the eland (*PI* = 0.83), giraffe (*PI* = 0.43), greater kudu (*PI* = 0.70), white rhinoceros (*PI* = 0.82) and tsessebe (*PI* = 0.27).

The Bonferroni Z-statistic showed that impala preferred the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket over the whole year. Impala accounted for 13.63% (122.98 Browser Units) of the total Browser Units represented in this study and 6.57% (75.47 Grazing Units) of the total Grazing Units. No wildlife showed any preference during the dry season.

Table 3.7. Preference Index and Bonferroni Z-statistic results for the selection of the *Acacia caffra* Short Open Woodland in the Mabula Game Reserve by wildlife from 2003 to 2004

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Herbivores	Percentage of total area	Preference Index				Bonferroni Z-statistic			
		Full year		Dry season		Full year		Dry season	
		Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	1.33	0.00	-1.00	0.00	-1.00	0.013	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	1.33	0.00	-1.00	0.00	-1.00	0.013	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	1.33	1.36	0.02	0.89	-0.33	0.013	0.000≤*p*≤0.027	No Pattern	-0.009≤*p*≤0.027	No Pattern
Eland										
Taurotragus oryx	1.33	7.95	0.83	0.00	-1.00	0.013	-0.005≤*p*≤0.164	No Pattern	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	1.33	0.00	-1.00	0.00	-1.00	0.013	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Giraffe										
Giraffa camelopardalis	1.33	1.09	-0.18	0.00	-1.00	0.013	-0.012≤*p*≤0.033	No Pattern	0.000≤*p*≤0.000	Not Used
Greater kudu										
Tragelaphus strepsiceros	1.33	2.34	0.43	1.33	0.01	0.013	-0.010≤*p*≤0.057	No Pattern	-0.025≤*p*≤0.052	No Pattern
Impala										
Aepyceros melampus	1.33	0.16	-0.88	0.23	-0.83	0.013	-0.002≤*p*≤0.005	Not Used	-0.004≤*p*≤0.009	Not Used
Red hartebeest										
Alcelaphus caama	1.33	0.00	-1.00	0.00	-1.00	0.013	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Tsessebe										
Damaliscus lunatus	1.33	0.00	-1.00	0.00	-1.00	0.013	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	1.33	0.62	-0.52	0.60	-0.58	0.013	-0.003≤p≤0.015	No Pattern	-0.006≤p≤0.017	No Pattern
Waterbuck										
Kobus ellipsiprymnus	1.33	0.00	-1.00	0.00	-1.00	0.013	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	1.33	0.00	-1.00	0.00	-1.00	0.013	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used

Table 3.8. Preference Index and Bonferroni Z-statistic results for the selection of the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	2.74	2.10	-0.26	0.01	-0.62	0.027	-0.004≤*p*≤0.045	No Pattern	-0.020≤*p*≤0.042	No Pattern
Blue wildebeest										
Connochaetes taurinus taurinus	2.74	0.83	-0.70	0.00	-1.00	0.027	-0.016≤p≤0.033	No Pattern	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	2.74	2.11	-0.24	1.79	-0.36	0.027	0.005≤*p*≤0.037	No Pattern	-0.008≤*p*≤0.044	No Pattern
Eland										
Taurotragus oryx	2.74	9.09	0.69	16.67	0.83	0.027	0.001≤*p*≤0.180	No Pattern	-0.032≤*p*≤0.365	No Pattern
Gemsbok										
Oryx gazella	2.74	4.08	0.32	2.50	-0.11	0.027	-0.018≤*p*≤0.099	No Pattern	-0.047≤*p*≤0.097	No Pattern
Giraffe										
Giraffa camelopardalis	2.74	3.28	0.15	4.90	0.43	0.027	-0.006≤*p*≤0.071	No Pattern	-0.013≤*p*≤0.111	No Pattern
Greater kudu										
Tragelaphus strepsiceros	2.74	7.60	0.63	9.33	0.70	0.027	0.017≤*p*≤0.135	No Pattern	-0.005≤*p*≤0.191	No Pattern
Impala										
Aepyceros melampus	2.74	11.41	0.76	1.15	-0.59	0.026	0.088≤*p*≤0.140	Preferred	-0.003≤*p*≤0.027	Not Used
Red hartebeest										
Alcelaphus caama	2.74	0.74	-0.74	0.62	-0.78	0.027	-0.005≤*p*≤0.020	Not Used	-0.012≤*p*≤0.024	Not Used
Tsessebe										
Damaliscus lunatus	2.74	7.62	0.63	3.85	0.27	0.027	0.001≤p≤0.151	No Pattern	-0.039≤p≤0.116	No Pattern
Warthog										
Phacochoerus africanus	2.74	4.68	0.40	1.40	-0.50	0.027	0.022≤p≤0.071	No Pattern	-0.004≤p≤0.032	No Pattern
Waterbuck										
Kobus ellipsiprymnus	2.74	2.17	-0.22	0.00	-1.00	0.027	-0.023≤p≤0.066	No Pattern	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	2.74	7.46	0.63	15.63	0.82	0.027	-0.019≤p≤0.168	No Pattern	-0.031≤p≤0.344	No Pattern

Acacia karroo Low Thicket (Table 3.9)

According to the preference index the types of herbivores which showed a preference for the *Acacia karroo* Low thicket over the whole year were the blue wildebeest (*PI* = 0.12) and giraffe (*PI* = 0.13).

The types of herbivores which showed preference during the dry season were also the blue wildebeest (*PI* = 0.44) and giraffe (*PI* = 0.25).

The Bonferroni Z-statistic showed that no herbivores preferred the *Acacia karroo* Low Thicket over the whole year or during the dry season.

The *Burkea africana - Terminalia sericea* Low Thicket (Table 3.10)

According to the preference index the types of herbivores which showed a preference for the *Burkea africana - Terminalia sericea* Low Thicket over the whole year were the giraffe (*PI* = 0.14), greater kudu (*PI* = 0.19), impala (*PI* = 0.47) and waterbuck (*PI* = 0.16).

The types of herbivores which showed preference during the dry season were the blesbok (*PI* = 0.41), blue wildebeest (*PI* = 0.54), eland (*PI* = 0.29), gemsbok (*PI* = 0.34), giraffe (*PI* = 0.30), impala (*PI* = 0.40) and waterbuck (*PI* = 0.38).

The Bonferroni Z-statistic showed that impala preferred the *Burkea africana - Terminalia sericea* Low Thicket over the whole year. Blue wildebeest and impala preferred this vegetation community during the dry season. This was the only vegetation community which blue wildebeest selected during the dry season. Blue wildebeest accounted for 1.28% of the Browser Units (11.54 Browser Units) and 5.60% of the Grazing Units (64.38 Grazing Units).

Table 3.9. Preference Index and Bonferroni Z-statistic results for the selection of the *Acacia karroo* Low Thicket in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	9.38	0.30	-0.96	0.01	-0.89	0.094	-0.007≤*p*≤0.014	Not Used	-0.020≤*p*≤0.042	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	9.38	10.83	0.12	16.98	0.44	0.094	0.025≤p≤0.191	No Pattern	0.019≤p≤0.320	No Pattern
Burchell's zebra										
Equus burchelii	9.38	7.98	-0.16	10.27	0.07	0.094	0.049≤*p*≤0.111	No Pattern	0.043≤*p*≤0.162	No Pattern
Eland										
Taurotragus oryx	9.38	0.00	-1.00	0.00	-1.00	0.094	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	9.38	9.18	-0.04	0.00	-1.00	0.094	0.007≤*p*≤0.177	No Pattern	0.000≤*p*≤0.000	Not Used
Giraffe										
Giraffa camelopardalis	9.38	10.93	0.13	12.75	0.25	0.094	0.042≤*p*≤0.177	No Pattern	0.031≤*p*≤0.224	No Pattern
Greater kudu										
Tragelaphus strepsiceros	9.38	4.68	-0.51	1.33	-0.86	0.094	0.000≤*p*≤0.094	Not Used	-0.025≤*p*≤0.052	Not Used
Impala										
Aepyceros melampus	9.38	5.70	-0.40	9.47	-0.01	0.094	0.038≤*p*≤0.076	Not Used	0.054≤*p*≤0.136	No pattern
Red hartebeest										
Alcelaphus caama	9.38	6.90	-0.28	8.07	-0.15	0.094	0.032≤*p*≤0.106	No Pattern	0.018≤*p*≤0.143	No Pattern
Tsessebe										
Damaliscus lunatus	9.38	0.95	-0.90	1.92	-0.80	0.094	-0.018≤p≤0.037	Not Used	-0.036≤p≤0.075	Not Used
Warthog										
Phacochoerus africanus	9.38	4.52	-0.53	7.00	-0.26	0.094	0.021≤p≤0.069	Not Used	0.031≤p≤0.110	No Pattern
Waterbuck										
Kobus ellipsiprymnus	9.38	9.78	0.02	8.33	-0.13	0.094	0.007≤p≤0.188	No Pattern	-0.021≤p≤0.187	No Pattern
White rhinoceros										
Ceratotherium simum	9.38	0.00	-1.00	0.00	-1.00	0.094	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used

Table 3.10. Preference Index and Bonferroni Z-statistic results for the selection of the *Burkea africana - Terminalia sericea* Low Thicket in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	16.21	9.00	-0.45	0.28	0.41	0.162	0.041≤*p*≤0.139	Not Used	0.144≤*p*≤0.416	No Pattern
Blue wildebeest										
Connochaetes taurinus taurinus	16.21	16.67	0.01	35.85	0.54	0.162	0.067≤p≤0.266	No Pattern	0.166≤p≤0.551	Preferred
Burchell's zebra										
Equus burchelii	16.21	15.21	-0.08	11.16	-0.32	0.162	0.111≤*p*≤0.193	No Pattern	0.050≤*p*≤0.173	No Pattern
Eland										
Taurotragus oryx	16.21	15.91	-0.04	23.33	0.29	0.162	0.045≤*p*≤0.273	No Pattern	0.008≤*p*≤0.459	No Pattern
Gemsbok										
Oryx gazella	16.21	16.33	-0.01	25.00	0.34	0.162	0.054≤*p*≤0.272	No Pattern	0.050≤*p*≤0.450	No Pattern
Giraffe										
Giraffa camelopardalis	16.21	19.13	0.14	23.53	0.30	0.162	0.106≤*p*≤0.276	No Pattern	0.113≤*p*≤0.358	No Pattern
Greater kudu										
Tragelaphus strepsiceros	16.21	20.47	0.19	16.00	-0.03	0.162	0.115≤*p*≤0.295	No Pattern	0.036≤*p*≤0.284	No Pattern
Impala										
Aepyceros melampus	16.21	24.22	0.47	27.48	0.40	0.162	0.207≤*p*≤0.277	Preferred	0.212≤*p*≤0.338	Preferred
Red hartebeest										
Alcelaphus caama	16.21	4.68	-0.72	7.45	-0.55	0.162	0.016≤*p*≤0.077	Not Used	0.014≤*p*≤0.135	Not Used
Tsessebe										
Damaliscus lunatus	16.21	0.95	-0.94	0.00	-1.00	0.162	-0.018≤p≤0.037	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	16.21	15.29	-0.70	10.10	-0.39	0.162	0.111≤p≤0.194	No Pattern	0.055≤p≤0.148	Not Used
Waterbuck										
Kobus ellipsiprymnus	16.21	19.57	0.16	26.67	0.38	0.162	0.075≤p≤0.316	No Pattern	0.100≤p≤0.433	No Pattern
White rhinoceros										
Ceratotherium simum	16.21	8.96	-0.46	0.00	-1.00	0.162	-0.012≤p≤0.191	No Pattern	0.000≤p≤0.000	Not Used

Combretum apiculatum Short Open Woodland (Table 3.11)

According to the preference index the type of herbivore which showed a preference for the *Combretum apiculatum* Short Open Woodland over the whole year was the greater kudu (*PI* = 0.62)

The types of herbivores which showed preference during the dry season were the greater kudu (*PI* = 0.62) and Burchell's zebra (*PI* = 0.24).

The Bonferroni Z-statistic showed that no herbivores preferred the *Combretum apiculatum* Short Open Woodland over the whole year or during the dry season.

The *Combretum apiculatum* - *Acacia caffra* Short Open Woodland (Table 3.12)

According to the preference index the types of herbivores which showed a preference for the *Combretum apiculatum* - *Acacia caffra* Short Open Woodland over the whole year were the blue wildebeest (*PI* = 0.79), gemsbok (*PI* = 0.84) and white rhinoceros (*PI* = 0.22).

The types of herbivores which showed preference during the dry season were the gemsbok (*PI* = 0.93) and impala (*PI* = 0.61).

The *Combretum apiculatum* – *Acacia caffra* Short Open Woodland was preferred by gemsbok over the whole year according to the Bonferroni Z-statistic. This was the only vegetation community that gemsbok showed a preference for during this time period. The *Combretum apiculatum* – *Acacia caffra* Short Open Woodland was also preferred by gemsbok during the dry season. This was the only vegetation community that gemsbok selected during this time period.

Table 3.11. Preference Index and Bonferroni Z-statistic results for the selection of the *Combretum apiculatum* Short Open Woodland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	15.31	0.00	-1.00	0.00	-1.00	0.153	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	15.31	0.00	-1.00	0.00	-1.00	0.153	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	15.31	3.92	-0.03	5.36	0.24	0.153	0.017≤*p*≤0.061	Not Used	0.010≤*p*≤0.098	Not Used
Eland										
Taurotragus oryx	15.31	0.00	-1.00	0.00	-1.00	0.153	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	15.31	0.00	-1.00	0.00	-1.00	0.153	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Giraffe										
Giraffa camelopardalis	15.31	4.37	0.07	3.92	-0.03	0.153	0.000≤*p*≤0.088	Not Used	-0.017≤*p*≤0.095	Not Used
Greater kudu										
Tragelaphus strepsiceros	15.31	10.53	0.62	10.67	0.62	0.153	0.037≤*p*≤0.174	No Pattern	0.003≤*p*≤0.210	No Pattern
Impala										
Aepyceros melampus	15.31	0.78	-0.81	0.23	-0.94	0.153	0.001≤*p*≤0.015	Not Used	-0.004≤*p*≤0.009	Not Used
Red hartebeest										
Alcelaphus caama	15.31	0.99	-0.76	0.00	-1.00	0.153	-0.004≤*p*≤0.024	Not Used	0.000≤*p*≤0.000	Not Used
Tsessebe										
Damaliscus lunatus	15.31	0.00	-1.00	0.00	-1.00	0.153	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	15.31	0.47	-0.88	0.00	-1.00	0.153	-0.003≤p≤0.013	Not Used	0.000≤p≤0.000	Not Used
Waterbuck										
Kobus ellipsiprymnus	15.31	1.09	-0.73	1.67	-0.59	0.153	-0.021≤p≤0.042	Not Used	-0.032≤p≤0.065	Not Used
White rhinoceros										
Ceratotherium simum	15.31	0.00	-1.00	0.00	-1.00	0.153	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used

Table 3.12. Preference Index and Bonferroni Z-statistic results for the selection of the *Combretum apiculatum - Acacia caffra* Short Open Woodland by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	3.98	0.70	-0.70	0.00	-1.00	0.040	-0.007≤*p*≤0.021	Not Used	0.000≤*p*≤0.000	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	3.98	10.83	0.79	0.00	-1.00	0.040	0.025≤p≤0.191	No pattern	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	3.98	1.96	-0.16	0.00	-1.00	0.040	0.004≤*p*≤0.035	Not used	0.000≤*p*≤0.000	Not Used
Eland										
Taurotragus oryx	3.98	0.00	-1.00	0.00	-1.00	0.040	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	3.98	14.29	0.84	35.00	0.93	0.040	0.040≤*p*≤0.246	Preferred	0.130≤*p*≤0.570	Preferred
Giraffe										
Giraffa camelopardalis	3.98	0.00	-1.00	0.00	-1.00	0.040	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Greater kudu										
Tragelaphus strepsiceros	3.98	0.00	-1.00	0.00	-1.00	0.040	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Impala										
Aepyceros melampus	3.98	2.27	-0.03	6.00	0.61	0.040	0.011≤*p*≤0.035	Not used	0.027≤*p*≤0.093	No pattern
Red hartebeest										
Alcelaphus caama	3.98	0.25	-0.89	0.62	-0.73	0.040	-0.005≤*p*≤0.010	Not Used	-0.012≤*p*≤0.024	Not Used
Tsessebe										
Damaliscus lunatus	3.98	0.00	-1.00	0.00	-1.00	0.040	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	3.98	1.40	-0.40	1.40	-0.39	0.040	0.000≤p≤0.028	Not used	-0.004≤p≤0.032	Not used
Waterbuck										
Kobus ellipsiprymnus	3.98	0.00	-1.00	0.00	-1.00	0.040	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	3.98	2.99	0.22	0.00	-1.00	0.040	-0.031≤p≤0.091	No Pattern	0.000≤p≤0.000	Not Used

The *Eragrostis gummiflua* Low Closed Grassland (Table 3.13)

According to the preference index the types of herbivores which showed a preference for the *Eragrostis gummiflua* Low Closed Grassland over the whole year were the blesbok (*PI* = 0.74), Burchell's zebra (*PI* = 0.46), impala (*PI* = 0.18), red hartebeest (*PI* = 0.64), tsessebe (*PI* = 0.75) and white rhinoceros (*PI* = 0.34).

The types of herbivores which showed preference during the dry season were the blesbok (*PI* = 0.87), red hartebeest (*PI* = 0.56) and tsessebe (*PI* = 0.80).

The *Eragrostis gummiflua* Low Closed Grassland was preferred by blesbok, Burchell's zebra, red hartebeest and tsessebe over the whole year according to the Bonferroni Z-statistic. This vegetation community was preferred by blesbok, red hartebeest and tsessebe during the dry season.

The *Melinis repens* Low Closed Grassland (Table 3.14)

According to the preference index the types of herbivores which showed a preference for the *Melinis repens* Low Closed Grassland over the whole year were the blesbok (*PI* = 0.64), Burchell's zebra (*PI* = 0.32), eland (*PI* = 0.34), giraffe (*PI* = 0.25), red hartebeest (*PI* = 0.56), tsessebe (*PI* = 0.57) and warthog (*PI* = 0.66).

The types of herbivores which showed preference during the dry season were the eland (*PI* = 0.78), giraffe (*PI* = 0.19), red hartebeest (*PI* = 0.58), tsessebe (*PI* = 0.49), warthog (*PI* = 0.71), waterbuck (*PI* = 0.15) and white rhinoceros (*PI* = 0.49).

The *Melinis repens* Low Closed Grassland was preferred by blesbok, Burchell's zebra, red hartebeest, tsessebe, warthog and white rhinoceros over the whole year according to the Bonferroni Z-statistic. The *Melinis repens* Low Closed Grassland was preferred by eland, red hartebeest and warthog during the dry season.

Table 3.13. Preference Index and Bonferroni Z-statistic results for the selection of the *Eragrostis gummiflua* Low Closed Grassland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	7.77	30.10	0.74	0.59	0.87	0.078	0.222≤*p*≤0.380	Preferred	0.443≤*p*≤0.740	Preferred
Blue wildebeest										
Connochaetes taurinus taurinus	7.77	3.33	-0.06	1.89	-0.76	0.078	-0.015≤p≤0.081	No Pattern	-0.036≤p≤0.073	Not Used
Burchell's zebra										
Equus burchelii	7.77	14.76	0.46	7.59	-0.04	0.078	0.107≤*p*≤0.188	Preferred	0.024≤*p*≤0.128	No Pattern
Eland										
Taurotragus oryx	7.77	0.00	-1.00	0.00	-1.00	0.078	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	7.77	5.10	-0.35	2.50	-0.68	0.078	-0.014≤*p*≤0.116	No Pattern	-0.047≤*p*≤0.097	No Pattern
Giraffe										
Giraffa camelopardalis	7.77	2.73	-0.65	4.90	-0.38	0.078	-0.008≤*p*≤0.063	Not used	-0.013≤*p*≤0.111	No Pattern
Greater kudu										
Tragelaphus strepsiceros	7.77	2.34	-0.70	2.67	-0.66	0.078	-0.010≤*p*≤0.057	Not used	-0.028≤*p*≤0.081	No Pattern
Impala										
Aepyceros melampus	7.77	9.69	0.18	5.54	-0.30	0.078	0.073≤*p*≤0.121	No Pattern	0.023≤*p*≤0.880	No Pattern
Red hartebeest										
Alcelaphus caama	7.77	21.67	0.64	18.01	0.56	0.078	0.157≤*p*≤0.277	Preferred	0.092≤*p*≤0.269	Preferred
Tsessebe										
Damaliscus lunatus	7.77	31.43	0.75	40.38	0.80	0.078	0.182≤p≤0.447	Preferred	0.205≤p≤0.603	Preferred
Warthog										
Phacochoerus africanus	7.77	8.11	0.03	7.60	-0.04	0.078	0.050≤p≤0.113	No Pattern	0.035≤p≤0.117	No Pattern
Waterbuck										
Kobus ellipsiprymnus	7.77	8.70	0.09	0.00	-1.00	0.078	0.001≤p≤0.172	No Pattern	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	7.77	11.94	0.34	6.25	-0.21	0.078	0.004≤p≤0.235	No Pattern	-0.062≤p≤0.187	No Pattern

Table 3.14. Preference Index and Bonferroni Z-statistic results for the selection of the *Melinis repens* Low Closed Grassland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	12.48	35.60	0.64	0.01	-0.92	0.125	0.274≤*p*≤0.439	Preferred	-0.020≤*p*≤0.042	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	12.48	11.67	-0.08	5.66	-0.55	0.125	0.031≤p≤0.202	No Pattern	-0.036≤p≤0.149	No Pattern
Burchell's zebra										
Equus burchelii	12.48	18.67	0.32	11.16	-0.12	0.125	0.143≤*p*≤0.231	Preferred	0.050≤*p*≤0.173	No Pattern
Eland										
Taurotragus oryx	12.48	19.32	0.34	56.67	0.78	0.125	0.070≤*p*≤0.316	No Pattern	0.302≤*p*≤0.420	Preferred
Gemsbok										
Oryx gazella	12.48	4.08	-0.68	0.00	-1.00	0.125	-0.018≤*p*≤0.099	Not Used	0.000≤*p*≤0.000	Not Used
Giraffe										
Giraffa camelopardalis	12.48	16.94	0.25	15.69	0.19	0.125	0.088≤*p*≤0.250	No Pattern	0.052≤*p*≤0.262	No Pattern
Greater kudu										
Tragelaphus strepsiceros	12.48	2.34	-0.82	5.33	-0.58	0.125	-0.010≤*p*≤0.057	Not Used	-0.022≤*p*≤0.129	No Pattern
Impala										
Aepyceros melampus	12.48	13.36	0.05	13.86	0.08	0.125	0.106≤*p*≤0.161	No Pattern	0.090≤*p*≤0.187	No Pattern
Red hartebeest										
Alcelaphus caama	12.48	28.82	0.56	30.43	0.58	0.125	0.223≤*p*≤0.354	Preferred	0.198≤*p*≤0.410	Preferred
Tsessebe										
Damaliscus lunatus	12.48	29.52	0.57	25.00	0.49	0.125	0.165≤p≤0.425	Preferred	0.075≤p≤0.425	No Pattern
Warthog										
Phacochoerus africanus	12.48	37.44	0.66	43.70	0.71	0.125	0.319≤p≤0.430	Preferred	0.360≤p≤0.514	Preferred
Waterbuck										
Kobus ellipsiprymnus	12.48	9.78	-0.23	15.00	0.15	0.125	0.007≤p≤0.188	No Pattern	0.015≤p≤0.285	No Pattern
White rhinoceros										
Ceratotherium simum	12.48	35.82	0.65	25.00	0.49	0.125	0.187≤p≤0.529	Preferred	0.026≤p≤0.474	No Pattern

The *Terminalia sericea - Acacia caffra* Low Open Woodland (Table 3.15)

According to the preference index the types of herbivores which showed a preference for the *Terminalia sericea - Acacia caffra* Low Open Woodland over the whole year were the Burchell's zebra (*PI* = 0.57), gemsbok (*PI* = 0.83), red hartebeest (*PI* = 0.61) and white rhinoceros (*PI* = 0.86).

The types of herbivores which showed preference during the dry season were the blesbok (*PI* = 0.43), blue wildebeest (*PI* = 0.35), Burchell's zebra (*PI* = 0.75), gemsbok (*PI* = 0.93), impala (*PI* = 0.41), red hartebeest (*PI* = 0.85), white rhinoceros (*PI* = 0.93).

The *Terminalia sericea - Acacia caffra* Low Open Woodland was preferred by red hartebeest during the dry season according to the Bonferroni Z-statistic. No herbivores selected this vegetation community during the whole year.

The *Terminalia sericea - Acacia* species Low Thicket (Table 3.16)

According to the preference index the types of herbivores which showed a preference for the *Terminalia sericea - Acacia species* Low Thicket over the whole year were the blue wildebeest (*PI* = 0.26) and giraffe (*PI* = 0.24).

The types of herbivores which showed preference during the dry season were the greater kudu (*PI* = 0.34) and impala (*PI* = 0.19).

The Bonferroni Z-statistic showed that no herbivores preferred *Terminalia sericea - Acacia species* Low Thicket over the whole year or during the dry season.

Table 3.15. Preference Index and Bonferroni Z-statistic results for the selection of the *Terminalia sericea - Acacia caffra* Low Open Woodland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	1.21	0.70	-0.44	0.02	0.43	0.012	-0.007≤*p*≤0.021	No Pattern	-0.022≤*p*≤0.065	No Pattern
Blue wildebeest										
Connochaetes taurinus taurinus	1.21	0.83	-0.33	1.89	0.35	0.012	-0.016≤p≤0.033	No Pattern	-0.036≤p≤0.073	No Pattern
Burchell's zebra										
Equus burchelii	1.21	2.86	0.57	4.91	0.75	0.012	0.010≤*p*≤0.048	No Pattern	0.007≤*p*≤0.091	No Pattern
Eland										
Taurotragus oryx	1.21	0.00	-1.00	0.00	-1.00	0.012	0.000≤*p*≤0.000	Not Used	-0.022≤*p*≤0.065	No pattern
Gemsbok										
Oryx gazella	1.21	7.14	0.83	17.50	0.93	0.012	-0.005≤*p*≤0.147	No Pattern	0.000≤*p*≤0.350	No Pattern
Giraffe										
Giraffa camelopardalis	1.21	0.00	-1.00	0.00	-1.00	0.012	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Greater kudu										
Tragelaphus strepsiceros	1.21	0.58	-0.53	1.33	0.07	0.012	-0.011≤*p*≤0.023	No Pattern	-0.025≤*p*≤0.052	No Pattern
Impala										
Aepyceros melampus	1.21	0.86	-0.31	2.08	0.41	0.012	0.001≤*p*≤0.016	No Pattern	0.001≤*p*≤0.041	No Pattern
Red hartebeest										
Alcelaphus caama	1.21	3.20	0.61	8.07	0.85	0.012	0.007≤*p*≤0.058	No Pattern	0.018≤*p*≤0.143	Preferred
Tsessebe										
Damaliscus lunatus	1.21	0.00	-1.00	0.00	-1.00	0.012	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	1.21	0.78	-0.37	0.80	-0.32	0.012	-0.002≤p≤0.018	No Pattern	-0.006≤p≤0.023	No Pattern
Waterbuck										
Kobus ellipsiprymnus	1.21	0.00	-1.00	0.00	-1.00	0.012	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	1.21	8.96	0.86	18.75	0.93	0.012	-0.012≤p≤0.191	No Pattern	-0.014≤p≤0.389	No Pattern

Table 3.16. Preference Index and Bonferroni Z-statistic results for the selection of the *Terminalia sericea - Acacia species* Low Thicket in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	6.10	0.00	-1.00	0.00	-1.00	0.061	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	6.10	8.33	0.26	0.00	-1.00	0.061	0.010≤p≤0.157	No Pattern	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	6.10	1.05	-0.83	2.68	-0.57	0.061	-0.00≤*p*≤0.022	Not Used	-0.005≤*p*≤0.058	Not Used
Eland										
Taurotragus oryx	6.10	0.00	-1.00	0.00	-1.00	0.061	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	6.10	0.00	-1.00	0.00	-1.00	0.061	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Giraffe										
Giraffa camelopardalis	6.10	8.20	0.24	1.96	-0.68	0.061	0.023≤*p*≤0.141	No Pattern	-0.020≤*p*≤0.060	Not Used
Greater kudu										
Tragelaphus strepsiceros	6.10	1.75	-0.72	9.33	0.34	0.061	-0.012≤*p*≤0.047	Not used	-0.005≤p≤0.191	No Pattern
Impala										
Aepyceros melampus	6.10	5.16	-0.17	7.62	0.19	0.061	0.034≤*p*≤0.070	No Pattern	0.039≤*p*≤0.113	No Pattern
Red hartebeest										
Alcelaphus caama	6.10	0.49	-0.92	1.24	-0.80	0.061	-0.005≤*p*≤0.015	Not Used	-0.013≤*p*≤0.038	Not Used
Tsessebe										
Damaliscus lunatus	6.10	0.00	-1.00	0.00	-1.00	0.061	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	6.10	3.28	-0.47	4.50	-0.27	0.061	0.012≤p≤0.053	Not Used	0.013≤p≤0.077	No Pattern
Waterbuck										
Kobus ellipsiprymnus	6.10	6.52	0.05	0.00	-1.00	0.061	-0.010≤p≤0.140	No Pattern	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	6.10	0.00	-1.00	0.00	-1.00	0.061	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used

The *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland (Table 3.17)

According to the preference index the types of herbivores which showed a preference for the *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland over the whole year were the greater kudu (*PI* = 0.12), red hartebeest (*PI* = 0.58), tsessebe (*PI* = 0.31) and waterbuck (*PI* = 0.59).

The types of herbivores which showed preference during the dry season were the tsessebe (*PI* = 0.58) and waterbuck (*PI* = 0.73).

The *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland was preferred by red hartebeest over the whole year according to the Bonferroni Z-statistic. This vegetation community was preferred by waterbuck during the dry season.

The *Terminalia sericea – Seriphium plumosum* Short Bushland (Table 3.18)

According to the preference index the types of herbivores which showed a preference for the *Terminalia sericea - Seriphium plumosum* Short Bushland over the whole year were the giraffe (*PI* = 0.48), impala (*PI* = 0.41) and warthog (*PI* = 0.90).

The types of herbivores which showed preference during the dry season were the greater kudu (*PI* = 0.36), warthog (*PI* = 0.45) and white rhinoceros (*PI* = 0.18).

The Bonferroni Z-statistic showed that impala showed preference for the *Terminalia sericea - Seriphium plumosum* Short Bushland over the whole year, but no wildlife species preference during the dry season.

Table 3.17. Preference Index and Bonferroni Z-statistic results for the selection of the *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	7.09	4.80	-0.33	0.00	-1.00	0.071	0.012≤*p*≤0.085	No Pattern	0.000≤*p*≤0.000	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	7.09	7.50	0.04	0.00	-1.00	0.071	0.005≤p≤0.145	No Pattern	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	7.09	3.77	-0.48	7.14	-0.01	0.071	0.016≤*p*≤0.059	Not Used	0.021≤*p*≤0.122	No Pattern
Eland										
Taurotragus oryx	7.09	0.00	-1.00	0.00	-1.00	0.071	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	7.09	1.02	-0.86	0.00	-1.00	0.071	-0.19≤*p*≤0.398	No pattern	0.000≤*p*≤0.000	Not Used
Giraffe										
Giraffa camelopardalis	7.09	6.56	-0.09	7.84	0.08	0.071	0.012≤*p*≤0.119	No Pattern	0.001≤*p*≤0.156	No Pattern
Greater kudu										
Tragelaphus strepsiceros	7.09	8.19	0.12	8.00	0.01	0.071	0.021≤*p*≤0.143	No Pattern	-0.011≤*p*≤0.172	No Pattern
Impala										
Aepyceros melampus	7.09	3.48	-0.55	4.39	-0.39	0.071	0.018≤*p*≤0.047	Not Used	0.015≤*p*≤0.073	No Pattern
Red hartebeest										
Alcelaphus caama	7.09	17.00	0.58	6.21	-0.14	0.071	0.116≤*p*≤0.224	Preferred	0.007≤*p*≤0.118	No Pattern
Tsessebe										
Damaliscus lunatus	7.09	10.48	0.31	17.31	0.58	0.071	0.017≤p≤0.192	No Pattern	0.020≤p≤0.326	No Pattern
Warthog										
Phacochoerus africanus	7.09	5.30	-0.26	5.90	-0.18	0.071	0.027≤p≤0.079	No Pattern	0.017≤p≤0.085	No Pattern
Waterbuck										
Kobus ellipsiprymnus	7.09	17.39	0.59	26.67	0.73	0.071	0.059≤p≤0.289	No Pattern	0.100≤p≤0.433	Preferred
White rhinoceros										
Ceratotherium simum	7.09	1.49	-0.79	0.00	-1.00	0.071	-0.028≤p≤0.058	Not Used	0.000≤p≤0.000	Not Used

Table 3.18. Preference Index and Bonferroni Z-statistic results for the selection of the *Terminalia sericea – Seriphium plumosum* Short Bushland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	2.51	0.00	-1.00	0.00	-1.00	0.025	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	2.51	0.00	-1.00	0.00	-1.00	0.025	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	2.55	0.00	-1.00	0.00	-1.00	0.025	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Eland										
Taurotragus oryx	2.51	0.00	-1.00	0.00	-1.00	0.025	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	2.51	1.02	-0.60	2.50	-0.02	0.025	-0.19≤*p*≤0.398	No Pattern	-0.047≤*p*≤0.097	No Pattern
Giraffe										
Giraffa camelopardalis	2.51	4.92	0.48	0.00	-1.00	0.025	0.003≤*p*≤0.096	No Pattern	0.000≤*p*≤0.000	Not Used
Greater kudu										
Tragelaphus strepsiceros	2.51	2.34	-0.08	4.00	0.36	0.025	-0.10≤*p*≤0.057	No Pattern	-0.026≤*p*≤0.106	No Pattern
Impala										
Aepyceros melampus	2.51	4.30	0.41	1.85	-0.28	0.025	0.026≤*p*≤0.060	Preferred	0.000≤*p*≤0.037	No Pattern
Red hartebeest										
Alcelaphus caama	2.51	0.74	-0.71	0.00	-1.00	0.025	-0.005≤*p*≤0.020	Not Used	0.000≤*p*≤0.000	Not Used
Tsessebe										
Damaliscus lunatus	2.55	0.00	-1.00	0.00	-1.00	0.025	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	2.55	2.81	0.90	5.10	0.45	0.025	0.009≤p≤0.047	No Pattern	0.023≤p≤0.096	No Pattern
Waterbuck										
Kobus ellipsiprymnus	2.55	1.09	-0.57	0.00	-1.00	0.025	-0.021≤p≤0.042	No Pattern	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	2.55	1.49	-0.42	3.13	0.18	0.025	-0.028≤p≤0.058	No Pattern	-0.059≤p≤0.121	No Pattern

The *Terminalia sericea – Trachypogon spicatus* Short Open Grassland (Table 3.19)

According to the preference index, impala showed a preference for the *Terminalia sericea - Trachypogon spicatus* Short Open Grassland over the whole year and during the dry season (*PI* = 0.55 & *PI* = 0.85 respectively).

The Bonferroni Z-statistic showed that no herbivores preferred *Terminalia sericea - Trachypogon spicatus* Short Open Grassland over the whole year or during the dry season.

Table 3.19. Preference Index and Bonferroni Z-statistic results for the selection of the *Terminalia sericea - Trachypogon spicatus* Short Open Grassland in the Mabula Game Reserve by wildlife from 2003 to 2004

		Preference Index					Bonferroni Z-statistic			
		Full year		Dry season			Full year		Dry season	
Herbivores	Percentage of total area	Percentage of use (*U*)	Preference Index (*PI*)	Percentage of use (*U*)	Preference Index (*PI*)	Proportion of total area	Confidence intervals	Habitat Use	Confidence intervals	Habitat use
Blesbok										
Damaliscus pygargus phillipsi	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Blue wildebeest										
Connochaetes taurinus taurinus	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Burchell's zebra										
Equus burchelii	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Eland										
Taurotragus oryx	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Gemsbok										
Oryx gazella	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Giraffe										
Giraffa camelopardalis	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Greater kudu										
Tragelaphus strepsiceros	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Impala										
Aepyceros melampus	0.28	0.63	0.55	1.85	0.85	0.003	0.000≤*p*≤0.013	No Pattern	0.000≤*p*≤0.037	No Pattern
Red hartebeest										
Alcelaphus caama	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤*p*≤0.000	Not Used	0.000≤*p*≤0.000	Not Used
Tsessebe										
Damaliscus lunatus	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Warthog										
Phacochoerus africanus	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
Waterbuck										
Kobus ellipsiprymnus	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used
White rhinoceros										
Ceratotherium simum	0.28	0.00	-1.00	0.00	-1.00	0.003	0.000≤p≤0.000	Not Used	0.000≤p≤0.000	Not Used

3.3.5 Browsing and Grazing Units for each vegetation community

Tables 2.20 to 2.23 show the actual number of browsing and grazing units represented by each of the herbivores which showed preference for a vegetation community according to the Bonferroni Z-statistic. The tables are separated into Browser and Grazing Units for both time periods.

If a herbivore only selected one vegetation community, then the Browser and Grazing Units for that herbivore were used as the number of units which may have occurred on that vegetation community. Where a herbivore selected more than one vegetation community, its Browser and Grazing Units were divided up between the vegetation communities selected in proportion to the sizes of the vegetation communities.

Table 2.20. The Browser Units represented by the different herbivores that showed a preference according to the Bonferroni Z-statistic for each vegetation community over the whole year on Mabula Game Reserve from 2003 to 2004

Vegetation community	Blesbok	Blue wildebeest	Burchell's zebra	Eland	Gemsbok	Giraffe	Greater kudu	Impala	Red hartebeest	Tsessebe	Warthog	Waterbuck	White rhinoceros	Total
Acacia caffra - Faurea saligna Short Open Woodland	0.0	0.0	0.0	122.4	0.0	0.0	153.0	0.0	0.0	0.0	0.0	0.0	0.0	275.4
Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5	0.0	0.0	0.0	0.0	0.0	19.5
Acacia karroo Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkea africana - Terminalia sericea Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	84.4	0.0	0.0	0.0	0.0	0.0	84.4
Combretum apiculatum Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combretum apiculatum - Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7
Eragrostis gummiflua Low Closed Grassland	2.6	0.0	14.6	0.0	0.0	0.0	0.0	0.0	9.7	22.3	0.0	0.0	0.0	49.2
Melinis repens Low Closed Grassland	4.3	0.0	24.2	0.0	0.0	0.0	0.0	0.0	16.2	37.1	59.4	0.0	0.0	141.2
Terminalia sericea - Acacia caffra Low Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Acacia species Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.3
Terminalia sericea – Seriphium plumosum Short Bushland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.1	0.0	0.0	0.0	0.0	0.0	19.1
Terminalia sericea - Trachypogon spicatus Short Open Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.9	0.0	38.8	122.4	0.0	0.0	153.0	123.0	25.9	59.4	59.4	0.0	0.0	609.8

Table 2.21. The Browser Units represented by the different herbivores that showed a preference according to the Bonferroni Z-statistic for each vegetation community over the dry season on Mabula Game Reserve from 2003 to 2004

Vegetation community	Blesbok	Blue wildebeest	Burchell's zebra	Eland	Gemsbok	Giraffe	Greater kudu	Impala	Red hartebeest	Tsessebe	Warthog	Waterbuck	White rhinoceros	Total
Acacia caffra - Faurea saligna Short Open Woodland	0.0	0.0	38.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	38.8
Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acacia karroo Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkea africana - Terminalia sericea Low Thicket	0.0	11.5	0.0	0.0	0.0	0.0	0.0	123.0	0.0	0.0	0.0	0.0	0.0	134.5
Combretum apiculatum Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combretum apiculatum - Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	10.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.7
Eragrostis gummiflua Low Closed Grassland	6.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.1	1.6	0.0	0.0	0.0	21.6
Melinis repens Low Closed Grassland	0.0	0.0	0.0	122.4	0.0	0.0	0.0	0.0	21.8	0.0	83.2	0.0	0.0	227.4
Terminalia sericea - Acacia caffra Low Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	0.0	0.0	0.0	0.0	1.4
Terminalia sericea - Acacia species Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.4	0.0	15.4
Terminalia sericea – Seriphium plumosum Short Bushland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Trachypogon spicatus Short Open Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	6.9	11.5	38.8	122.4	10.7	0	0	123	36.3	1.6	83.2	15.4	0	449.8

Table 2.22. The Grazing Units represented by the different herbivores that showed a preference according to the Bonferroni Z-statistic for each vegetation community over the whole year on Mabula Game Reserve from 2003 to 2004

Vegetation community	Blesbok	Blue wildebeest	Burchell's zebra	Eland	Gemsbok	Giraffe	Greater kudu	Impala	Red hartebeest	Tsessebe	Warthog	Waterbuck	White rhinoceros	Total
Acacia caffra - Faurea saligna Short Open Woodland	0.0	0.0	0.0	102.0	0.0	0.0	21.6	0.0	0.0	0.0	0.0	0.0	0.0	123.6
Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.0	0.0	0.0	0.0	0.0	12.0
Acacia karroo Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkea africana - Terminalia sericea Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.8	0.0	0.0	0.0	0.0	0.0	51.8
Combretum apiculatum Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combretum apiculatum - Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	42.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.1
Eragrostis gummiflua Low Closed Grassland	19.4	0.0	159.6	0.0	0.0	0.0	0.0	0.0	22.7	9.0	0.0	0.0	0.0	210.7
Melinis repens Low Closed Grassland	32.3	0.0	265.2	0.0	0.0	0.0	0.0	0.0	37.7	15.0	83.2	0.0	104.5	537.8
Terminalia sericea - Acacia caffra Low Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Acacia species Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.1	0.0	0.0	0.0	0.0	24.1
Terminalia sericea – Seriphium plumosum Short Bushland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.7	0.0	0.0	0.0	0.0	0.0	11.7
Terminalia sericea - Trachypogon spicatus Short Open Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	51.7	0.0	424.8	102.0	42.1	0.0	21.6	75.5	84.5	24.0	83.2	0.0	104.5	1013.8

Table 2.23. The Grazing Units represented by the different herbivores that showed a preference according to the Bonferroni Z-statistic for each vegetation community over the dry season on Mabula Game Reserve from 2003 to 2004

Vegetation community	Blesbok	Blue wildebeest	Burchell's zebra	Eland	Gemsbok	Giraffe	Greater kudu	Impala	Red hartebeest	Tsessebe	Warthog	Waterbuck	White rhinoceros	Total
Acacia caffra - Faurea saligna Short Open Woodland	0.0	0.0	424.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	424.8
Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Acacia karroo Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Burkea africana - Terminalia sericea Low Thicket	0.0	64.4	0.0	0.0	0.0	0.0	0.0	75.5	0.0	0.0	0.0	0.0	0.0	139.9
Combretum apiculatum Short Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Combretum apiculatum - Acacia caffra Short Open Woodland	0.0	0.0	0.0	0.0	42.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	42.1
Eragrostis gummiflua Low Closed Grassland	51.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.6	23.9	0.0	0.0	0.0	106.3
Melinis repens Low Closed Grassland	0.0	0.0	0.0	102.0	0.0	0.0	0.0	0.0	50.8	0.0	83.2	0.0	0.0	236.0
Terminalia sericea - Acacia caffra Low Open Woodland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0	3.2
Terminalia sericea - Acacia species Low Thicket	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	68.4	0.0	68.4
Terminalia sericea – Seriphium plumosum Short Bushland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Terminalia sericea - Trachypogon spicatus Short Open Grassland	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	51.8	64.4	424.8	102.0	42.1	0.0	0.0	75.5	84.6	23.9	83.2	68.4	0.0	1020.7

3.4 DISCUSSION

3.4.1 Statistical analysis

The preference index gave a general indication of the large herbivores that utilise the different habitats on Mabula Game Reserve (Table 3.24) and was used in conjunction with the Bonferroni Z-statistic as is discussed below.

According to the Chi-square values all herbivores, except giraffe, showed that utilisation did not occur in proportion to availability. Therefore only the giraffe utilised the vegetation communities in proportion to their availability (size). This was also evident in the Bonferroni Z-statistic, as giraffe showed no preference for any of the vegetation communities. The Bonferroni Z-statistic results indicated the preference for particular vegetation communities by the large herbivores (other than giraffe) (Table 3.25). The terms 'selected' or 'not selected' will be used where the Bonferroni Z-statistic did or did not, respectively, indicate a preference.

Where the preference index showed a positive value above 0.1, but the Bonferroni Z-statistic showed that a vegetation community was not selected by an individual herbivore, the vegetation community was then generally utilised by the herbivore. This is important to identify because the herbivore is adding to the browsing and grazing pressure on that vegetation community. This is also important when a vegetation community is not specifically selected for, but is utilised by many large herbivores. Additionally, large herbivores may change their preference for vegetation communities over time. The combination of the two methods can potentially give an indication of this change.

3.4.2 Comparison of the documented natural habitats of large herbivores to habitats selected by the herbivores on the Mabula Game Reserve.

The blesbok *Damaliscus pygargus phillipsi* not originally found in this region. This herbivore is endemic to the grasslands of South African Highveld (Estes 1996, Skinner & Smithers 1990). The blesbok on Mabula Game Reserve selected the *Melinis repens* Low Closed Grassland and the *Eragrostis gummiflua* Low Closed Grassland communities

and therefore were selecting a habitat similar to their natural habitat. Blesbok also utilised the *Terminalia sericea – Acacia caffra* Low Open Woodland. However this vegetation community borders the *Eragrostis gummiflua* Low Closed Grassland in the southeastern section of the reserve.

Blue wildebeest *Connochaetes taurinus taurinus* did originally occur in this region and their natural habitat is open woodlands associated with *Acacia* species and *Spirostachys africana* in East Africa. The blue wildebeest on Mabula Game Reserve selected the *Combretum apiculatum – Acacia caffra* Short Open Woodland, which is their natural habitat. Blue wildebeest also utilised the *Acacia caffra – Faurea saligna* Short Open Woodland and the *Terminalia sericea – Acacia caffra* Low Open Woodland. Blue wildebeest naturally occur on short-grass areas during the dry season (Skinner & Smithers 1990). This was not evident on Mabula Game Reserve as no grassland communities were specifically selected or utilised. Blue wildebeest also generally utilised three Low Thicket communities, which conforms to Estes's (1997) habitat description of *Acacia* savannas.

Burchell's zebra *Equus burchelli* also originally occurred in this region. This wildlife species inhabits open areas of woodland, open scrub and grassland. The Burchell's zebra on Mabula Game Reserve selected the *Melinis repens* Low Closed Grassland and the *Eragrostis gummiflua* Low Closed Grassland over the whole year. They preferred the *Acacia caffra – Faurea saligna* Short Open Woodland during the dry season. Burchell's zebra utilised three other woodland communities and one thicket community. Although Burchell's zebra have a great adaptive flexibility, they have a definite choice of habitat (Skinner & Smithers 1990), which was evident on Mabula Game Reserve.

Eland *Taurotragus oryx* were originally spread throughout southern Africa and may have occurred in this region. They are highly versatile in their habitat selection (Skinner & Smithers 1990). This can be seen with the common eland on Mabula Game Reserve, where grassland, woodland and thicket communities were utilised. Eland only selected the *Acacia caffra – Faurea saligna* Short Open Woodland over the whole year and the *Melinis repens* Short Closed Grassland during the dry season. According to Estes

Table 3.24. Summary of the types of herbivores which have a positive Preference Index value > 0.10 for the different vegetation communities over the whole year (Y) and the dry season (DS) on Mabula Game Reserve from 2003 to 2004

	Acacia caffra - *Faurea saligna* Short Open Woodland		*Acacia caffra* Short Open Woodland		*Acacia karroo* - *Acacia robusta* - *Euclea undulata* Short Closed Low Thicket		*Acacia karroo* Low Thicket		*Burkea africana* - *Terminalia sericea* Low Thicket		*Combretum apiculatum* Short Open Woodland		*Combretum apiculatum* - *Acacia caffra* Short Open Woodland		*Eragrostis gummiflua* Low Closed Grassland		*Melinis repens* Low Closed Grassland		*Terminalia sericea* - *Acacia caffra* Low Open Woodland		*Terminalia sericea* - *Acacia* species Low Thicket		*Terminalia sericea* - *Hyperthelia dissoluta* Tall Closed Grassland		*Terminalia sericea* – *Seriphium plumosum* Short Bushland		*Terminalia sericea* - *Trachypogon spicatus* Short Open Grassland	
Species	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS
Blesbok										■					■	■	■			■								
Blue wildebeest	■	■					■	■		■			■							■	■							
Burchell's zebra		■	■									■			■		■		■	■								
Common eland	■		■		■	■				■							■	■										
Gemsbok	■				■					■			■	■					■	■								
Giraffe					■	■	■	■	■	■							■	■			■				■			
Greater kudu	■	■	■	■	■	■			■		■	■										■	■			■		
Impala					■				■	■				■	■					■		■			■		■	■
Red hartebeest															■	■	■	■	■	■			■					
Tsessebe					■	■									■	■	■	■					■	■				
Warthog					■												■	■							■	■		
Waterbuck									■	■								■					■	■				
White rhinoceros		■			■	■							■		■		■	■	■	■						■		

Table 3.25. Summary of the types of herbivores which showed preference (selected) for the different vegetation communities over the whole year (Y) and the dry season (DS) on Mabula Game Reserve from 2003 to 2004

	Acacia caffra - Faurea saligna Short Open Woodland		*Acacia caffra* Short Open Woodland		*Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket		*Acacia karroo* Low Thicket		*Burkea africana - Terminalia sericea* Low Thicket		*Combretum apiculatum* Short Open Woodland		*Combretum apiculatum - Acacia caffra* Short Open Woodland		*Eragrostis gummiflua* Low Closed Grassland		*Melinis repens* Low Closed Grassland		*Terminalia sericea - Acacia caffra* Low Open Woodland		*Terminalia sericea - Acacia* species Low Thicket		*Terminalia sericea - Hyperthelia dissoluta* Tall Closed Grassland		*Terminalia sericea – Seriphium plumosum* Short Bushland		*Terminalia sericea - Trachypogon spicatus* Short Open Grassland	
Species	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS	Y	DS
Blesbok																												
Blue wildebeest																												
Burchell's zebra																												
Common eland																												
Gemsbok																												
Giraffe																												
Greater kudu																												
Impala																												
Red hartebeest																												
Tsessebe																												
Warthog																												
Waterbuck																												
White rhinoceros																												

(1997) and Skinner and Smithers (1990) pure grasslands are not a preferred habitat. Eland are found in small herds and form groups during the mating period (Skinner & Smithers 1990) therefore the recording of all the eland in one place during the survey has potentially corrupted the results during this time period. Future monitoring of this herbivore will determine whether this grassland community is actually selected by the eland.

Gemsbok *Oryx gazella* did not originally occur in this region and are found in arid biomes in South Africa and in the savannas of East Africa and Zimbabwe (Estes 1996). Gemsbok occur in open grassland, open bush savanna and light open woodland (Skinner & Smithers 1990). The gemsbok on Mabula Game Reserve selected the *Combretum apiculatum – Acacia caffra* Short Open Woodland and utilised two other open woodland communities, which are similar to their natural habitat. They did not select the grassland communities, which may be due to the high concentration of other herbivores in these communities. Gemsbok utilised the *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thicket, which is not their natural habitat.

Giraffe *Giraffa camelopardalis* did originally occur in this region. They are naturally associated with a wide variety of dry savanna vegetation types ranging from scrub to woodland. Giraffe are seldom found on grasslands (Skinner & Smithers 1990). The giraffe on Mabula Game Reserve did not select any particular vegetation community. This wildlife species utilised five thicket/bushland communities on the reserve which conforms to their natural habitat. They utilised one grassland community, although grasslands are not naturally preferred habitats. However the grassland community on Mabula Game Reserve contain *Acacia tortilis,* which is a preferred food for the giraffe on the reserve (Smallwood 2001).

Greater kudu *Tragelaphus strepsiceros* did originally occur in this region and are naturally associated with savanna woodland. They seldom occur on open grassland, but do so in clearings in woodlands (Skinner & Smithers 1990). Greater kudu disperse in deciduous woodland in the rainy season, as occurred on Mabula Game Reserve where they selected the *Acacia caffra – Faurea Saligna* Short Open Woodland over the whole year. They generally utilised two other open woodland communities and two thicket communities over the whole year. Greater kudu did not specifically select any vegetation communities during the dry season, but did utilise all the thicket/bush land communities, except the *Acacia karroo* Low Thicket. Most of

these thicket/bushland communities are associated with drainage lines. They also utilised the *Acacia caffra* Short Open Woodland during the dry season which is associated with the ridge of the mountain range running through the reserve. According to Estes (1996) greater kudu occur where the richest, most varied vegetation is found in the dry season, such as riparian areas and hillside bases. Greater kudu conformed to their natural habitat selection on Mabula Game Reserve, except for the utilization of scattered trees and shrubs on the *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland.

Impala *Aepyceros melampus* did originally occur to this region and are associated with woodland, preferring light open areas (Skinner & Smithers 1990). The impala on Mabula Game Reserve selected three different thicket/bushland communities. As thickets/bushland are not a natural habitat, further monitoring of this wildlife species is required to determine why this habitat selection has occurred. The impala did, however, utilise two woodland communities which conform with their natural habitat. Two grassland communities were utilised, which is also not a natural habitat for impala. One possible explanation is that impala occur in ecotones (Estes 1996).

Red hartebeest *Alcelapus caama* did not originally occur in this region. This wildlife species is associated predominantly with open country and occur on grassland of various types including floodplain grassland and vleis; in semi-desert bush savanna; and to a lesser extent in open woodland (Skinner & Smithers 1990). The red hartebeest on Mabula Game Reserve selected the three major grassland communities and one open woodland community, which conforms to their natural habitats. They did not utilise any other vegetation communities.

Tsessebe *Damalicus lunatus* did originally occur in this region. This wildlife species' natural habitats are grasslands in the arid and savanna biomes (Estes 1996). Tsessebe are known to favour the fringes of grassland and drainage lines (Skinner & Smithers 1990). The tsessebe on Mabula Game Reserve preferred the *Melinis repens* Low Closed Grassland and the *Eragrostis gummiflua* Low Closed Grassland. They also utilised the *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland and the *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thicket, which occurs along drainage lines. Therefore the tsessebe on the reserve selected and utilised habitats similar to their natural habitats.

Warthog *Phacochoerus africanus* did originally occur in this region. This wildlife species inhabits open woodland and bushland, short grassland, floodplains, vleis and open areas around waterholes and pans (Skinner & Smithers 1990). They avoid forests and dense undergrowth (Estes 1996). Although warthog have a variety of habitats, they only selected the *Melinis repens* Low Closed Grassland on Mabula Game Reserve. They utilised one other grassland community and two thicket/bushland communities.

Waterbuck *Kobus ellipsiprymnus* did originally occur in this region and its natural habitat is grassland close to water (Estes 1996). This was evident on Mabula Game Reserve as the waterbuck selected the *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland during the dry season and were generally located close to dams. They utilised two other grassland communities and three thicket communities associated with drainage lines.

The white rhinoceros *Ceratotherium simum simum* did originally occur in this region (Pienaar 1994). This herbivore inhabits savanna areas and occurs in wooded grasslands, with relatively flat terrain and in close proximity to water (Skinner & Smithers 1990). The white rhinoceros on Mabula Game Reserve only selected for the *Melinis repens* Low Closed Grassland, which meets their habitat requirements. They also utilised one other grassland community, three open woodland communities and two thicket/bushland communities.

3.4.3 Habitat selection of the vegetation communities in relation to utilization pressure of browsers and grazers.

The main purpose for determining the selection of vegetation communities by large herbivores was to determine the impact that these herbivores have on the different vegetation communities in relation to the monitoring of the grazing (Chapter 4) and browsing capacity (Chapter 5). The results of this chapter will be compared to those in the subsequent chapters. The browsing and grazing values that are used for each vegetation unit are estimates of the potential utilisation pressure and not the true values. The values are derived from individual herbivores which specifically selected the particular vegetation community. Additional browsing pressure will occur from herbivores which utilised, but did not select particular vegetation communities. It is important to note that the actual Browser and Grazing Units which occur on a

vegetation community will be higher than the current estimates. Therefore, these results are useful for identifying potentially overutilised vegetation communities.

The *Melinis repens* Low Closed Grassland and the *Eragrostis gummiflua* Low Closed Grassland were the most heavily utilised vegetation communities. The *Melinis repens* Low Closed Grassland vegetation community was selected by seven herbivores for both time periods covered in this study. This vegetation community was further utilised but not selected by a few other herbivores. The *Eragrostis gummiflua* Low Closed Grassland was utilised by four herbivores. These herbivores were predominantly grazers. This vegetation community was utilised by another two herbivores during the two time periods. Combined, these grassland communities were preferred by nearly half of the total Grazing Units over the whole year. However, the grazing pressure substantially decreased during the dry season. These two vegetation communities were potentially overutilised and must be closely monitored for future management (see Chapters 4 & 5).

The *Acacia caffra – Faurea saligna* Short Open Woodland was selected by the eland and greater kudu over the whole year, and they did not select any other vegetation communities. These large herbivores account for 275.4 Browser Units, suggesting a strong browsing pressure. However, no browsers selected this vegetation community during the dry season. Only Burchell's zebra preferred this vegetation community in the dry season and they accounted for 424.75 Grazing Units. Therefore there is a potential for overgrazing, which will be discussed in Chapter 4. Only a few other herbivores utilised, without selecting, this vegetation community over the whole year and during the dry season. The *Acacia caffra – Faurea saligna* Short Open Woodland showed a strong utilisation by browsers and grazers. However, it was the largest vegetation community covering 24 % of the surface area of the game reserve.

The *Combretum apiculatum – Acacia caffra* Short Open Woodland was specifically selected by gemsbok over the whole year and the dry season. This herbivore accounts for 10.7 Browser Units and 42.08 Grazing Units. This is a relatively small vegetation community and therefore may be of importance for reserve management. This vegetation was utilised (but not selected) by the blue wildebeest and white rhinoceros.

The *Burkea africana – Terminalia sericea* Low Thicket was selected only by the impala over the whole year. Impala also selected two other vegetation communities

over the whole year, therefore an estimated 84.4 Browser Units and 51.8 Grazing Units utilise this vegetation community over the whole year. The *Burkea africana – Terminalia sericea* Low Thicket was selected by the blue wildebeest and impala during the dry season. This is the only vegetation community which both herbivores selected during this time period and together accounted for 134.5 Browser Units and 139.9 Grazing Units. The *Burkea africana – Terminalia sericea* Low Thicket was utilised (but not selected) by four herbivores over the whole year and five species during the dry season.

The *Terminalia sericea - Hyperthelia dissoluta* Tall Closed Grassland was selected by red hartebeest over the whole year, which also selected three other vegetation communities. Therefore an estimated 10.3 Browser Units and 24.1 Grazing Units utilise this vegetation community over the whole year. The waterbuck selected this vegetation community during the dry season, therefore an estimated 15.4 Browser Units and 68.4 Grazing Units utilise this vegetation community over the dry season. This vegetation community was utilised (but not selected) by four herbivores over the whole year and three during the dry season.

The *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thicket was selected by impala. As the impala also selected two other vegetation communities, an estimated 19.5 Browser Units and 12.0 Grazing Units utilise this vegetation community over the whole year. However, this vegetation community was utilised (but not selected) by an additional seven herbivores over the whole year which increased the utilisation of this community. Five species utilised (but did not select) this vegetation community during the dry period.

The *Terminalia sericea – Acacia caffra* Low Open Woodland was only selected by the red hartebeest in the dry season, accounting for 1.35 Browser Units and 3.16 Grazing Units. Four wildlife species utilised (but did not select) this vegetation community over the whole year. Seven wildlife species utilised (but did not select) this vegetation community during the dry season. As this is a small vegetation community, there is potentially overutilisation during the dry season.

The *Terminalia sericea – Seriphium plumosum* Short Bushland was selected by the impala over the whole year accounting for 19.1 Browser Units and 24.1 Grazing Units. No herbivores selected this vegetation community during the dry season. Only

a few herbivores generally utilised this vegetation community during both time periods.

The *Acacia caffra* Short Open Woodland, the *Acacia karroo* Low Thicket, the *Combretum apiculatum* Short Open Woodland, *Terminalia sericea – Acacia* species Low Thicket and the *Terminalia sericea – Trachypogon spicatus* Short Open Grassland were not selected by any herbivores for the two time periods studied. These vegetation communities were utilised (but not selected) by many of the herbivores.

It is important to note that elephants have not been included in the habitat selection study due to the minimal amount of sightings during the surveys. There are 10 elephants on Mabula Game Reserve, which cause damage to the woody layer when feeding. They also knock down trees during social behaviour and when utilising the roots of plants (Anderson & Walker 1974). The long term impact of the elephants on Mabula Game Reserve will need to be properly addressed by reserve managers through specific studies of these large herbivores. There was also insufficient data to provide information of the habitat selection of buffalo and hippopotamus.

3.5 CONCLUSION

The methods that were used for the initial trial for the monitoring of large herbivores provided substantial information on the in selection of the vegetation communities on Mabula Game Reserve. The giraffe was the only herbivore which did not select specific vegetation communities on the reserve. All of the herbivores selected vegetation communities which are similar to their natural habitats, except the impala. When the habitat selection of all herbivores was compared to the individual vegetation communities, it was found that two of the vegetation communities were selected by seven of the 14 large herbivores. These vegetation communities were potentially being overgrazed and/or overbrowsed, which will be addressed in Chapters 4 and 5. Overutilisation of areas is of great concern for wildlife reserves, especially when wildlife populations are fenced into small reserves and can not move to other areas.

Chapter 4

MONITORING OF THE HERBACEOUS LAYER

4.1 INTRODUCTION

The assessment of veld condition was carried out by the determination of the quality of the herbaceous layer, in terms of its plant species composition, abundance of various species present and grass cover. Different species vary in nutrient composition and forage production. The species with a higher nutrient and forage production for longer periods of the year are needed for the optimal sustainable grazing capacity (Trollope *et al.* 1989, Tainton 1999). Species composition also reflects successional stages and rangeland degradation, indicating whether the veld has been over- or underutilised.

The assessment of the grazing capacity is therefore directly linked to veld condition. Management objectives can be developed which aim to improve the herbaceous layer through grazing and burning programmes (Trollope *et al.* 1989, Tainton 1999). Annual monitoring programmes enable the identification of changes in veld condition, which in turn will influence management decisions. The long-term collection of such data in combination with data collected from other monitoring and management systems such as burning programmes will help in the further understanding of savanna dynamics in terms of traditional successional models or event-driven dynamics.

One of the earlier analyses on veld condition in relation to succession, was conducted by Dyksterhuis (1949; In: Foran *et al.* 1978) on grassland, where the veld had degenerated back to a pioneer stage. This analysis established the notion of Decreasers, Increasers and Invader plant species. The method was called the Quantitative Climax Method and was later adopted as part of the assessment of three grasslands in KwaZulu-Natal by Foran *et al.* (1978). Further studies in KwaZulu-Natal by Tainton *et al.* (1980; In: Vorster 1982) classified species into Decreasers, Increasers I, Increasers II and Increasers III, based on the same principles. The Ecological Index Method is an adaptation of the method used by

Foran *et al.* (1978) and was developed specifically for the Karoo region (Vorster 1982). It is based on the principle that the veld in a certain topographical unit in a reasonably homogeneous farming area is measured against a benchmark on a similar topographical unit within the same area. Plant species in the homogeneous units are indexed according to their ecological status. The ecological groups for the Karoo areas are Decreasers; Increasers IIa, which occur due to moderate overgrazing; Increasers IIb, which occur due to heavy overgrazing; Increasers IIc, which occur due to excessive overgrazing; and Invaders, which are foreign and increase aggressively. The Increaser groups are less common in veld in excellent condition, where mainly Decreasers occur. A veld condition score is calculated by multiplying the percentage of each group with a weighted grazing value. The representative weightings for Decreasers: Increasers IIa; Increasers IIb: Increasers IIc: Invaders are 10:7:4:1:1. The veld condition score ranges from 0 (poor veld) to 1000 (excellent veld) (Vorster 1982).

The veld condition score is then compared to a benchmark on a percentage basis which gives a veld condition index. Danckwertz (1982) developed an equation to determine the stocking density of a vegetation community, using the veld condition index and rainfall. Grazing capacity describes the productivity of the grazeable portion of a vegetation community and the number of Grazing Units that can be sustained on a unit area of land (Danckwertz 1989a & b). Although it is argued by Trollope (1990) that this method is not completely accurate as it was developed for cattle production. It is however the most widely accepted method and does give a good indication of changes in the herbaceous layer for monitoring purposes. Danckwertz's (1982) equation was applied in the present study. Resent modification have been made to the method by Bothma *et al.* (2004), which were also used in this present study.

Fire is a naturally occurring event for the southern African savannas and grasslands. Fire is a primary tool for suspending successional development at an intermediate stage, which is preferable for antelope and other herbivores which have adapted to this successional stage (Tainton 1999). Fire is also a tool to combat bush encroachment (Tainton 1999), which poses a threat to the herbaceous layer, hence a threat to grazers. The development of a fire management programme is therefore essential in most savanna regions. Before fire regimes can be implemented the fuel loads (biomass) must be determined in order to assess whether there is enough fuel

for a fire to be sustained and to estimate how intense the fire will be. Other methods for determining the biomass are the comparative yield method and the dry mass rank method, which involve harvesting quadrates or strips and weighing the dried herbage (Kelly & McNeill 1980). These methods are fairly accurate, but also time consuming, labour intensive and expensive.

Monitoring of the herbaceous layer has been conducted on Mabula Game Reserve for the past 10 years. Serfontein (2007) assessed the changes in the veld condition score and grazing capacity that occurred during that period. In the present study additional monitoring techniques were investigated which could supplement the information gained from the current monitoring programme. A method to determine grass cover was introduced into the existing monitoring method to improve the determination of grazing capacity by applying the equation developed by Bothma *et al.* (2004). The disc-pasture meter method for estimating the biomass of the herbaceous layer was also incorporated. The latter information is required before implementing burning programmes (Trollope & Potgieter 1986).

4.2 METHODS

The descending point method (Novellie & Strydom 1987) was used for data collection on the herbaceous layer. It is similar to the step point method (Mentis 1981) which is commonly used to monitor the herbaceous layer. Instead of randomly collecting data, the method, however, involves a transect marked out by permanent steel posts. A steel measuring tape is run between that is five posts. This ensures that the method is repeatable from year to year, with a directly comparable data set. The total length of the transect is 200 m. The plant species which intersected the tape at each metre mark was recorded. If no plant intersected the tape at that particular point, the first plant which intersected the tape from the point back along the tape for 0.5 m was recorded. If no plant was encountered before the 0.5 m cut-off, no plant was recorded for that point. There are 48 grass monitoring sites across the reserve (Figure 4.1). The grass monitoring sites are distributed across 10 of the 14 vegetation communities, with five vegetation communities containing 35 of the sites (Table 4.1).

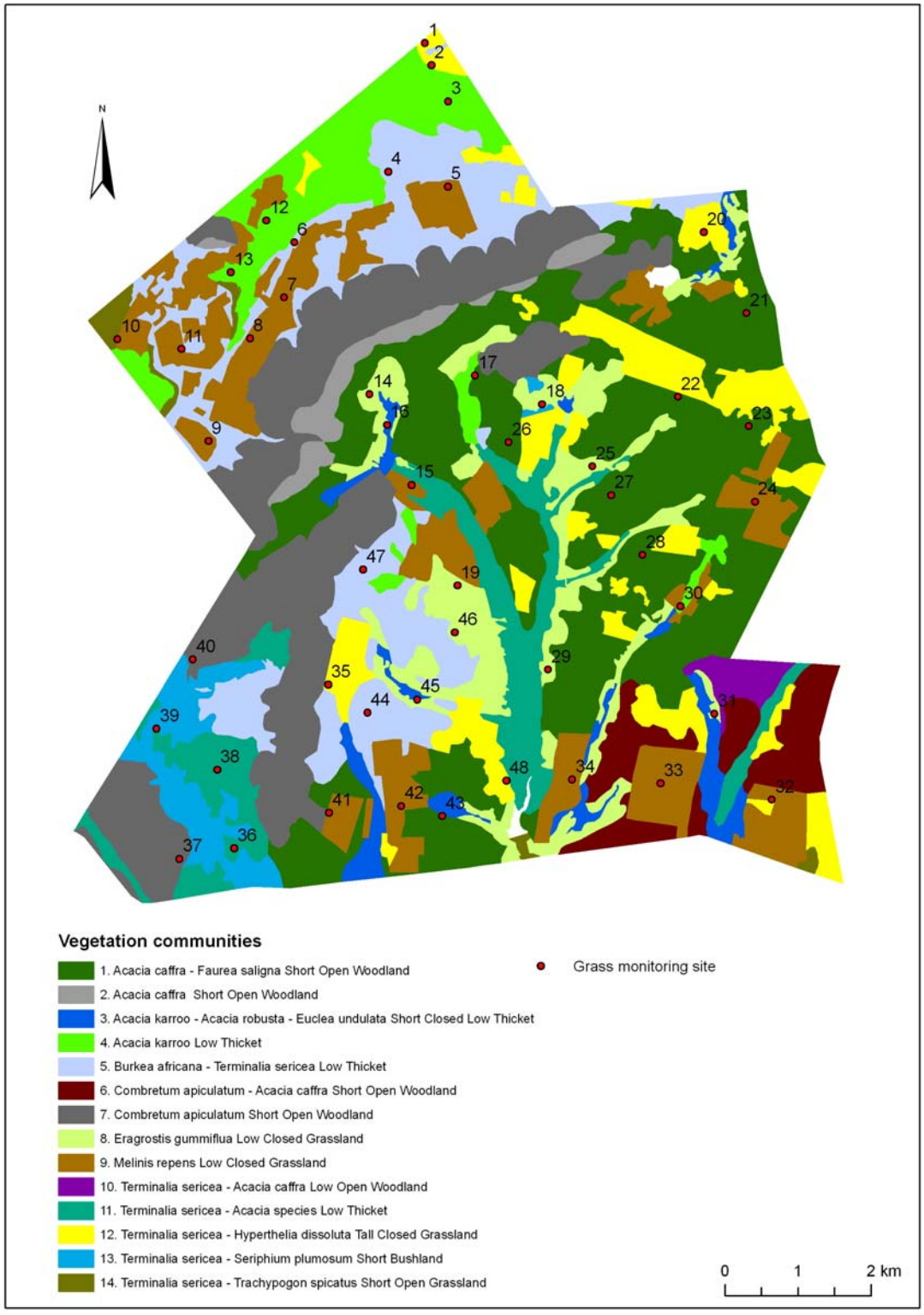


Figure 4.1. The distribution of the grass monitoring sites across the vegetation communities on Mabula Game Reserve from 1998 to present.

Table 4.1. The distribution of the existing 48 grass monitoring sites across the vegetation communities on Mabula Game Reserve

Vegetation community	Monitoring sites	Total
Acacia caffra - Faurea saligna Short Open Woodland	21,22,23,26,27,28	6
Acacia caffra Short Open Woodland	-	0
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	43,45	2
Acacia karroo Low Thicket	3,12,13,17,30	5
Burkea africana - Terminalia sericea Low Thicket	4,6,9,35,44,47	6
Combretum apiculatum Short Open Woodland	37,40	2
Combretum apiculatum - Acacia caffra Short Open Woodland	-	0
Eragrostis gummiflua Low Closed Grassland	14,16,18,19,25,29,31,46	8
Melinis repens Low Closed Grassland	5,7,8,10,11,15,24,32,33,34,41,42	12
Terminalia sericea - Acacia caffra Low Open Woodland	-	0
Terminalia sericea - Acacia species Low Thicket	36,38	2
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	1,2,20,48	4
Terminalia sericea - Seriphium plumosum Short Bushland	39	1
Terminalia sericea - Trachypogon spicatus Short Open Grassland	-	0

4.2.1 Veld condition score

The grass species that were identified in the transects were classified into the following ecological categories which are based on their reaction to utilisation (Van Rooyen 2002a):

- Decreasers – species that decrease with over- or underutilisation
- Increaser I – species that increase with underutilisation
- Increaser IIa – species that increase with moderate overutilisation
- Increaser IIb – species that increase with excessive overutilisation
- Increaser IIc – species that increase with extensive overutilisation
- Herbs – non-grass herbaceous species

Each category has the following relative forage value, and the species were weighted accordingly (Van Rooyen 2002b):

- Decreasers – 10
- Increaser I – 7
- Increaser IIa – 5
- Increaser IIb – 4
- Increaser IIc – 1
- Herbs – 1

The frequency of each species is determined by the following equation (Van Rooyen 2002b):

$$\text{Percentage frequency} = \frac{\text{Number of nearest recordings of a species x 100}}{\text{Total number of points (200)}}$$

The percentage frequency of all the grass species belonging to an ecological category is summed and then multiplied by its respective forage value. The sum of all weighted ecological categories gives the veld condition score which was evaluated by using the following scale (Van Rooyen 2002b):

- 0 to 399 – poor veld condition
- 400 to 599 – moderate veld condition
- 600 to 1000 – good veld condition

4.2.2 Grazing capacity

The veld condition score and the mean annual rainfall were applied to the Danckwertz (1989b) equation:

$$GC = (-0.03 + 0.00289\ X_1) + [(X_2 - 419.7) \times 0.000633]$$

Where: GC = Grazing capacity expressed in Large Stock Units per ha

X_1 = Percentage veld condition index

X_2 = Mean annual rainfall (mm)

419.7 = The mean annual rainfall for South African savannas (mm)

This is the basis for determining the stocking density of an area, based on the number of Live Stock Units an area can sustain. A Large Stock Unit is the grazing equivalent of one adult cow (250 kg).

Bothma *et al*.'s (2004) equation

The following equation developed by Bothma *et al*. (2004) for the determination of the grazing capacity expands on the equation developed by Danckwertz (1989b):

$$GU/100\ ha = 0.547 \times \{[c + (r - 419) \times 0.23] \times a \times f \times (\log_{10} g - 1)^{0.4}\}$$

Where:

GU = Grazer Units (based on a 180 kg blue wildebeest = 1GU)
c = range condition index
r = the annual rainfall over the past two years (mm)
419 = the long-term annual rainfall for the South African savannas (mm)
a = a topographical index of accessibility which indicates the degree of accessibility of the habitat to plains wildlife on a scale of 0.1 to 1.0, with 1.0 = fully accessible
f = fire factor on a scale of 0.8 – 1.0, with 0.8 = recent fire and 1.0 = the absence of fire
g = the percentage grass cover.

4.2.3 Percentage grass cover

The enhanced monitoring method developed for this study included monitoring the percentage grass cover which was incorporated into the existing monitoring system on Mabula Game Reserve by adding a crown strike value to the descending point method when recording each grass species and sub-species. The crown represents the leaf material of a tuft of grass. This was compared to the line intercept method to test the accuracy of the point method. The additional crown strike method was done simultaneously with the descending point method in use on Mabula Game Reserve. When a grass was recorded along the transect at 1.0 m intervals, whether the point hits or misses the crown of the grass tuft was also recorded.

The persentage grass cover was determined by the equation:

$$\text{Percentage grass cover} = \frac{\text{Total crown hits}}{200} \times 100$$

The line intercept method was conducted to test the accuracy of the point method. These surveys were carried out only at 10 of the monitoring sites. Two typical transects were randomly chosen from the following five vegetation communities as they contained 35 of the 48 monitoring sites across Mabula Game Reserve:

Acacia caffra – Faurea saligna Short Open Woodland
Burkea africana – Terminalia sericea Low Thicket
Eragrostis gummiflua Low Closed Grassland
Melinis repens Low Closed Grassland
Terminalia sericea – Hyperthelia dissoluta Tall Closed Grassland

The line intercept method was conducted along the present transects. The plant material directly under the tape was recorded. The distance where the crown of each species intersected the tape was recorded along with the species or sub-species name.

The equation used was:

$$\text{Percentage crown cover} = \frac{\text{Total intercept for all grasses}}{\text{Total length of line}} \times 100$$

4.2.4 Topography index

Bothma *et al.* (2004) also includes a topographical index. A map of the reserve was generated using ArcGIS (Figure 4.2), representing the slope of the reserve and the distribution of monitoring sites. Slope was used to determine the topographical index. For areas with a minor slope of < 1.9 degrees a value of 1.0 was given. For slopes of 2 to 4.9 degrees a value of 0.8 was given. For slopes from 5.0 to 9.9 degrees, a value of 0.6 was given. For slopes of 10 to 14.9 degrees, a value of 0.4 was given. For slopes > 15 degrees a value of 0.2 was given.

4.2.5 Fire factor

Bothma *et al.* (2004) also included the frequency of fire with a value of 0.8 for recent fires and 1 for absence of fire. The reserve's burning program was consulted for each monitoring site (Figure 4.3). If burning occurred in the previous two years for the majority of sites in a vegetation community a value of 0.8 was given. If burning occurred over the previous five years for the majority of sites, a value of 0.9 was given. If burning had not occurred for more than five years for the majority of sites, a value of 1 was given.

4.2.6 Estimating the biomass of the herbaceous layer using the disc pasture meter

The disc pasture meter was used to determine the biomass of the herbaceous layer. This method has been adopted as the main method for estimating the biomass of large areas, as the procedure is non-destructive, objective, repeatable and simplistic. The disc pasture meter consists of a circular flat surface area connected to a free moving sleeve on a central rod. The disk is raised to the height of 60 cm. The disc is placed over the required measuring point and dropped, making sure there are no obstructions, such as sticks and rocks, as this will prevent the true reading when dropped. The measurement is taken off the central rod, at the top of the sleeve (Trollope & Potgieter 1986).

The disc pasture meter measurements were taken along the monitoring tape every 5 m. From the centre pole, measurements were recorded 2 m from the tape on the right hand side.

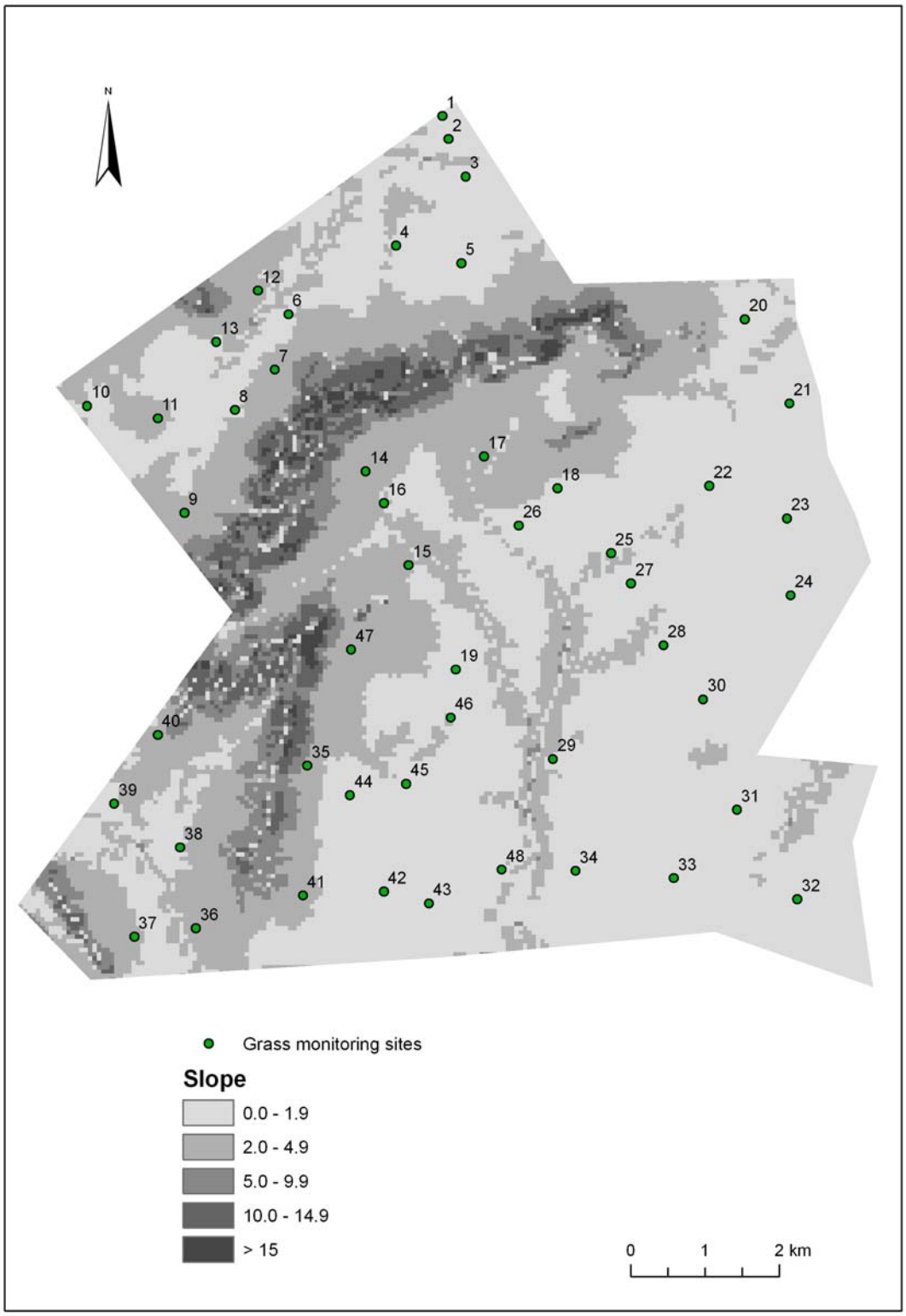


Figure 4.3. The grass monitoring sites and slope on Mabula Game Reserve in1998.

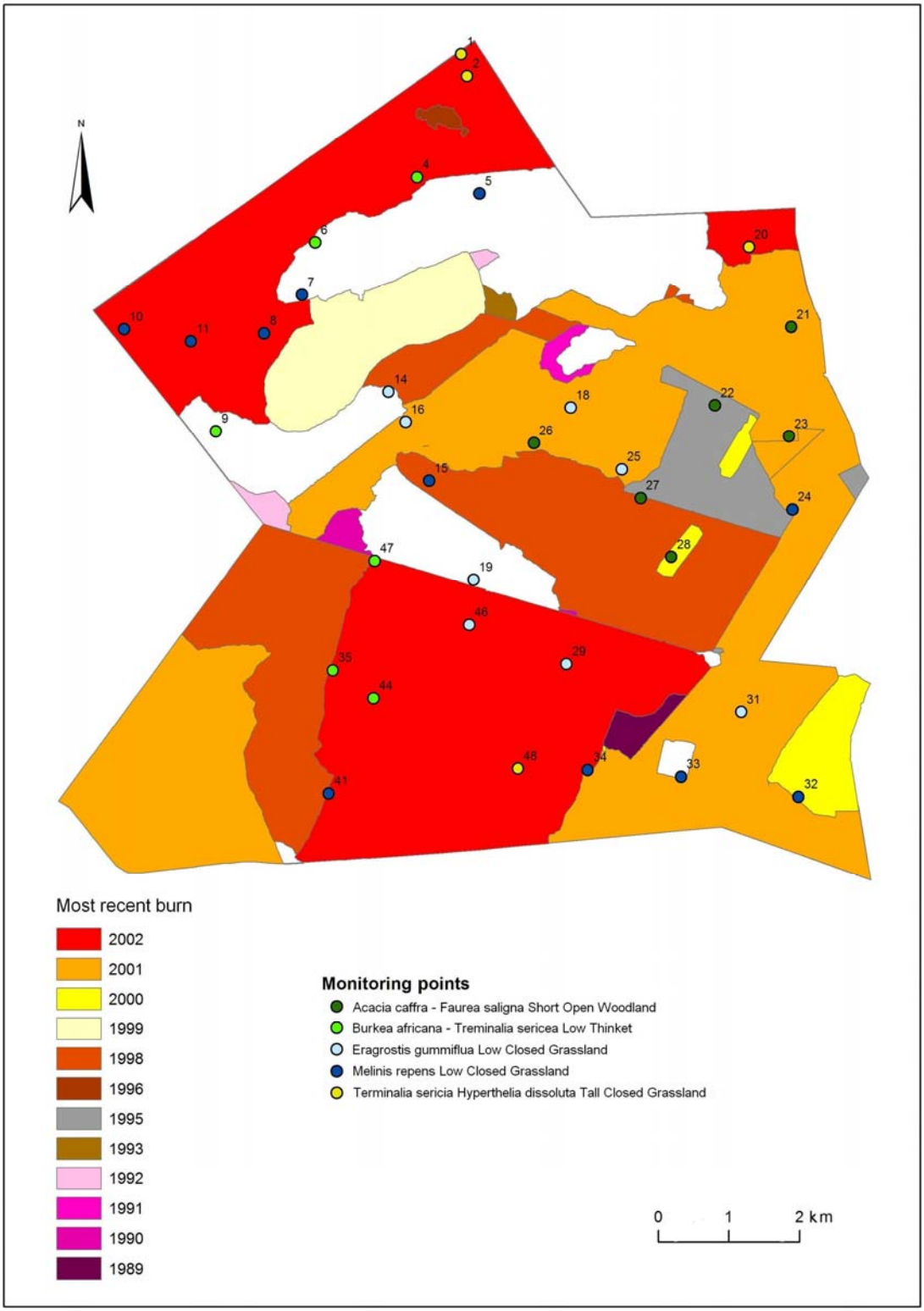


Figure 4.4. The grass monitoring sites and burning blocks from 1989 to 2006 on Mabula Game Reserve.

The disc pasture meter has to be calibrated for areas which have not previously been calibrated. Trollope and Potgieter (1986) described the method of calibration through the use of linear regressions, comparing the actual dry mass of the plant material to the disc pasture meter's readings, which were conducted in the Kruger National Park. The regression equation derived was used to estimate the total biomass within a homogeneous vegetation unit in kg per ha. Hardy and Mentis (1985) found that the biomass estimates obtained with the disc pasture were within 10.5% of the estimated herbage mass. This was considered adequate for larger scale estimation of biomass in relation to estimating fuel loads for fire regimes. Dörgeloh (2002) derived a series of regression equations over a range of habitats for the Mixed Bushveld region of South Africa on the Nylsvley Nature Reserve. His results proved to be successful when compared to other studies falling within the Savanna Biome. This model will used for the present study, as Mabula Game Reserve lies in the same region where the regression model was developed for determining biomass by Dörgeloh (2002).

The mean of the 40 points per transect was derived and used in the following regression equation from Dörgeloh (2002), to determine the fuel load:

$$\hat{y} = 681.8542 + 300.369\ x$$

Where: $\hat{y}$ = estimated fuel load (kg/ha)
x = mean disc height (cm)

4.3 RESULTS

4.3.1 Assessment of the veld condition trends of the herbaceous layer on Mabula Game Reserve

Serfontein (2007) initially assessed Mabula Game Reserve's monitoring of the herbaceous layer by using the method outlined by Van Rooyen (2002a & b) for determining the veld condition score. The overall veld condition score given in Table 4.2 was calculated in relation to the areas of the vegetation community to produce a weighted score.

The veld condition scores for the grassland vegetation communities are represented in Figure 4.4. Except for the *Terminalia sericea - Hyperthelia dissoluta* Tall Closed Grassland from 1998 to 2001, all the veld condition scores represented veld in a poor condition. The veld condition scores for the *Terminalia sericea - Hyperthelia dissoluta* Tall Closed Grassland decreased over the 10 years. The veld condition scores for the *Eragrostis gummiflua* Low Closed Grassland showed no veld improvement or deterioration whereas the veld condition scores for the *Melinis repens* Low Closed Grassland substantially improvement over the 10 years. The veld condition scores for the woodland vegetation communities are represented in Figure 4.5. The veld in both vegetation communities showed no veld improvement or deterioration over the 10 years. The *Acacia caffra - Faurea saligna* Short Open Woodland maintained a good veld condition over the 10 years, whereas the *Combretum apiculatum* Short Open Woodland maintained a poor veld condition. The veld condition scores for the shrubland and thicket vegetation communities are represented in Figure 4.6. In general, these vegetation communities showed a widely fluctuating veld condition with little or no overall veld improvement or deterioration over the 10 years and generally remained in the poor veld condition range. However, *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket and *Acacia karroo* Low Thicket did show a slight overall improvement in veld condition.

The overall veld condition for Mabula Game Reserve from 1998 to 2007 has remained in the moderate range except for 2004 when a poor veld occurred (Figure 4.7). There was a positive linear relationship between veld condition score and rainfall, showing that there is no significant difference (R^2 = 0.23, P = 0.48, Figure 4.8). There was significant difference between veld condition score and grazing

pressure (R^2 = 0.0005, P = 0.02; Figure 4.9). Therefore only rainfall had an effect on the veld condition score.

The grazing capacity was determined from the veld condition index according to Danckwertz's (1989b) equation to give an indication of stocking density. The results for live stock units (LSU) were converted to Grazing Units (Table 4.3). The estimated ecological grazing capacity varied between 2329 and 2581 Grazing Units over the 10 for the whole reserve covering a surface area 8362.4 ha. The estimated economic grazing capacity for the reserve varied between 1630 and 1806 Grazing Units.

Table 4.2. The veld condition scores for all the vegetation communities represented in the monitoring programme and the overall veld condition scores for Mabula Game Reserve from 1998 to 2007

	Year									
Vegetation community	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Acacia caffra - Faurea saligna Short Open Woodland	693	674	672	701	769	727	730	709	768	683
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	258	228	302	415	307	302	250	333	308	348
Acacia karroo Low Thicket	319	365	414	407	414	408	350	410	385	443
Burkea africana - Terminalia sericea Low Thicket	340	386	414	408	384	371	273	373	327	365
Combretum apiculatum Short Open Woodland	401	342	339	367	291	315	227	341	406	359
Eragrostis gummiflua Low Closed Grassland	325	298	304	344	316	327	260	293	277	324
Melinis repens Low Closed Grassland	158	189	232	216	250	260	242	262	283	307
Terminalia sericea - Acacia species Low Thicket	331	382	404	334	361	342	210	344	373	389
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	416	416	421	400	363	373	308	357	359	324
Terminalia sericea - Seriphium plumosum Short Bushland	369	303	333	363	364	282	242	359	388	430
Overall veld condition score	418	415	431	440	440	431	378	430	453	439

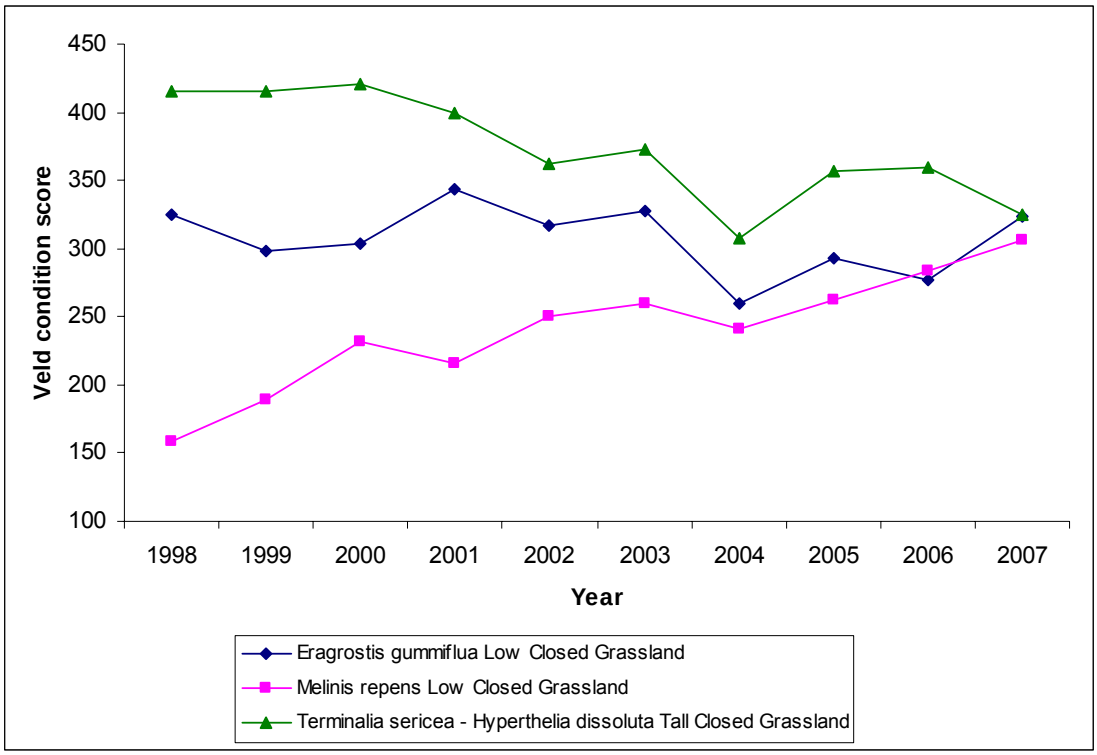


Figure 4.4. The veld condition score for the grassland vegetation communities on Mabula Game Reserve from 1998 to 2007.

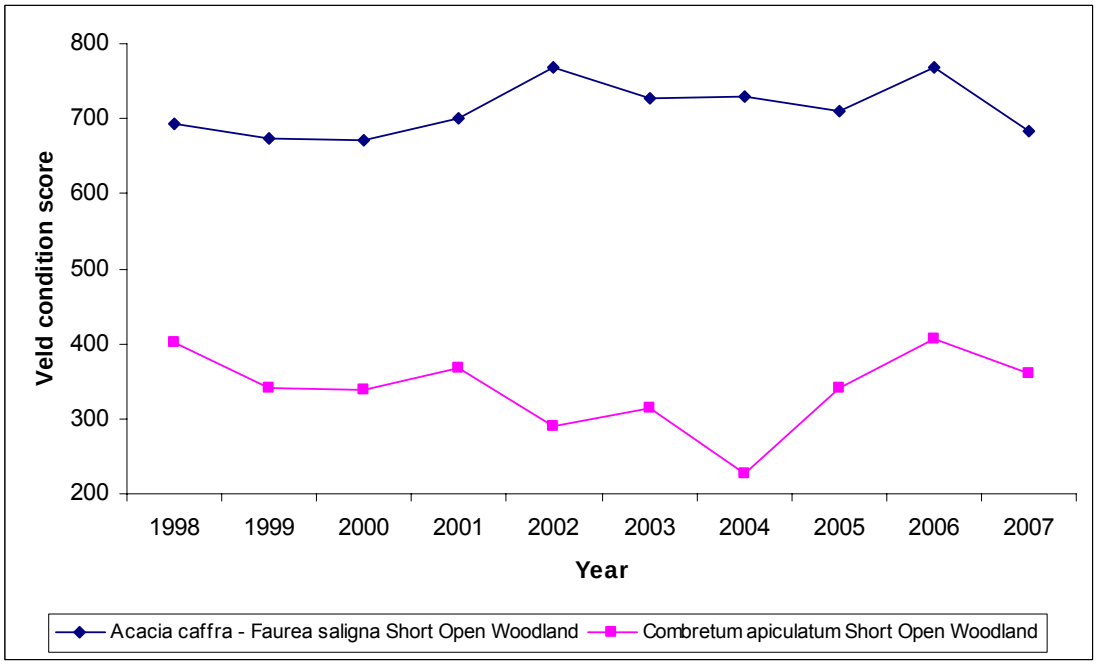


Figure 4.5. The veld condition score for the woodland vegetation communities on Mabula Game Reserve from 1998 to 2007.

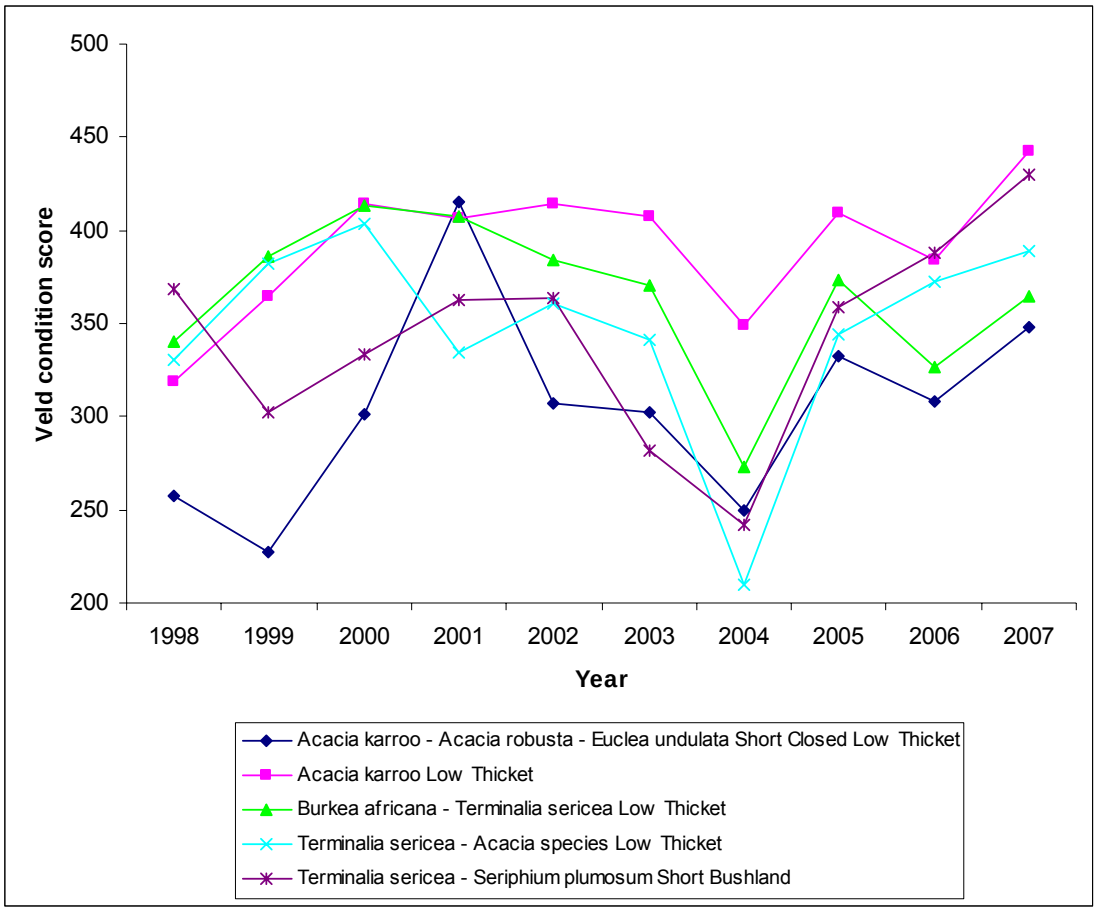


Figure 4.6. The veld condition score for the bushland and thicket vegetation communities on Mabula Game Reserve from 1998 to 2007.

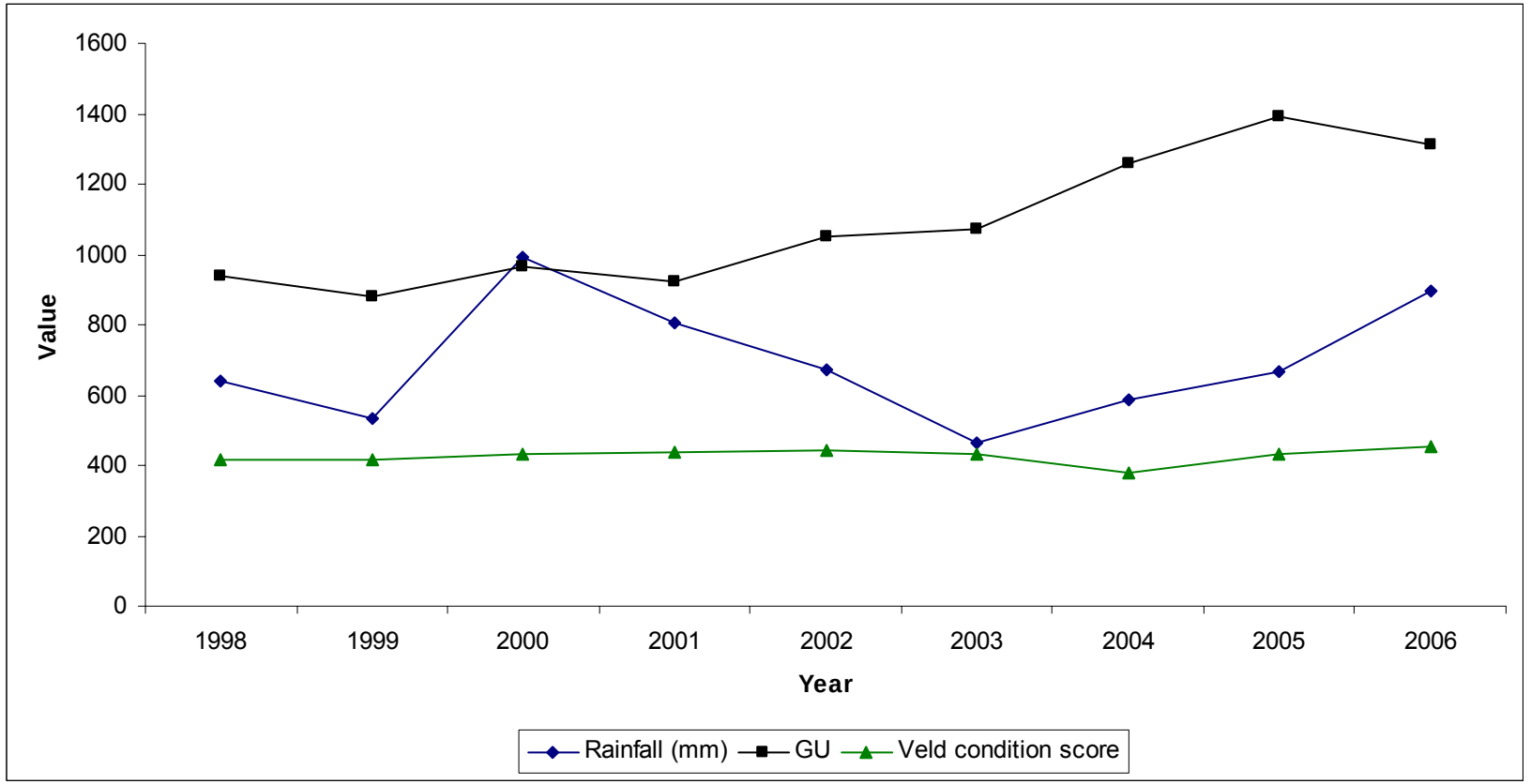


Figure 4.7. Comparison of annual rainfall, veld index score and the actual number of Grazing Units stocked on Mabula Game Reserve from 1998 to 2006.

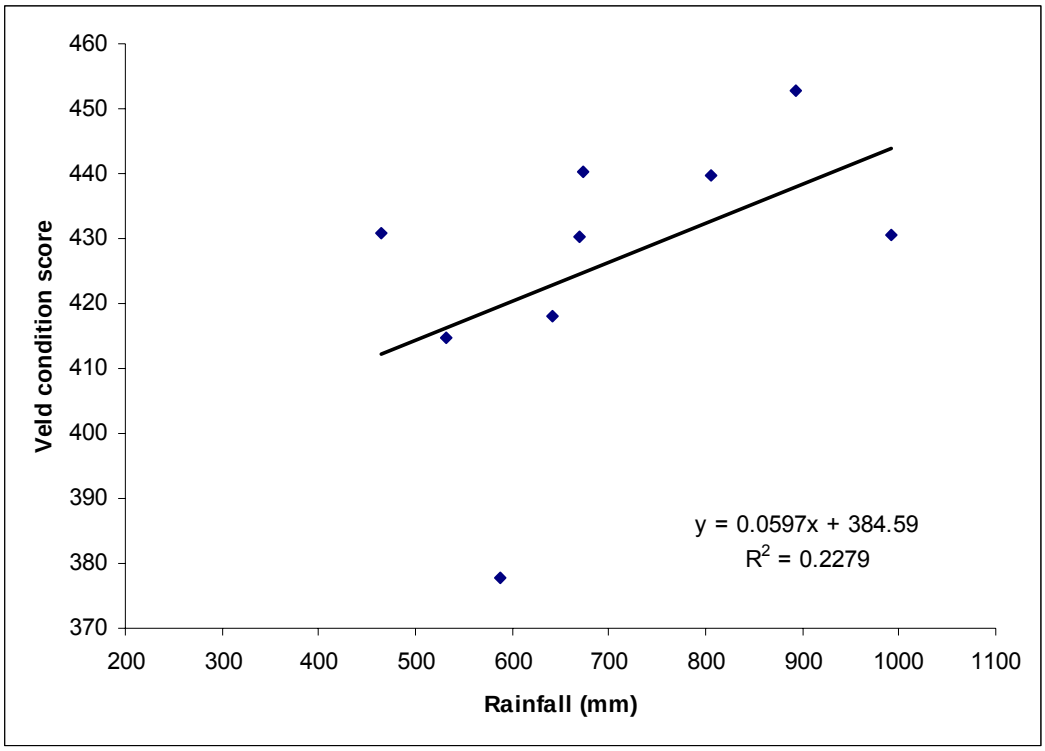


Figure 4.8. Linear relationship between veld condition score and rainfall recorded on Mabula Game Reserve from 1998 to 2006.

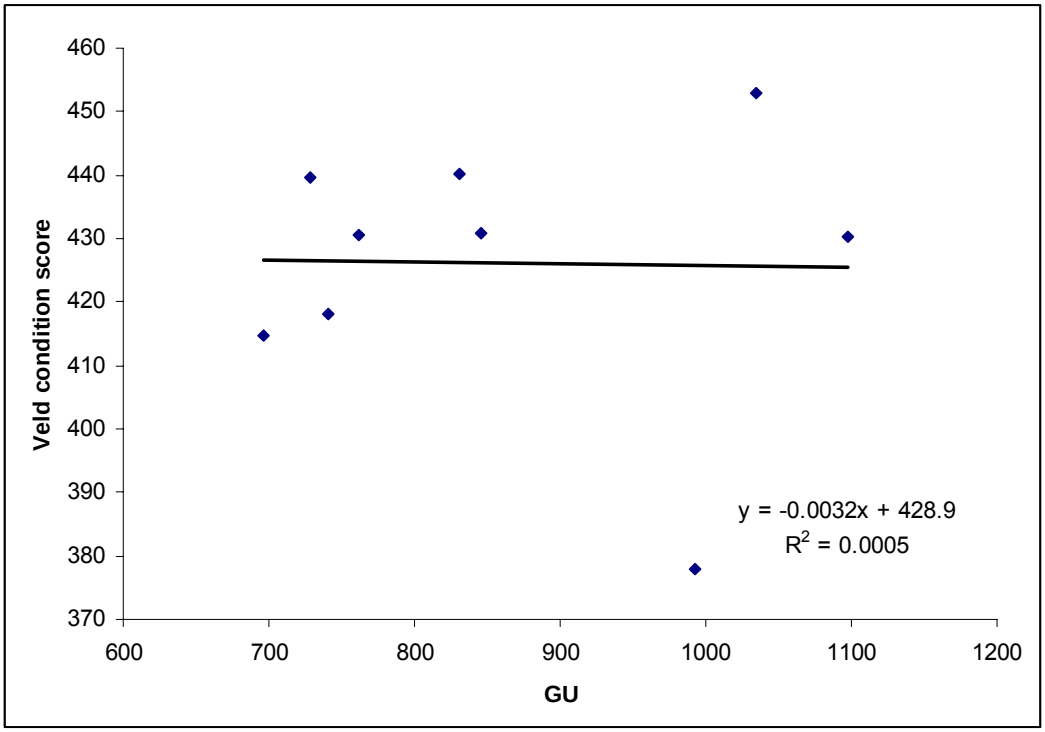


Figure 4.9. Linear relationship between veld condition score and the total number of Grazing Units present on Mabula Game Reserve from 1998 to 2006.

Table 4.3. The determination of ecological and economic (70% of ecological) grazing capacity on Mabula Game Reserve from 1998 to 2007 using Danckwertz's (1989b) equation, and the actual number of Grazing Units stocked on the reserve

	Year									
	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Veld condition index	41.8	41.5	43.1	44	44	43.1	37.8	43	45.3	43.9
Mabula's mean rainfall (mm)	611	611	611	611	611	611	611	611	611	611
LSU/ha (ecological capacity)	0.212	0.211	0.216	0.218	0.218	0.216	0.2	0.215	0.222	0.218
LSU for 7809.9 ha	1656	1648	1684	1705	1705	1684	1565	1682	1734	1702
LSU estimate for total area	1773	1765	1803	1826	1826	1803	1676	1801	1857	1822
GU for 7809.9	2302	2291	2341	2370	2370	2341	2175	2338	2410	2366
GU estimate for whole reserve	2465	2453	2506	2538	2538	2506	2329	2503	2581	2533
70% GU for 7809.9 ha	1611	1604	1639	1659	1659	1639	1523	1637	1687	1656
70% GU estimate for whole reserve	1725	1717	1754	1776	1776	1754	1630	1752	1806	1773
Actual GU stocked	939	882	966	924	1053	1072	1353	1391	1312	939

4.3.2 Estimating grass cover

The percentage grass cover as estimated by the line intercept and descending point methods in 2005 are compared in Table 4.4. The results from the two methods were positively linearly related and the difference between the results was not significant (R^2 = 0.44, P = 0.66; Figure 4.10). The descending point method consistently underestimating the grass cover, but the descending point method is more practical for future use in the monitoring programme. Therefore the results determined by the descending point method were used for determining the grazing capacity. Also all monitoring sites were used for the determining percentage grass cover using the descending point method.

4.3.3 Calculation of stocking density according to the Bothma et al. (2004) equation

The topography index for the grass monitoring sites within the *Eragrostis gummiflua* Low Closed Grassland, the *Melinis repens* Low Closed Grassland and the *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland vegetation communities were given a value of 1. These communities were found on plains and gentle slopes. The *Acacia caffra – Faurea saligna* Short Open Woodland and the *Burkea africana – Terminalia sericea* Low Thicket, were generally found on gentle slopes and plains, but also border on steeper areas towards the mountainous areas on the reserve. Therefore, the topographic index given to these vegetation communities was 0.9. The *Combretum apiculatum* Short Open Woodland and the *Acacia caffra* Short Open Woodland were found on the mountain range running through the reserve, therefore these vegetation communities should be given a topographic index of 0.4. The *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thicket, the *Terminalia sericea – Acacia* species Low Thicket and the *Terminalia sericea - Seriphium plumosum* Short Bushland were all associated with drainage lines and were given a topographic index of 0.8. The *Acacia karroo* Low Thicket was also associated with drainage lines and erosion areas in the northwestern section of the reserve. This vegetation community was given a topographic index of 0.7.

The fire factor for all vegetation communities was taken as 0.9. No monitoring sites were burnt in the previous two years; therefore no sites were given a value of 0.8. Most of the sites were burnt within four years prior to 1995, with only a few sites not experiencing a fire for over 10 years. Therefore an overall fire factor of 0.9 was used.

Table 4.4. The percentage grass cover determined by the line intercept method and descending point method for each of the specified vegetation communities on Mabula Game Reserve in 2004.

Vegetation community	Grass cover (%)	
	Line intercept	Descending point
Acacia caffra - Faurea saligna Short Open Woodland	29.8	23.1
Burkea africana - Terminalia sericea Low Thicket	22.6	17.5
Eragrostis gummiflua Low Closed Grassland	26.3	21.4
Melinis repens Low Closed Grassland	29.9	21.5
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	23.2	21.9
Acacia karroo Low Thicket		18.2
Acacia karroo – Acacia robusta – Euclea undulata Short Closed Low Thicket		15.8
Combretum apiculatum Short Open Woodland		15.8
Terminalia sericea - Seriphium plumosum Short Bushland		10.0
Terminalia sericea – Acacia species Low Thicket		12.3

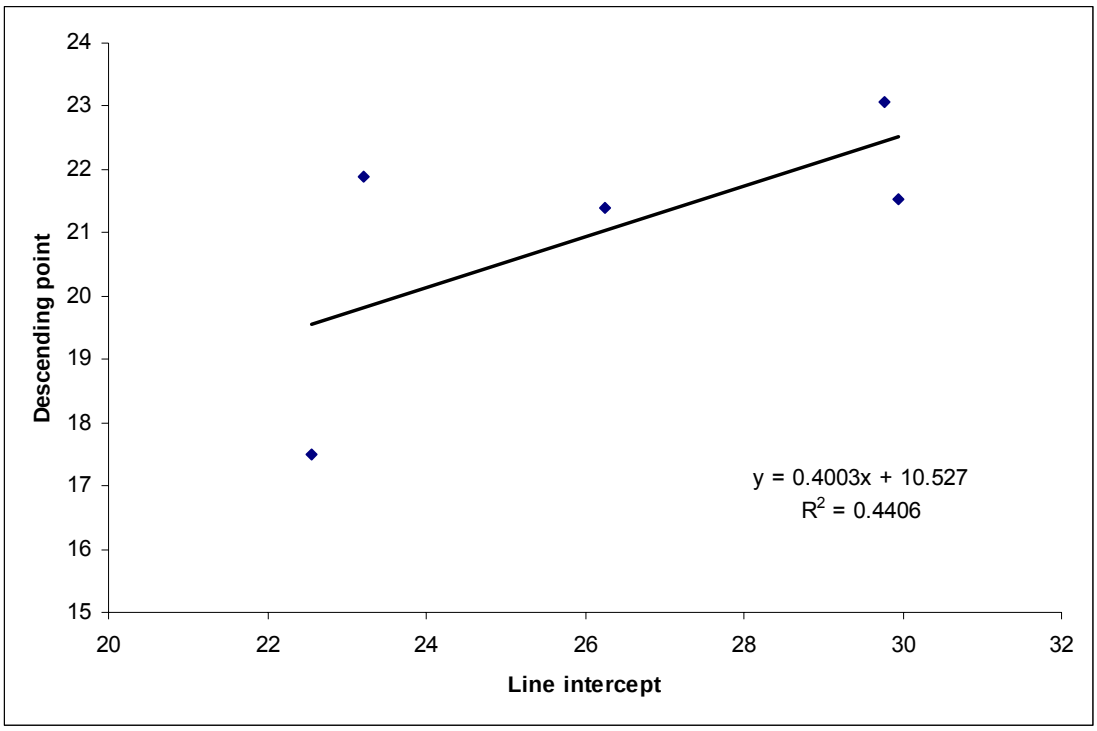


Figure 4.10. Linear correlation between the percentage canopy cover derived from the line intercept method and with that of the descending point method on Mabula Game Reserve in 2004.

The mean rainfall for 2003 and 2004 was 628.5 mm. The mean rain fall was obtained from the rainfall data collected on Mabula Game Reserve.

From the veld condition index, the mean annual rainfall from 2003 to 2004, topological index, fire factor and percentage grass cover the grazing capacity for each vegetation community was calculated (Table 4.5). The *Acacia caffra – Faurea saligna* Open Woodland yielded the highest stocking density (35.22 Grazing Units/100 ha) of all the vegetation communities. This vegetation community also covers the largest surface area. The other vegetation communities had stocking densities which were substantially less than the *Acacia caffra – Faurea saligna* Open Woodland (Table 4.5). The total number of Gazing Units for the 10 vegetation communities covering 7809.91 ha was 1737, therefore the estimated ecological grazing capacity for the whole surface area of Mabula Game Reserve is 1842 Grazing Units. According to Van Rooyen (2002a, b) the economic grazing capacity for maximum wildlife production is 70 to 80 % of the ecological grazing capacity because wildlife range over the whole reserve and rotational grazing cannot be practised as with livestock. A conservative threshold of 70% was used for calculating the economic capacity. Therefore, at 70% of the ecological capacity the reserve would be able to stock 1301 Grazing Units.

4.3.4 Estimating biomass of the herbaceous layer

Table 4.6 shows the biomass of the herbaceous plants for each vegetation community for the years 2004 and 2005. There was an overall 21% increase in the biomass of the herbaceous layer between the monitoring periods. This is due to the absence of fire and an increase in rainfall of 80 mm in 2005. Figure 4.11 shows the increase in biomass for each of the vegetation communities. The exception was the *Terminalia sericea – Seriphium plumosum* Short Bushland which decreased in biomass between 2004 and 2005.

Table 4.5. Stocking densities per vegetation community according to the method of Bothma *et al.* (2004) on Mabula Game Reserve for 2004

Vegetation Community	Number of monitoring points	Veld condition index (%)	Mean rainfall (mm)	Topographical index	Fire factor	% Grass cover	Gazing Units per 100 ha	Surface area (ha)	Total Grazing Units
Acacia caffra - Faurea saligna Short open woodland	6	71	628.5	0.9	0.9	23.08	35.2	1979.0	697.0
Acacia karroo Low Thicket	5	41	628.5	0.7	0.9	18.20	17.9	471.2	84.5
Acacia karroo – Acacia robusta – Euclea undulata Short Closed Low Thicket	2	33	628.5	0.8	0.9	15.75	16.7	214.5	35.8
Burkea africana - Terminalia sericea Low thicket	6	37	628.5	0.9	0.9	17.50	21.4	927.8	198.9
Combretum apiculatum Short Open Woodland	2	34	628.5	0.4	0.9	15.75	8.5	1280.0	108.2
Eragrostis gummiflua Low closed grassland	8	29	628.5	1.0	0.9	21.38	24.4	589.0	143.7
Melinis repens Low closed grassland	11	26	628.5	1.0	0.9	21.54	23.5	978.7	230.3
Terminalia sericea – Acacia species Low Thicket	2	34	628.5	0.8	0.9	12.25	12.3	534.4	65.5
Terminalia sericea - Hyperthelia dissoluta Tall closed grassland	4	36	628.5	1.0	0.9	21.88	26.9	625.1	168.3
Terminalia sericea - Seriphium plumosum Short Bushland	1	36	628.5	0.8	0.9	10.04	2.6	210.3	5.5
Total								7810.0	1737.7

Table 4.6. Estimates of the herbaceous biomass for each vegetation community on Mabula Game Reserve for 2004 and 2005

Vegetation communities	No.	Mean biomass 2004 (kg/ha)	Mean biomass 2005 (kg/ha)	Area (ha)	Total biomass 2004 (tonne)	Total biomass 2005 (tonne)
Acacia caffra – Faurea saligna Short Open Woodland	1	2906.5	3189.3	1979	5751.9	6311.6
Acacia karroo – Acacia robusta – Euclea undulata Short Closed Low Thicket	3	2611.7	3278.2	215	561.5	704.8
Acacia karroo Short Open Woodland	4	2329.2	2872.8	471	1097.0	1353.1
Burkea africana – Terminalia sericea Low Thicket	5	1821.3	2670.3	928	1690.1	2478.0
Combretum apiculatum Short Open Woodland	7	2611.7	3278.2	1280	3343.0	4196.1
Eragrostis gummiflua Low Closed Grassland	8	2452.2	3263.3	589	1444.3	1922.1
Melinis repens Low Closed Grassland	9	2047.3	2558.2	979	2004.4	2504.5
Terminalia sericea – Acacia species Low Thicket	11	1506.0	2529.1	534	804.2	1350.6
Terminalia sericea – Hyperthelia dissoluta Tall Closed Grassland	12	2423.4	3433.8	625	1514.6	2146.1
Terminalia sericea – Seriphium plumosum Short Bushland	13	1710.6	1688.1	210	359.2	354.5
Total		22419.9	28761.3	7810	18570.2	23321.4

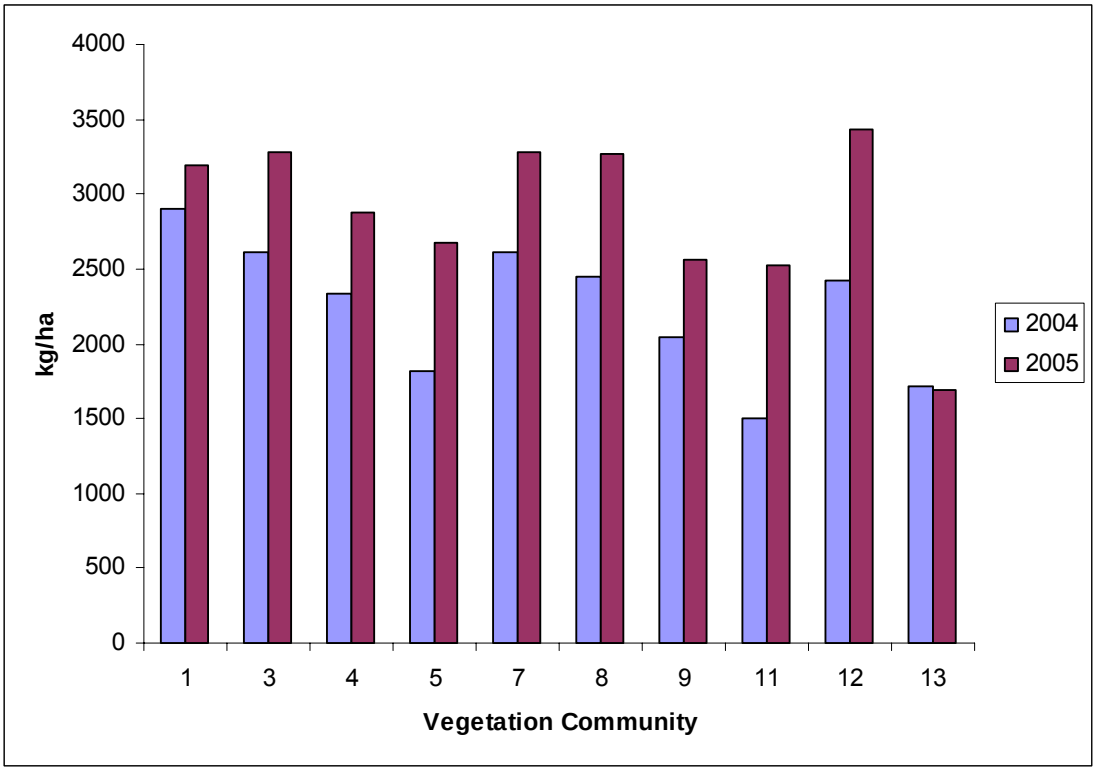


Figure 4.11. Estimation of biomass of herbaceous material in kg/ha by means of the disc pasture meter for the monitored vegetation communities on Mabula Game Reserve in 2004 and 2005. Community numbers correspond to the numbers in Table 4.6.

4.4 DISCUSSION

4.4.1 Assessment of the veld condition trends on Mabula Game Reserve and the existing herbaceous monitoring system

The monitoring points were placed prior to the assessment of the vegetation communities. The grass monitoring sites were not distributed in proportion to the size of the different vegetation communities and four vegetation communities contained no monitoring points (Table 4.1). However, the present monitoring system did allow for a good estimate of the veld condition score and index across the reserve. The five vegetation communities which were properly sampled, with a minimum of five sites per vegetation community, covered nearly 60% of the reserve. The other five vegetation communities that had few monitoring sites, covered 34% of the reserve. The four vegetation communities that were not sampled only covered around 6% of the reserve. For a more accurate calculation of the veld condition scores and index, the monitoring points should be distributed in proportion to the vegetation community's size. This will be discussed in Chapter 6.

The weighted veld condition score for Mabula Game Reserve remained in the moderate condition range from 1998 to 2007, except for 2004 where a low veld condition occurred. The veld condition score fluctuated from year to year in direct relation to rainfall from each of the wet seasons. There was no evidence that grazing affected the overall veld condition score for Mabula Game Reserve.

The grassland communities on Mabula Game Reserve were properly sampled, allowing for accurate determination of the veld condition score. The results showed a decrease in the veld condition of the *Eragrostis gummiflua* Low Closed Grassland. This vegetation community remained in a moderate veld condition for the first three years of monitoring, but dropped to a poor veld condition for the following years. This may be due to the high grazing pressure (see Chapter 3). This is a management issue which will have to be addressed and will be further discussed in Chapter 6. The *Melinis repens* Low Closed Grassland was also subject to high grazing pressure, but showed an increase in the veld condition score over the monitoring period. This vegetation community had a veld condition score of 158 in 1998 which steadily increased to 307 in 2007. The *Melinis repens* Low Closed Grassland is abandoned agricultural land in an early successional

stage and the veld condition score there should keep increasing with proper management. The *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland showed neither an increase nor decrease in veld condition score over the monitoring period. This grassland was in a climax stage of succession, therefore the veld condition score is not likely to increase.

The woodland communities both showed no increase or decrease in the veld condition score. The *Acacia caffra – Faurea saligna* Short Open Woodland had the highest veld condition score and was the only vegetation community with veld in the good condition. This vegetation community was responsible for the overall veld condition score of the reserve being in the moderate range over the monitoring period. This was due to the size of the vegetation community and the high veld condition scores. All other vegetation communities generally had veld in poor condition. The *Combretum apiculatum* Short Open Woodland had a poor veld condition for all years except 1998 and 2006, when the veld condition score was 401 and 406 respectively showing an improvement in veld condition from poor to moderate. Only two monitoring sites were sampled in this vegetation community. The *Combretum apiculatum* Short Open Woodland occurred on the mountains running through the reserve and therefore minimal monitoring was possible due to the rugged terrain. In relation to the results from Chapter 3, no large herbivores selected this vegetation community and therefore monitoring its condition was not important in management decisions.

The mean veld condition scores for the thicket and bushland communities over the monitoring period showed veld in a poor condition. None of these vegetation communities showed a marked improvement in veld condition score over the 10 years. The results from Chapter 3 showed that there was no overutilisation by grazers for any of these vegetation communities. The fluctuating veld condition scores for all these vegetation communities over the monitoring period was due to the different rainfall received each year.

The estimated ecological grazing capacity, derived from Danckwertz (1982) equation, for Mabula Game Reserve ranged from 2329 to 2581 Grazing Units over the 10 years of monitoring. The estimated economic grazing capacity ranged from 1630 to 1806 grazing Units for the entire reserve. The lowest quantity of Grazer Units occurred in 2004 and

the highest quantity of Grazing Units occurred in 2006. The total quantity of grazer units stocked on the reserve from 1998 to 2007 remained under the ecological and economic grazing capacity. This may be why grazing pressure had no influence on the veld condition scores over the 10 years.

4.4.2 Calculation of stocking density by using the equation proposed by Bothma et al. (2004)

This method of determining the grazing capacity is more comprehensive than the Danckwertz's (1989b) equation and covers a wider range of influences on grazing. The data required for the Bothma *et al.* (2004) equation were collected for an initial trial period in 2005. The method was applied to the individual vegetation communities and was compared to the results of Chapter 3 in relation to the selection of the vegetation communities by large herbivores during the dry season and over the whole year. As the herbaceous monitoring occurred in January of 2005, it is appropriate to use the wildlife count numbers from the previous year when the monitoring was conducted. As the equation proposed by Bothma *et al*. (2004) takes into account the rainfall for the past two year the results of this method could only be applied to the game count figure of that period. Hence, only the 2004 Grazing Units were calculated.

The use of the rainfall data from the past two periods gave a more precise calculation of the grazing capacity than Danckwertz's (1989b) equation. The determination of grass cover, using a simple hit or miss record at the meter intervals on the tape measure, was a quick and easy addition to the descending point method. Although the values for grass cover were higher when using the line intercept method, the descending point method was relatively similar and less time consuming. The assessment of the topographical index and fire factor was easily determined by using GIS software. The topographical index can be made constant once it had been determined for the monitoring points in a vegetation community. The fire factor will have to be assessed constantly as future burning programmes may vary.

The combined ecological grazing capacity for all the vegetation communities was 1860 Grazing Units and the economic grazing capacity at 70% of ecological capacity was 1302 Grazing Units. Therefore the number of Grazing Units stocked on the reserve was

lower than the ecological capacity for 2004. However, the quantity of grazers stocked on the reserve was higher than the economic grazing capacity by 51 Grazing Units. Table 4.7 gives a summary of the estimated Grazing Units occurring in each of the vegetation communities and the ecological and economic grazing capacities of the vegetation communities according to the equation proposed by Bothma *et al.* (2004).

The *Acacia caffra – Faurea saligna* Short Open Woodland had a substantially higher grazing capacity (697.02 Grazing Units) than the other vegetation communities, due to its size and good veld condition. The results from Chapter 3 showed that two browsing herbivores selected this vegetation community over the whole year, accounting for 123.60 Grazing Units. Burchell's zebra, which accounted for 424.75 Grazing Units only selected this vegetation community during the dry season. Other large herbivores utilised this vegetation community (without selecting), but overall it was undergrazed.

The *Melinis repens* Low Closed Grassland had an ecological grazing capacity of 230.32 Grazing Units. Six herbivores selected this vegetation community over the whole year. In combination the Grazing Units of all six herbivores numbered 537.82. Although four of these herbivores also selected other vegetation communities over the whole year, there was a high risk of overgrazing. The large herbivores which selected this vegetation community during the dry season accounted for 235.96 Grazing Units, indicating potential overgrazing. There were other herbivores which utilised the *Melinis repens* Low Closed Grassland, therefore this vegetation community was potentially overgrazed.

The *Burkea africana – Terminalia sericea* Low Thicket had an ecological grazing capacity of 198.88 Grazing Units. This vegetation community was selected by impala over the whole year (51.77 Grazing Units) and was preferred by blue wildebeest during the dry season, which accounted for 139.85 Grazing Units. Six other types of herbivores utilised this vegetation community, but overall, the *Burkea africana – Terminalia sericea* Low Thicket was grazed below its ecological grazing capacity.

The *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland had an ecological grazing capacity of 168.30 Grazing Units. This vegetation community was grazed below its ecological grazing capacity over the whole year and during the dry season.

Table 4.7. A summary of the estimated Grazing Units that occur on the vegetation communities and the grazing capacities on Mabula Game Reserve in 2004

Vegetation community	Actual Grazing Units		Ecological grazing capacity (Grazing Units)	Economic grazing capacity (Grazing Units)
	Whole year	Dry season		
Acacia caffra - Faurea saligna Short Open Woodland	123.6	424.8	697.0	487.9
Acacia caffra Short Open Woodland	0	0		
Acacia karroo Low Thicket	12	0	84.5	59.2
Acacia karroo - Acacia robusta - Euclea undulata Short Closed Low Thicket	0	0	35.8	25.1
Burkea africana - Terminalia sericea Low Thicket	51.8	139.9	198.9	139.2
Combretum apiculatum Short Open Woodland	0	0	108.2	75.7
Combretum apiculatum - Acacia caffra Short Open Woodland	42.1	42.1		
Eragrostis gummiflua Low Closed Grassland	210.7	106.3	143.7	100.6
Melinis repens Low Closed Grassland	537.8	236	230.3	161.2
Terminalia sericea - Acacia caffra Low Open Woodland	0	3.2		
Terminalia sericea - Acacia species Low Thicket	0	0	65.5	45.9
Terminalia sericea - Hyperthelia dissoluta Tall Closed Grassland	24.1	68.4	168.3	117.8
Terminalia sericea – Seriphium plumosum Short Bushland	11.7	0	5.5	3.9
Terminalia sericea - Trachypogon spicatus Short Open Grassland	0	0		
Total	1013.8	1020.7	1737.7	1216.4

The *Eragrostis gummiflua* Low Closed Grassland had an ecological grazing capacity of 143.66 Grazing Units. However, the results from Chapter 3 show that four herbivores selected this vegetation community over the whole year, which accounted for an estimated 210.72 Grazing Units. Two other herbivores utilised, without selecting, the *Eragrostis gummiflua* Low Closed Grassland, therefore this vegetation community was grazed above its ecological grazing capacity over the whole year. Three types of herbivore selected this vegetation community during the dry season, representing an estimated 106.26 Grazing Units and no other wildlife species generally utilised this vegetation community. Therefore, the *Eragrostis gummiflua* Low Closed Grassland was grazed below its ecological grazing capacity during the dry season.

The *Combretum apiculatum* Short Open Woodland had an ecological grazing capacity of 108.24 Grazing Units and was grazed below the ecological grazing capacity. This vegetation community occurs on the mountains running through the reserve and its steep rocky terrain is not suitable for gazers.

The *Acacia karroo* Low Thicket had an ecological grazing capacity of 84.51 Grazing Units and was not grazed above its ecological grazing capacity as no large herbivores selected this vegetation community.

The *Terminalia sericea – Acacia* species Low Thicket had an ecological grazing capacity of 65.47 GUs and was not grazed above its ecological grazing capacity as no large herbivores selected this vegetation community.

The *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket had an ecological grazing capacity of 35.84 Grazing Units. Impala selected this vegetation community over the whole year, at an estimated 11.97 Grazing Units. This type of herbivore did not overgraze this vegetation community. However, according to the preference index, seven other grazing types of herbivore utilised The *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket. Therefore, this vegetation community was potentially overgrazed throughout the year. No herbivores selected this vegetation community during the dry season. However five types of herbivore utilised this vegetation community without selecting for it. This is therefore an important vegetation community for future monitoring.

The *Terminalia sericea – Seriphium plumosum* Short Open Grassland had an ecological grazing capacity of 5.48 Grazing Units and was overgrazed as impala selected this vegetation community (11.73 Grazing Units over the whole year). However, this vegetation community only had one monitoring site and therefore the results could not be considered as being reliable.

The only vegetation communities which are of concern for reserve management were the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket, the *Eragrostis gummiflua* Low Closed Grassland and the *Melinis repens* Low Closed Grassland. All the other vegetation communities seemed to be grazed under their ecological grazing capacity. Out of the four vegetation communities which were not included in the monitoring programme, two vegetation communities must be included in the monitoring programme. The *Combretum apiculatum - Acacia caffra* Short Open Woodland was a relatively small vegetation community and was selected by two grazing herbivores, and the *Terminalia sericea - Acacia caffra* Low Open Woodland was selected by a dominant grazer, but was only a small community covering 60.83 ha. Therefore these vegetation communities are potentially overgrazed. The other two vegetation communities were not selected by grazers, but still have to be assessed to enable the proper determination of the ecological and economical grazing capacity of Mabula Game Reserve. This will be further discussed in Chapter 6.

4.4.3 Assessment of biomass estimations

The biomass measurements when using the disc pasture meter were easily conducted in conjunction with the descending point method. All the vegetation communities showed an increase in biomass from 2004 to 2005, except for the *Terminalia sericea – Acacia* species Low Thicket. The main purpose for determining the biomass is for burning programmes. According to Trollope & Potgieter (1986) if the biomass is less than 1 500 kg/ha there will be insufficient fuel for burning. If the biomass is higher than 4 000 kg/ha a fire may be too intense and cause damage to plants. All the biomass estimates for the vegetation communities on Mabula Game Reserve were between 1 500 kg/ha and 4 000 kg/ha, and therefore were optimal for burning. If the biomass estimates become too high,

then burning during the winter months may be required, when the air temperature is lowest.

4.5 CONCLUSION

The existing monitoring system provided a good indication of the veld condition score for Mabula Game Reserve from 1998 to 2007. However, it cannot be said that it provided an accurate assessment, as only five vegetation communities, covering 60% of the reserve, were properly sampled. Another five vegetation communities, covering 34% of the reserve were sampled with a few monitoring sites. Four small vegetation communities were not sampled. From the estimated veld condition score, Mabula Game Reserve had an overall moderate veld condition. The reserve stocked grazers under the ecological and economic grazing capacity as determined using Danckwertz's (1982) equation.

The additional monitoring methods were easily combined with the existing monitoring method. With the additional information the equation proposed by Bothma *et al.* (2004) was used and the fuel loads were determined for burning programmes. The equation proposed by Bothma *et al.* (2004) provided specific ecological grazing capacities for the different vegetation communities and also a more accurate method for determining the ecological grazing capacity. This was due to the additional information on grass cover, topography, fire and the rainfall from the past two wet seasons. The values derived from Danckwertz's (1982) equation were much higher than the value derived by the equation proposed by Bothma *et al.* (2004). Therefore, as the equation proposed by Bothma *et al*. (2004) incorporated more data and the values were more conservative than the values derived from Danckwertz's (1982) equation, the equation proposed by Bothma *et al*. (2004) is recommended for future monitoring of the vegetation of Mabula Game Reserve.

The combination of the information gathered from initial monitoring of the habitat selection for large herbivores and calculation of grazing capacities for the individual vegetation communities provided information on vegetation communities which were being potentially overgrazed. This can be addressed by reserve management and the progress of any management decisions on this matter can be further monitored.

Chapter 5

MONITORING OF THE WOODY LAYER

5.1 INTRODUCTION

Different measuring techniques to assess changes in plant species composition and density of the woody plant layer were evaluated to find a practical, efficient and repeatable method. The method must also provide information on browsing capacity. Furthermore, the method needs to be simple so that the reserve management staff can collect the required data for further analysis. A brief overview of the methods that were considered is provided below.

The point or plot-less methods, such as the Point Centre Quarter and Line Intercept methods provide information on the relative percentages of species frequency, density, height, canopy diameter and dominance at different height classes. These methods, on their own, are not suitable as they give no information of the available plant material for utilisation by herbivores. However, the line intercept method was useful when combined with another method as discussed below.

The plant number scale method derived by Westfall *et al.* (1996) determines the crown cover of woody plant species within a vegetation community at differing height classes. This method was developed for the Waterberg region which is similar to the mixed bushveld of the Savanna Biome in which Mabula is situated. The method determines frequency, density, height, canopy diameter and dominance per woody plant species. The results gained can be extrapolated for the total area of a vegetation community. The main problem with this method in relation to monitoring is that the quadrate size may vary for consecutive monitoring periods. This prevents direct comparison of results over time. An additional issue arose when the method was tried experimentally in the field. The method requires a calculation to be made in the field to determine the length of the transects. The reserve staff found this problematic and took a substantial amount of time to do these calculations. This problem rendered the method inefficient for the stated purpose and it had to be abandoned.

Telfer (1969) devised the twig count method to assess the quantity of material utilized by browsers. The method attempted to determine the mean quantity of vegetation browsed, by measuring the twig diameters and dry mass of twigs on trees that had not been browsed. The method is destructive, as vegetation needs to be removed, and because some plant material is removed the plot is no longer suitable for monitoring. The concept of measuring woody biomass also gave rise to the Biomass Estimates from Canopy VOLume (BECVOL) method. The BECVOL method is based on the concept of the measurement of an ideal tree and calculates its spatial volume. *Acacia karroo* was initially used to develop the method. Tree measurements were used to estimate the spatial volume and the dry leaf mass was obtained from the harvested *Acacia karroo* trees. The true leaf mass and the spatial tree volume were significantly correlated, indicating that spatial volume is a useful substitute for biomass measurements. Spatial dimensions and leaf biomass were obtained for other woody plant species and general regression equations were developed for a selection of woody species (Smit 1989a; Smit 1989b). The BECVOL method makes use of a transect to determine the biomass of different woody plant species. The BECVOL requires a fixed transect, therefore sampling can be repeated over consecutive monitoring periods. The results for the monitoring periods can be directly compared.

Biomass Estimates from Canopy VOLume (BECVOL) has been set up as a computer program developed to estimate actual leaf volume and leaf mass from which the Evapotranspiration Tree Equivalent (defined as the leaf volume equivalent of a 1.5 m single stemmed *Acacia karroo* tree), the Browse Tree Equivalent (defined as the leaf volume equivalent of a 1.5 m single stemmed *Acacia karroo* tree) and the Canopied Subhabitat Index (defined as the canopy spread area of those trees in a transect under which *Panicum maximum* is most likely to occur, expressed as a percentage of the total transect area) are derived. The BECVOL analysis provides information on leaf volume and leaf mass for three heights of utilisation. For example, browse below 1.5 m is available for impala *Aepyceros melampus*, below 2.0 m for the greater kudu *Tragelaphus strepsiceros* and below 5.0 m for the giraffe *Giraffa camelopardalis* (Smit 1996). The BECVOL method does not give the actual browse potential, but this information can be derived from the results of the analysis. The BECVOL method has been criticised as it only measures woody plants on a broad scale (Melville *et al.* 1999). However, this is not a problem for monitoring purposes, as an indication of the

vegetative changes between monitoring periods is required. The results can also be used to give an indication of the browser capacity of the different vegetation communities for reserve management.

As no individual method covered all the requirements of a monitoring system, a combination of methods was used for monitoring the woody layer. The line intercept method and the BECVOL method were used to provide data for the determination of frequency, relative frequency, relative density, relative dominance, importance values and biomass values for the woody species. Another method included was fixed photography for qualitative analysis. Fixed point photography enables managers to visualise any changes in the woody layer between monitoring periods. This study focused on quantitative methods and did not use qualitative methods for monitoring, such a fixed photography.

5.2 METHODS

5.2.1 Selection of monitoring points

Thirty-five monitoring points were chosen (Figure 5.1). Monitoring points were not selected purely to cover the range of the vegetation communities. Mabula's reserve management requested a woody monitoring system that could also directly assess the possible adverse impacts of elephants and bush encroachment on the woody vegetation of the reserve. Sites were also selected on eroded areas which were under rehabilitation and on old abandoned croplands where woody vegetation was re-establishing. The monitoring sites chosen assessed many of the vegetation communities on Mabula Game Reserve (Table 5.1). Additional monitoring points were added to the dominant vegetation communities to enable a proper assessment of the available browse.

The *Acacia caffra - Faurea saligna* Short Open Woodland, covers 24% of the surface area of Mabula Game Reserve. Therefore 10 monitoring sites were dedicated to this vegetation community. The next predominant vegetation community was the *Combretum apiculatum* Short Open Woodland, covering 15% of the surface area of the reserve. This community was only allocated one survey site due to the inaccessibility of the mountain area and its minimal utilisation by browsers, which can be seen in the results from Chapter 3. The *Acacia caffra* Short Open Woodland, covering 2% of the surface area of the reserve, was not chosen for the same reason. The *Melinis repens* Low Closed

Grassland covers 12% of the surface area of the reserve. This vegetation community occurs on abandoned lands and has minimal woody vegetation. However, as the cultivation activities have been stopped, the woody vegetation is re-establishing naturally. Three monitoring sites were placed in this community to assess the re-establishment of woody vegetation. The *Burkea africana - Terminalia sericea* Low Thicket is densely populated with woody vegetation and covers 11% of the surface area of the reserve. As it is one of the largest vegetation communities and has a high density of woody species, eight monitoring sites were assigned to this area. The *Acacia karroo* Low Thicket covers 6% of the surface area of the reserve and was assigned three monitoring points. Two monitoring sites were assigned to the *Terminalia sericea* - Acacia species Low Thicket which covers 6% of the surface area of the reserve and the *Combretum apiculatum - Acacia caffra* Short Open Woodland which covers 4% of the surface area of the reserve and was assigned four monitoring points. The *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket, consisting of riparian vegetation, covers 3% of the surface area of the reserve and was assigned four monitoring points. The *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland is found on abandoned agricultural fields and due to reserve management's efforts to reduce *Hyperthelia dissoluta*, many areas are being slashed, therefore woody monitoring in this vegetation community was not practical. No monitoring points were established on the *Eragrostis gummiflua* Low Closed Grassland as it is natural grassland with minimal woody vegetation. The *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland and *Eragrostis gummiflua* Low Closed Grassland together, cover 14% of the surface area of Mabula Game Reserve. The *Terminalia sericea - Acacia caffra* Low Open Woodland, *Terminalia sericea - Seriphium plumosum* Short Bushland and *Terminalia sericea - Trachypogon spicatus* Short Open Grassland were not assigned monitoring points as they are minor vegetation communities covering together 4% of the surface area of the reserve.

A total of 13 monitoring points were assigned specifically to assess the impact of the elephants on Mabula Game Reserve. These monitoring points were selected by the reserve management, based on their observation of preferred areas of elephant use during the supplementary feeding programme (McMullen pers. comm.[1]). There are 10 elephants on the reserve, consisting of five adults and five juveniles. The elephants have

[1] J. McMullen. Witfontein 526 KQ, Limpopo

access to an area of 8 362 ha and therefore the number of elephants exceeds the long-term ecological capacity of the reserve to support these large herbivores.

Four sites were established to assess bush encroachment. According to the reserve management the main encroachment is caused by *Terminalia sericea*. This species forms exceptionally dense stands which are a problem for game viewing. Three sites were allocated to address this impact. One site was allocated to *Dichrostachys cinerea* encroachment which is not a substantial problem on the reserve at present, but may become so in the future.

Substantial erosion has occurred in the northwestern section of Mabula Game Reserve. Efforts have been made to reclaim these eroded areas and to prevent further erosion. Two sites were placed in areas where erosion has occurred and erosion control has been established.

5.2.2 BECVOL data collection

A 100 m by 2 m belt transect was set out at each monitoring site. All the trees that were rooted within the belt transect were identified and measured by using a 2 m calibrated range rod. The rods were made of a 2 m piece of white electrical piping. Increments were marked at 10 cm intervals in black and at 50 cm intervals in red. The lines were thick to ensure that they were visible from a distance. To take the measurements one of the workers held the range rod vertical as close to the stem as possible. The other person moved back 10 m, where possible, and estimated the proportional heights. A pencil or pen was used to determine the proportion of 2 m and then the pen was moved up the tree, to gain a total height measurement. The same approach was used for measuring the diameter, except that the range rod was held horizontally. For shrub and small trees the measurements were taken directly at the plant if it dose not exceed the length of the range rod by more than 1 m in width.

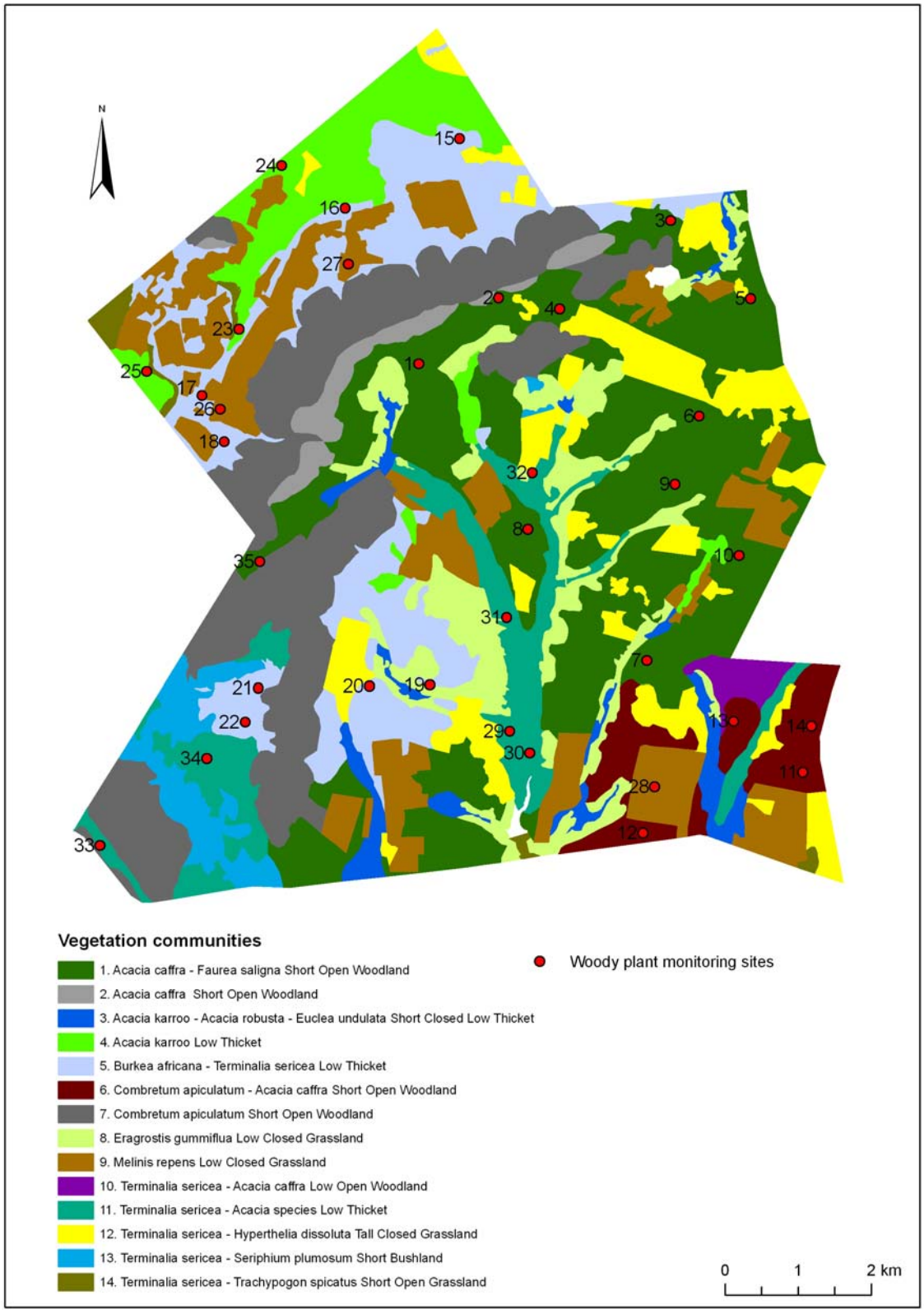


Figure 5.1. The distribution of 35 points which were used to monitor the woody vegetation across the vegetation communities on Mabula Game Reserve in 2004.

Table 5.1. The woody plant monitoring points on Mabula Game Reserve that were used for assessment of the browser production of the vegetation communities and management issues in 2004

Site	Vegetation community	Impact agent
1	*Acacia caffra - Faurea saligna* Short Open Woodland	None
2	*Acacia caffra - Faurea saligna* Short Open Woodland	Elephant
3	*Acacia caffra - Faurea saligna* Short Open Woodland	None
4	*Acacia caffra - Faurea saligna* Short Open Woodland	None
5	*Acacia caffra - Faurea saligna* Short Open Woodland	Elephant
6	*Acacia caffra - Faurea saligna* Short Open Woodland	None
7	*Acacia caffra - Faurea saligna* Short Open Woodland	None
8	*Acacia caffra - Faurea saligna* Short Open Woodland	None
9	*Acacia caffra - Faurea saligna* Short Open Woodland	None
10	*Acacia caffra - Faurea saligna* Short Open Woodland	Elephant
11	*Combretum apiculatum - Acacia caffra* Short Open Woodland	Elephant
12	*Combretum apiculatum - Acacia caffra* Short Open Woodland	Elephant
13	*Combretum apiculatum - Acacia caffra* Short Open Woodland	Elephant
14	*Combretum apiculatum - Acacia caffra* Short Open Woodland	Elephant
15	*Burkea africana - Terminalia sericea* Low Thicket	Elephant
16	*Burkea africana - Terminalia sericea* Low Thicket	Elephant
17	*Burkea africana - Terminalia sericea* Low Thicket	Bush encroachment
18	*Burkea africana - Terminalia sericea* Low Thicket	Elephant
19	*Burkea africana - Terminalia sericea* Low Thicket	Bush encroachment
20	*Burkea africana - Terminalia sericea* Low Thicket	Bush encroachment
21	*Burkea africana - Terminalia sericea* Low Thicket	None
22	*Burkea africana - Terminalia sericea* Low Thicket	Bush encroachment
23	*Acacia karroo* Low Thicket	Erosion
24	*Acacia karroo* Low Thicket	None
25	*Acacia karroo* Low Thicket	Erosion
26	*Melinis repens* Low Closed Grassland	Old cultivated land
27	*Melinis repens* Low Closed Grassland	Old cultivated land
28	*Melinis repens* Low Closed Grassland	Old cultivated land
29	*Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket	None
30	*Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket	None
31	*Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket	None
32	*Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket	None
33	*Terminalia sericea - Acacia* species Low Thicket	Elephant
34	*Terminalia sericea - Acacia* species Low Thicket	Elephant
35	*Combretum apiculatum* Short Open Woodland	Elephant

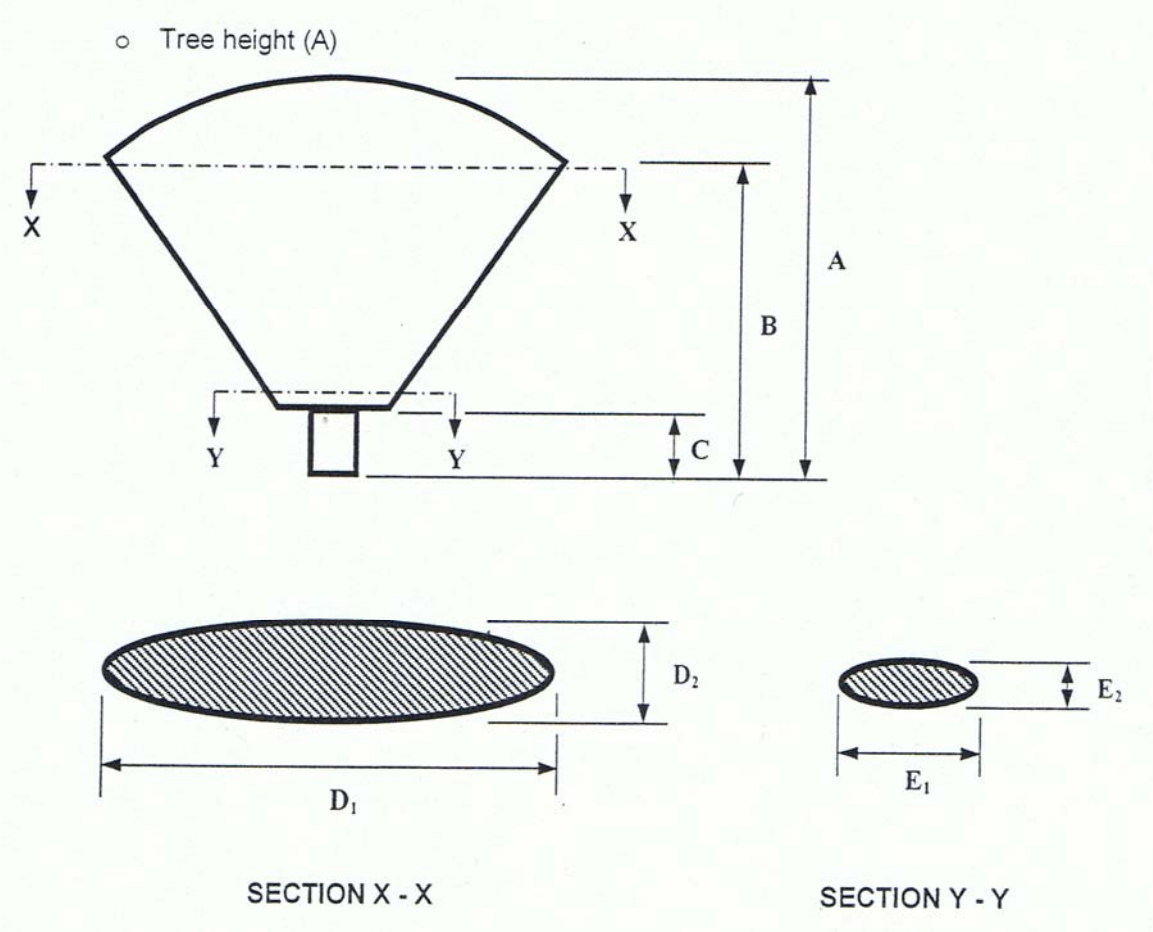
Each woody plant species was recorded together with the measurements as given in Figure 5.2, as well as the distance along the measuring tape and the distance from the measuring tape. The distance from the measuring tape was determined by using the range rod and ensured that the plants were rooted within the 2 m width of each transect. If the permanent markers of the monitoring transect are removed the additional measurements can be used to reposition the measuring tape. This will be discussed further in the section relating to locations of the monitoring areas.

The measurements were recorded in meters on BECVOL data sheets. The maximum canopy diameter was measured at the widest and lowest cross section (D1 & E1) and the second measurement was taken 90º to the widest and lowest cross section (D2 & E2). The lowest branches measured must be part of the canopy and not a single lower branch or coppice. Any odd branches were left out of the assessment.

5.2.3 BECVOL analysis

All the data collected on the BECVOL data sheets were entered into the computer program. The output provided the values in units per hectare, for example, kg/ha for leaf biomass. The leaf biomass was multiplied by the area of the community to determine the total leaf biomass for that particular homogeneous unit.

Von Holdt (1999) determined that browsers utilise no more that 10% of the total browse, therefore 10% of the biomass estimates from BECVOL were used for calculating the stocking density for browsers. The stocking density was determined by dividing the available browse by 1 533, which is the quantity of leaf material one Browse Unit (BU) will consume in a year. A Browser Unit is equivalent to a 140 kg kudu that browses 4.5 kg leaf dry mass per day (Bothma *et al.* 2004).



Measurement taken in meters per tree:

1. Tree height (A)
2. Height at maximum canopy diameter (B)
3. Height of lowest branch with leaves (C)
4. Maximum canopy diameter (two directions perpendicular to one another) (D1 & D2)
5. Minimum canopy diameter at lowest branch with leaves (two direction perpendicular to one another) (E1 & E2)

Figure 5.2. Dimensions of a tree which were measured as required for the BECVOL analysis (Smit 1989a) to assess the volume of woody plants.

5.2.4 Line intercept

The measurements for the line intercept method were taken from one side of the BECVOL transect, along the measuring tape from 0 m to 100 m. The plant woody species which intersected the measuring tape were recorded. Only the portion of the plant which intersected the line was recorded. The plants were separated into two height classes; those ≤ 2 m and those >2 m. The numbers of plants in each height class of the same species was counted, along with the total number of plants measured. The values were then entered into the equations below.

$$\text{Relative density (\%)} = \frac{\text{Total number of individuals of a plant species}}{\text{Total number of individuals of all plant species}} \times 100$$

$$\text{Relative dominance (\%)} = \frac{\text{Total intercept length for a plant species}}{\text{Total intercept length for all plant species}} \times 100$$

$$\text{Frequency} = \frac{\text{Number of intervals in which a plant species is found}}{\text{Total number of intervals}} \times 100$$

$$\text{Relative frequency (\%)} = \frac{\text{Frequency for a plant species}}{\text{Total frequency}} \times 100$$

$$\text{Importance value (IV)} = \frac{\text{Relative density + relative dominance + relative frequency}}{3}$$

5.3 RESULTS

As these are the initial surveys for a future monitoring programme the immediate results are of limited importance. Tables 5.2 to 5.8 show the BECVOL results and tables 5.9 to 5.15 the line intercept results for each of the monitoring transects set out across Mabula Game Reserve, to determine composition, density and structure of the woody plant layer and the browsing capacity. For the purpose of this chapter only the BECVOL results for the seven vegetation communities that were sampled will be discussed. The results from Chapter 3, in relation to the habitat selection by browsers present on Mabula Game Reserve, will be compared to the determination of browsing capacity in this chapter.

5.3.1 *Acacia caffra - Faurea saligna* Short Open Woodland

According to the BECVOL results (Table 5.2) this vegetation community produced the fourth largest biomass of dry leaf material per hectare (1634.3 kg/ ha). Due to the size of this vegetation community it can sustain the second highest number of Browse Units for a plant height of ≤ 1.5 m high (21.5 Browser Units), ≤ 2.0 m high (28.9 Browser Units) and ≤ 5.0 m high (145.2 Browser Units).

According to the importance values derived from the line intercept method (Table 5.9), the woody plant species with the highest values for the woody vegetation > 2 m high were *Combretum zeyheri* and *Faurea saligna*. These species had the highest leaf dry mass per hectare, with *Faurea saligna* yielding 328.2 kg/ha and *Combretum zeyheri* yielding 300.2 kg/ha. *Vitex rehmannii* had the highest importance value of 32.8, for the woody vegetation ≤ 2 m high. *Ochna pulchra* had the second highest importance value of 10.2, but had a low leaf dry mass per hectare (15.5 kg/ha). *Euclea undulata* had the next highest importance value, along with *Acacia caffra* for the ≤ 2 m height class.

5.3.2 *Combretum apiculatum - Acacia caffra* Short Open Woodland

According to the BECVOL results (Table 5.3) this vegetation community produced the third highest biomass of dry leaf material per hectare (2270.7 kg/ha). The *Combretum apiculatum - Acacia caffra* Short Open Woodland can sustain the lowest quantity of Browse Units for ≤ 1.5 m high (3.4 Browser Units) and ≤ 2.0 m (5.0 Browser Units) high but the third lowest number of Browse Units ≤ 5.0 m high (31.3 Browser Units).

According to the importance values derived from the line intercept method (Table 5.10), the woody plant species with the highest values for woody vegetation > 2 m high was *Combretum apiculatum*, with a value of 48.2. This woody plant species also had the highest biomass of dry leaf material with 1030.7 kg/ha. *Combretum zeyheri* had the second highest importance value of 21.8 and the second highest biomass of dry leaf material of 513.9 kg/ha. The species with the highest importance values for woody vegetation ≤ 2 m high were *Dichrostachys cinerea* with a value of 35.2 and *Combretum apiculatum* and *Vitex rehmannii* both, with a value of 16.2.

5.3.3 Burkea africana - Terminalia sericea Low Thicket

According to the BECVOL results (Table 5.4) this vegetation community produced the second largest biomass of dry leaf material per hectare (3010.4 kg/ha). The *Burkea africana - Terminalia sericea* Low Thicket can sustain the highest quantity of Browse Units for ≤ 1.5 m high (45.2 Browser Units), ≤ 2.0 m high (56.6 Browser Units) and ≤ 5.0 m high (146.7 Browser Units).

According to the importance values derived from the line intercept method (Table 5.11), the woody plant species with the highest values for the woody vegetation > 2 m high was *Terminalia sericea*, with a value of 28.0. *Terminalia sericea* had the largest biomass of leaf material, with 722.6 kg/ha. *Dichrostachys cinerea* had the second highest importance value of 21.7, followed by *Burkea africana* with a value of 6.7. Both species had relatively high biomass of dry leaf material. The species with the highest importance values for the woody vegetation ≤ 2 m high were *Dichrostachys cinerea* with a value of 25.7 and *Clerodendrum glabrum* with a value of 15.5.

5.3.4 Acacia karroo Low Thicket

According to the BECVOL results (Table 5.5) this vegetation community produced the third lowest biomass of dry leaf material per hectare (1473.5 kg/ha). The *Acacia karroo* Low Thicket can sustain the third lowest number of Browse Units for ≤ 1.5 m high (8.3 Browser Units), ≤ 2.0 m high (12.1 Browser Units) and the fourth lowest ≤ 5.0 m high (35.7 Browser Units).

According to the importance values derived from the line intercept method (Table 5.12), the species with the highest values for the woody vegetation > 2 m high were *Terminalia sericea* with a value of 21.5 and *Euclea undulata* with a value of 20.4. *Terminalia sericea* had a biomass of dry leaf material of 521.9 kg/ha and *Euclea undulata* had a biomass of dry leaf material of 125.3 kg/ha. *Burkea africana* and *Acacia erubescens* had the next highest importance values with 15.5 (286.3 kg/ha dry leaf mass) and 14.8 (219.5 kg/ha dry leaf mass). The woody plant species with the highest importance values for the woody vegetation ≤ 2 m high were *Gymnosporia buxifolia* with a value of 19.6,

Terminalia sericea with a value of 18.9, *Euclea undulata* with a value of 14.5 and *Carissa bispinosa* with a value of 13.1.

5.3.5 *Melinis repens* Low Closed Grassland

According to the BECVOL results (Table 5.6) this vegetation community produced the lowest biomass of dry leaf material per hectare (481.3 kg/ha). The *Melinis repens* Low Closed Grassland can sustain the fourth lowest quantity of Browse Units for ≤ 1.5 m high (9.1 Browser Units) and ≤ 2.0 m high (14.0 Browser Units) and the third lowest number of Browser Units ≤ 5.0 m high (30.7 Browser Units).

According to the importance values derived from the line intercept method (Table 5.13), the woody plant species with the highest values for the woody vegetation > 2 m high were *Acacia tortilis* with a value of 42.0 (162.9 kg/ha dry leaf mass) and *Burkea africana* had the next highest importance value of 22.3 (123.0 kg/ha dry leaf mass). The species with the highest importance value for the woody vegetation ≤ 2 m high was *Dichrostachys cinerea* with a value of 59.4.

5.3.6 *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket

According to the BECVOL results (Table 5.7) this vegetation community produced the second lowest biomass of dry leaf material per hectare (963.0 kg/ha). The *Acacia karroo - Acacia robust - Euclea undulata* Short Closed Low Thicket can sustain the second lowest quantity of Browse Units for ≤ 1.5 m high (5.0 Browser Units) and ≤ 2.0 m (6.0 Browser Units) and the lowest number of browse units ≤ 5.0 m high (11.1 Browser Units).

According to the importance values derived from the line intercept method (Table 5.14), the woody plant species with the highest values for the woody vegetation > 2 m high were *Terminalia sericea* with a value of 40.1 (187.9 kg/ha dry leaf mass) and *Peltophorum africanum* with a value of 23.8 (229.2 kg/ha dry leaf mass). The woody plant species with the highest importance values for the woody vegetation ≤ 2 m high were *Acacia karroo* with a value of 41.5, *Terminalia sericea* with a value of 13.0 and *Euclea undulata* with a value of 10.6.

5.3.7 Terminalia sericea - Acacia species Low Thicket

According to the BECVOL results (Table 5.8) this vegetation community produced the highest biomass of dry leaf material per hectare (3518.0 kg/ha). The *Terminalia sericea - Acacia* species Low Thicket can sustain the third highest quantity of Browse Units for ≤ 1.5 m high (15.0 Browser Units), ≤ 2.0 m high (23.7 Browser Units) and ≤ 5.0 m high (98.3 Browser Units).

According to the importance values derived from the line intercept method (Table 5.15), the woody plant species with the highest values for the woody vegetation > 2 m high were *Acacia tortilis* with a value of 43.8 (1075.3 kg/ha dry leaf mass) and *Dichrostachys cinerea* with a value of 32.5 (1448.8 kg/ha dry leaf mass). The woody plant species with the highest importance value for the woody vegetation ≤ 2 m high was *Dichrostachys cinerea* with a value of 82.0.

5.4 DISCUSSION

A total of 48 woody plant species was sampled over all the monitoring sites. The line intercept method provided information on the composition and structure of the individual monitoring sites and the seven vegetation communities. These results generally agreed with the leaf biomass results for individual woody plant species based on the BECVOL method. The BECVOL results are particularly important in relation to the management of herbivore populations when assessing the browsing capacity. The results for the line intercept method are not discussed in depth here because this is the initial study for the monitoring programme. Once data have been collected over several time intervals, the changes in the species composition and structure can be assessed. However, the BECVOL results will be fully discussed as they are relevant to the immediate management of Mabula Game Reserve. The monitoring for woody plant species composition and structure will be of great importance in the future as there is overutilisation of the woody layer. This overutilisation may have substantial effects in the future on the composition and structure of the woody layer.

Table 5.2. Determination of browsing capacity based on the BECVOL method for the *Acacia caffra - Faurea saligna* Short Open Woodland on Mabula Game Reserve in 2004

	Dry leaf mass (kg/ha)				Browser Units per community		
Woody plant	Total	< 1.5 m	< 2.0 m	< 5.0 m	< 1.5 m	< 2.0 m	< 5.0 m
Acacia caffra	206.8	25.5	30.9	124.6	3.3	4.0	16.1
Acacia karroo	4.4	1.2	2.6	4.4	0.2	0.3	0.6
Brachylaena rotundata	1.6	1.6	1.6	1.6	0.2	0.2	0.2
Burkea africana	90.2	4.0	6.0	66.1	0.5	0.8	8.5
Clerodendrum glabrum	13.4	8.3	11.0	13.4	1.1	1.4	1.7
Combretum apiculatum	120.3	0.1	0.8	63.3	0.0	0.1	8.2
Combretum molle	0.3	0.3	0.3	0.3	0.0	0.0	0.0
Combretum zeyheri	300.2	11.5	19.9	229.8	1.5	2.6	29.7
Commiphora mollis	0.2	0.2	0.2	0.2	0.0	0.0	0.0
Dichrostachys cinerea	4.7	4.4	4.6	4.7	0.6	0.6	0.6
Dombeya rotundifolia	67.0	10.4	12.7	56.9	1.3	1.6	7.4
Euclea crispa	32.8	22.6	27.1	32.8	2.9	3.5	4.2
Euclea divinorum	2.0	0.1	1.1	2.0	0.0	0.1	0.3
Euclea undulata	0.6	0.6	0.6	0.6	0.1	0.1	0.1
Faurea saligna	328.2	13.2	23.0	201.6	1.7	3.0	26.0
Grewia flava	8.0	0.3	2.0	8.0	0.0	0.3	1.0
Grewia flavescens	0.6	0.6	0.6	0.6	0.1	0.1	0.1
Grewia monticola	3.7	3.7	3.7	3.7	0.5	0.5	0.5
Gymnosporia nemorosa	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lannea discolor	80.4	2.2	2.3	54.9	0.3	0.3	7.1
Ochna pulchra	15.5	2.5	2.5	15.5	0.3	0.3	2.0
Ozoroa paniculosa	4.3	0.5	1.1	4.3	0.1	0.1	0.6
Pappea capensis	1.7	1.7	1.7	1.7	0.2	0.2	0.2
Peltophorum africanum	168.6	7.2	9.2	82.8	0.9	1.2	10.7
Searsia lancea	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Searsia leptodictya	35.5	5.5	11.4	35.5	0.7	1.5	4.6
Searsia pyroides	0.3	0.3	0.3	0.3	0.0	0.0	0.0
Terminalia brachystemma	27.4	0.9	1.0	23.3	0.1	0.1	3.0
Terminalia sericea	54.5	5.2	5.8	34.4	0.7	0.8	4.4
Vitex rehmannii	60.9	31.7	40.1	57.5	4.1	5.2	7.4
Ziziphus mucronata	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Total	1634.4	166.3	224.2	1125.1	21.4	28.9	145.2

Table 5.3. Determination of browsing capacity based on the BECVOL method for the *Combretum apiculatum - Acacia caffra* Short Open Woodland on Mabula Game Reserve in 2004

	Dry Leaf Mass (kg/ha)				Browser Units per community		
Woody plant	Total	< 1.5 m	< 2.0 m	< 5.0 m	< 1.5 m	< 2.0 m	< 5.0 m
Acacia caffra	136.5	6.1	12.4	95.3	0.1	0.2	1.8
Acacia tortilis	5.6	5.6	5.6	5.6	0.1	0.1	0.1
Burkea africana	130.3	0.4	0.4	89.8	0.0	0.0	1.7
Combretum apiculatum	1030.7	33.7	51.1	751.1	0.6	1.0	14.3
Combretum zeyheri	513.9	1.2	19.2	375.1	0.0	0.4	7.1
Dichrostachys cinerea	93.4	25.1	32.7	81.1	0.5	0.6	1.5
Dombeya rotundifolia	2.8	2.8	2.8	2.8	0.1	0.1	0.1
Euclea crispa	13.2	13.2	13.2	13.2	0.3	0.3	0.3
Euclea divinorum	8.3	3.3	6.6	8.3	0.1	0.1	0.2
Euclea undulata	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Grewia monticola	14.4	13.0	14.3	14.4	0.3	0.3	0.3
Gymnosporia buxifolia	16.5	1.6	5.0	16.5	0.0	0.1	0.3
Lannea discolor	1.2	1.2	1.2	1.2	0.0	0.0	0.0
Ozoroa paniculosa	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Pappea capensis	0.4	0.4	0.4	0.4	0.0	0.0	0.0
Peltophorum africanum	50.1	24.0	36.8	50.1	0.5	0.7	1.0
Pterocarpus rotundifolius	1.0	1.0	1.0	1.0	0.0	0.0	0.0
Searsia lancea	2.2	2.2	2.2	2.2	0.0	0.0	0.0
Searsia leptodictya	40.3	4.6	6.1	40.3	0.1	0.1	0.8
Searsia pyroides	41.6	12.0	21.3	41.6	0.2	0.4	0.8
Sclerocarya birrea	125.3	0.0	0.0	11.1	0.0	0.0	0.2
Vitex rehmannii	39.5	24.4	26.5	39.5	0.5	0.5	0.8
Ximenia caffra	3.4	1.0	2.8	3.4	0.0	0.1	0.1
Total	2270.7	176.9	261.7	1644.3	3.4	5.0	31.3

Table 5.4. Determination of browsing capacity based on the BECVOL method for the *Burkea africana - Terminalia sericea* Low Thicket on Mabula Game Reserve in 2004

	Dry Leaf Mass (kg/ha)				Browser Units per community		
Woody plant	Total	< 1.5 m	< 2.0 m	< 5.0 m	< 1.5 m	< 2.0 m	< 5.0 m
Acacia caffra	11.3	11.3	11.3	11.3	0.7	0.7	0.7
Acacia karroo	131.4	5.4	8.2	84.5	0.3	0.5	5.1
Acacia tortilis	98.7	2.0	3.4	30.7	0.1	0.2	1.9
Albizia anthelmintica	27.7	0.0	1.4	15.3	0.0	0.1	0.9
Albizia tanganyicensis	95.3	4.8	10.2	67.3	0.3	0.6	4.1
Burkea africana	105.1	4.2	4.7	94.0	0.3	0.3	5.7
Clerodendrum glabrum	146.3	89.1	113.2	132.1	5.4	6.9	8.0
Combretum apiculatum	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Combretum molle	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Combretum zeyheri	345.0	19.4	48.2	279.3	1.2	2.9	16.9
Commiphora mollis	22.4	1.9	4.0	18.5	0.1	0.2	1.1
Dichrostachys cinerea	323.2	102.9	140.9	318.2	6.2	8.5	19.3
Dombeya rotundifolia	43.8	3.0	5.8	42.4	0.2	0.4	2.6
Ehretia rigida	3.9	0.3	1.1	3.9	0.0	0.1	0.2
Euclea crispa	7.0	5.0	5.1	7.0	0.3	0.3	0.4
Euclea undulata	0.4	0.3	0.4	0.4	0.0	0.0	0.0
Faurea saligna	155.6	145.9	145.9	153.6	8.8	8.8	9.3
Grewia flava	57.6	47.1	52.4	57.6	2.9	3.2	3.5
Grewia flavescens	131.8	124.8	127.2	131.8	7.6	7.7	8.0
Grewia monticola	78.1	50.3	69.7	78.1	3.0	4.2	4.7
Gymnosporia senegalensis	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Jacaranda mimosifolia	22.9	5.0	10.1	22.9	0.3	0.6	1.4
Ochna pulchra	0.4	0.4	0.4	0.4	0.0	0.0	0.0
Olea europaea	44.4	1.0	1.8	30.6	0.1	0.1	1.9
Pappea capensis	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Peltophorum africanum	22.2	9.8	14.7	22.2	0.6	0.9	1.3
Searsia lancea	310.9	20.4	41.8	224.4	1.2	2.5	13.6
Searsia leptodictya	2.4	2.4	2.4	2.4	0.2	0.2	0.2
Searsia pyroides	0.2	0.2	0.2	0.2	0.0	0.0	0.0
Terminalia brachystemma	58.1	21.6	22.4	33.5	1.3	1.4	2.0
Terminalia sericea	722.6	68.6	85.5	528.5	4.2	5.2	32.0
Ziziphus mucronata	41.2	0.0	1.8	32.9	0.0	0.1	2.0
Total	3010.4	747.3	934.4	2424.5	45.2	56.5	146.7

Table 5.5. Determination of browsing capacity based on the BECVOL method for the *Acacia karroo* Low Thicket on Mabula Game Reserve in 2004

	Dry Leaf Mass (kg/ha)				Browser Units per community		
Woody plant	Total	< 1.5 m	< 2.0 m	< 5.0 m	< 1.5 m	< 2.0 m	< 5.0 m
Acacia caffra	0.6	0.6	0.6	0.6	0.0	0.0	0.0
Acacia erubescens	219.5	43.0	97.9	219.5	1.3	3.0	6.8
Acacia hebeclada	17.8	0.0	3.7	17.8	0.0	0.1	0.6
Acacia karroo	148.3	9.0	14.0	126.1	0.3	0.4	3.9
Albizia anthelmintica	0.2	0.2	0.2	0.2	0.0	0.0	0.0
Burkea africana	286.3	3.3	5.2	85.2	0.1	0.2	2.6
Carissa bispinosa	16.1	16.1	16.1	16.1	0.5	0.5	0.5
Combretum imberbe	10.0	3.1	5.7	10.0	0.1	0.2	0.3
Dichrostachys cinerea	17.5	6.1	6.1	17.5	0.2	0.2	0.5
Dombeya rotundifolia	1.8	1.8	1.8	1.8	0.1	0.1	0.1
Ehretia rigida	1.1	1.1	1.1	1.1	0.0	0.0	0.0
Euclea crispa	6.1	3.9	5.8	6.1	0.1	0.2	0.2
Euclea undulata	125.3	69.7	97.4	125.3	2.1	3.0	3.9
Grewia flava	8.1	7.6	8.1	8.1	0.2	0.3	0.3
Grewia flavescens	16.6	16.6	16.6	16.6	0.5	0.5	0.5
Grewia monticola	9.4	9.0	9.4	9.4	0.3	0.3	0.3
Gymnosporia buxifolia	19.1	17.6	19.1	19.1	0.5	0.6	0.6
Olea capensis	5.6	5.6	5.6	5.6	0.2	0.2	0.2
Olea europaea	35.1	12.8	22.9	35.1	0.4	0.7	1.1
Ozoroa paniculosa	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Peltophorum africanum	1.0	1.0	1.0	1.0	0.0	0.0	0.0
Searsia lancea	3.4	3.0	3.4	3.4	0.1	0.1	0.1
Searsia leptodictya	1.5	1.5	1.5	1.5	0.1	0.1	0.1
Terminalia brachystemma	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Terminalia sericea	521.9	37.1	49.1	434.1	1.1	1.5	13.3
Ziziphus mucronata	1.3	1.3	0.5	1.3	0.0	0.0	0.0
Total	1473.5	270.9	392.7	1162.4	8.3	12.1	35.7

Table 5.6. Determination of browsing capacity based on the BECVOL method for the *Melinis repens* Low Closed Grassland on Mabula Game Reserve in 2004

	Dry Leaf Mass (kg/ha)				Browser Units per community		
Woody plant	Total	< 1.5 m	< 2.0 m	< 5.0 m	< 1.5 m	< 2.0 m	< 5.0 m
Acacia erubescens	0.9	0.9	0.9	0.9	0.1	0.1	0.1
Acacia karroo	46.3	3.2	8.0	46.3	0.2	0.5	3.0
Acacia tortilis	162.9	39.5	68.9	162.9	2.5	4.4	10.4
Burkea africana	56.2	8.9	17.5	56.2	0.6	1.1	3.6
Dichrostachys cinerea	123.0	30.4	49.1	123.0	1.9	3.1	7.9
Dombeya rotundifolia	7.2	6.6	7.2	7.2	0.4	0.5	0.5
Euclea crispa	20.9	2.2	6.0	20.9	0.1	0.4	1.3
Grewia flavescens	7.2	3.4	4.7	7.2	0.2	0.3	0.5
Grewia monticola	10.8	9.7	10.8	10.8	0.6	0.7	0.7
Ochna pulchra	0.3	0.3	0.3	0.3	0.0	0.0	0.0
Pappea capensis	0.4	0.4	0.4	0.4	0.0	0.0	0.0
Peltophorum africanum	11.2	11.2	11.2	11.2	0.7	0.7	0.7
Searsia lancea	4.4	4.4	4.4	4.4	0.3	0.3	0.3
Searsia leptodictya	0.4	0.4	0.4	0.4	0.0	0.0	0.0
Searsia pyroides	1.0	1.0	1.0	1.0	0.1	0.1	0.1
Terminalia brachystemma	3.2	3.2	3.2	3.2	0.2	0.2	0.2
Terminalia sericea	25.0	17.2	24.5	25.0	1.1	1.6	1.6
Total	481.3	142.8	218.5	481.3	9.1	13.9	30.7

Table 5.7. Determination of browsing capacity based on the BECVOL method for the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket on Mabula Game Reserve in 2004

	Dry Leaf Mass (kg/ha)				Browser Units per community		
Woody plant	Total	< 1.5 m	< 2.0 m	< 5.0 m	< 1.5 m	< 2.0 m	< 5.0 m
Acacia caffra	6.9	6.1	6.4	6.9	0.1	0.1	0.1
Acacia karroo	192.6	152.7	176.3	192.6	2.1	2.5	2.7
Burkea africana	55.9	1.3	1.3	15.2	0.0	0.0	0.2
Carissa bispinosa	2.6	2.6	2.6	2.6	0.0	0.0	0.0
Clerodendrum glabrum	0.3	0.3	0.3	0.3	0.0	0.0	0.0
Combretum apiculatum	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Combretum hereroense	0.3	0.3	0.3	0.3	0.0	0.0	0.0
Combretum molle	0.2	0.2	0.2	0.2	0.0	0.0	0.0
Combretum zeyheri	0.5	0.5	0.5	0.5	0.0	0.0	0.0
Commiphora mollis	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Dichrostachys cinerea	4.2	4.2	4.2	4.2	0.1	0.1	0.1
Diospyros lycioides	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Euclea crispa	5.6	3.9	3.9	5.6	0.1	0.1	0.1
Euclea undulata	5.4	4.8	5.4	5.4	0.1	0.1	0.1
Grewia flava	5.0	5.0	5.0	5.0	0.1	0.1	0.1
Grewia monticola	9.2	9.1	9.2	9.2	0.1	0.1	0.1
Gymnosporia buxifolia	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Gymnosporia nemorosa	1.5	1.5	1.5	1.5	0.0	0.0	0.0
Ochna pulchra	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Olea europaea	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Peltophorum africanum	229.2	57.4	67.0	141.8	0.8	0.9	2.0
Searsia lancea	178.0	56.5	75.4	178.0	0.8	1.1	2.5
Searsia leptodictya	50.0	12.3	17.0	50.0	0.2	0.2	0.7
Searsia pyroides	5.0	5.0	5.0	5.0	0.1	0.1	0.1
Sclerocarya birrea	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Terminalia brachystemma	15.2	6.5	9.1	15.2	0.1	0.1	0.2
Terminalia sericea	187.9	21.0	27.2	146.0	0.3	0.4	2.0
Vitex rehmannii	1.6	1.6	1.6	1.6	0.0	0.0	0.0
Ziziphus mucronata	5.5	5.1	5.5	5.5	0.1	0.1	0.1
Total	963.0	358.2	425.2	793.0	5.0	6.0	11.1

Table 5.8. Determination of browsing capacity based on the BECVOL method for the *Terminalia sericea* - *Acacia* species Low Thicket on Mabula Game Reserve in 2004

	Dry Leaf Mass (kg/ha)				Browser Units per community		
Woody plant	Total	< 1.5 m	< 2.0 m	< 5.0 m	< 1.5 m	< 2.0 m	< 5.0 m
Acacia karroo	493.5	1.8	6.6	326.5	0.1	0.2	11.4
Acacia tortilis	1075.3	96.9	156.9	652.2	3.4	5.5	22.7
Clerodendrum glabrum	1.5	1.5	1.5	1.5	0.1	0.1	0.1
Combretum imberbe	2.7	2.7	2.7	2.7	0.1	0.1	0.1
Dichrostachys cinerea	1448.8	175.9	311.9	1407.6	6.1	10.9	49.1
Ehretia rigida	76.1	18.7	30.4	76.1	0.7	1.1	2.7
Euclea crispa	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Euclea undulata	8.9	6.6	8.5	8.9	0.2	0.3	0.3
Grewia flava	18.1	18.1	18.1	18.1	0.6	0.6	0.6
Grewia flavescens	39.8	39.8	39.8	39.8	1.4	1.4	1.4
Grewia monticola	47.0	33.9	39.5	47.0	1.2	1.4	1.6
Gymnosporia senegalensis	0.7	0.7	0.7	0.7	0.0	0.0	0.0
Searsia lancea	203.6	30.4	60.7	203.6	1.1	2.1	7.1
Searsia leptodictya	1.9	1.9	1.9	1.9	0.1	0.1	0.1
Sclerocarya birrea	0.4	0.0	0.0	0.4	0.0	0.0	0.0
Terminalia sericea	70.2	1.2	1.2	14.5	0.0	0.0	0.5
Ziziphus mucronata	29.7	0.8	0.8	19.1	0.0	0.0	0.7
Total	3518.0	430.6	680.8	2820.3	15.0	23.7	98.3

Table 5.9. The line intercept results for the woody vegetation in the *Acacia caffra* - *Faurea saligna* Short Open Woodland on Mabula Game Reserve in 2004

Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
≤ 2 m	*Acacia caffra*	2.8	8	7	9.9	10.3	5.7	8.6	0.3
≤ 2 m	*Burkea africana*	0.8	1	1	1.2	1.5	1.7	1.5	0.1
≤ 2 m	*Clerodendrum glabrum*	0.5	1	1	1.2	1.5	0.9	1.2	0.1
≤ 2 m	*Dichrostachys cinerea*	2.6	6	6	7.4	8.8	5.4	7.2	0.3
≤ 2 m	*Dombeya rotundifolia*	0.6	1	1	1.2	1.5	1.2	1.3	0.1
≤ 2 m	*Euclea crispa*	4.1	7	6	8.6	8.8	8.4	8.6	0.4
≤ 2 m	*Euclea undulata*	3.1	3	2	3.7	2.9	6.4	4.4	0.3
≤ 2 m	*Faurea saligna*	2.9	4	4	4.9	5.9	6.0	5.6	0.3
≤ 2 m	*Grewia monticola*	2.9	3	3	3.7	4.4	5.9	4.7	0.3
≤ 2 m	*Lannea discolor*	1.4	3	3	3.7	4.4	2.8	3.6	0.1
≤ 2 m	*Ochna pulchra*	1.9	12	8	14.8	11.8	4.0	10.2	0.2
≤ 2 m	*Ozoroa paniculosa*	0.5	1	1	1.2	1.5	1.0	1.2	0.1
≤ 2 m	*Searsia leptodictya*	1.3	4	4	4.9	5.9	2.7	4.5	0.1
≤ 2 m	*Terminalia sericea*	2.7	3	3	3.7	4.4	5.6	4.6	0.3
≤ 2 m	*Vitex rehmannii*	20.6	24	18	29.6	26.5	42.3	32.8	2.1
	Total	48.6	81.0	68.0	100.0	100.0	100.0	100.0	4.9
Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
> 2 m	*Acacia caffra*	36.4	10	9	8.7	8.7	10.1	9.2	0.1
> 2 m	*Acacia karroo*	0.5	1	1	0.9	1.0	0.1	0.7	4.3
> 2 m	*Burkea africana*	42.6	11	11	9.6	10.7	11.8	10.7	0.1
> 2 m	*Clerodendrum glabrum*	0.7	1	1	0.9	1.0	0.2	0.7	2.6
> 2 m	*Combretum apiculatum*	25.8	7	7	6.1	6.8	7.1	6.7	7.4
> 2 m	*Combretum zeyheri*	73.5	18	16	15.7	15.5	20.3	17.2	1.0
> 2 m	*Dombeya rotundifolia*	9.8	4	4	3.5	3.9	2.7	3.4	0.8
> 2 m	*Euclea crispa*	8.3	8	7	7.0	6.8	2.3	5.4	0.1
> 2 m	*Euclea undulata*	1.1	1	1	0.9	1.0	0.3	0.7	7.0
> 2 m	*Faurea saligna*	70.1	19	16	16.5	15.5	19.4	17.1	0.4
> 2 m	*Grewia flava*	3.7	1	1	0.9	1.0	1.0	1.0	1.0
> 2 m	*Lannea discolor*	9.9	2	2	1.7	1.9	2.7	2.1	0.4
> 2 m	*Ochna pulchra*	4.0	2	2	1.7	1.9	1.1	1.6	0.1
> 2 m	*Pappea capensis*	0.6	1	1	0.9	1.0	0.2	0.7	3.7
> 2 m	*Peltophorum africanum*	36.6	10	5	8.7	4.9	10.1	7.9	0.1
> 2 m	*Searsia lancea*	0.9	1	1	0.9	1.0	0.3	0.7	1.2
> 2 m	*Searsia leptodictya*	12.0	5	5	4.4	4.9	3.3	4.2	0.1
> 2 m	*Searsia pyroides*	1.0	1	1	0.9	1.0	0.3	0.7	1.4
> 2 m	*Terminalia brachystemma*	14.1	4	4	3.5	3.9	3.9	3.8	0.4
> 2 m	*Terminalia sericea*	4.2	2	2	1.7	1.9	1.2	1.6	0.6
> 2 m	*Vitex rehmannii*	6.2	6	6	5.2	5.8	1.7	4.3	36.2
	Total	361.9	115.0	103.0	100.0	100.0	100.0	100.0	68.8

Table 5.10. The line intercept results for the woody vegetation in the *Combretum apiculatum - Acacia caffra* Short Open Woodland on Mabula Game Reserve in 2004

Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
≤ 2 m	*Acacia caffra*	0.7	4	4	7.0	7.8	0.9	5.2	0.2
≤ 2 m	*Acacia karroo*	0.4	1	1	1.8	2.0	0.5	1.4	0.1
≤ 2 m	*Combretum apiculatum*	7.5	11	10	19.3	19.6	9.6	16.2	1.9
≤ 2 m	*Dichrostachys cinerea*	54.0	12	8	21.1	15.7	68.7	35.2	13.5
≤ 2 m	*Dombeya rotundifolia*	1.0	3	3	5.3	5.9	1.3	4.1	0.3
≤ 2 m	*Euclea crispa*	2.6	4	4	7.0	7.8	3.3	6.1	0.7
≤ 2 m	*Grewia flava*	1.7	2	2	3.5	3.9	2.1	3.2	0.4
≤ 2 m	*Grewia monticola*	2.6	3	3	5.3	5.9	3.3	4.8	0.7
≤ 2 m	*Pappea capensis*	0.6	1	1	1.8	2.0	0.8	1.5	0.2
≤ 2 m	*Peltophorum africanum*	2.0	2	2	3.5	3.9	2.5	3.3	0.5
≤ 2 m	*Searsia leptodictya*	0.9	1	1	1.8	2.0	1.1	1.6	0.2
≤ 2 m	*Searsia pyroides*	0.1	1	1	1.8	2.0	0.2	1.3	0.0
≤ 2 m	*Vitex rehmannii*	4.6	12	11	21.1	21.6	5.8	16.2	1.2
	Total	78.6	57.0	51.0	100.0	100.0	100.0	100.0	19.7
Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
> 2 m	*Acacia caffra*	4.9	2	2	5.0	5.3	3.0	4.4	1.2
> 2 m	*Burkea africana*	7.9	2	2	5.0	5.3	4.8	5.0	2.0
> 2 m	*Combretum apiculatum*	86.8	19	17	47.5	44.7	52.4	48.2	21.7
> 2 m	*Combretum zeyheri*	40.3	8	8	20.0	21.1	24.4	21.8	10.1
> 2 m	*Dichrostachys cinerea*	2.1	2	2	5.0	5.3	1.3	3.8	0.5
> 2 m	*Faurea saligna*	0.7	1	1	2.5	2.6	0.4	1.9	0.2
> 2 m	*Gymnosporia buxifolia*	2.8	1	1	2.5	2.6	1.7	2.3	0.7
> 2 m	*Peltophorum africanum*	2.4	1	1	2.5	2.6	1.5	2.2	0.6
> 2 m	*Searsia pyroides*	7.4	3	3	7.5	7.9	4.5	6.6	1.9
> 2 m	*Sclerocarya birrea*	10.2	1	1	2.5	2.6	6.2	3.8	2.6
	Total	165.5	40.0	38.0	100.0	100.0	100.0	100.0	41.4

Table 5.11. The line intercept results for the woody vegetation in the *Burkea africana* - *Terminalia sericea* Low Thicket on Mabula Game Reserve in 2004

Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
≤ 2 m	*Acacia caffra*	1.5	3	3	1.6	2.0	1.1	1.6	0.2
≤ 2 m	*Acacia erubescens*	0.2	1	1	0.5	0.7	0.2	0.5	0.0
≤ 2 m	*Burkea africana*	2.5	8	8	4.3	5.3	1.9	3.8	0.3
≤ 2 m	*Carissa bispinosa*	0.4	1	1	0.5	0.7	0.3	0.5	0.0
≤ 2 m	*Clerodendrum glabrum*	13.5	31	30	16.5	19.9	10.1	15.5	1.7
≤ 2 m	*Combretum zeyheri*	1.3	1	1	0.5	0.7	1.0	0.7	0.2
≤ 2 m	*Dichrostachys cinerea*	36.1	54	32	28.7	21.2	27.1	25.7	4.5
≤ 2 m	*Dombeya rotundifolia*	0.5	1	1	0.5	0.7	0.4	0.5	0.1
≤ 2 m	*Ehretia rigida*	0.2	1	1	0.5	0.7	0.2	0.5	0.0
≤ 2 m	*Euclea crispa*	3.1	6	5	3.2	3.3	2.4	3.0	0.4
≤ 2 m	*Grewia flava*	6.0	14	12	7.5	8.0	4.5	6.6	0.7
≤ 2 m	*Grewia flavescens*	26.9	20	16	10.6	10.6	20.2	13.8	3.4
≤ 2 m	*Grewia monticola*	12.3	12	10	6.4	6.6	9.3	7.4	1.5
≤ 2 m	*Ochna pulchra*	0.4	1	1	0.5	0.7	0.3	0.5	0.1
≤ 2 m	*Olea capensis*	0.5	1	1	0.5	0.7	0.4	0.5	0.1
≤ 2 m	*Searsia leptodictya*	1.1	3	3	1.6	2.0	0.8	1.5	0.1
≤ 2 m	*Terminalia brachystemma*	5.5	8	8	4.3	5.3	4.2	4.6	0.7
≤ 2 m	*Terminalia sericea*	21.3	22	17	11.7	11.3	16.0	13.0	2.7
	Total	133.2	188.0	151.0	100.0	100.0	100.0	100.0	16.7
Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
> 2 m	*Acacia karroo*	18.9	4	4	3.4	4.2	4.9	4.2	2.4
> 2 m	*Acacia tortilis*	12.3	3	3	2.5	3.1	3.2	3.0	1.5
> 2 m	*Albizia anthelmintica*	5.1	1	1	0.9	1.0	1.3	1.1	0.6
> 2 m	*Burkea africana*	23.2	8	7	6.8	7.3	6.1	6.7	2.9
> 2 m	*Clerodendrum glabrum*	16.1	6	4	5.1	4.2	4.2	4.5	2.0
> 2 m	*Combretum zeyheri*	32.7	6	5	5.1	5.2	8.6	6.3	4.1
> 2 m	*Dichrostachys cinerea*	60.9	32	21	27.1	21.9	16.0	21.7	7.6
> 2 m	*Dombeya rotundifolia*	2.5	1	1	0.9	1.0	0.6	0.8	0.3
> 2 m	*Faurea saligna*	13.5	3	3	2.5	3.1	3.6	3.1	1.7
> 2 m	*Grewia flava*	2.6	2	2	1.7	2.1	0.7	1.5	0.3
> 2 m	*Grewia monticola*	3.4	4	4	3.4	4.2	0.9	2.8	0.4
> 2 m	*Jacaranda mimosifolia*	2.6	1	1	0.9	1.0	0.7	0.9	0.3
> 2 m	*Olea europaea*	6.7	1	1	0.9	1.0	1.8	1.2	0.8
> 2 m	*Peltophorum africanum*	19.2	4	4	3.4	4.2	5.0	4.2	2.4
> 2 m	*Searsia lancea*	16.9	7	7	5.9	7.3	4.4	5.9	2.1
> 2 m	*Searsia pyroides*	2.3	1	1	0.9	1.0	0.6	0.8	0.3
> 2 m	*Terminalia brachystemma*	0.8	1	1	0.9	1.0	0.2	0.7	0.1
> 2 m	*Terminalia sericea*	131.9	30	23	25.4	24.0	34.6	28.0	16.5
> 2 m	*Ziziphus mucronata*	9.7	3	3	2.5	3.1	2.6	2.7	1.2
	Total	381.3	118.0	96.0	100.0	100.0	100.0	100.0	47.7

Table 5.12. The line intercept results for the woody vegetation in the *Acacia karroo* Low Thicket on Mabula Game Reserve in 2004

Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
≤ 2 m	*Acacia karroo*	0.9	1	1	1.8	2.3	3.2	2.4	0.3
≤ 2 m	*Albizia anthelmintica*	0.2	1	1	1.8	2.3	0.8	1.6	0.1
≤ 2 m	*Burkea africana*	0.4	1	1	1.8	2.3	1.4	1.8	0.1
≤ 2 m	*Carissa bispinosa*	5.2	5	5	8.8	11.4	19.2	13.1	1.7
≤ 2 m	*Combretum imberbe*	0.3	1	1	1.8	2.3	1.0	1.7	0.1
≤ 2 m	*Dichrostachys cinerea*	0.7	4	4	7.0	9.1	2.6	6.2	0.2
≤ 2 m	*Euclea undulata*	4.3	8	6	14.0	13.6	15.8	14.5	1.4
≤ 2 m	*Grewia flava*	0.8	1	1	1.8	2.3	2.9	2.3	0.3
≤ 2 m	*Grewia flavescens*	1.9	3	3	5.3	6.8	7.1	6.4	0.7
≤ 2 m	*Gymnosporia buxifolia*	5.0	14	7	24.6	15.9	18.3	19.6	1.7
≤ 2 m	*Olea capensis*	1.5	2	2	3.5	4.6	5.3	4.5	0.5
≤ 2 m	*Searsia lancea*	0.1	1	1	1.8	2.3	0.3	1.4	0.0
≤ 2 m	*Terminalia brachystemma*	0.5	1	1	1.8	2.3	1.7	1.9	0.2
≤ 2 m	*Terminalia sericea*	4.8	12	8	21.1	18.2	17.5	18.9	1.6
≤ 2 m	*Ziziphus mucronata*	0.8	2	2	3.5	4.6	3.0	3.7	0.3
	Total	27.3	57.0	44.0	100.0	100.0	100.0	100.0	9.1
Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
> 2 m	*Acacia caffra*	3.0	1	1	2.9	2.9	2.7	2.8	1.0
> 2 m	*Acacia erubescens*	17.6	5	5	14.3	14.7	15.5	14.8	5.9
> 2 m	*Acacia hebeclada*	2.6	1	1	2.9	2.9	2.3	2.7	0.9
> 2 m	*Acacia karroo*	7.4	2	2	5.7	5.9	6.5	6.0	2.5
> 2 m	*Albizia anthelmintica*	0.2	1	1	2.9	2.9	0.2	2.0	0.1
> 2 m	*Burkea africana*	20.1	5	5	14.3	14.7	17.6	15.5	6.7
> 2 m	*Combretum imberbe*	0.9	1	1	2.9	2.9	0.8	2.2	0.3
> 2 m	*Euclea undulata*	23.7	7	7	20.0	20.6	20.7	20.4	7.9
> 2 m	*Olea europaea*	5.0	2	2	5.7	5.9	4.3	5.3	1.7
> 2 m	*Peltophorum africanum*	9.5	2	2	5.7	5.9	8.4	6.7	3.2
> 2 m	*Terminalia sericea*	24.1	8	7	22.9	20.6	21.1	21.5	8.0
	Total	114.2	35.0	34.0	100.0	100.0	100.0	100.0	38.1

Table 5.13. The line intercept results for the woody vegetation in the *Melinis repens* Low Closed Grassland on Mabula Game Reserve in 2004

Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
≤ 2 m	*Dichrostachys cinerea*	4.1	5	5	62.5	62.5	53.2	59.4	1.4
≤ 2 m	*Dombeya rotundifolia*	0.6	1	1	12.5	12.5	7.8	10.9	0.2
≤ 2 m	*Grewia monticola*	2.5	1	1	12.5	12.5	32.5	19.2	0.8
≤ 2 m	*Searsia pyroides*	0.5	1	1	12.5	12.5	6.5	10.5	0.2
	Total	7.7	8.0	8.0	100.0	100.0	100.0	100.0	2.6
Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
> 2 m	*Acacia tortilis*	13.0	3	3	37.5	37.5	51.1	42.0	4.3
> 2 m	*Burkea africana*	4.3	2	2	25.0	25.0	17.0	22.3	1.4
> 2 m	*Dichrostachys cinerea*	4.2	1	1	12.5	12.5	16.6	13.9	1.4
> 2 m	*Euclea crispa*	2.9	1	1	12.5	12.5	11.4	12.2	1.0
> 2 m	*Grewia flavescens*	1.0	1	1	12.5	12.5	3.9	9.7	0.3
	Total	25.4	8.0	8.0	100.0	100.0	100.0	100.0	8.5

Table 5.14. The line intercept results for the woody vegetation in the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket on Mabula Game Reserve in 2004

Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
≤ 2 m	*Acacia caffra*	0.2	1	1	0.9	1.1	0.2	0.8	0.1
≤ 2 m	*Acacia karroo*	38.1	51	32	46.4	36.0	42.2	41.5	9.5
≤ 2 m	*Burkea africana*	0.9	2	2	1.8	2.3	1.0	1.7	0.2
≤ 2 m	*Combretum apiculatum*	0.3	1	1	0.9	1.1	0.4	0.8	0.1
≤ 2 m	*Combretum hereroense*	1.0	1	1	0.9	1.1	1.1	1.0	0.2
≤ 2 m	*Dichrostachys cinerea*	2.2	10	9	9.1	10.1	2.4	7.2	0.5
≤ 2 m	*Euclea crispa*	1.4	3	3	2.7	3.4	1.6	2.6	0.4
≤ 2 m	*Grewia flava*	8.1	5	5	4.6	5.6	8.9	6.4	2.0
≤ 2 m	*Grewia monticola*	1.1	2	2	1.8	2.3	1.2	1.8	0.3
≤ 2 m	*Ochna pulchra*	0.2	1	1	0.9	1.1	0.2	0.8	0.1
≤ 2 m	*Peltophorum africanum*	3.1	2	2	1.8	2.3	3.5	2.5	0.8
≤ 2 m	*Searsia lancea*	13.2	9	8	8.2	9.0	14.7	10.6	3.3
≤ 2 m	*Searsia leptodictya*	0.2	2	2	1.8	2.3	0.2	1.4	0.1
≤ 2 m	*Searsia pyroides*	3.7	2	2	1.8	2.3	4.1	2.7	0.9
≤ 2 m	*Terminalia brachystemma*	1.7	4	4	3.6	4.5	1.9	3.3	0.4
≤ 2 m	*Terminalia sericea*	13.2	12	12	10.9	13.5	14.6	13.0	3.3
≤ 2 m	*Ziziphus mucronata*	1.7	2	2	1.8	2.3	1.9	2.0	0.4
	Total	90.2	110.0	89.0	100.0	100.0	100.0	100.0	22.6
Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
> 2 m	*Acacia karroo*	2.4	2	2	8.0	10.0	3.2	7.1	0.6
> 2 m	*Burkea africana*	13.9	1	1	4.0	5.0	19.0	9.3	3.5
> 2 m	*Combretum hereroense*	1.8	2	2	8.0	10.0	2.5	6.8	0.5
> 2 m	*Peltophorum africanum*	19.2	5	5	20.0	25.0	26.3	23.8	4.8
> 2 m	*Searsia lancea*	6.4	2	2	8.0	10.0	8.7	8.9	1.6
> 2 m	*Terminalia brachystemma*	2.3	1	1	4.0	5.0	3.1	4.0	0.6
> 2 m	*Terminalia sericea*	27.2	12	7	48.0	35.0	37.2	40.1	6.8
	Total	73.1	25.0	20.0	100.0	100.0	100.0	100.0	18.3

Table 5.15. The line intercept results for the woody vegetation in the *Terminalia sericea* - *Acacia* species Low Thicket on Mabula Game Reserve in 2004

Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
≤ 2 m	*Acacia tortilis*	0.3	1	1	7.1	11.1	4.8	7.7	0.2
≤ 2 m	*Dichrostachys cinerea*	5.2	12	7	85.7	77.8	82.5	82.0	2.6
≤ 2 m	*Grewia flava*	0.8	1	1	7.1	11.1	12.7	10.3	0.4
	Total	6.3	14.0	9.0	100.0	100.0	100.0	100.0	3.2
Height	Woody plant	Intercept length	No. of plants	No. of intervals	Relative density (%)	Relative frequency (%)	Relative dominance (%)	Importance value	Canopy cover (%)
> 2 m	*Acacia karroo*	3.9	2	2	6.5	7.4	3.2	5.7	2.0
> 2 m	*Acacia tortilis*	63.3	12	11	38.7	40.7	52.1	43.8	31.6
> 2 m	*Dichrostachys cinerea*	30.8	12	9	38.7	33.3	25.3	32.5	15.4
> 2 m	*Euclea undulata*	1.1	1	1	3.2	3.7	0.9	2.6	0.6
> 2 m	*Searsia lancea*	0.7	1	1	3.2	3.7	0.6	2.5	0.4
> 2 m	*Searsia pyroides*	0.4	1	1	3.2	3.7	0.3	2.4	0.2
> 2 m	*Terminalia sericea*	19.0	1	1	3.2	3.7	15.6	7.5	9.5
> 2 m	*Ziziphus mucronata*	2.4	1	1	3.2	3.7	2.0	3.0	1.2
	Total	121.5	31.0	27.0	100.0	100.0	100.0	100.0	60.8

The BECVOL results revealed that the combined browsing capacity on Mabula Game Reserve for the seven vegetation communities was 107.5 Browser Units for different types of herbivores which browse ≤ 1.5 m. The ecological browsing capacity for different types of herbivores which browse ≤ 2.0 m was 146.2 Browser Units. The ecological browsing capacity for the different types of herbivores which browse ≤ 5.0 m was 494.1 Browser Units. The number of Browser Units, including all herbivores and not just the different types of herbivores recorded in the habitat selection survey, utilising the vegetation ≤ 1.5 m was 258.6 Browser Units. The number of Browser Units of herbivores utilising the vegetation ≤ 2 m was, 375.0 Browser Units. Therefore the total Browser Units utilising the vegetation ≤ 2 m was 633.6. The giraffe and elephant are able to utilise the vegetation ≤ 5 m and constitute 408.5 Browser Units. The total Browser Units are therefore 1042.1. The actual Browser Units present on Mabula Game Reserve are more than double the ecological browsing capacity determined from the BECVOL results. The ecological browsing capacity was determined only for seven of the 14 vegetation communities (74% of the total surface area), therefore the overall browsing capacity could be higher for the whole reserve. However, the bulk of the remaining area is covered by grassland. Therefore Mabula Game Reserve is clearly overstocked with large browsing herbivores that browse at all heights. For an economic browsing capacity, when the ecological browsing capacity should be reduced by 20% to 30%, the reserve is greatly over stocked with browsers. The BECVOL results will now be further discussed in relation to results from Chapter 3 for the individual vegetation communities:

There were 31 woody plant species present in the BECVOL results in the *Acacia caffra* – *Faurea saligna* Short Open Woodland. The line intercept recorded 15 woody plant species ≤ 2 m high and 21 woody plant species > 2 m high. This vegetation community was dominated by woody plants > 2 m high. The dominant tree species were *Combretum zeyheri*, *Faurea saligna*, *Burkea africana* and *Acacia caffra*. In terms of recruitment, *Faurea saligna* and *Acacia caffra* both had a high dominance and importance value for juvenile trees ≤ 2 m high. Therefore, these woody plant species should remain dominant in the future as the older trees die off or are knocked down by elephants. No *Combretum zeyheri* plants were recorded ≤ 2 m high, therefore the recruiting potential of this species seems to be limited. *Ochna pulchra* had a high dominance and importance value for plants ≤ 2 m high. Therefore, this species may, in time, become a more dominant species in the > 2 m high layer. The woody plant layer ≤

2 m high was heavily dominated by *Vitex rehmannii*. The *Acacia caffra – Faurea saligna* Short Open Woodland was selected by the eland and greater kudu over the whole year. These herbivores which browse to a height of 2.0 m account for 275.4 Browser Units, however, the calculated ecological browsing capacity for this vegetation community ≤ 2.0 m high is 28.9 Browser Units. Therefore, the *Acacia caffra – Faurea saligna* Short Open Woodland is potentially overbrowsed. This is an issue which will need to be monitored and assessed, but it is recommended that the management staff of Mabula Game Reserve reduce the numbers of these larger herbivores.

There were 23 woody plant species present in the BECVOL results in the *Combretum apiculatum – Acacia caffra* Short Open Woodland. The line intercept recorded 13 woody plant species ≤ 2 m high and 10 woody species > 2 m high. *Combretum apiculatum* was the most prevalent woody plant species, followed by *Combretum zeyheri*, for woody plant species > 2 m high. *Combretum apiculatum* had the second highest importance value for woody plants ≤ 2 m high. Therefore, this woody plant species should remain dominant. Once again, *Combretum zeyheri* saplings were not found ≤ 2 m high. *Dichrostachys cinerea* is the most prevalent woody plant species ≤ 2 m high. As this woody plant species is responsible for bush encroachment, it will need to be monitored. The *Combretum apiculatum – Acacia caffra* Short Open Woodland had an ecological browsing capacity of 3.4 ≤ 1.5 m high and 5.0 ≤ 2.0 m high. This vegetation community was also potentially over utilised by the gemsbok over the whole year and dry season, which are estimated at 10.7 Browser Units and browse above 1.5 m. Therefore this vegetation community is potentially overbrowsed.

The *Burkea africana – Terminalia sericea* Low Thicket was the most diverse vegetation community, with 32 woody plant species present in the BECVOL results. The line intercept recorded 18 woody plant species ≤ 2 m high and 19 woody plant species > 2 m high. This vegetation community was dominated by *Dichrostachys cinerea* and *Terminalia sericea* in the > 2 m high layer. Both these woody plant species are responsible for bush encroachment and both have a high dominance and importance value in the < 2 m high layer. The *Burkea africana – Terminalia sericea* Low Thicket can sustain the largest number of browsers ≤ 1.5 m high (45.2 Browser Units) and ≤ 2.0 m high (56.6 Browser Units). The impala selected this vegetation community over the whole year, with an estimated 84.4 Browser Units utilising this vegetation community.

The blue wildebeest and impala selected this vegetation community during the dry season and a combined estimation of 134.5 Browser Units utilised this vegetation community. Therefore, the *Burkea africana – Terminalia sericea* Low Thicket is potentially overbrowsed.

There were 26 woody plant species present in the BECVOL results in the *Acacia karroo* Low Thicket. The line intercept recorded 15 woody plant species ≤ 2 m high and 11 woody plant species > 2 m high. No individual woody species dominated this vegetation community for both height classes. Four woody plant species in each height class had high importance values. The *Acacia karroo* Low Thicket has a moderate browsing capacity, but no herbivores selected this vegetation community. Therefore, utilisation occurred below the vegetation community's ecological browsing capacity.

There were 17 woody plant species present in the BECVOL results in the *Melinis repens* Low Closed Grassland. The line intercept recorded 4 woody plant species ≤ 2 m high and 4 woody plant species > 2 m high. As this vegetation community occurs on old cultivated land, the woody vegetation is re-establishing and is still sparse. *Acacia tortilis* is the dominant woody plant species > 2 m high, which is a semi-evergreen species preferred by giraffe (Smallwood 2001). *Dichrostachys cinerea* is the dominant woody plant species ≤ 2 m high and therefore potentially a sign of bush encroachment. The *Melinis repens* Low Closed Grassland is preferred by many types of herbivores. Most of these herbivores which prefer this vegetation community over the whole year are primarily grazers, but the combined Browser Units for these herbivores are substantially higher than the ecological browsing capacity for all height classes. Therefore this vegetation community is potentially overbrowsed for both time periods.

There were 29 woody plant species present in the BECVOL results in the *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thick, which is a large number of woody plant species for all the vegetation communities sampled. The line intercept recorded 17 woody plant species ≤ 2 m high and seven woody plant species > 2 m high. The *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thick has a low ecological browsing capacity and is selected by the impala over the whole year which account for a large number of Browser Units. This vegetation community is utilised (but not selected) by four types of herbivores which have the highest number of Browser

Units. Therefore the *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thick is potentially overbrowsed.

There were 17 woody plant species present in the BECVOL results in the *Terminalia sericea – Acacia* species Low Thicket. The line intercept recorded three woody plant species ≤ 2 m high and eight woody plant species > 2 m high. *Acacia tortilis* is the dominant woody plant species >2 m high, providing good browse. *Dichrostachys cinerea* is the second most dominant woody species > 2 m high and the most dominant woody species ≤ 2 m high. Therefore, bush encroachment is a potential issue. The *Terminalia sericea – Acacia* species Low Thicket is not selected by any herbivores, but a few types of herbivores generally utilise this vegetation community. The *Terminalia sericea – Acacia* species Low Thicket has a relatively high ecological browsing capacity and therefore it is underutilised by browsers.

5.5 CONCLUSION

The combination of the BECVOL and the line intercept methods provided information on the woody plants composition of species, density, structure and the browsing capacity for the seven vegetation communities represented in this study. The monitoring should be expanded to all the vegetation communities, but this will mean that more monitoring sites will be required. This will be further discussed in Chapter 6 in terms of the number of sites required and the time suggested intervals between monitoring periods. The use of the BECVOL method has provided information on the ecological browsing capacity for the reserve and the individual woody plants in the vegetation communities represented in this initial monitoring system. The number of Browser Units stocked on Mabula Game Reserve is higher than the ecological browsing capacity for all the plant height classes in the BECVOL results. The BECVOL results for the individual vegetation communities show that five of the seven vegetation communities are potentially overbrowsed. This will need to be addressed by the reserve management and will be further discussed in Chapter 6. The monitoring of the structure of the woody plants for the sites will help in assessing the impact of browser. Hence it will become an important addition to the holistic monitoring system for Mabula Game Reserve in the future.

Chapter 6

PROPOSED ECOLOGICAL MONITORING PROGRAMMES AND PROVISIONAL MANAGEMENT PROPOSALS

6.1 INTRODUCTION

The newly implemented monitoring programmes for the large herbivores and woody plant layer were set up as initial trials to test the effectiveness of the methods used. In general, the methods for the monitoring programmes proved to be successful, but some changes will need to be implemented.

6.2 ASSESSMENT OF THE ECOLOGICAL MONITORING PROGRAMS

6.2.1 Re-assessment of the vegetation communities on Mabula Game Reserve

A full assessment of all the vegetation communities present on Mabula Game Reserve is essential as they provide discreet units from which all the information from the monitoring programmes can be determined and compared. It is suggested that Mabula Game Reserve conducts a new vegetation survey encompassing the whole reserve. The vegetation communities that were used in the present study were derived by combining vegetation surveys of separate sections of the reserve which were conducted over ten years ago. Once the vegetation communities have been re-assessed, monitoring sites and transects can be selected to properly represent each vegetation community. This will enable an accurate assessment of the ecological and economic grazing and browsing capacities and the habitat selection of the large herbivores across the reserve.

6.2.2 The herbaceous layer monitoring programme

The herbaceous layer monitoring programme has been running successfully over ten years. Monitoring has occurred on a yearly basis and should continue on this time schedule. The additional monitoring techniques for determining grass cover and plant biomass proved to be efficient, adding a maximum of 15 minutes to the total time for sampling each site. The main problem with the herbaceous layer monitoring programme

was that the vegetation communities across the reserve were not adequately represented. Although the total number of monitoring sites should remain approximately the same, some of the monitoring sites will have to be redistributed among the unsampled vegetation communities. This should not be problematic as five of the 14 vegetation communities contain 36 of the 48 monitoring sites. Therefore some of the sites are redundant. Ideally, the monitoring sites per vegetation community should be proportional to the size of the vegetation community. For instance, if the present vegetation communities are to be used, the distribution of the 48 monitoring points could be as follows:

- The *Acacia caffra - Faurea saligna* Short Open Woodland – seven sites.
- The *Acacia caffra* Short Open Woodland – at lease two sites (Mountainous area) or three if possible.
- The *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket – three sites.
- The *Acacia karroo* Low Thicket – four sites.
- The *Burkea africana - Terminalia sericea* Low Thicket – five sites.
- The *Combretum apiculatum - Acacia caffra* Short Open Woodland – three sites.
- The *Combretum apiculatum* Short Open Woodland is a large vegetation community, but occurs on the mountainous areas on the reserve and is not selected by any of the large herbivores monitored in Chapter 3. Therefore two sites should be allocated to this vegetation community or three if possible.
- The *Eragrostis gummiflua* Low Closed Grassland – four sites.
- The *Melinis repens* Low Closed Grassland – five sites.
- The *Terminalia sericea - Acacia caffra* Low Open Woodland - two sites.
- The *Terminalia sericea – Acacia* species Low Thicket – four sites.
- *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland – four sites.
- The *Terminalia sericea – Seriphium plumosum* Short Bushland – three sites.
- The *Terminalia sericea - Trachypogon spicatus* Short Open Grasslands – two sites.

If a thorough vegetation survey were conducted on the Mabula Game Reserve, then the assigning of monitoring points will differ, but the distribution should be performed in a similar manner.

6.2.3 The woody plant layer monitoring programme

The monitoring of the woody layer was done as a trial and will require more sites to be added to establish a proper representation for each vegetation community so as to allow for a more accurate assessment of the browsing capacity of the reserve.

The BECVOL and line intercept methods are time consuming in the field taking a mean time of four hours per site, including travelling and setting up the site. Two sites were generally completed in a day, with two people measuring and one recording. Overall, 20 days should be allocated for the 35 sites. If there were six people conducting the monitoring, they can be split into two teams and reduce the time taken to sample each site. An additional, time saving, technique can be implemented when there are many shrubs of the same species in a transect. Prior to recording the measurements of each species for the BECVOL method, the transect can be walked and three of the most abundant shrub species identified. For each such shrub species three plants can be selected which can be a representative of a small plant, a medium plant and a large plant. These are then measured and recorded separately. If a plant of that shrub species is then encountered during the measuring of the total transect it can be recorded with a small, medium or large symbol (S, M or L). The previously determined measurements are assigned to the plant. This technique has to be carefully done over the whole transect. In doing so in the present study, it was found that the sampling time was halved for many of the sites. However, this technique should not be used for woody individuals over the height of 2 m high, as this will cause a large margin of error in the results.

The line intercept method was done relatively quickly, taking no more than 20 minutes per site. Two height classes were used to reduce time, but another two or more height classes can be added to provide more specific information on the plant structure, without taking up much more time. An additional height class of 1.5 m and one of 5.0 m will give more information on the structure of the woody plant vegetation and be directly comparable to the results of the BECVOL method. A height class of 0.5 m would provide

information on the recruitment of seedlings of woody plant species. An alternative method for determining the relative frequency, relative density, relative dominance and importance value can be derived from the BECVOL data.

Monitoring sites should be placed in the vegetation communities that were not represented in the present study and additional monitoring sites in the vegetation communities which are poorly represented. There should be a total of 50 monitoring sites. 47 monitoring sites would give a good representation of all vegetation communities and an additional three monitoring sites can be allocated by reserve managers according to any specific management requirements. The 47 monitoring points should be distributed as follows:

- The *Acacia caffra* - *Faurea saligna* Short Open Woodland currently has ten monitoring sites, which can be reduced to six sites. As this is a large vegetation community, it should have the highest number of monitoring sites.

- The *Acacia caffra* Short Open Woodland is a small vegetation community and occurs on the mountainous areas on the reserve. As it is not selected by any of the large herbivores monitored in Chapter 3, two sites should be allocated to this vegetation community.

- The *Acacia karroo* - *Acacia robusta* - *Euclea undulata* Short Closed Low Thicket has four monitoring sites which is sufficient for this vegetation community.

- The *Acacia karroo* Low Thicket has three monitoring sites. One additional site should be added to this vegetation community.

- The *Burkea africana* - *Terminalia sericea* Low Thicket currently has eight monitoring sites. This can be reduced to five monitoring sites.

- The *Combretum apiculatum* - *Acacia caffra* Short Open Woodland currently has four monitoring sites. This is a small vegetation community and all the

monitoring sites also were placed to monitor the impact of elephant's impact on the woody vegetation. Therefore these monitoring sites should remain.

- The *Combretum apiculatum* Short Open Woodland is a large vegetation community, but it occurs on the mountainous areas on the reserve and is not selected by any of the large herbivores monitored in Chapter 3. Therefore a maximum of four sites should be allocated to this vegetation community.

- The *Eragrostis gummiflua* Low Closed Grassland naturally occurs as vlei grasslands, with minimal woody species occurring in this vegetation community. Therefore a maximum of two monitoring sites should be placed in this vegetation community.

- The *Melinis repens* Low Closed Grassland and the *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland are large vegetation communities and should contain four monitoring sites each. These communities are important to monitor as they are associated with old cultivated lands where the woody species will gradually re-establish.

- The *Terminalia sericea - Acacia caffra* Low Open Woodland is the second smallest vegetation community and should have one monitoring site.

- The *Terminalia sericea – Acacia* species Low Thicket is not represented at present and should have four monitoring sites.

- The *Terminalia sericea – Hyperthelia dissoluta* Tall Closed Grassland is not represented at present and should have four monitoring sites.

- The *Terminalia sericea – Seriphium plumosum* Short Bushland is not represented at present and should have two monitoring sites.

- The *Terminalia sericea - Trachypogon spicatus* Short Open Grassland is the smallest vegetation community and should have one monitoring site.

This distribution of monitoring sites may change if a new vegetation survey is conducted. Although the sampling of 47 to 50 monitoring sites may take around 30 to 40 days, monitoring of the woody vegetation has to be conducted every three years.

6.2.4 The large herbivore monitoring program

Changes to the large herbivore monitoring programme will have to be made once the vegetation communities on the reserve have been re-assessed. The data collected, as mentioned in the methods for Chapter 3, can be used for more detailed assessment of the habitat selection by the large herbivores with a larger data set collected over a few years of monitoring. Specific information can also be collected on the habitat selection of different sexes or age classes. Additional data can be collected such as the feeding behaviour of the browsers. This would provide information on the preferred woody plant species, which can then be compared to the results from the BECVOL method. A more precise estimate of the ecological browsing capacity for the different types of herbivores can therefore potentially be determined. However, if the reserve management only requires information on the broad selection of vegetation communities for the entire population of a type of herbivore, then only data on population size and activity would be required. This would substantially reduce the time taken to monitor each transect as aging and sexing the individuals in a herd is relatively time consuming. The latter is only advised where wildlife counts are conducted. Another way to reduce the time taken whilst monitoring is to reduce the width of the transect to 50 m. This is possible for Mabula Game Reserve where the wildlife have grown accustomed to the many vehicles traversing the reserve. Also the time taken can be reduced if there are three persons taking part in the survey, with one person concentrating on driving and the others focusing on observing and recording the wildlife.

The monitoring of the large herbivores should be conducted over a five-year period on a monthly basis to compile an adequate database. This will provide enough data to properly determine the habitat selection of the large herbivore to see if there are changes in the selection of the vegetation communities from year to year. The initial trial that was conducted in the present study failed to gain enough data on many of the rarer wildlife on Mabula Game Reserve. However, five years of data collection will provide

sufficient data for analysis. After the first five years the monitoring can be conducted every three years to coincide with the woody vegetation monitoring or every year to coincide with the herbaceous vegetation monitoring. If new herbivores are released or others are removed from the reserve, then monitoring should be conducted yearly for up to three years to identify any changes in habitat selection. If the monitoring shows no changes in habitat selection, then managers can decide on extending the interval between monitoring periods. It is important to understand that many factor, such as weather conditions, may influence the habitat selection of the different types of herbivores. Therefore, it would be more viable to run the monitoring program for up to ten consecutive years. For the rarer wildlife, if insufficient data are collected on a yearly basis, then consecutive years can be combined to form a broader time-based habitat selection determination. However, for the elephants and buffalo in the African savanna, which have a substantial impact on vegetation, the reserve should develop a more specific monitoring.

6.3 PROVISIONAL MANAGEMENT RECOMMENDATIONS

The herbaceous vegetation monitoring programme showed that Mabula Game Reserve was generally stocked under the ecological and economic grazing capacity over the ten years of monitoring according to the Danckwertz's (1989b) equation. The equation proposed by Bothma *et al*. (2004), however, showed that the reserve was stocked under the ecological grazing capacity in 2004 in comparison to the 2004 game counts, but was stocked slightly over the economic grazing capacity. The stocking of the types of large herbivores under the ecological grazing capacity was further collaborated by the veld index scores, which were not influenced by the number of Grazing Units. However, the grazing pressure is not evenly distributed over the entire reserve.

When the individual vegetation communities were assessed three vegetation communities were potentially overgrazed according to the equation proposed by Bothma *et al*. (2004). It is important to note that not all the types of herbivores occurring on the reserve were included in the habitat selection study. Therefore, the estimated Browser and Grazing Units occurring in the different vegetation communities are underestimates. These were the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket and the *Eragrostis gummiflua* Low Closed Grassland and the *Melinis repens*

Low Closed Grassland. The monitoring of the large herbivores identified the herbivores responsible for overutilising these vegetation communities. To reduce the grazing pressure on these vegetation communities, the populations of these identified herbivores should be reduced through culling or game capture. To reduce the grazing pressure of the *Acacia karroo - Acacia robusta - Euclea undulata* Short Closed Low Thicket, the population of impala has to be reduced. The types of herbivores with relatively large populations that selected both the grassland communities were the blesbok, red hartebeest, warthog and Burchell's zebra. From the wildlife counts the populations of blesbok and red hartebeest were reduced from 2004 to 2006. However, the population of Burchell's zebra increased slightly from 2004 to 2006 and the population of warthog increased from 396 in 2004 to 545 in 2006. Therefore, increasing the grazing pressure on the vegetation communities that the Burchell's zebra and warthog selected.

Mabula Game Reserve is currently well overstocked with browsers. This was specifically true for the *Acacia caffra – Faurea saligna* Short Open Woodland, the *Acacia karroo – Acacia robusta – Euclea undulata* Short Closed Low Thicket, the *Burkea africana – Terminalia sericea* Low Thicket the *Combretum apiculatum – Acacia caffra* Short Open Woodland and the *Melinis repens* Low Closed Grassland. The populations of large herbivores responsible for overbrowsing these vegetation communities have to be reduced. The eland, greater kudu and impala were responsible for most of the overbrowsing of these two woodland and thicket communities. The populations of the eland and impala were reduced from 2004 to 2006, but the population of impala increased. The gemsbok population should not be reduced to prevent overbrowsing for the *Combretum apiculatum – Acacia caffra* Short Open Woodland, as their numbers are small and the gemsbok is also predominantly a grazer.

Although these monitoring programmes did show potential overutilisation of some of the vegetation communities, they are only the initial step in a holistic monitoring approach. The monitoring sites should be relocated to cover all the vegetation communities and then a few years' data should be collected before the information gained can be used properly in the reserve's management decision-making. The habitat selection by the large herbivores may change from year to year and no immediate decisions on the stocking densities should be made without determining the true patterns of use. This is the case for the assessment of Grazing Units across the reserve. However, as the

quantity of browsers stocked on the reserve is substantially higher than the ecological browsing capacity, the reserve management should consider reducing the number of Browser Units on Mabula Game Reserve immediately. This should prevent potential damage to the woody layer until more accurate information is gathered from a revised monitoring programme. The types of large herbivores which should be reduced are the eland (122.4 Browser Units), Impala (123.0 Browser Units) and greater kudu (153.0). These herbivores browse below 2 m high and this height is where the overbrowsing is occurring on the vegetation communities. A 50% reduction in population should reduce the browsing pressure until more information is gathered through a revised monitoring programme. As eland are not a naturally occurring, the reserve management should consider removing them completely.

6.4 PROPOSED SCHEDULE FOR FUTURE MONITORING

The three proposed monitoring methods should be conducted as follows:

- Large herbivore monitoring: Once a month for each year over the first five years. Then, once every year if the reserve management wishes to focus on grazers or every three year for browsers, to coincide with the respective vegetation monitoring programme. Monitoring should occur for three consecutive years after release or removal of wildlife.

- Herbaceous monitoring: Every year. Sampling should occur in January to February.

- Woody monitoring: This should be done every three years. Sampling should occur from December to March when there is maximum leaf matter.

Chapter 7

CONCLUSIONS

This initial trial of the holistic ecological monitoring system that was conducted on Mabula Game Reserve provided valuable information to aid the future ecological management of the reserve. All the monitoring methods were simplistic and easily conducted in the field, proving to be suitable for reserve staff. Valid scientific data were collected from both the reserve's herbaceous monitoring method and the monitoring methods implemented by the present study. Although costs were not discussed, all the methods can be conducted with basic tools which will not heavily impact on a reserve's budget. The only relatively expensive tools used were a disc pasture meter and a Global Positioning System, which all wildlife reserves should possess. The main costs in implementing the monitoring system involve payment for the workers time and fuel. Fuel was used for transportation to the vegetation monitoring sites and for conducting the wildlife monitoring transects.

The data collected from the herbaceous layer monitoring conducted by the Mabula Game Reserve managers allowed for the assessment of the veld condition and the ecological and economic grazing capacities of the vegetation communities which were sampled. The combined veld condition scores of the vegetation communities sampled enabled estimation of the grazing capacity of the whole reserve. These ecological and economic grazing capacities were determined initially by using the Danckwertz (1989b) equation. The data collected by using the additional monitoring methods applied in this study and the data from the reserve manager's monitoring system enabled application of the more recent equation developed by Bothma *et al.* (2004). This equation proved to be more reliable for determining the grazing capacities through its incorporation of more variables and specific rainfall values.

Monitoring of the plant biomass will help future burning programmes. The data collected for the woody layer monitoring enabled the determination of ecological and economic browsing capacities. Also, changes in woody species composition and structure can be assessed over time. Monitoring of large herbivores gave an indication of utilisation pressure on the vegetation communities, which was specifically assessed by

comparison to the browsing and grazing capacities of the two vegetation monitoring systems. Future holistic monitoring on Mabula Game Reserve can potentially show how utilisation by the different herbivores may change the plant species composition of the herbaceous and woody layers. Also, the effects of browsers on the structure of the woody layer may be investigated.

Because the vegetation communities used in this study were determined by combining two old vegetation surveys covering two separate sections of the reserve, a new vegetation survey has to be conducted encompassing the whole reserve. The proper assessment of the vegetation communities on Mabula Game Reserve is of great importance as the vegetation communities provide the discreet units that enable direct association between the three components of the holistic monitoring system. Once this has been achieved the three monitoring methods can be implemented directly. Other than the re-assessment of the vegetation communities, no other studies are required prior to the implementation of the holistic monitoring system. However, the monitoring system itself should be periodically reassessed and improved, in accordance with the requirements of a thorough active adaptive management approach. Studies should be conducted to determine a monitoring system for the habitat selection of the elephant and african savanna buffalo.

Once the monitoring system is properly established it will directly influence management decisions and strategies on Mabula Game Reserve. The most fundamental ecological management decision on Mabula Game Reserve relates to the stocking rate of the large herbivores. The holistic monitoring system will provide specific information on how many of each type of herbivore should be stocked in order to provide an enjoyable wildlife viewing atmosphere for guests to the reserve as well to provide revenue from wildlife sales. These activities can then coincide with management strategies to improve the quality of the vegetation on Mabula Game Reserve and inevitably increase the grazing and browsing capacity of the reserve. The collection of data from the monitoring system over time may show changes in the vegetation layers, which can be compared to wildlife utilisation patterns. This will enable the determination of how individual types of herbivores are specifically influencing the vegetation layers over time. Overall, this holistic monitoring system will be beneficial to the future active adaptive ecological management of Mabula Game Reserve.

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