The effect of vegetation on the behaviour and movements of Burchell's Zebra, *Equus burchelli* (Gray 1824) in the Telperion Nature Reserve, Mpumalanga, South Africa.

by

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Submitted in partial fulfillment of the requirements for the degree

Magister Scientia

in the Faculty of Natural and Agricultural Sciences
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ABSTRACT

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Telperion is a portion of the eZemvelo Nature Reserve, located in Mpumalanga Province of South Africa. It falls within the Grassland Biome that comprise of a wide diversity of habitats and of which only 2.3% is currently conserved in reserves. The objective of this study was to determine the interaction of Telperion zebras with their vegetation habitats, the influence of vegetation on their movement and how it differs seasonally, focusing specifically on two groups in distinctly different habitat types. The first, Rocky Highveld Grassland, the second a Mixed Grassland community. Hourly zebra observations took place distinguishing between stallions, mares and foals during different times of the day, throughout a year. Zebra habitat was thereby identified and vegetation surveys were conducted in each of these sites according to the Braun-Blanquet vegetation sampling method. The plant species recorded for each sample plot were captured in the vegetation database TURBOVEG. The database was exported into the working directory JUICE. The results indicate no difference between feeding rates of the habitat types. Mares spent most time feeding, then stallions followed by foals, all of which were highest during afternoons. A vegetation gradient was identified, implying that zebras utilise both vegetation communities, as well as the transition between the communities. Zebras were less vigilant during

grazing when large numbers were gathered in the same area. Tracking zebras revealed their migrating behaviour from a central point to the rest of the reserve in summer and more specifically to rocky ridges in winter. The understanding of zebra behaviour contributes to management and mitigation for good veld conditions in Telperion.

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1. INTRODUCTION

1.1. Background

It comes natural to group living things into categories based on the observation that certain individuals resemble each other more than other individuals. It is this desire that lead to the classification of species.

One of these species, *Equus burchelli,* or commonly known as Plains zebra, is easily recognisable from their black and white striping and distinguished from other zebra species by their pony-like appearance with shorter heads and smaller ears (Groves 1974; MacClintock 1976). In spite of the suggestion by Skinner & Chimimba (2005) that the Plains zebra should be named *Equus quagga* Boddaert, 1785, and that it is distinct from *Equus burchellii* Gray 1824 of East Africa, it was decided to follow Groves & Bell (2004) and use the name *Equus burchelli* for the Plains zebra in this thesis (see also the discussions in sections 3.2 and 3.11). The Plains zebras' distribution ranges from southern Sudan to northern South Africa (Groves 1974; MacClintock 1976; Theron 1991; Hack & Rubenstein 1998; Bowland *et al.* 2001). It is this wide geographic distribution that caused noticeable differences in stripe pattern, belly patterns and mane characteristics (Stahl 1971; Groves 1974; Groves & Bell 2004).

As with animals, plants are also described according to their geographical distribution. Similar climatic conditions that occur over large areas, are the main causes for these vegetation types and thus also the reason why similar vegetation repeat themselves all over the world. These vegetation types are called biomes (Van Wyk & Smith 2001). The Grassland biome is located centrally in South Africa (Bredenkamp 1999; O'Connor & Bredenkamp 2003) of which only 2.3 % is conserved (Low & Rebelo 1998) in nature reserves such as Witbank, Suikerbosrand, Rustenburg, Abe Bailey, Boskop Dam and Rietvlei Nature Reserve (Swanepoel 2006) as well as eZemvelo Nature Reserve.

Telperion falls within the far north of the Grassland biome and is but a portion of the 13 000 ha eZemvelo Nature Reserve, located in Mpumalanga Province of South

Africa. The vegetation type was recognised by Acocks (1988) as Bankenveld, while Bredenkamp and Van Rooyen (1998) classified it as Rocky Highveld Grassland. This area is also known as the Rand Highveld Grassland from the Vegetation of South Africa, Lesotho and Swaziland (Mucina & Rutherford 2006). Currently 60-80 % of grasslands are already transformed by agriculture, industrialisation, urbanisation and mining (O'Connor & Bredenkamp 1997). It is therefore of critical importance to manage grasslands currently conserved in reserves (Low & Rebelo 1998).

1.2. Objectives

In order to aid in management strategies the objective of the study is to determine the interaction between the zebras and the vegetation habitats in Telperion Nature Reserve, focusing specifically on two groups of zebra in distinctly different habitat types. The first is Rocky Highveld Grassland while the second consist of a Plains Grassland community. In addition, this study will determine if such an interaction is influenced by different seasons of a year.

The aims of this study are to:

- give a detailed quantitative vegetation description at preferred zebra grazing sites;
- identify floristic similarities or differences between grazing sites;
- determine the difference in zebra feeding
    - between two habitat types;
    - during different times of the day;
    - during different seasons of the year;
    - between different members of a family group;
- determine the seasonal movement of zebras on Telperion; and
- provide possible management tools or strategies to ensure viable and vital zebra populations.

1.3. References

ACOCKS, J.P.H. 1988. Veld Types of South Africa. *Memoirs of the Botanical Survey of South Africa* No. 57.

BOWLAND, A. E., BISHOP, K.S., TAYLOR, P.J., LAMB, J., VAN DER BANK, F.H., VAN WYK, E. & YORK, D. 2001. Estimation and management of genetic diversity in small populations of plains zebra (*Equus quagga*) in KwaZulu-Natal, South Africa. *Biochemical Systematics and Ecology* 29: 563–583.

BREDENKAMP, G.J. 1999. Grassland. In: Knobel, J. *The magnificent natural heritage of South Africa.* Sunbird Publishing, Llandudno.

BREDENKAMP, G.J. & VAN ROOYEN, N. 1996. Rocky Highveld Grassland. In: Low, A.B. & Rebelo, A.G. (eds). *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs and Tourism, Pretoria.

GROVES, C.P. 1974. *Horses, asses and zebras in the wild*. David & Charles Newton Abbot, London.

GROVES, C.P. & BELL, C.H. 2004. New investigations on the taxonomy of the zebras genus *Equus*, subgenus *Hippotigris*. *Mammalian Biology* 69:182–196.

HACK, M.A. & RUBENSTEIN, D.I. 1998. Zebra zones. *Natural History* 107 (2): 26–28.

LOW, A. B. & REBELO, A. G. 1998. *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs and Tourism, Pretoria.

MACCLINTOCK, D. 1976. *A natural history of zebras*. Charles Scribner's sons, New York.

MUCINA, L. & RUTHERFORD, M.C. (eds.) 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. South African Biodiversity Institute, Pretoria.

O'CONNOR, T.G., BREDENKAMP, G.J. 1997. Grassland. In: Cowling, R.M., Richardson, D.M., Pierce, S.M. (Eds.). *Vegetation of Southern Africa*. Cambridge University Press, Cambridge, pp. 615.

SKINNER, J.D. & CHIMIMBA, T.C. 2005. The Mammals of the Southern African Subregion. 3rd edition. Cambridge University Press, Cape Town.

STAHL, B. 1971. *The elusive zebra.* Addison-Wesley Publishing Company, Massachusetts.

SWANEPOEL, B.A. 2006. *The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspruit, South Africa.* M.Sc. Dissertation (Botany), University of Pretoria, Pretoria.

THERON, A. 1991. *The behavioural ecology of two zebra species on game farms in the Waterberg, northern Transvaal*. M.Sc. Dissertation (Wildlife Management). University of Pretoria, Pretoria.

VAN WYK, A.E., SMITH, G.F. 2001. *Regions of Floristic Endemism in Southern Africa. A review with emphasis on Succulents.* Umdaus Press, South Africa.

2. STUDY AREA

2.1. The history of eZemvelo Nature Reserve

The historical land use of an area has a significant influence on the current and future states of its animal and plant communities (Cowling *et al*. 1997). The land use history of the eZemvelo Nature Reserve will therefore be discussed in order to place current vegetation patterns and animal distributions into perspective.

The reserve is a privately owned by the Oppenheimer family and consists of an assembly of farmlands purchased over the years (Figure 2.1, Helm 2006).

In 1974 the eastern portion of the current reserve was purchased by the Oppenheimers to build a house and grow an organic garden. The area was approximately 1 640 ha and named Telperion Farm (Section 1, Helm 2006). The name Telperion is derived from the Lord of the Rings – Telperion was the most ancient of trees. Telperion contains old cycads *Encephalatus middelburgensis* – hence the name Telperion.

The farmland of Captain P. Grobler was bought in 1980. It was 855 ha in size and by that time black wildebeest (*Connochaetes gnou*) and blue wildebeest (*Connochaetes taurinus taurinus*) were already present on the farm. This area bordered the southern area of the Telperion Farm. The collection of the two farms was then named Telperion Nature Reserve (Section 2). A 386 ha area was purchased south of the reserve (Section 3) totalling the size to 2 881 ha of which 2 ha were used to produce lucerne (*Medicago sativa*) to sell to the public (Helm 2006).

Telperion Nature Reserve's size increased to 3 794 ha when another 913 ha along its northern boundary were added in 1988 (Section 4). It was named Tshuswane or ant and the older part Isipethu meaning little stream (Helm 2006).

In 1990 crop production stopped. Instead, they started breeding with Nguni cattle. It did not last long because the intermingling of the cattle and wildebeests resulted in continuous malignant catarrhal fever (Helm 2006).

The western neighbouring farm, owned by G. Britz, was bought by the Oppenheimers in 1994 (Section 5). Previously several farming practices were exercised on the farm. Crop production included maize (*Zea mays*), sunflower (*Helianthus annuus*), potatoes (*Solanum tuberosum*), feed sorghum (*Sorgum* species) as well as lucerne or alfalfa (*Medicago sativa*). Animals such as cattle, wildlife, sheep, goats and chicken were some of the species bred on the farm. This farm was 2 590 ha in size and was named Bohlokwa meaning ‘important’ in zulu. From 1997 to 2003 a peach orchid with 6 500 trees were cultivated on the Bohlokwa section (Helm 2006).

The farm west of Bohlokwa, named eZemvelo, was owned by the Van Wyk’s. eZemvelo was 2 084 ha and contained a diversity of wildlife. Animals present here included eland (*Taurotragus oryx*), kudu (*Tragelaphus strepsiceros*), impala (*Aepyceros melampus melampus*), white rhinoceros (*Ceratotherium simum*), ostrich (*Struthio camelus*), waterbuck (*Kobus ellipsiprymnus*), blesbuck (*Damaliscus pygargis phillipsi*) and black wildebeest (*Connochaetes gnou*). The Oppenheimers bought this game farm in 1998 (Section 6). They named the newly amalgamated block of land eZemvelo (Helm 2006).

In 2000 a flood washed the boundary fence, initially kept to separate Isipethu and Bohlokwa, away. Game migrated accross the Wilge River and intermingled with game on the other portion of the farm. In 2002, the fence between Bohlokwa and eZemvelo was taken down and the Nguni cattle removed (Helm 2006).

Fences were lifted and game were allowed to move freely on a newly acquired area to the east of Telperion in 2007, increasing the total size of eZemvelo and Telperion Nature Reserve to 13 000 ha (Section 7).

During 2008, Telperion Nature Reserve was separated from the eZemvelo Nature Reserve when E Oppenheimer & Son (Pty) Ltd donated the 4 500 ha eZemvelo Nature Reserve to Maharishi Institute, South Africa’s first free university. However, the game on eZemvelo still belongs to E Oppenheimer & Son (Pty) Ltd. Although not separated by fences, the two Reserves are separated by the Wilge River.

Today eZemvelo and Telperion Nature Reserve houses 33 game species and 300 bird species. A summary of typical species found on the reserve today is presented in table 2.1.

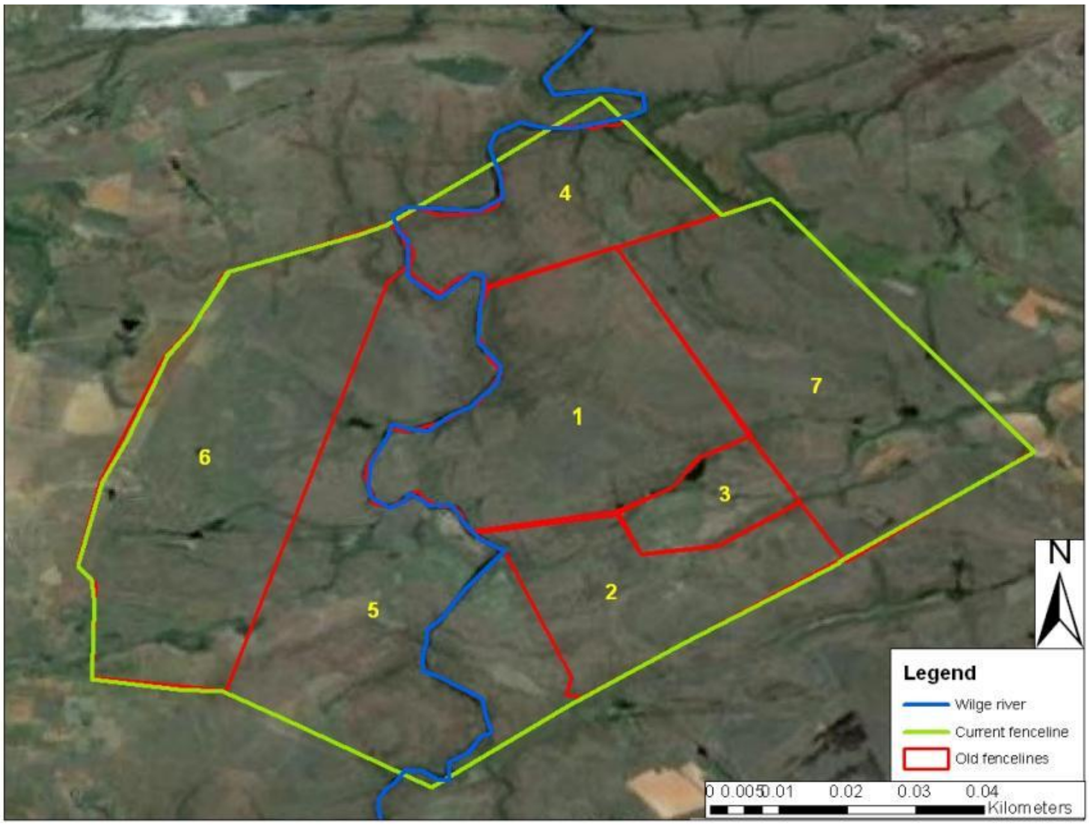

Figure 2.1. Areas purchased by the Oppenheimer's from 1974. Numbers are in order of purchase: 1. Telperion farm, 2. Telperion Nature Reserve, 3. Telperion Nature Reserve, 4. Tshuswane and Isipethu, 5. Bohlokwa, 6. eZemvelo and 7. Telperion Nature Reserve (Helm 2006).

Table 2.1. Some species found on eZemvelo Nature Reserve.

Common name	Scientific name
Aardvark	*Orycteropus afer*
Aardwolf	*Proteles cristatus*
African Civet	*Civettictis civetta*
Baboon	*Papio cynocephalus*
Black-backed Jackal	*Canis mesomelas*
Black Wildebeest	*Connochaetes gnou*
Blesbok	*Damaliscus pygargis phillipsi*
Blue Wildebeest	*Connochaetes taurinus taurinus*
Brown Hyaena	*Parahyaena brunnea*
Burchell's Zebra	*Equus burchelii*
Bush pig	*Potamochoerus larvatus*
Caracal	*Caracal caracal*
Common Reedbuck	*Redunca arundinum*
Eland	*Taurotragus oryx*
Gemsbok	*Oryx gazelle*
Giraffe	*Giraffa camelopardalis*
Greater Kudu	*Tragelaphus strepsiceros*
Grey Duiker	*Sylvicapra grimmia*
Guinea Fowl	*Numida meleagris*
Impala	*Aepyceros melampus melampus*
Klipspringer	*Oreotragus oreatragus*
Leopard	*Panthera pardus*
Mountain Reedbuck	*Redunca fulvorufula*
Oribi	*Ourebia ourebi*
Ostrich	*Struthio camelus*
Red Hartebeest	*Alcelaphus buselaphus caama*
Reedbuck	*Redunca redunca*
Serval	*Felis serval*
Springbok	*Antidorcas marsupialis*

Steenbok	*Raphicerus campestris*
Vervet Monkey	*Chlorocebus aethiops pygerythrus*
Warthog	*Phacochoerus africanus*
Waterbuck	*Kobus ellipsiprymnus*
White Rhinoceros	*Ceratotherium simum*

2.2. Location

The isiZulu word eZemvelo, translated to English means: 'back to nature'. It is therefore an appropriate name to one of the important nature reserves in the Grassland Biome. Ezemvelo Nature Reserve is located approximately 24 kilometres north-east of Bronkhorstspruit on the border of Gauteng and Mpumalanga provinces of South Africa (Figure 2.2). The reserve is situated north of the National Route 4 and can be reached from the R25 to Globersdal. The reserve is approximately 13 000 ha in size and divided by the Wilge River into two portions: eZemvelo and Telperion. Telperion falls within Mpumalanga and can be located between southern latitudes 25° 38' and 25° 45' and eastern longitudes 28° 55' and 29° 03'. Farmlands surrounding the reserve practice mainly crop agriculture, cattle production or game ranching.

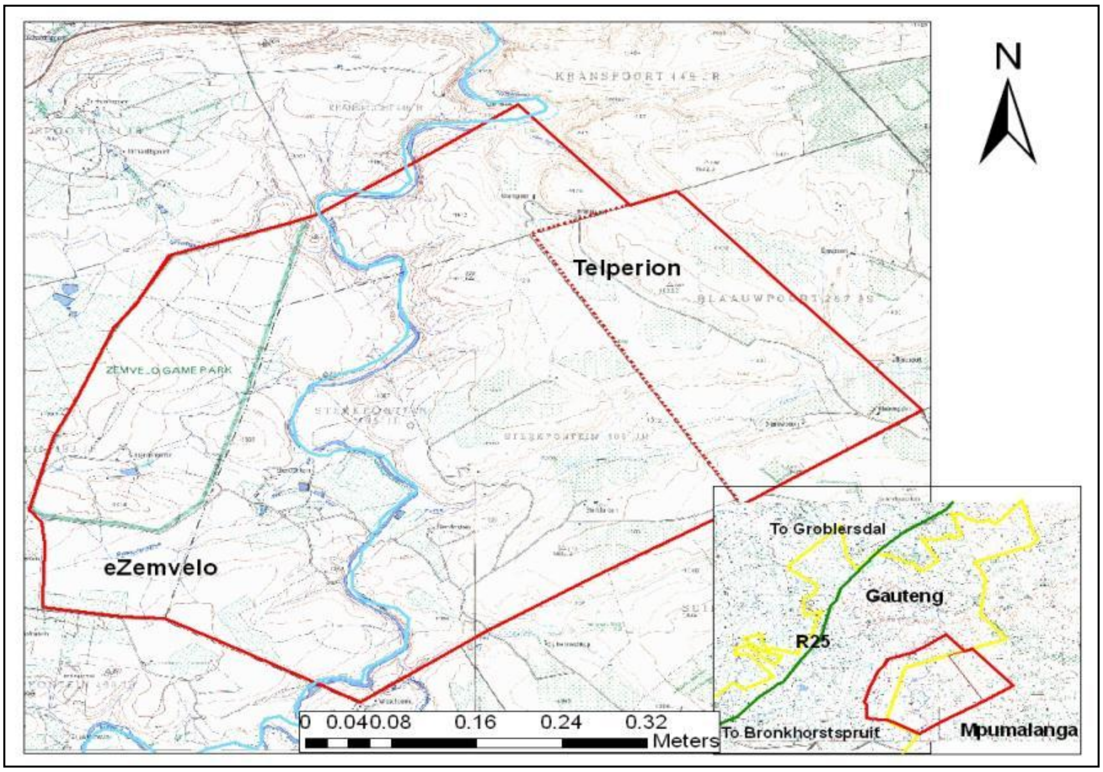

Figure 2.2. eZemvelo Nature Reserve locality.

2.3. Climate

Temperature

For the last 13 years (1994-2006), temperatures were measured by Witbank weather station (SAWS, 2008)(no. 0515320 8). According to them the highest temperatures occur during January and February with a maximum daily temperature of 26.1 °C and a minimum daily temperature of 14.9 °C. The coldest time of the year is during the month of July with the maximum and minimum temperatures reaching 18.2 °C and 4.0 °C respectively (Figure 2.3). During May to August frost may occur (SAWS, 2008) (no. 0515320 8).

Rainfall

eZemvelo Nature Reserve receives summer rainfall. Data obtained from the Witbank weather station for the past 46 years and from Bronkhorstspruit for the past 13 years indicate that the mean annual rainfall is 625 mm (SAWS, 2008)(no. 0514408 X) and 674 mm (SAWS, 2008)(no. 0515320 8) at Bronkhorstspruit and Witbank respectively. The rainy season peaks in summer from October to March while the drier months are in winter, June to August (Figure 2.4, SAWS, 2008).

2.4. Topography and Hydrology

The Wilge River, tributary to the Olifant's River, flows northwards through the reserve. It receives water from several higher-lying streams and wetlands. The Grootspruit joins the Wilge River in the north and the Sterkfonteinspruit in the middle of eZemvelo NR (Figure 2.5). These and numerous other smaller streams provide water throughout the year. Two large dams are present; one in the eastern and the other in the western part of the reserve. A small dam is situated in the north-western portion of the reserve.

eZemvelo Nature Reserve lies at an altitude of between 1 240 m to 1 500 m above sea level. The landscape associated with the eastern section of the Wilge River is characterised as a plateau while the western section flows through highly dissected undulating terrain characterised by ridges and valleys. To the south-easterly portion of the reserve the Wilge River has naturally eroded the landscape to form rocky cliffs and ridges. An open plateau is bound on the north by steep slopes.

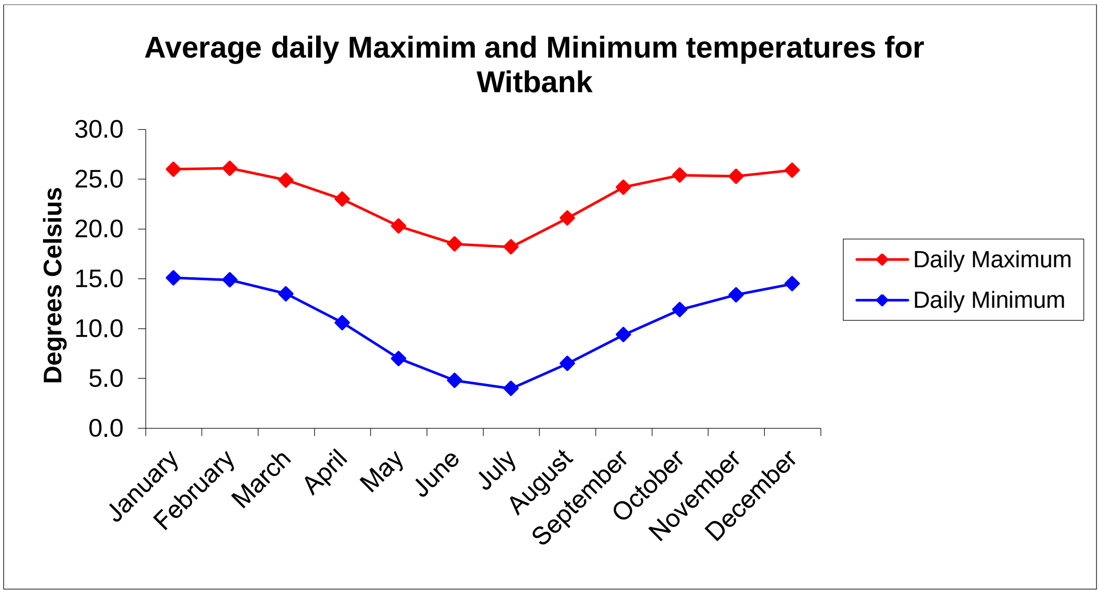

Figure 2.3. Mean daily maximum and minimum temperatures.

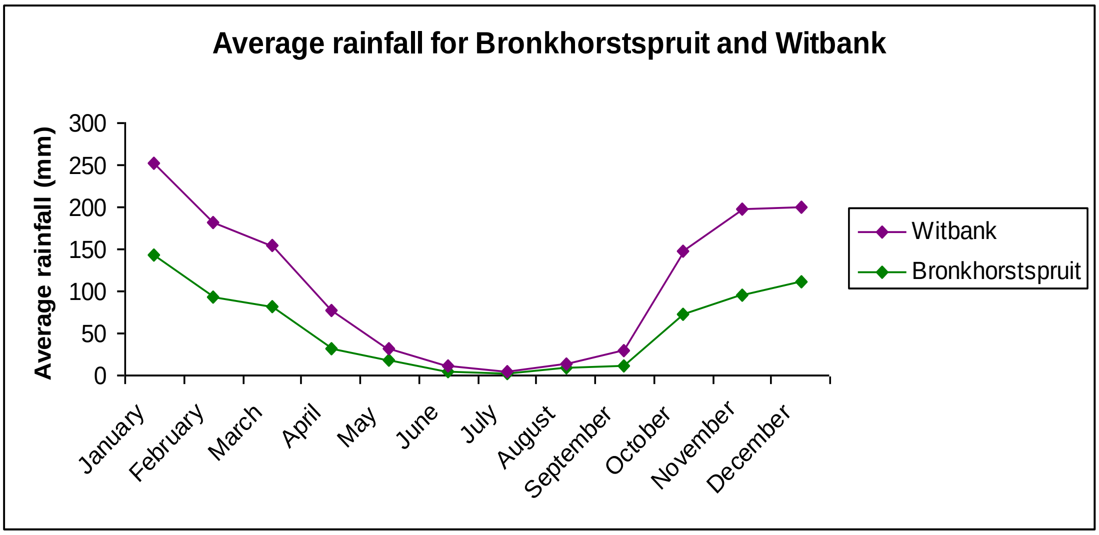

Figure 2.4. Average monthly rainfall for Bronkhorstspruit and Witbank.

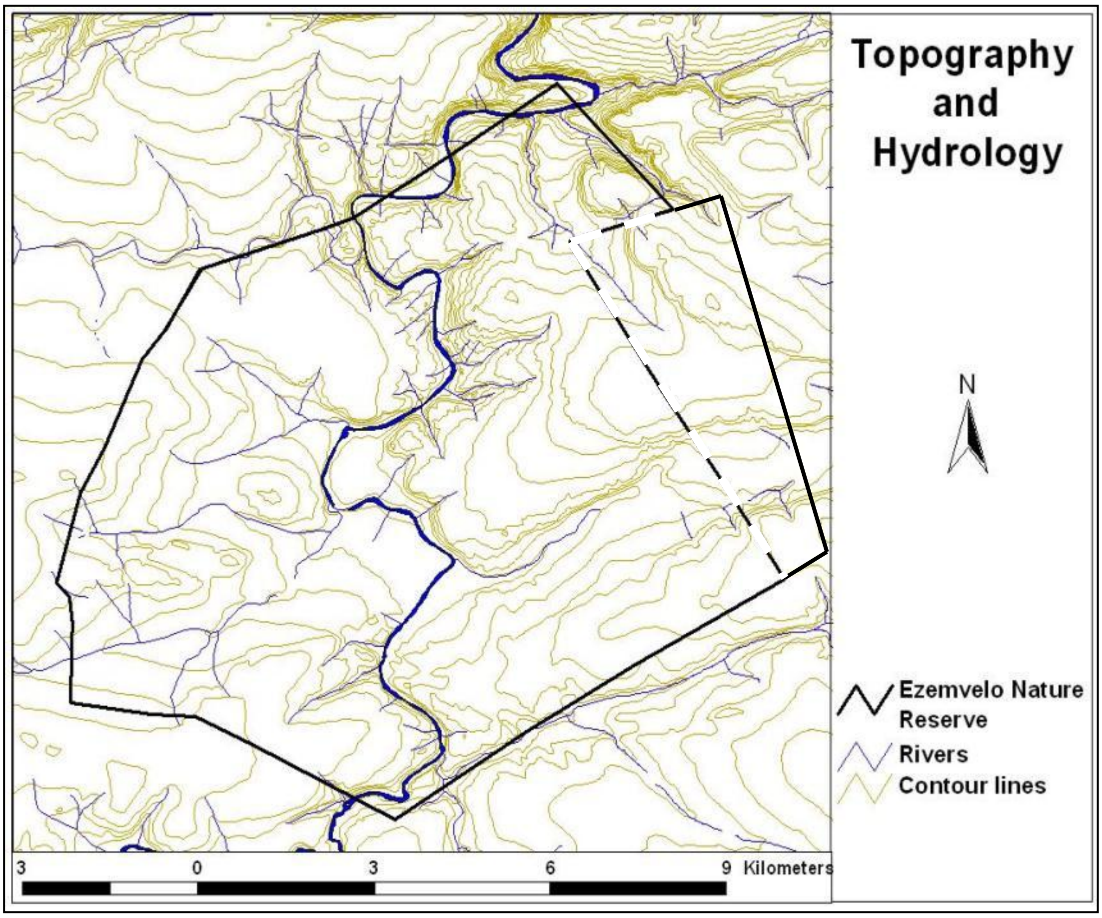

Figure 2.5. Topography and hydrology of eZemvelo Nature Reserve (adapted from Swanepoel 2006).

2.5. Geology and soils

Land types display terrain form, soil pattern and climate. Terrain form can be divided in units such as crest, scarp, midslope, footslope, valley bottom or floodplains. Soil pattern, on the other hand, is determined by factors such as geology and topographic position. Climate boundaries can be established through vegetation, soils, crop performance, altitude and topography (Land Type Survey Staff 1987).

West of the Loskop Dam, the Bankenveld is underlain by diabase sills and the Pretoria Group (Transvaal sequence) which comprise of alternating quartzite and shale. To the east, the Bankenveld is underlain by intrusions of norite, gabbro, granite, granophyre and rhyolite (Land Type Survey Staff 1987). The geology of eZemvelo Nature Reserve is depicted in figure 2.6.

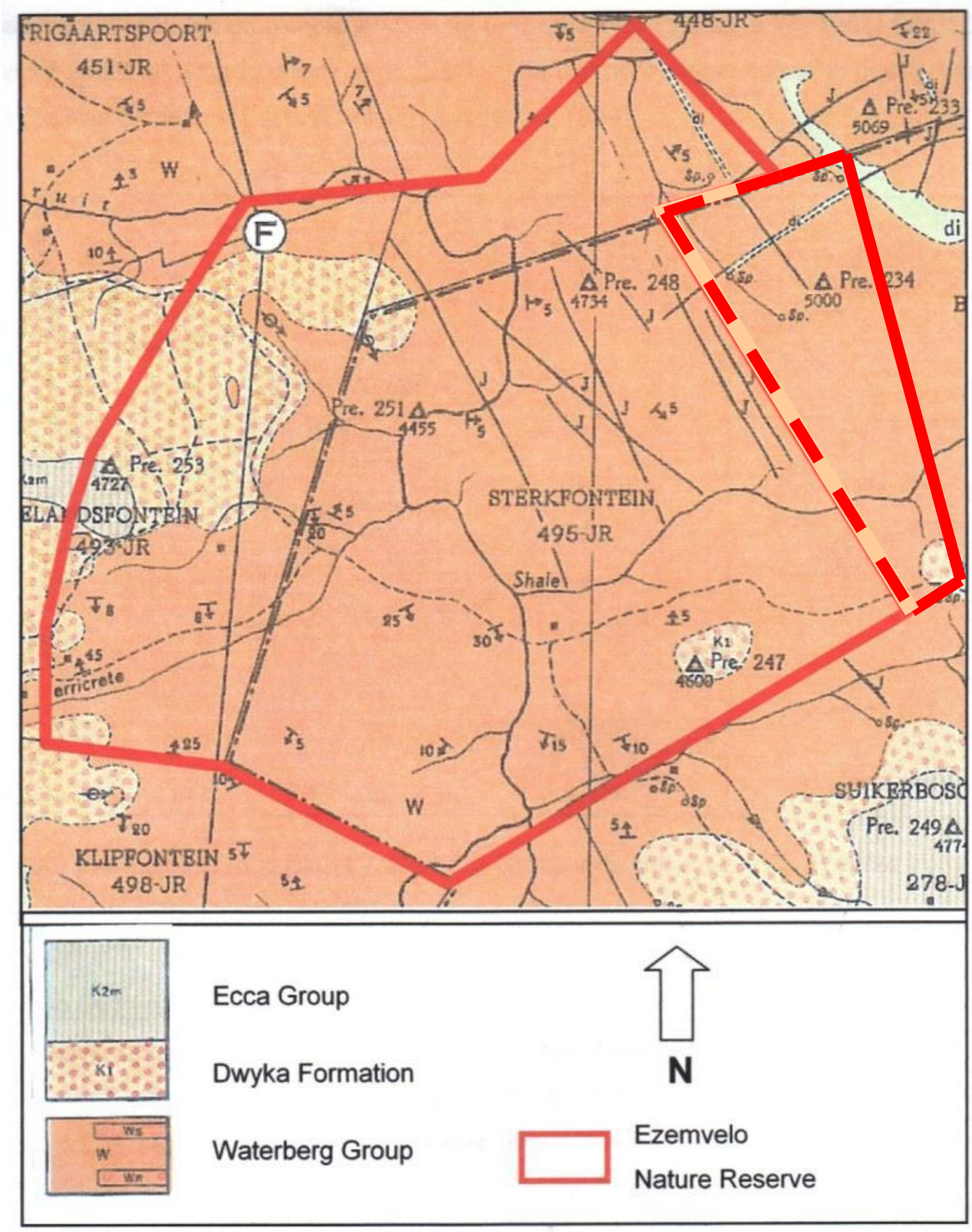

Figure 2.6. Geology of eZemvelo Nature reserve (adapted from 1:125 000 scale map of 2528D(Bronkhorstspruit) and 2529C (Witbank) geological Survey adated from Swanepoel 2006).

2.6. References

COWLING, R.M., RICHARDSON, D. M. & PIERCE, S. M. 1997. *Vegetation of southern Africa.* Cambridge University Press. Cambridge.

HELM, C.V. 2006. *Ecological separation of the black and blue wildebeest at Ezemvelo Nature Reserve in the Central grasslands of South Africa.* M.Sc. Dissertation (Wildlife Management), University of Pretoria, Pretoria.

LAND TYPE SURVEY STAFF. 1987. Land types of the maps 2526 Rustenburg, 2528 Pretoria. Memoirs on the Agricultural Natural Resources of South Africa No. 8.

SOUTH AFRICAN WEATHER SERVICES. 2008. Maximum and Minimum temperatures for Witbank Station 0515320 8 from 1993 to 2008.

SOUTH AFRICAN WEATHER SERVICES. 2008. Climate statistics for Witbank Station 0515320 8 from 1993 to 2006.

SOUTH AFRICAN WEATHER SERVICES. 2008. Monthly daily rain for Kungwini Local Municipality 051440 8 X from 1978-2008.

SOUTH AFRICAN WEATHER SERVICES. 2008. Monthly daily rainfall for Witbank Station 0515320 8 from 1993 to 2008.

SWANEPOEL, B.A. 2006. *The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspruit, South Africa.* M.Sc. Dissertation (Botany), University of Pretoria, Pretoria.

3. AN INTRODUCTION TO ZEBRAS

3.1. Introduction

The name zebra is said to originate in one of two languages. The Amharic or ancient Semitic word used for guinea fowl is zĭgra and its derivatives zĭgora and zĭbra. Originally this may have been used to name zebras as it translates "of a striped black and white colour". The Hebrew word tzĕbi means splendour or beauty (MacClintock 1976). This chapter gives an overview of *Equus*.

3.2. Taxonomic Classification

According to the hierarchical classification of Carl Linnaeus, also known as Carl von Linné, zebras belong to the Animalia, Chordata, Mammalia and order perissodactyla. Perissodactylians are odd-toed hoofed animals that include extinct paleotheres, titanotheres, chalicotheres and extant tapirs and rhinoceroses (Groves 1974; Smuts 1974). They are mesaxonic, their main weight baring axis of each foot moves through the middle toe, which is the longest. In the family Equidae, zebras, horses and asses are closely related and alike and are thus grouped into a single genus, *Equus* (Groves 1974; Smuts 1974). Today *Equus* is the only extant genus of the Equidae. It can be divided into the subgenus *Equus* which refers to horses while asses and onagers are classified into the subgenus *Asinus*. Zebras belong to the subgenus *Hippotigris* (Groves & Bell 2004). Three kinds of zebras exist, the Plains zebra, Grévy's zebra and Mountain zebra (Smuts 1974; MacClintock 1976; Groves & Bell 2004). The species *Equus burchelli* (Burchell's zebra) or *Equus quagga* (Plains zebra) include bontequagga, quagga, Burchell's zebra or plains zebra. Currently the mountain zebra is classified into one species *Equus zebra* and subdivided into two subspecies, *Equus zebra zebra* and *Equus zebra hartmannae*. Grévy's zebra, *Equus grevyi* does not have any subspecies (Groves & Bell 2004).

3.3. African Zebras today

3.3.1. Grévy's zebra

The Grévy's zebra (Figure 3.1) is monotypic but some variation between Kenya and Ethiopia exist (Groves & Bell 2004). It is the largest of the zebras (Stahl 1971; Groves

1974; MacClintock 1976), the height to its shoulders approximately 1.43 meters. Stallions can weigh anything between 354-431 kilograms. They have numerous narrow close-set vertical stripes and a characteristic triple-arch on either side of their rump where the croup, flank and hind leg stripes meet. A broad black stripe bordered by white can be seen on their spine, with the widest part being in the mid-back (Groves 1974; MacClintock 1976). They have a white belly (Stahl 1971; Groves 1974; MacClintock 1976), their facial stripes do not extend up to their brown nose patch and their gray muzzle and legs are banded to the hoofs. A tall thick erect mane expands from between rounded hairy ears to the back (Groves 1974; MacClintock 1976).

Figure 3.1. The typical striping pattern of a Grévy's zebra (*Equus grévyi*).

The distribution of these animals ranges from the desert to semi-arid southern Ethiopia, northern Kenya and small parts of Somalia (Groves 1974; MacClintock 1976; Groves & Bell 2004).

3.3.2. Mountain zebra

A mountain zebra can be identified by means of two characteristics. The first being a dewlap or pendant skin fold in their neck and then a grid-iron pattern formed by small transverse stripes that connect the spinal and upper most rump stripes (Groves 1974; MacClintock 1976). Interestingly, the hair along midrib of the back grows forward instead of backwards as in other zebra species (Groves 1974). These animals are small, donkey-like and stand only as tall as 1.2 meters. The manes is thick and erect. Their vertical stripes do not extend up to their flanks, leaving a white belly (Stahl 1971; MacClintock 1976). They connect with the spinal stripes and continue to the back of the tail. Broad horizontal black and white stripes are present on the rear legs. Legs are banded to the hoofs. The muzzle is brown and the facial stripes narrow and brown (MacClintock 1976).

The mountain zebra is a small animal with thick black stripes, so much so that they seem black with white stripes. These animals can be found from southern Angola, western coast of Namibia into South Africa (Groves 1974; MacClintock 1976; Theron 1991; Hack & Rubenstein 1998).

The rare Cape Mountain zebra (Figure 3.2), *Equus zebra zebra*, was the first to get scientific recognition as a mountain zebra (Stahl 1971; MacClintock 1976). The Afrikaners of South Africa call them bergkwaggas. This zebra exhibits sexual dimorphism where females are larger than males. The stripes are not as thin and the interspaces between stripes are smaller than the stripes and interspaces of *Equus zebra hartmannae.* They are mainly found in the southern Cape of South Africa (Groves & Bell 2004).

Figure 3.2. The Cape Mountain zebra (*Equus zebra zebra*).

The Hartmann's mountain zebra (Figure 3.3), *Equus zebra hartmannae*, is another subspecies but its body size is larger than the Cape mountain zebra. They have narrower stripes, an off-white ground colour and overlaps (Groves 1974; MacClintock 1976; Groves & Bell 2004). They do not exhibit sexual dimorphism as the Cape Mountain zebras do. They range from Southern Angola, through Namibia into the north-west corner of South Africa (Groves & Bell 2004).

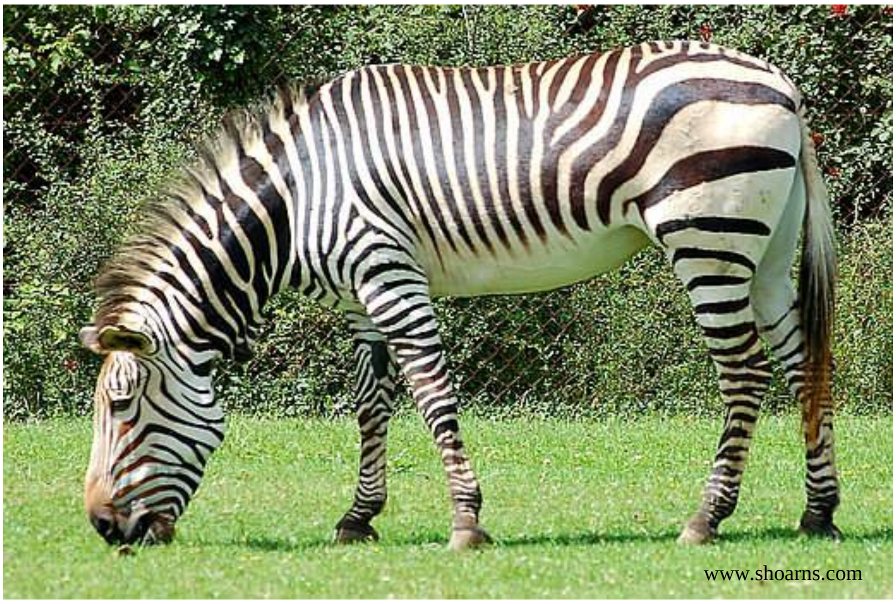

Figure 3.3. Hartmann's Mountain zebra (*Equus zebra hartmannae*).

3.3.3. Plains zebra

Plains zebras are pony-like with shorter heads and smaller ears and are numerous and widespread (Figure 3.4,; Groves 1974; MacClintock 1976). Their distribution ranges in plains from southern Sudan, to Angola and northern South Africa (Groves 1974; MacClintock 1976; Theron 1991; Hack & Rubenstein 1998; Bowland *et al.* 2001; Groves & Bell 2004). The northern Plains zebras are the largest of all the plains zebras and the only one to show sexual dimorphism and sexual dimorphic manelessness (Groves & Bell 2004). The wide distribution of plains zebra caused noticeable differences in stripe pattern. The most northern zebras' stripes are pure black on a pure white background while the contrast between the stripes decrease and shadow stripes appear on southern herds (Stahl 1971, Groves 1974; Groves & Bell 2004).

Figure 3.4. Burchell's or Plains zebra (*Equus burchelli*).

3.4. Patterns and Striping

In plains zebra a gradient in stripe and belly patterns as well as mane characteristics is present with a distribution range from north to south. The reduction in leg bands is accompanied with a reduction in belly striping (Groves 1974; MacClintock 1976; Groves & Bell 2004). It is believed that the narrow stripes of Grevy's zebras are most primitive. The gridiron on the croup and increase is black stripes on the hindquarters lead to the patterning of the mountain zebra. The progressive decrease in stripes led to the Plains zebras while the Quagga, with its partially covered stripe pattern, may have been the initial step to solid colouration (MacClintock 1976).

It was observed that northern Africa and East African zebras have shorter, stockier manes than southern ones (Groves 1974; Groves & Bell 2004). In Somalia all adult zebras are maneless while some female zebras along the Juba River, Uganda and southern Sudan have manes. Upon birth all foals have manes but it is lost when sexual maturity is reached (Groves 1974).

After adventurer Francis Galton returned from his explorations in Africa during 1853, he stated that zebra stripes are used for camouflage. This statement caused uproar in the scientific world (Stahl 1971). Several theories exist on reason for stripe pattern (Stahl 1971; MacClintock 1976; Ruxton 2002). American artist-naturalist Abbot H.

Thayer and his son Gerald H. Thayer believed that the striping of zebras looked like light coloured reeds on a shadowed background. They argued that the reeds eliminate a zebras outlines. The dark stripes was said to be upward continuations of the grasses while the white stripes mimic downward extension of the sky (MacClintock 1976). Thayer described the bold patterns as disruptive that distract the viewer from the outline (Stahl 1971). Theodore Roosevelt, a former president of the United State, disagreed with Thayer and wrote lengthy critical remarks against the views of Thayer. Roosevelt argued that colouration of animals could be best explained by hunters. According to them, zebras and various other animals stood out from their background and were easy targets (Stahl 1971).

The British soldier and explorer Captain Frederick J.D. Lugard believed that the striping resembles the sunbeams and shadows of flickering light in a forest. Others believed that zebras' survival depends on alertness, speed and protection of the herd formation rather than camouflage, as they run away at the face of danger instead of standing still and relying on their surrounding environment, as seen by camouflaged animals (Stahl 1971; MacClintock 1976).

According to MacClintock (1976), the protective function of the zebra stripes must be seen in relation to zebra-predator interactions. Factors to consider include time of day zebras become more vulnerable as prey, the behaviour of predators and at predator attack range. When present in open spaces, zebras appear entirely dark or light depending on the light intensity. It often seems if their stripes shimmer. It is the result of hot air rising off the sun-baked earth surface forming mirages (MacClintock 1976). The outlines of zebra become grayer during sunrise and sunset, a time when they are more vulnerable as prey (Stahl 1971; MacClintock 1976). The black stripes, broader above and tapering below, eliminates the effects of three dimensional lighting and visual clues by which animals are recognised. The zebra is therefore concealed by counter shading (Stahl 1971; MacClintock 1976). According to Ruxton (2002) this theory is the most plausible for all cripsis theories.

Charles Darwin did not believe that stripes were only useful for camouflage, he believed it functioned as mate attraction too. His theory was based on the actions of Lord Clive, best known for his conquests in India. Lord Clive wanted to cross-breed a zebra female with a male ass. When the female rejected the male, Lord Clive requested that stripes be painted on the ass. Only then did the female accept the ass (Stahl 1971).

A British naturalist, Sir Richard Lydekker stated that at a distance where zebra stripes seem to blur, stripes of the same width and direction throughout is more conspicuous. The stripe characteristic y-shaped saddle of plains zebra therefore produces the optical illusion of two animals (MacClintock 1976). Stripes results in a confusion of form. Narrow portions of the body make the zebra appear further than the broader stripes flanks which may cause confusion about the direction in which the zebra is moving. In addition, individuals are often hard to distinguish when tightly gathered in herds (MacClintock 1976).

According to Ruxton (2002) the theory backed with the most evidence is the protection against tsetse flies. It is believed that striping reduce the number of biting flies as these flies prefer a dark solid colouration. However, tsetse flies' distribution does not range within mountain zebra distribution range. The problem therewith is the presence of extensive striping on a mountain zebra, hence questioning the viability of this theory (Ruxton 2002).

Zebras seldom seek shade. It is suggested that stripes may form part of a temperature regulating function. The black stripes absorb slightly more sunlight than the white reflective parts (MacClintock 1976). Ruxton (2002) compared several theories and of all existing theories, he was convinced thermoregulation is the most far-fetched explanation.

3.5. Social Organization

Zebra groups are non-territorial, nomadic, and often migratory and their social structure is unique among hoofed animals. Social units are formed from personal bonds by individuals of different small groups (MacClintock 1976; Schilder & Boer 1987; Theron 1991; Hack & Rubenstein 1998).

Zebra family groups comprise of a stallion with one to six mares and their offspring (Groves 1971; Smuts 1974; MacClintock 1976; Theron 1991; Hack & Rubenstein 1998). The total number of individuals in such a group may be up to sixteen but generally a family consists of seven members. A dominance hierarchy exists within groups. The male is dominant but during migration, the group is generally led by a mare. She is typically the oldest. In two separate studies done by Andersen (1992a) and Pluháček *et al.* (2006) it is agreed that the rank of a mare is indeed linked to her age. Others will follow her in their specific rank and be threatened by bared teeth and kicks if they were to move ahead of their place. Mares are followed by her foals with the youngest closest. The ranking may remain constant or change every couple of months. The stallion usually walks behind his group but often guides the leading female to change direction of migration and follow tracts to water (Groves 1974; MacClintock 1976; Theron 1991). When a member is missing, other members of the group will search for it. While mares will only search for their own foal, stallions will keep track of all members of his group (Groves 1974; MacClintock 1976).

Interestingly, Pluháček & Bartoš (2000) found evidence of infanticide in captive plains zebra when they placed a new bachelor in a group of breeding females. The stallion either force copulation with a pregnant mare which resulted in abortion of the foetus or fatally attacked the foals. They found that abortions increased to a ratio of 3:1 when a new stallion was introduced. Fatal foal attacks increased to 4:1 (Pluháček & Bartoš 2000). This infanticide was not just focused on male foals but female foals as well. Pluháček & Bartoš (2000) suggested that it may be due to the fact that female foals often leave their herds with their first oestrous reducing the probability of a new mate for the new stallion.

Group mares are said to be antagonistic against mares of other groups while stallions will communicate via a ritual meeting. The meeting is preceded with whinnying back and forth and then followed by nose-to-nose contact. After the head is coerced against the other’s flanks, they sniff each other’s genitals which are again followed by nose-to-nose contact. A jump on the hind legs forms the last part of the greeting. The greeting of a stallion with a meek young stallion only involves nose-to-nose contact (MacClintock 1976; Hack & Rubenstein 1998).

Stallions are only replaced when they are weak from illness or old age or killed by a predator. If the latter should occur, stallions of other groups may take over the group along with their own. Replaced stallions live in bachelor groups, often also consisting of colts and young stallions (Groves 1974; Smuts 1974; MacClintock 1976; Penzhorn & Novellie 1991; Theron 1991; Hack & Rubenstein 1998). Colts between their first and fourth year is often found in these groups when the bond between mare and colt is broken by a new sibling (Groves 1974; MacClintock 1976; Penzhorn & Novellie 1991). As with mountain zebras a single colt in a family group may seek playmates in a bachelor group. Bachelor groups vary between two to fifteen stallions but consist mostly of three individuals (Groves 1974; MacClintock 1976; Theron 1991; Hack & Rubenstein 1998).

When fillies reach one and a half or two years old they are abducted by other herd stallions. The stallion of the group attempts to protect the oestrous filly. During such a fight a third stallion normally succeeds in the abduction. Should a stallion be able to protect a filly, she will only truly become part of the group after two and a half years. Conception rarely occurs before this age (Groves 1974; MacClintock 1976).

3.6. Reproduction

The first oestrous of fillies occurs at approximately thirteen months, followed by twenty one day intervals in which the filly will stand with a slightly elevated hindquarter, raised tail, ears back and open mouth position. It is named as the oestrous posture, indicating her readiness for mating. Fillies may continue this posture for as long as a week while mares only display it during the height of oestrous at the approach of the herd stallion. This posture is believed to encourage stallions (Groves 1974; MacClintock 1976).

Mares and fillies in oestrous urinate more frequently. Stallions will sniff the urine and respond by flehming. Flehmen is the raised head with open mouth and upper lips in curled position. It allows stallions to determine the reproductive stage of the mare. An odour reaches a tubelike structure in the roof of the mouth, lined with an olfactory receptor (Jacobson’s organ) which is sensitive to varying concentrations of sex hormone by-products. Copulation is usually repeated in one to three hour intervals during the day (MacClintock 1976).

Schilder & Boer (1987), Andersen (1992a) and Pluháček *et al.* (2006) found that older mares often interfere with mating of the stallion with younger mares. They ascribed it to the protection of resources for the older mare's offspring.

3.7. Mares and offspring

Gestation takes approximately 371 to 385 days and foaling occurs throughout the year (Groves 1974; Smuts 1974; MacClintock 1976; Theron 1991; Hack & Rubenstein 1998; Neuhaus & Ruckstuhl 2002; Grange *et al.* 2004; Fay & Greeff 2006). Approximately 85 percent is born between October and March with a peak during January (Groves 1974; Smuts 1974). The mare-foal bond is believed to be formed when the mare licks the nostrils, eyes and ears of the foal removing the amniotic fluid after birth (MacClintock 1976).

After birth a foal stands after approximately eleven minutes, staggers by nineteen, walks well after thirty two. By forty four minutes it gallops and after one hour the foal is able to run. They look woolly due to their long, soft body hairs and weigh approximately 27–32 kilograms at birth. Suckling takes place after the first hour. After birth, a mare will keep other zebras away as the mare-foal bond will only be established after a few days. Foals recognise its mother by scent, stripe pattern and call. Plains zebra foals are weaned any time from seven (MacClintock 1976) to eleven months (Theron 1991). In a study done by Pluháček *et al.* (2006) they found that pregnant captive plain zebra females weaned their foals up to 50 days sooner than non-pregnant females. More investment is made in male foals; so that if the next offspring was a male, the current offspring will be weaned earlier than if it was to be a female foal (Pluháček *et al.* 2006).

3.8. Activities

3.8.1. Grazing

Zebras have upper and lower incisors allowing them to bite off grass rather than pluck it like other plains grazer species (MacClintock 1976). They graze mainly the coarse taller grasses and use both stem and leave components different to the wildebeest that prefer the softer shorter and horizontal grasses (Groves 1974; MacClintock 1976; Penzhorn & Novellie 1991; Bodenstein *et al.* 2000). As there is no competition, this association is the most common of all African herbivores (Fay & Greeff 2006). During times of lowest phosphorous and protein percentages in grasses, both zebras and blue wildebeest has been seen browsing on *Grewia* species to supplement their nutritional needs (Bodenstein *et al.* 2000). In fact, Wildebeest is hardly seen without zebras.

Species such as Coke's hartebeest (*Alcelaphus buselaphus cokii*), impalas (*Aepyceros melampus melampus*), giraffes (*Giraffa camelopardalis*), elephants (*Loxodonta africana*), buffalo's (*Syncerus caffer*) and warthogs (*Phacochoerus africanus*) are also often seen with zebras. These associations allow more safety as most species in the assemblage can sense the alarm of the other, there are more ears, eyes and sent is detected more easily (MacClintock 1976; Theron 1991; Hack & Rubenstein 1998; Fay & Greeff 2006). These mixed groups however, may also result in competition (Penzhorn & Novellie 1991). According to Andersen (1992b) the congregations of different species still allow for different ranks between the species groups. Generally the largest animals are the more dominant. This dominance is most often displayed by displacement (Andersen 1992b).

Other species often found close to zebras are cattle egrets (*Bubulcus ibis*), and oxpeckers (*Buphagus africanus*). The former walk alongside the forelegs catching insects that jumps due to the disturbance of the grass while the latter eat ticks on the zebra (MacClintock 1976).

All equids, digest food inefficiently and thus require many hours a day to graze. Pregnant and lactating mares need even more uninterrupted feeding time (Hack & Rubenstein 1998).

Also, according to MacClintock (1976), zebras and wildebeest go to water between eight and eleven o'clock. Their ears flick and they drink water through closed teeth (MacClintock 1976). Andersen (1992a) found that drinking is influenced by temperature. In his studies on zebras (*Equus burchelli*) in three different zoo's, he found that during hotter days zebras had more drinking bouts than during colder times.

3.8.2. Grooming

In addition to cleaning, grooming serves to promote group bonding. Standing shoulder towards each other, they nibble with their incisors on places that cannot be reached by them (MacClintock 1976; Andersen 1992a). Mares groom their foals while stallions groom mares and foals of his choice. Stallions often prefer some mares above the others (MacClintock 1976). It was confirmed by Andersen (1992a) when all three groups of zebras in the different zoo's had a preference for specific grooming partners. The grooming of each other is known as allogrooming (Andersen 1992a).

3.8.3. Shuddering and rubbing

Zebras have a thin muscular layer called the cutaneous muscle present on the forearms, shoulders, back and flanks. It is closely attached to the skin which allows them to shudder or shake ridding them of insects. This muscle is absent from areas in the range of the tail (MacClintock 1976).

In addition to shuddering, removal of dead skin and loose hair occurs through rubbing and rolling. Rubbing often occurs on tree trunks, rocks and termite mounds. Zebras also rub their heads against their forelegs, behind their ears with their hind legs or hind leg with hind leg to remove itching and ticks (MacClintock 1976). Dust-bathing is another method of removing biting flies and other ectoparasites (Andersen 1992a). It is the shape of a zebras' body that allows it to roll from one side to the other and back (MacClintock 1976).

3.8.4. Sleeping

During the last hours of a day zebras and other plains herbivores become most active. Fights often break out between colts and stallions as they make their way from their grazing grounds back to the short-grassed sleeping areas. They rest and sleep during the night and day. Young animals lie down for their complete rest while older animals lie down less frequently and for shorter times. One herd member will always be alert and on its feet while the rest of the group is sleeping (MacClintock 1976; Theron 1991).

To lie down, all four legs are drawn together under their body, they then collapse to one side with their legs facing the opposite side and their upright head with curved neck over their fore legs. To stand up zebras stretch their fore legs and lifts themselves up front first. Hind legs then push the backside up. It is often followed with a shake or stretching of the legs (MacClintock 1976).

A zebra is able to sleep on its feet. This is possible due to a system of opposing tendons and ligaments which counterbalance each other. The stifle or patella acts as a lock system that slides upward to engage an articular surface on the femur. Reciprocal action of the peroneus terius and the superficial digital flexor causes the hock to lock. Check ligaments and fibrous white bands, two in each fore leg and one in each hind leg reduce muscle strain. Sometimes a hind leg is rested by flexion of its joint so that only the hoof rests on the ground (MacClintock 1976).

3.9. Diseases

Various parasites trouble zebras. External parasites include ticks from the order Ixodida and flies from the order Diptera. Several flies lay their eggs in open sores or underneath the skin. Other internal parasites are species such as nematodes and tapeworms. Tapeworms are often found within the muscles. However like most African wild animals, zebras are immune to trypanosomiasis caused by a single-celled trypanosome. Contagious bacterial diseases include Anthrax (*Bacillus anthracis*) and rodlike bacteria that cause tetanus named *Clostridium tetani* (MacClintock 1976).

3.10. Predators

Spherical eyes, pointed ears, flaring nostrils, high-speed running and the formation of herds are but a few adaptations shaped by evolution for survival. One of the most effective methods of protection for zebras is small herd formations. It is well known that vigilance decreases with an increase in group number (Scheel 1993). Single file walking from one place to next reduces the chance of zebras to come across a predator (MacClintock 1976).
Upon confrontation with a predator, foals learn that evasion is more important. This is accomplished by the mares with foals moving behind other individuals in their group.

This, in addition allows them to learn the difference between predator walking and stalking behaviour. Stallions will move in front of its herd and attack a predator aggressively (MacClintock 1976).

The most common predator of zebras is lions (Stahl 1971; MacClintock 1976; Fay & Greeff 2006; Grange & Duncan 2006). It was found that they are second most to wildebeest killing percentages. If lions hunt during the day they rely on ambush. They are opportunists therefore on the lookout for young and sick animals in a herd (MacClintock 1976). As lions, spotted hyenas scavenge during the day and are also opportunists. During nights they are hunters. Zebras, wildebeest and gazelles are preferred prey. A single hyena will hunt gazelles, one or two will hunt wildebeest and a clan of up to twenty five will hunt zebras. The social wild dog packs hunt during the day. Hunting takes place mostly during early morning and late afternoons. They run in and around a zebra group to scatter them and close in on an individual. Cheetahs are build for speed but are light weight, have weak jaws and are solitary therefore they rarely attack zebras. On exceptional occasions will they hunt for zebra foals and wildebeest calves. If a zebra herd walks within a leopard’s territory a foal may be ambushed but generally they will also prey on smaller animals such as gazelles, reedbucks, baboons, jackals etc. (MacClintock 1976).

3.11. The quagga – an extinct zebra

A zebra slightly taller and stockier than the plains zebra use to exist (Figure 3.5). It was reddish-brown in colour and had stripes only on its head, neck and forequarters (Stahl 1971, Groves 1974, MacClintock 1976, Ruxton 2002). The quagga (*Equus quagga*) had an erect mane, dark spinal stripe that widened over its croup, legs, belly and white tail (MacClintock 1976).

Figure 3.5. The extinct quagga (*Equus quagga*).

A debate exists between mammalogists regarding the status of a quagga. Some believe that they were a distinct species as shown by their different skeletal and banding characteristics. It was determined from DNA of a preserved skin that it was indeed a subspecies of *Equus burchelli* (Ruxton 2002). Groves and Bell (2004) on the other hand, found no differences in cranial or external characteristics between the extinct quagga and the extant plains zebra (*Equus burchelli*) therefore rendering statements that the quagga was a distinct species as unfounded (Groves & Bell 2004). They (Groves & Bell 2004) stated that plain zebra's (*Equus burchelli*) external characteristics can be extremely different but also intermediate to those of the quagga. They concluded by stating that the subspecies *Equus quagga burchelli* still exists in Kwa-Zulu Natal and in Etosha and that the true quagga (*Equus quagga quagga*) was a distinct subspecies that graded into *Equus quagga burchelli* morphologically (Groves & Bell 2004).

3.12. References

ANDERSEN, K.F. 1992a. Size, design and interspecific interactions as restrictors of natural behaviour in multi-species exhibits. 1. Activity and intraspecific interactions of Plains zebra (*Equus burchelli*). *Applied Animal Behaviour Science* 34: 157–174.

ANDERSEN, K.F. 1992b. Size, design and interspecific interactions as restrictors of natural behaviour in multi-species exhibits. 3. Interspecific interactions of Plains zebra (*Equus burchelli*) and Eland (*Tautotragus oryx*). *Applied Animal Behaviour Science* 34: 273–284.

BODENSTEIN, V., MEISSNER, H.H. & VAN HOVEN, W. 2000. Food selection by Burchell's zebra and blue wildebeest in the Timbavati area of the Northern Province Lowveld. *South African Journal of Wildlife Research* 30: 63–72.

BOWLAND, A. E., BISHOP, K.S., TAYLOR, P.J., LAMB, J., VAN DER BANK, F.H., VAN WYK, E. & YORK, D. 2001. Estimation and management of genetic diversity in small populations of plains zebra (Equus quagga) in KwaZulu-Natal, South Africa. *Biochemical Systematics and Ecology* 29: 563–583.

FAY, T.H. & GREEFF, J.C. 2006. Lion, wildebeest and zebra: A predator-prey model. *Ecological modelling* 196: 237–244.

GRANGE, S., DUNCAN, P., GAILLARD, J., SINCLAIR, A.R.E., GOGAN, P.J.P, PACKER, C., HOFER, H. & EAST, M. 2004. What limits the Serengeti zebra population? *Oecologia* 140: 523–532.

GROVES, C.P. 1974. *Horses, asses and zebras in the wild*. David & Charles Newton Abbot, London.

GROVES, C.P. & BELL, C.H. 2004. New investigations on the taxonomy of the zebras genus *Equus*, subgenus *Hippotigris*. *Mammalian Biology* 69:182–196.

HACK, M.A. & RUBENSTEIN, D.I. 1998. Zebra zones. *Natural History* 107 (2): 26–28.

MACCLINTOCK, D. 1976. *A natural history of zebras*. Charles Scribner's Sons, New York.

NEUHAUS, P. & RUCKSTUHL, K.E. 2002. The link between sexual dimorphism, activity budgets, and group cohesion: the case of the plains zebra (*Equus burchelli*). *Canadian Journal of Zoology* 80: 1437–1441.

PENZHORN, B.L. & NOVELLIE, P.A. 1991. Some behavioural traits of Cape mountain zebras (*Equus zebra zebra*) and their implications for the management of a small conservation area. *Applied Animal Behavioural Science* 29: 293–299.

PLUHAČEK, J. & BARTOŠ, L. 2000. Male infanticide in captive plains zebra, *Equus burchelli*. *Animal Behaviour* 59: 689–694.

PLUHAČEK, J., BARTOŠ, L. & ČULÍK, L. 2006. High ranking mares of captive plains zebras *Equus burchelli* have a greater reproductive success than low-ranking mares. *Applied Animal Behaviour Science* 99: 315–329.

PLUHAČEK, J., BARTOŠ, L., DOLEŽALOVA, M., BARTOŠ-VÍCHOVA, J. 2006. Sex of the foetus determines the time of weaning of the previous offspring of captive plains zebra (*Equus burchelli*). *Applied Animal Behaviour Science*, in press.

RUXTON, G. 2002. The possible fitness benefits of striped coat coloration for zebra. *Mammal Review* 32: 237–244.

SCHEEL, D. 1993. Watching for lions in the grass: the usefulness of scanning and its effects during hunts. *Animal Behaviour* 46: 695–704.

SCHILDER, M.B.H. & BOER, P.L. 1987. Etological investigations on a herd of Plains Zebra in a Safari Park: Time-Budgets, Reproduction and Food Competition. *Applied Animal Behaviour Science* 18: 45–56.

SMUTS, G.L. 1974. *Growth, reproduction and population characteristics of Burchell's zebra (Equus burchelli antiquorum, H. Smith, 1841) in the Kruger National Park.* Ph.D Thesis. University of Pretoria, Pretoria.

STAHL, B. 1971. *The elusive zebra.* Addison-Wesley Publishing Company, Massachusetts.

THERON, A. 1991. *The behavioural ecology of two zebra species on game farms in the Waterberg, northern Transvaal*. M.Sc. Dissertation (Wildlife Management). University of Pretoria, Pretoria.

4. GRASSLANDS OF TELPERION NATURE RESERVE

4.1. Introduction

Vegetation can be described as the plant species composition and combined structure formed by the plants of a given area (Kent & Coker 1992). When looking at these growth forms on a wider scale, it can be divided into vegetation types worldwide. Similar climatic conditions that occur over large areas, are the main causes for the existence of these vegetation types and thus also the reason why similar vegetation repeat themselves all over the world. These vegetation types are called biomes (Van Wyk & Smith 2001).

Plant distribution forms part of the many characteristics of plants i.e. a species may be described on morphology, anatomy, ecology, distribution etc. There are three main methods used to study distribution (Van Wyk & Smith 2001). (a) In ecology the focus lies largely on the species and communities of an area. Here, special attention is given to habitat suitability, species tolerances, competition, interaction, herbivory and disturbances. (b) Floristic geography on the other hand, is flora-centred and is directed at floristic assemblages. Some of the main aims are to describe floristic areas and elements with specific attention to endemics. (c) Historical geography focuses on the taxon itself and tries to explain how climatic, geological, migrational and evolutionary events have determined the distribution of species.

Distributions of species can be mapped on the basis of biomes, floristic composition, phytochoria etc. allowing one to identify areas with high concentrations of species and a limited distribution (Van Wyk & Smith 2001). According to Low and Rebelo (1996) as well as Van Wyk and Smith (2001) South-Africa is divided into eight vegetation biomes. More recently, Mucina & Rutherford (2006) added one more biome based on floristic diversity (Figure 4.1.). Telperion Nature Reserve is located within the Grassland Biome.

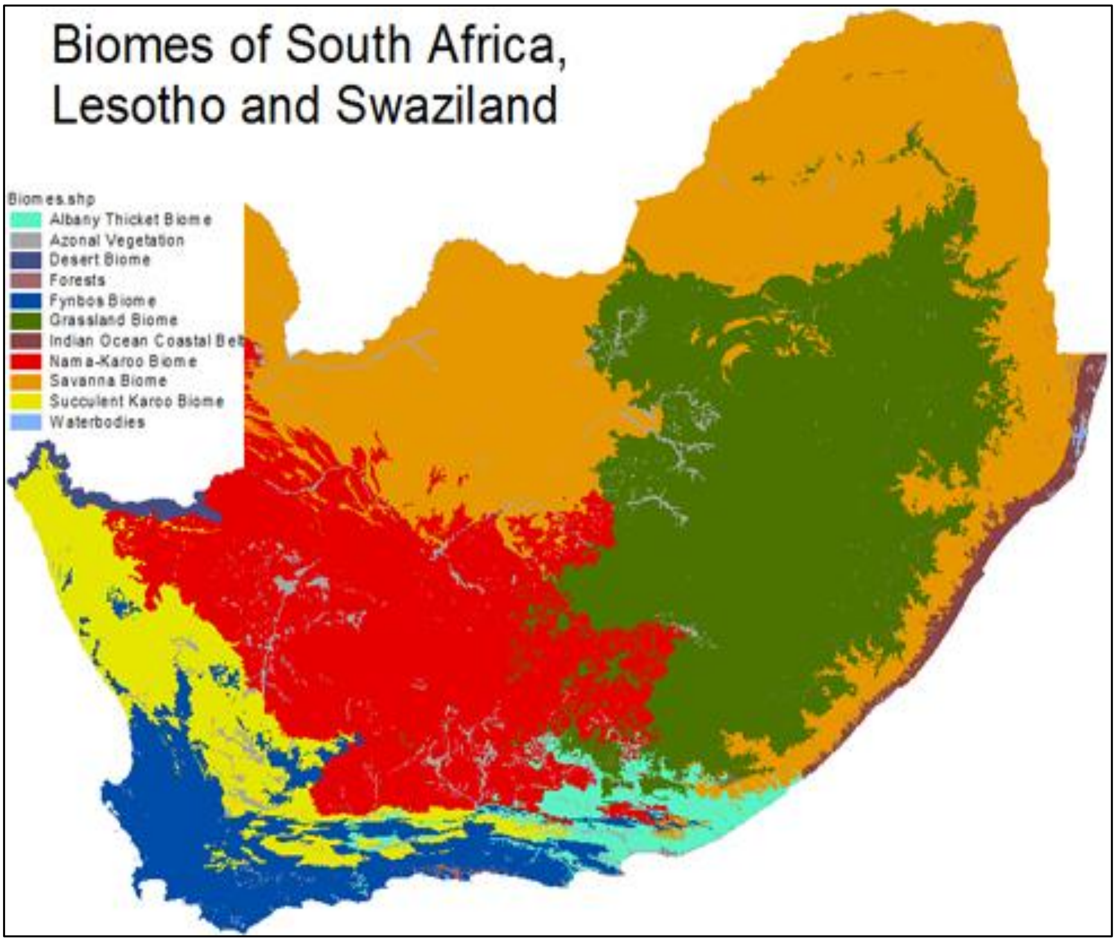

Figure 4.1. Vegetation biomes of South Africa (http://bgis.sanbi.org/vegmap/biomes.asp).

4.2. The Grassland Biome

South African grasslands form part of one of these biomes and are located centrally in this country (Bredenkamp1999; O'Connor & Bredenkamp 1997). In South Africa, the grassland biome occupies 26% of our land cover (Bredenkamp 1999) or 349 174 km^2 (O'Connor & Bredenkamp 1997) and consists out of a very rich diversity of plants due to the large range of environmental factors. These variations include altitudes from sea level to 3000 meters above sea level, mostly summer rainfall with a gradient from 400 – > 1200 mm (Bredenkamp 1999; O'Connor & Bredenkamp 1997), and topographic diversity ranging from flat plains to the Drakensberg mountain range. Temperatures for this biome are described as temperate to tropical (Bredenkamp 1999). In the arid and semi-arid areas of South Africa drought is a common phenomenon (Oosthuizen & Snyman 2003). Moisture stress in these systems is widespread due to protracted rain-free winters, frequent droughts and unpredictable rainfall (Snyman 1993).

The grassland biome of South Africa consist of six major regions comprising of 14 grassland vegetation types (O'Connor & Bredenkamp 1997; Bredenkamp 1999), each with its own set of characteristic species and unique soil sequences. The plant biodiversity of these grasslands is estimated to be 3 378 species making it the third highest species diverse biome in South Africa. This diversity is said to be the result of the very old grasslands in South Africa. Fossil pollen records and the long history of drier, cooler climatic conditions in southern Africa favouring grasslands are said to be the evidence thereof (Bredenkamp 1999).

The prominent grasses of this biome include *Themeda triandra, Eragrostis curvula, Cymbopogon plurinodis, Setaria sphacelata, Digitaria eriantha, Hyparrhenia hirta* and *Cynodon dactylon.* In the greater part of this biome *Themeda triandra* is the dominant species (O'Connor & Bredenkamp 1997).

Only 2.3% of the grasslands are currently conserved (Low & Rebelo 1996) in nature reserves such as Witbank, Suikerbosrand, Rustenburg, Abe Bailey, Boskop Dam and Rietvlei Nature Reserve (Low & Rebelo 1996; Swanepoel 2006). Approximately 60 to 80% thereof is irreversibly transformed by agriculture, industrialization, urbanization, mining and commercial forestry. The gold, coal and diamond mining industries in particular, resulted in large portions being transformed. Due to these disturbances several alien and invasive species have colonised the South African grasslands. They include species such as *Acacia dealbata*, *Acacia mearnsii*, *Eucalyptus* species, *Melia azadarach*, *Prunus persica* and *Rubus* species (O'Connor & Bredenkamp 1997). In addition, degradation of grassland communities due to poor grazing practices results in a shift in the sweet and sour grass species ratio of mixed grasslands and savanna, karoo invasion, as well as bush encroachment (Bredenkamp 1999; Tainton 1999).

4.3. The Rocky Highveld Grassland vegetation type

According to Acocks (1988) eZemvelo Nature Reserve is located in the Bankenveld vegetation type. Bredenkamp and Van Rooyen (1998) described the area as Rocky

Highveld Grassland while Mucina & Rutherford (2006) refer to it as the Rand Highveld Grassland. It is located on the extreme north of the Grassland Biome and linked to the Drakensberg to the east, Savanna to the north and Kalahari to the west, containing floristic elements representative of all these areas (Bredenkamp & Brown 2003).

The Bankenveld vegetation type mainly occurs on and between rocky ridges from Pretoria to Witbank, with extremities from Stoffberg and Roossenekal in the east, to Krugersdorp, Potchefstroom and Derby in the west. Its distribution ranges therefore in Gauteng, North-West, Mpumalanga and Free State provinces of South Africa (Mucina & Rutherford 2006).

The area is characterized by sloping and undulating plains, rocky hills and ridges such as Magaliesberg, Timeball Hill, Daspoort, Suikerbosrand and Witwatersrand (Acocks 1988; O'Connor & Bredenkamp 2003; Mucina & Rutherford 2006). Altitudes range from 1300 – 1600 m above sea level (Bredenkamp & Van Rooyen 1998; Mucina & Rutherford 2006) but may be as high as 1 760 m above sea level in some areas (Mucina & Rutherford 2006). The soil is shallow and rocky with leached, acidic lithosols (Bredenkamp & Van Rooyen 1998). The high rainfall, winter frost, frequent veld fires and shallow soil renders this veld type predominantly sour (Acocks 1988). In sour grasslands nutrients are translocated from leaves to the roots during winter allowing re-sprouting of new shoots during spring. This is a classic adaption to veld fires that often occur in sour veld due to the high fuel load. In spring sour grasses produce valuable grazing. If overgrazed however, recovery rate is slow (Bredenkamp 1999; Tainton 1999).

The Rocky Highveld Grassland vegetation type consists of several vegetation communities, their location dependent on their locality and topography (Bredenkamp & Brown 2003). Dominant graminoid species include *Ctenium concinnum, Cynodon dactylon, Digitaria monodactyla, Diheteropogon amplectens, Eragrostis chloromelas, Heteropogon contortus, Loudetia simplex, Monocymbium ceresiiforme, Panicum natalense, Schizachyrium sanguineum, Setaria sphacelata, Themeda triandra, Trachypogon spicatus, Tristachya biserata* and *T. rehmannii.* Characteristic herb species are *Acanthospermum australe*, *Justica anagalloides* and *Pollichia campestris* and the dominant succulent shrub is *Lopholaena coriifolia*. Seven percent have been invaded by alien species such as *Acacia mearnsii* (Mucina & Rutherford 2006).

Mucina & Rutherford (2006) classify this vegetation type as endangered. Approximately 33.6% of this vegetation type is already transformed while only 0.8% (Reyers *et al.* 2001) to 1% (Mucina & Rutherford 2006) is conserved in small patchy distributed reserves such as Kwaggavoetpad, Van Riebeeck Park, Bronkhorstspruit, Boskop Dam Reserve, Doornkop, Mpopomeni, Renosterpoort and eZemvelo.

4.4. Telperion Nature Reserve vegetation

Geologically, this area consist of quite similar substrates and is infringed by the Savanna, Grassland and Forest Biomes, which together form the basis of the floristic diversity found in the Bankenveld (Bredenkamp 1975; Bredenkamp & Theron 1978; Bredenkamp & Brown 2003). Bredenkamp & Brown (2003) state that Bankenveld can be interpreted as a "mosaic of grassland and woodland communities controlled by (micro-) climatic conditions that exists in the topographically heterogeneous landscape". In Telperion and eZemvelo Nature Reserves, these mosaic distribution patterns are highly noticeable, with the presence of grasslands on the plains, wetlands in the bottomlands, floodplains and streams, woodlands on the slopes of ridges and hills and forests in the valleys adjacent to the Wilge River (Figure 4.2, Swanepoel 2006).

Vegetation communities of eZemevelo Nature Reserve were identified by Grobler (1999) and Swanepoel (2006) of which the latter comprised of a detailed study. Swanepoel (2006) described 22 vegetation communities of which 13 communities were identified as Wetland and Riverine communities. They were described as *Hyparrhenia tamba–Imperata cylindrica–Paspalum urvillei* dry disturbed wetland, *Ischaemum fasciculatum* wetland, *Pennisetum macrourum* wetland, *Typha capensis–Paspalum urvillei* wetland, *Imperata cylindrica* seepage wetland, *Paspalum urvillei–Eragrostis inamoena–Mariscus keniensis* narrow rocky wetland, *Leersia hexandra–Eragrostis plana* wetland, *Floscopa glomerata–Leersia hexandra* drainage line wetland, *Phragmites australis–Thelypteris confluens* tall dense wetland and *Schoenoplectus corymbosus* wetland (Swanepoel 2006).

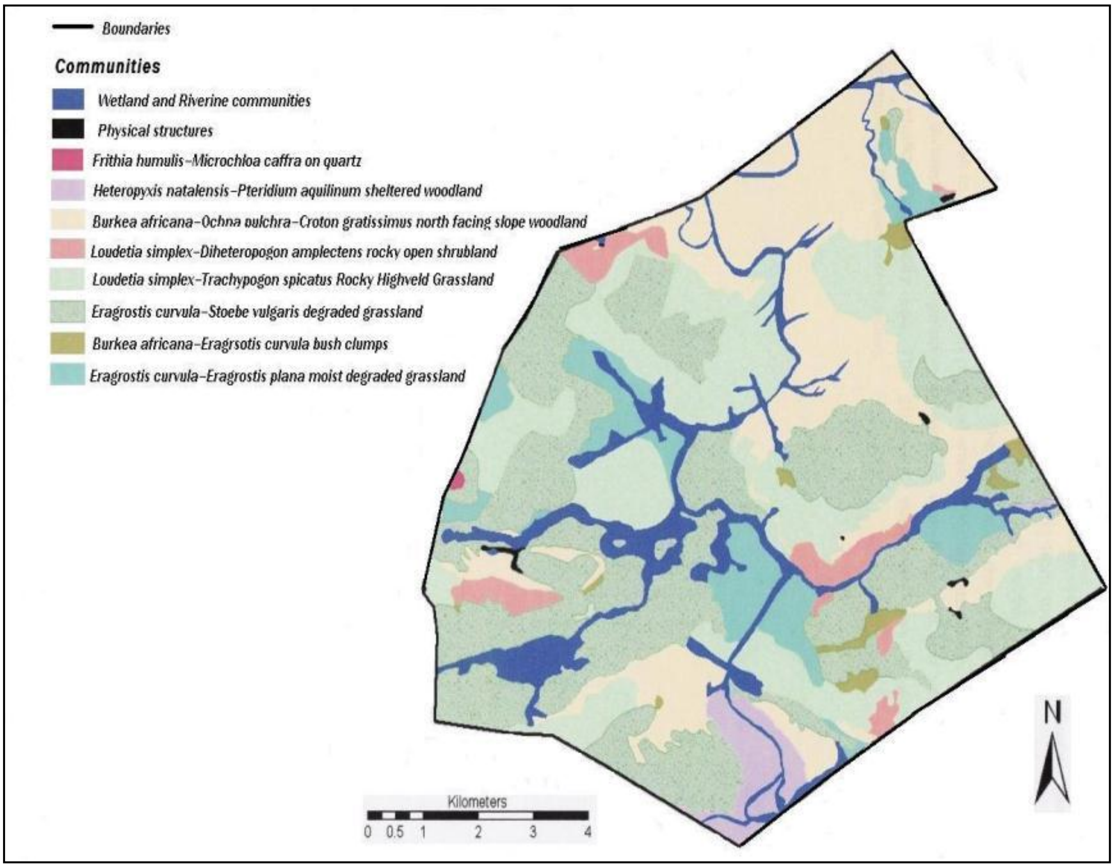

Figure 4.2. Vegetation communities of eZemvelo Nature Reserve (Swanepoel 2006).

The woody and rocky vegetation of Ezemvelo Nature Reserve were divided into seven communities; *Frithia humulis–Microchloa caffra* on quartz, *Populus X canescens* dense woodland, *Combretum erythrophyllum–Panicum maximum* riverine woodland, *Acacia caffra–Celtis africana* bush clumps on the foot of slopes, *Heteropyxis natalensis–Pteridium aquilinum* sheltered woodland, *Burkea africana–Ochna pulchra–Croton gratissimus* north facing slope woodland and *Loudetia simplex–Diheteropogon amplectens* rocky open shrubland (Swanepoel 2006).

The grasslands consist of five communities. They were described by Swanepoel (2006) as *Loudetia simplex–Trachypogon spicatus* Rocky Highveld Grassland, *Eragrostis curvula–Seriphium plumosum* degraded grassland, *Burkea africana–Eragrsotis curvula* bush clumps, *Eragrostis curvula–Eragrostis plana* moist degraded grassland and *Acacia dealbata* riverine woodland.

Swanepoel (2006) found several invasive alien species present on the reserve, of which the most numerous included *Populus X canescens* and *Eucalyptus* *camaldulensis*. As the ridges, Wilge River and wetlands are relatively untransformed and provide habitat for the vast majority of fauna and flora (Swanepoel 2006), it is critical importance that good conservation practices and management be executed within these remaining natural ecosystems on the reserve.

4.5. References

ACOCKS, J.P.H. 1988. Veld Types of South Africa. *Memoirs of the Botanical Survey of South Africa* No. 57.

BREDENKAMP, G.J. 1975. *'n Plantsosiologiese studie van die Suikerbosrand natuurreservaat.* M.sc. Dissertation. University of Pretoria, Pretoria.

BREDENKAMP, G.J. 1999. Grassland. In: Knobel, J. *The magnificent natural heritage of South Africa.* Sunbird Publishing, Llandudno.

BREDENKAMP, G.J. & BROWN, L.R. 2003. A reappraisal of Acocks' Bankenveld: origin and diversity of vegetation types. *South African Journal of Botany* 69(1): 7–26.

BREDENKAMP, G.J. & THERON, G.K. 1978. A synecological account of the Suikerbosrand Nature Reserve, Part I: The phytosociology of the Witwatersrand geological system. *Bothalia* 12: 513–529.

BREDENKAMP, G.J. & VAN ROOYEN, N. 1998. Rocky Highveld Grassland. In: Low, A.B. & Rebelo, A.G. (eds). *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs and Tourism, Pretoria.

GROBLER, A. 1999. Phytosociology & Veld condition assessment of Ezemvelo Game Reserve. B.Sc (Hons). University of Pretoria, Pretoria.

KENT, M. & COKER, P. 1992. *Vegetation description: A practical approach*. J. Wiley and Sons, Chichester.

LOW, A. B. & REBELO, A. G. 1996. *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs and Tourism, Pretoria.

MUCINA, L. & RUTHERFORD, M.C. (eds.) 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. South African Biodiversity Institute, Pretoria.

O'CONNOR, T.G., BREDENKAMP, G.J. 1997. Grassland. In: Cowling, R.M., Richardson, D.M., Pierce, S.M. (Eds.). *Vegetation of Southern Africa*. Cambridge University Press, Cambridge, pp. 615.

OOSTHUIZEN, I.B. & SNYMAN, H.A. 2003. Impact of water stress on growth reserves and re-growth of *Themeda triandra* (Forssk.) following defoliation. *African Journal of Range & Forage Science* 20: 41-45.

REYERS, B., FAIRBANKS, D.H.K., VAN JAARSVELD, A.S. & THOMPSON, M. 2001. Priority areas for the conservation of South African vegetation: A course filter approach. *Diversity and Distributions* 7:77–96.

SNYMAN, H.A. 1993. The effect of defoliation during wilting on the production of *Themeda triandra* and *Eragrostis lehmanniana* in semi-arid grassland. *African Journal of Range & Forage Science* 10(3): 113-117.

SWANEPOEL, B.A. 2006. *The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspruit, South Africa.* M.Sc. Dissertation (Botany), University of Pretoria, Pretoria.

TAINTON, N.M. 1999. *Veld management in South Africa*. University of Natal Press, Pietermaritzburg.

VAN WYK, A.E., SMITH, G.F. 2001. *Regions of Floristic Endemism in Southern Africa. A review with emphasis on Succulents.* Umdaus Press, South Africa.

5. METHODS

5.1. Introduction

A plant community consists out of a group of species occurring in a specific habitat (Bredenkamp 2001; Bredenkamp & Brown 2001). Krohne (2001) defines a community as an 'ensemble of species in some area delimited by the practical extent of interspecific interactions'. According to Kent & Coker (1994) a plant community can merely be defined as the assemblage of populations of species at a particular habitat. At this community level, the interaction between the plant species and their environment characterize an ecosystem. Different plant communities may be easily recognisable because of their distinct boundaries or alternatively, plant communities may lay along a gradient where one community gradually changes into the next. The communities within an ecosystem form a complex mosaic and a self-sustainable system determined by the biological and physical environment (Bredenkamp 2001; Bredenkamp & Brown 2001).

Species grow together in a specific habitat because they have similar resource requirements. Light, water and temperature are but a few environmental factors that determine plant's growth requirements. Plant populations comprise of individuals of a specific species grouped together. Also, individuals in a community often share tolerance of factors such as human activities and trampling and grazing by animals. It is the level at which man can understand vegetation and observe variance in its cover. When scientists study ecosystems, plant communities are investigated because these groupings of populations describe vegetation the best (Kent & Coker 1994). Thus, different species present in a community may represent the particular characteristics of that ecosystem. For example, one species may be an indicator for a particular combination of environmental factors within a specific habitat (Bredenkamp 2001; Bredenkamp & Brown 2001). The indicator species of a habitat is not necessarily the dominant species. They may be inconspicuous, herbaceous wild flowers (Bredenkamp 2001). If the environment changes, changes in species composition of a community occur. This in turn, may influence the animals present in that habitat (Bredenkamp 2001; Bredenkamp & Brown 2001). Thus, plant communities are regarded as an important ecosystem level at which to apply conservation and environmental management plans (Kent & Coker 1994). Hence the plant community approach was chosen in conjunction with the study of the Telperion Plains zebras.

5.2. Background Information

During a site visit before the onset of the study, two areas were chosen visually based on general habitat type impression. The first, an area of Rocky Highveld Grassland (Figure 5.1), and the second of Mixed Grassland (Figure 5.2). A detailed study of the vegetation of the chosen areas was to follow in the study itself. Two groups of Plains zebras, one closest to each chosen area were the targets of study.

5.3. Data Collection

5.3.1. Observation of Plains Zebras

Zebra feeding behaviour

During the initial stages of the study, observations took place per foot but the skittishness of the zebras kept them far which often made it difficult to record their behaviour, even through binoculars. Thereafter, observations were carried out from within a car. The distance from which the zebra groups could be observed was reduced remarkably. It continued to decrease as they became habituated to us. They were observed with the naked eye. Binoculars (10 x 16) were also used if necessary. The position of a herd of zebras closest to each habitat was recorded with a Global Positioning System (GPS).

Neuhaus & Ruckstuhl (2002) identified zebra individuals by their pattern striping. If it was not possible they averaged observations for all the individuals of the same sex to reach one data point. During the infant stages of this study, individual zebras where to be identified for each group based on their striping. The chosen zebras’ behaviour and feeding pattern where to be recorded throughout the year. However, individuals within groups had very similar pattern striping and distinguishing individuals where nearly impossible hence the abandonment of that strategy. This similar patterning may be a result of the isolated game farm populations (Bowland *et al.* 2001). Therefore, during each sampling session a random stallion, mare and foal were chosen for morning, afternoon and evening observations throughout a year.

Figure 5.1. Habitat 1 - Rocky Highveld Grassland.

Figure 5.2. Habitat 2 – Mixed Grassland Community.

Adult male and female plains zebras, *Equus burchelli*, are similar in size hence the assumption that bite sizes will be similar. The main factor which will then determine rate of food intake is the bite rate (Neuhaus & Ruckstuhl 2002). Within these groups, the bytes per hour were noted for each randomly chosen individual by means of a stop watch. Bytes were defined as the time a zebra's head is in the grass or on the ground. As soon as it lifted its head, the time was stopped and recorded. When a zebra resumed feeding, the watch was restarted. This was repeated per group several times during one hour, three times a day, and two days every month for one year during June 2007 to May 2008.

Each random foal chosen was old enough to feed on grass and leave their mother's side even if they still nursed. As observed by Neuhaus & Ruckstuhl (2002) pregnant and lactating females where always present in the focal group due to female year round reproduction (Groves 1974; MacClintock 1976; Hack & Rubenstein 1998; Neuhaus & Ruckstuhl 2002; Fay & Greeff 2006). During this study no distinction where made between females lactating, pregnant or not pregnant or lactating. This was due to the determination of an average value of bite rate for females throughout the year, as well as the likelihood of early pregnancies that cannot be determined by casual observation only.

Zebra migration through Telperion

Not only were the locations of zebras in each identified area marked with a GPS, their movement or migration were recorded by taking a GPS point at the start and end of their trips. It was done in this manner as not to disturb their 'intentional' route, as tracking them by foot would have alarmed them and resulted in them altering their course. During their journey they were observed either with the naked eye or through binoculars (10 x 16).

5.3.2. Distribution, number and size of vegetation sampling plots

The location of the sample plots were chosen by the presence of the zebra group of each chosen habitat. We used the GPS points that was recorded during the zebra behavioural observations and returned to the site to determine the vegetation present. The plots on the sites where visually chosen to ensure that a representative view of the plant species and their abundance was recorded. A habitat and vegetation survey was conducted in each of these sites according to the Braun-Blanquet vegetation sampling method (Westhoff & Van der Maarel 1973; Mueller-Dombois & Ellenberg 1974; Werger 1974). The Braun-Blanquet or also known as the Zürich-Montpellier method was created and described by Professor Braun-Blanquet in 1928. In this book published by him, he described the vegetation of the French Mediterranean and the central Alps. His method was further developed by both Professor Rheinhold Tüxen of Germany and Professor Braun-Blanquet himself until the 1960's (Kent & Coker 1994; Barbour *et al*. 1999). Since the first description of this method, it has been a reliable tool used for vegetation surveys and classification in countries world-wide (Werger 1974).

There is no clear indication of precise how many relevés should be performed in a study area. It is determined by the vegetation heterogeneity of the survey area, the species richness and how in detail the study is to be performed (Werger 1974; Bredenkamp 1982). The number of sample plots in each identified area was determined by the size of the vegetation heterogeneity to ensure that the site was equally represented with the other sites. A total number of 52 plots were surveyed. The generally recognized plot size for savanna and wooded grassland of approximately 200 m^2 (10x20 m) were used as determinants for the plot sizes. All species present though, are given a cover or abundance estimate by placing it into one of seven categories (Table 5.1; Werger 1974; Mueller-Dombois & Ellerberg 1974; Barbour *et al.* 1999). From Table 5.1 it is clear that categories 3-5 refer to cover while the other categories refer to cover as well as abundance (Werger 1974). The reason for the use of categories is to standardise estimation of plant species cover between different investigators (Werger 1974; Barbour *et al.* 1999). This scale is often criticized because it is said that the grouping of abundance or cover in the same category is illogical. It received its most criticism because of the broad unit of category 2. Hence, this category was divided to define closer related groups (Table 5.2).

The vegetation data collection took place between November 2007 and March 2008. The study sites where described using the following factors:

- GPS points of sample plots

Table 5.1. The cover estimate categories of the Braun-Blanquet method (Werger 1974; Mueller-Dombois & Ellerberg 1974; Barbour *et al.* 1999).

Category	Range of cover (%)	Description
5	75-100	Covering 75-100 % independent of abundance
4	50-75	Covering 50-75 % independent of abundance
3	25-50	Covering 25-50 % independent of abundance
2	5-25	Covering less than 5 % or covering 5-25 % independent of the abundance
1	1-5	Numerous but covering less than 1 % of the quadrate area or not abundant and covering 1-5 % of the sample area
+	1	Present (not abundant) but with a small cover value
r		Very rare – usually only one individual

Table 5.2. Subdivision of category 2 for the cover-abundance scale of the Braun-Blanquet method (Werger 1974).

Category	Description
2 m	Very numerous covering less than 5 %
2 a	Covering 5-12 % independent of abundance
2 b	Covering 13-25 % independent of abundance

- The general abiotic characteristics of the sample plots. These were:
- Soil characteristics: Typical texture of soil present on the sample site was recorded. The major categories used were gravel, sandy, loam or clay. In addition, the colour of the soil was noted.
- Aspect: The major direction to which a slope faced at a sample plot was categorized in N, NE, E, SE, S, SW, W or NW.
- Rock cover: It was described based on the percentage of the sample plot being covered by rock. It was visually estimated.
- Gradient: It was visually estimated and recorded as percentage.

Any other characteristics of the site that would subsequently help in describing the plant communities were also recorded. Factors such as trampling, overgrazing, bare patches of soil, high percentage of alien species, old fields and large areas of anthropogenically planted pastures were recorded.

All the species were identified on the reserve or at the H.G.W.J. Schweickerdt Herbarium at the University of Pretoria. References consulted included Van Wyk & Malan (1997), Van Wyk & Van Wyk (1997), Pooley (1998) and Van Oudtshoorn (2004). Alien invasive species was identified from Landcare South Africa brochure and Bromilow (2001) and species of Medicinal value were identified from Van Wyk *et al.* (2000) and Van Wyk & Gericke (2003).

5.4. Data Analysis

5.4.1. Plains Zebras

All data was captured in the Microsoft Excel Package. Here it was processed and charts were designed to allow comparison of data. The analysis of variance (ANOVA) in the Microsoft Excel Package was used where appropriate ($\alpha = 0.05$).

5.4.2. Vegetation analysis

Classification

The plant species recorded for each sample plot were captured in the vegetation database TURBOVEG for Windows (Hennekens 1996; Hennekens & Schaminee

2001). The database was exported as a Cornell Condensed File (CC-file) into the working directory JUICE. JUICE is a Microsoft Windows application that allows one to edit, classify and analyse large phytosociological tables and databases. To date, JUICE has the capacity for the input of 30 000 relevés and 4 000 species. It allows one to select relevés in eight different colours and sort, move, aggregate and delete species or relevés with the mouse. The program extracts the statistically determined diagnostic, frequent and dominant species and boast many different functions for the manipulation of the phytosociological table (Tichỳ 2002). It is specifically this function that was required for this study as it allows one to manually select diagnostic species and subjectively modify the table in accordance with the traditional Braun-Blanquet method (Tichỳ 2002). As the areas of study were mainly grasslands, the woody species recorded were excluded from the Braun-Blanquet data after being imported into JUICE. This was decided because it skewed the results by concealing the true pattern by giving these woody species a high weighting value. The final phytosociological table indicate the different plant communities present on the preferred zebra grazing sites. The hierarchical level of this classification was drawn as a dendrogram.

Ordination

As an opposite of classification, ordination is a gradient analysis. Here, vegetation relationships are assessed as phenomena that occur along a gradient and samples are arranged according to their position along this gradient. This indicates that changes in community composition are related to changes of specific environmental factors. Using the ordination programme PCOrd (McCune & Mefford 1999) a Detrended Correspondence Analysis (DECORANA) ordination was applied to the data set. This was done to confirm the identity of the plant communities and identify the gradients between the different communities on the study site.

The results are described in three chapters, 6. Zebra feeding behaviour, 7. Vegetation description and 8. Discussion.

5.5. References

BARBOUR, M.G., BURK, J.H., PITTS, W.D., GILLIAM, F.S. & SCHWARZ, M.W. 1999 .*Terrestrial plant ecology*. Addison Wesley Longman, Menlo Park, California.

BOWLAND, A. E., BISHOP, K.S., TAYLOR, P.J., LAMB, J., VAN DER BANK, F.H., VAN WYK, E. & YORK, D. 2001. Estimation and management of genetic diversity in small populations of plains zebra (*Equus quagga*) in KwaZulu-Natal, South Africa. *Biochemical Systematics and Ecology* 29: 563–583.

BREDENKAMP, G.J. 1982. *'n Plantekologiese studie van die Manyeleti-Wildtuin*. DSc Thesis, University of Pretoria, Pretoria.

BREDENKAMP, G.J. 2001. Vegetation – more than just a species list! IAIA Newsletter 2001.

BREDENKAMP, G.J. & BROWN, L.R. 2001. Vegetation – A reliable ecological basis for environmental planning. Urban Greenfile, Nov/Dec 2001.

BROMILOW, C. 2001. *Problem Plants of South Africa*. Briza Publications CC, Pretoria.

FAY, T.H. & GREEFF, J.C. 2006. Lion, wildebeest and zebra: A predator-prey model. *Ecological modelling* 196: 237–244.

GROVES, C.P. 1974. *Horses, asses and zebras in the wild*. David & Charles Newton Abbot, London.

HACK, M.A. & RUBENSTEIN, D.I. 1998. Zebra zones. *Natural History* 107 (2): 26–28.

HENNEKENS, S.M. 1996. *TURBOVEG: A Software Package for Constructing Phytosociological Tables*. IDLO, Wageningen.

HENNEKENS, S.M. & SCHAMINEE, J.H.J. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. *Journal of Vegetation Science* 12:589–591.

KENT, M. & COKER, P. 2000. *Vegetation Description and Analysis, A Practical Approach*. John Wiley & Sons, Chishester.

KROHNE, D.T. 2001. *General ecology*. Brook/Cole. A division of Thompson Learning, Inc, Pacific Grove.

LANDCARE SOUTH AFRICA. Brochure. CARA Legislation Made Easy. The Conservation of Agricultural Resources Act 1983 (Act No 43 of 1983) (CARA).

MACCLINTOCK, D. 1976. *A natural history of zebras*. Charles Scribner's Sons, New York.

McCUNE, B. & MEFFORD, M.J. 1999. *Multivariate analysis of ecological data.* Version 4.0.MjM Software, Gleneden Beach, Oregon, USA.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. *Aims and Methods of Vegetation Ecology*. Wiley, New York.

NEUHAUS, P. & RUCKSTUHL, K.E. 2002. The link between sexual dimorphism, activity budgets, and group cohesion: the case of the plains zebra (*Equus burchelli*). *Canadian Journal of Zoology* 80: 1437–1441.

POOLEY, E. 1998. *A field guide to wild flowers of Kwa-Zulu Natal and the Eastern Region.* Natal Flora Publications Trust, Durban.

TICHỲ, L. 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science* 13:451–453.

VAN OUDTSHOORN, F. 2004. *Guide to Grasses of Southern Africa*. Briza, Pretoria.

VAN WYK, B-E. & GERICKE, N. 2003. *People's plants – A guide to useful plants of Southern Africa*. Briza Publications, Arcadia.

VAN WYK, B. & MALAN, S. 1997. *Field guide to the Wild Flowers of the Highveld*. Struik Publishers, Cape Town.

VAN WYK, B. & VAN WYK, P. 1997. *Field guide to the trees of southern Africa*. Struik Publishers, Cape Town.

VAN WYK, B-E., VAN OUDTSHOORN, B. & GERICKE, N. *2000. Medicinal Plants of South Africa.* Briza Publications, Arcadia.

WERGER, M.J.A. 1974. On concepts and techniques applied in the Zürich-Montpellier method of vegetation survey. *Bothalia* 11:309–323.

WESTHOFF, V. & VAN DER MAAREL, E. 1973. The Braun-Blanquet approach. In: *R.H. Whittaker, Handbook of vegetation science.* The Hague: Junk.

6. ZEBRA FEEDING BEHAVIOUR

6.1. Introduction

This section presents the difference in feeding behaviour between the zebras found on the Rocky Highveld Grassland and Mixed Grassland. It further expresses the differences in feeding behaviour between the different times of the day and months of the year for both habitats. From this data it was also possible to determine differences in vigilance in the group during different times of the day between the different habitat types.

6.2. Results

6.2.1. Rocky Highveld Grassland versus Mixed Grassland

A summary of the recorded feeding data between the two habitat types can be seen in table 6.1. This table also includes the statistical results as from the Analysis of variance (ANOVA). The mean feeding rates for plains zebras in the Rocky Highveld Grassland during this study was 28.80 minutes per hour while Mixed Grassland plains zebras fed for 29.42 minutes per hour (Figure 6.1.). These differences are non-significant ($p > 0.05$). From the summary presented in table 6.2., feeding rates for stallions and foals were highest in the Mixed Grassland with a mean of 29.49 and 28.09 minutes feeding per hour respectively. Mares spent longer times feeding in the Rocky Highveld Grassland with a mean of 32.38 minutes per hour (Figure 6.2). No significant difference was found for feeding rates between the stallions, mares and foals in the different habitat types. The difference in feeding rate within the habitat types for each individual: stallion, mare and foal, were also non-significant.

The differences in mean feeding rates between the two habitat types for each month of the year are non significant ($p > 0.05$). Table 6.3 presents a summary of this data. The trends however for the mean feeding rate between the Rocky Highveld Grassland and the Mixed Grassland communities are similar during winter and spring months (Figure 6.3). During summer and autumn, the mean feeding rate tends to be higher in the Mixed Grassland community than in that of the Rocky Highveld community.

Table 6.1. A summary of the total zebra feeding recordings that compares the data between the Rocky Highveld Grassland and Mixed Grassland communities followed by the ANOVA results.

	Rocky Highveld Grassland			Mixed Grassland		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Total recordings	222	28.80	6.43	231	29.42	8.26
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	0.57005956	1	0.57006	0.01040435	0.923664	7.708647
Within Groups	219.162092	4	54.79052			
Total	219.732152	5				

Table 6.2. A summary of the zebra feeding recordings that compares the data between stallions, mares and foals of the Rocky Highveld Grassland and Mixed Grassland communities followed by the ANOVA results.

	Rocky Highveld Grassland			Mixed Grassland		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Stallions	74	28.48	6.73	77	29.49	8.43
Mares	74	32.38	7.23	77	30.69	9.20
Foals	74	25.54	5.46	77	28.09	7.20
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	0.57005956	1	0.57006	0.0846581	0.785545	7.708647
Within Groups	26.9346723	4	6.733668			
Total	27.5047318	5				

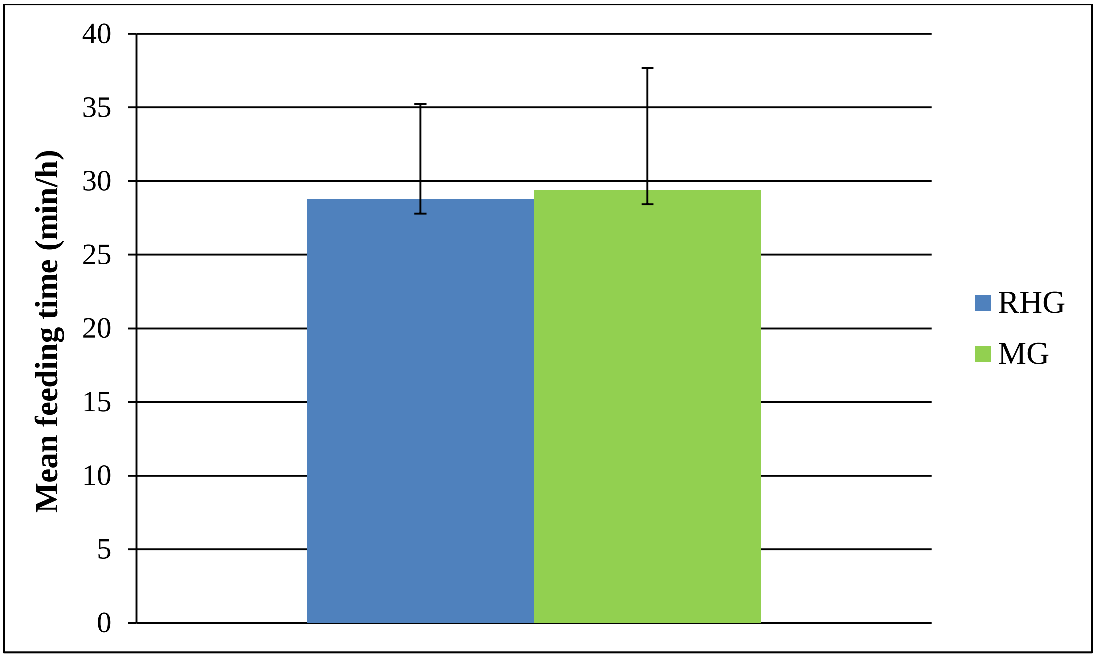

Figure 6.1. A comparison between the feeding rates of Telperion zebras in the Rocky Highveld Grassland (RHG) and the Mixed Grassland (MG) communities with standard deviation bars.

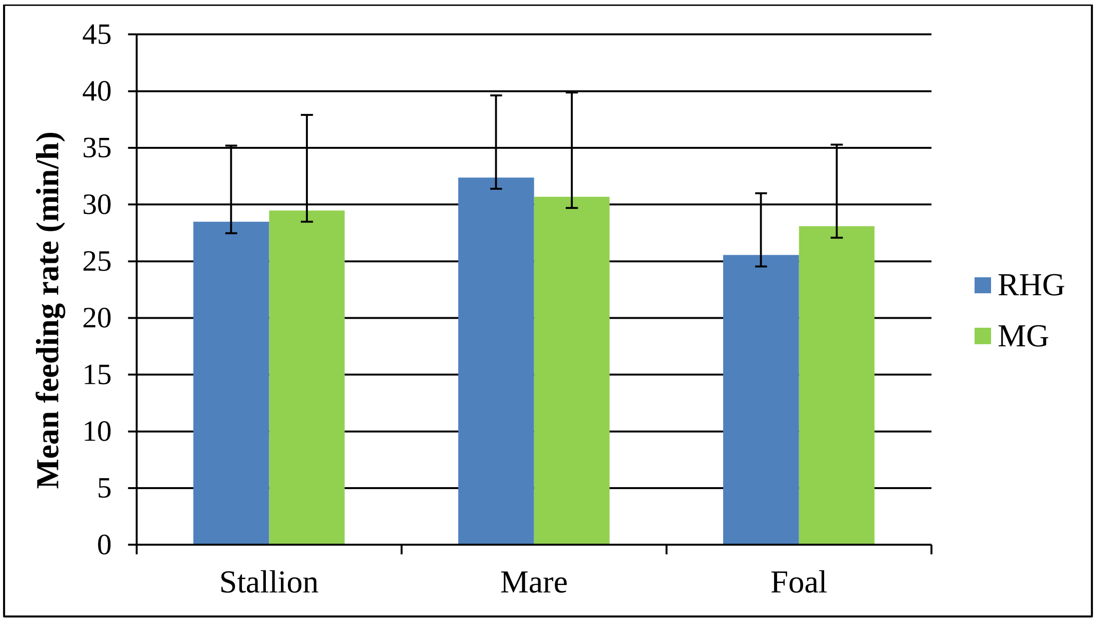

Figure 6.2. Average feeding rates of Stallions, Mares and Foals between the Rocky Highveld Grassland (RHG) and Mixed Grassland (MG) with standard deviation bars.

The highest rate of feeding was found in September in the Rocky Highveld Grassland with a mean of 40.82 minutes per hour while the least time feeding was 19.53 minutes per hour in the same habitat type. In the Mixed Grassland community, zebras spent the most time feeding during March with a mean of 36.66 minutes feeding per hour and the least amount of time feeding in December with a mean of 19.94 minutes per hour.

The comparison between time spent feeding by stallions between the Rocky Highveld Grassland and the Mixed Grassland throughout the year is depicted in table 6.4. No significant differences ($p > 0.05$) were observed for feeding rates between the habitat types throughout the year. The mean feeding rate per hour of stallions in the Rocky Highveld Grassland and Mixed Grassland is most similar in November with mean values of 31.74 and 31.73 respectively. From January to April the mean feeding rate for the Mixed Grassland community per hour is much higher but not significantly different ($p > 0.05$) than that of the Rocky Highveld Grassland. Stallions in the Rocky Highveld Grassland spent the most time feeding in May with a mean of 40.61 minutes per hour while stallions in the Mixed Grassland community spent most time feeding during October with a mean of 37.66 minutes per hour (Figure 6.4).

When comparing mares of the different habitat types no significant difference ($p > 0.05$) occurs in their mean hourly feeding rates (Table 6.5). The general trend throughout the year is very similar in both habitat types but mares of the Rocky Highveld Grassland's mean feeding rates are slightly higher than the mares of the Mixed Grassland community between February and April (Figure 6.5). The trend during this time of the year is opposite than that observed for stallions (Figure 6.4). In September mares of the Rocky Highveld Grassland spent most time feeding with mean of 41.36 minutes per hour while a maximum feeding rate of 40.57 minutes per hour was found in May in the Mixed Grassland community zebra group.

A summary of foals feeding rates are presented in table 6.6. Foals in the Mixed Grassland community's mean feeding rate tend to be more than the mean feeding rates of foals in Rocky Highveld Grassland (Figure 6.6), except for July, September, November and May when Rocky Highveld Grasslands' foal's mean feeding rate was

Table 6.3. A summary of the zebra feeding recordings that compares the data between the Rocky Highveld Grassland and Mixed Grassland communities throughout the year followed by the ANOVA results.

	Rocky Highveld Grassland			Mixed Grassland		
	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV
Total yearly recording:						
June	18	21.36	1.63	9	22.80	9.54
July	30	30.44	17.87	39	27.69	8.27
August	21	23.75	11.49	21	27.72	11.58
September	18	40.82	13.40	18	33.57	14.05
October	18	28.32	6.26	18	35.08	21.26
November	18	30.62	7.77	18	29.98	2.54
December	18	24.92	11.03	18	19.94	1.84
January	18	22.80	21.30	18	31.02	12.18
February	9	19.53	8.55	18	22.50	15.15
March	18	27.20	15.68	18	36.66	11.88
April	18	27.37	12.74	18	30.10	14.24
May	18	38.96	10.75	18	37.25	10.31
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	13.8284179	1	13.82842	0.36994882	0.549261	4.300949
Within Groups	822.344008	22	37.37927			
Total	836.172425	23				

Table 6.4. A summary of the stallion feeding recordings that compares the data between the Rocky Highveld Grassland and Mixed Grassland communities throughout the year followed by the ANOVA results.

	Rocky Highveld Grassland			Mixed Grassland		
	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV
Stallion yearly recording:						
June	6	26.28	3.46	3	15.96	14.85
July	10	30.37	16.23	13	27.09	10.46
August	7	29.23	5.19	7	29.85	12.98
September	6	37.65	13.79	6	33.55	6.83
October	6	33.75	2.80	6	37.66	19.41
November	6	31.74	4.12	6	31.73	1.99
December	6	20.09	18.79	6	14.21	1.78
January	6	20.40	20.27	6	29.38	14.17
February	3	21.22	10.30	6	28.07	16.54
March	6	23.13	17.72	6	35.23	16.59
April	6	22.24	10.65	6	30.93	12.27
May	6	40.61	14.21	6	36.99	3.41
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	8.0723112	1	8.07231	0.1564295	0.69627	4.30095
Within Groups	1135.277	22	51.6035			
Total	1143.3493	23				

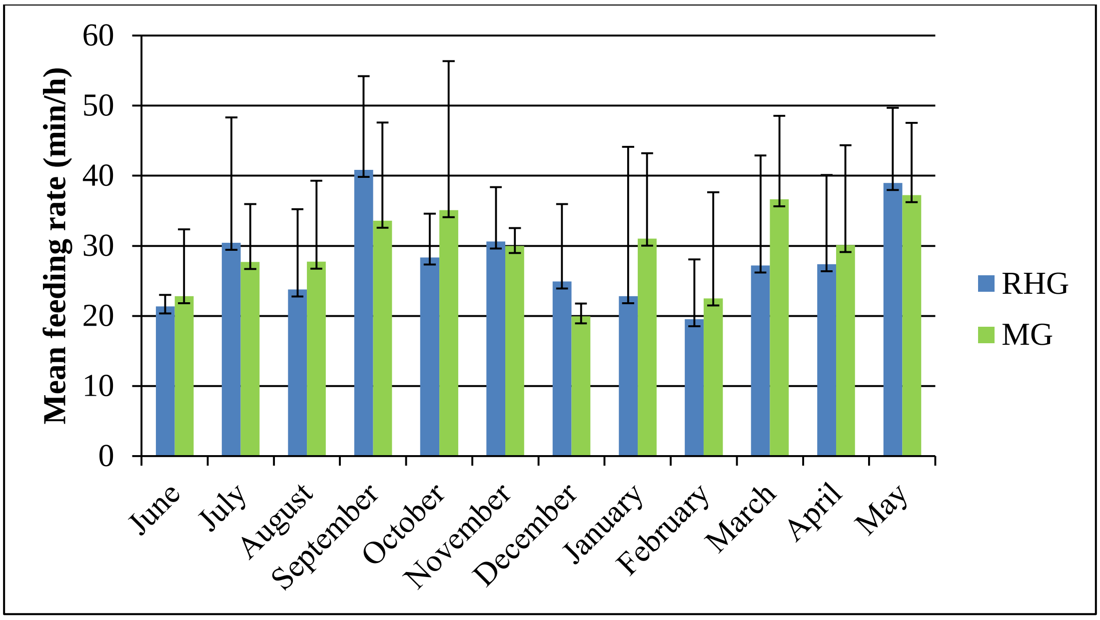

Figure 6.3. Average feeding rates between the Rocky Highveld Grassland (RHG) and Mixed Grassland (MG) throughout the year with standard deviation bars.

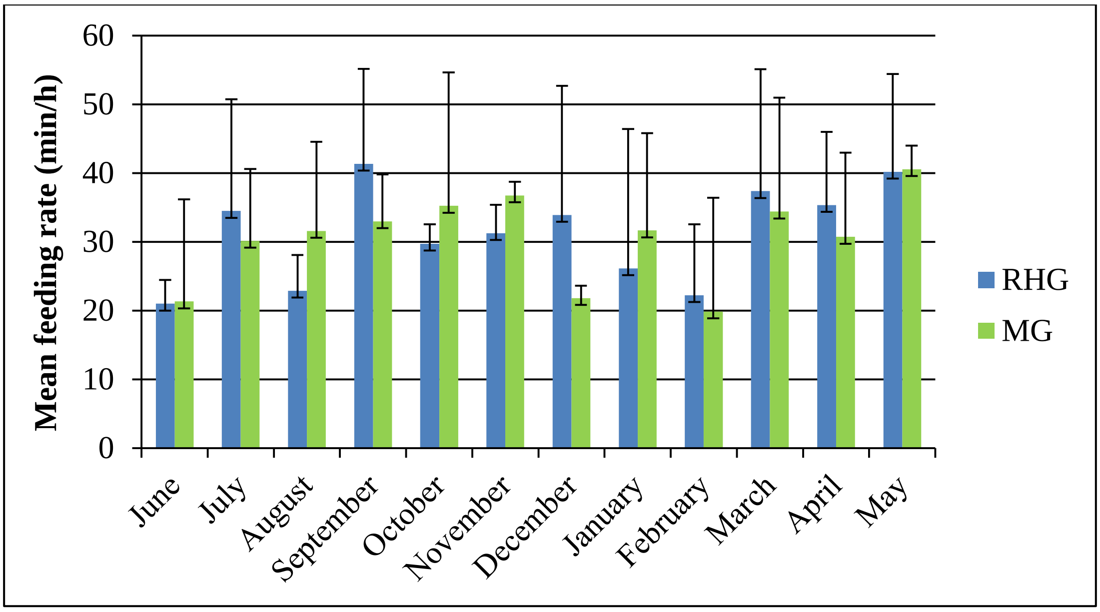

Figure 6.4. Mean time stallions spent feeding throughout the year between Rocky Highveld Grassland (RHG) and Mixed Grassland (MG) communities with standard deviation bars.

Table 6.5. A summary of the mare feeding recordings that compares the data between the Rocky Highveld Grassland and Mixed Grassland communities throughout the year followed by the ANOVA results.

	Rocky Highveld Grassland			Mixed Grassland		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Mare yearly recording:						
June	6	21.01	4.22	3	21.34	9.50
July	10	34.50	19.11	13	30.15	6.40
August	7	22.91	16.19	7	31.59	20.06
September	6	41.36	13.34	6	33.00	22.62
October	6	29.74	7.92	6	35.23	23.63
November	6	31.27	9.62	6	36.76	4.63
December	6	33.91	9.50	6	21.83	4.64
January	6	26.16	22.72	6	31.66	12.81
February	3	22.25	10.25	6	19.88	13.71
March	6	37.39	12.80	6	34.40	16.45
April	6	35.37	19.00	6	30.72	17.07
May	6	40.21	10.88	6	40.57	9.56
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	3.32348972	1	3.32349	0.07329375	0.789124	4.300949
Within Groups	997.585351	22	45.34479			
Total	1000.90884	23				

Table 6.6. A summary of the foal feeding recordings that compares the data between the Rocky Highveld Grassland and Mixed Grassland communities throughout the year followed by the ANOVA results.

	Rocky Highveld Grassland			**Mixed Grassland**		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Foal yearly recording:						
June	6	16.79	2.13	3	31.11	22.95
July	10	26.44	19.05	13	25.84	8.10
August	7	19.13	14.80	7	21.72	5.75
September	6	43.46	13.95	6	34.15	15.56
October	6	21.49	15.82	6	32.34	21.47
November	6	28.86	9.87	6	21.45	12.38
December	6	20.74	10.07	6	23.77	2.29
January	6	21.84	24.65	6	32.03	9.74
February	3	15.13	6.22	6	19.56	16.34
March	6	21.07	16.74	6	40.34	8.99
April	6	24.49	12.26	6	28.65	13.74
May	6	36.05	7.52	6	34.19	18.69
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	102.77574	1	102.776	1.9222699	0.1795	4.30095
Within Groups	1176.2481	22	53.4658			
Total	1279.0238	23				

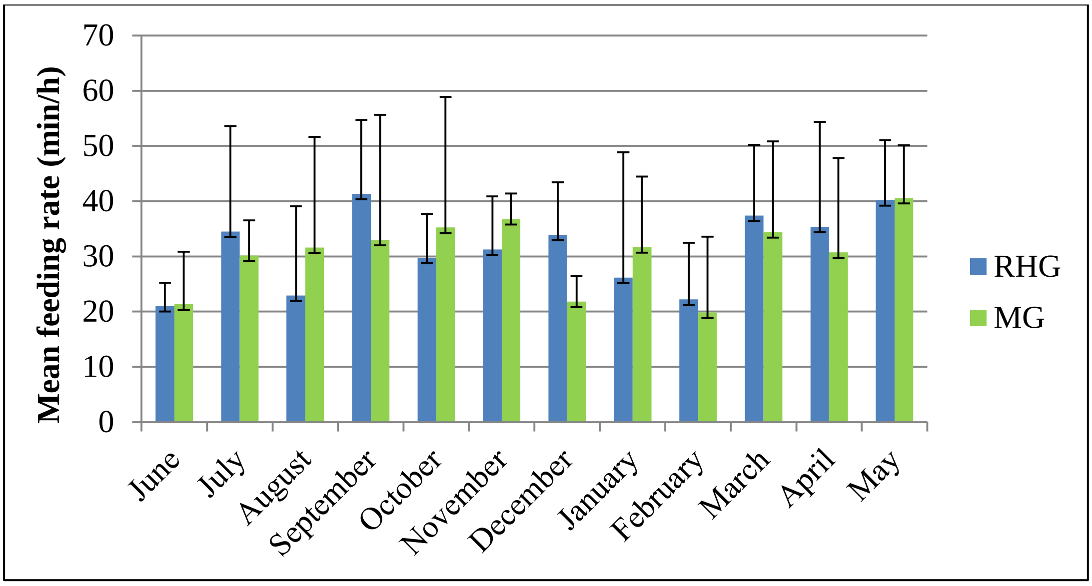

Figure 6.5. Mean time mares spent feeding throughout the year between Rocky Highveld Grassland (RHG) and Mixed Grassland (MG) communities with standard deviation bars.

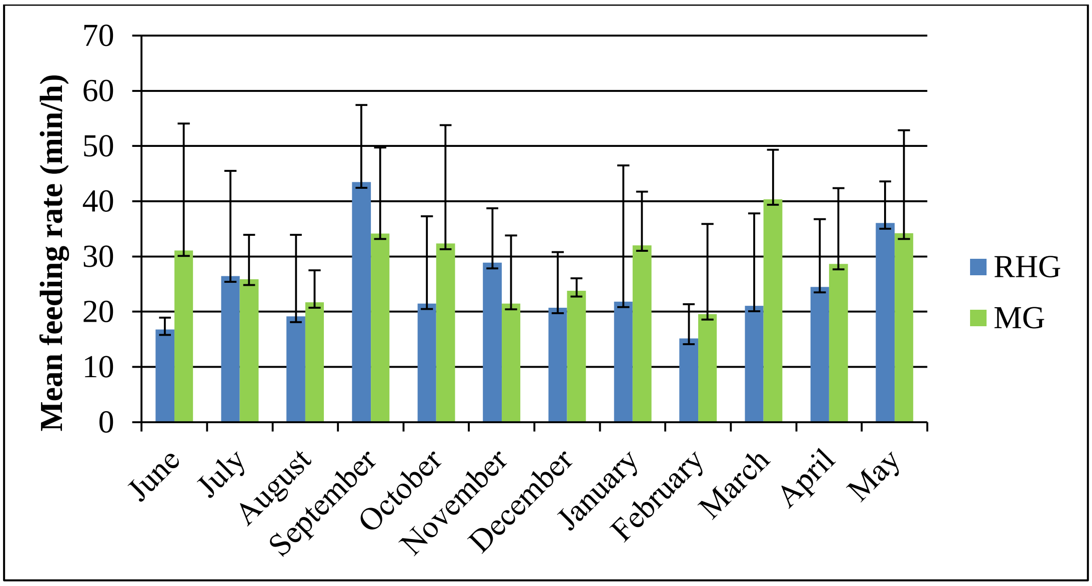

Figure 6.6. Mean time foals spent feeding throughout the year between Rocky Highveld Grassland (RHG) and Mixed Grassland (MG) communities with standard deviation bars.

higher. The general trend for foals of the Rocky Highveld Grassland habitat type is an increase in mean feeding rates from time feeding with a mean of 43.46 minutes per hour in September. Foals in the Mixed Grassland's highest feeding rate took place in March with a mean of 40.34 minutes feeding per hour. No significant differences occurred between the foals of the two different habitat types ($p > 0.05$).

6.2.2. Differences in morning, midday and evening feeding behaviour

Mean feeding rates per hour differed between stallions, mares and foals during different times of the day (Table 6.7). From figure 6.7 and figure 6.8 one can see that in both habitat types, stallions, mares and foals generally fed for shorter periods during the morning, followed by midday. Feeding rates were highest in the evening. These differences are more significant in the Mixed Grassland community ($p = 0.0000546$) than in the Rocky Highveld Grassland community ($p = 0.013348$).

In zebras observed in the Rocky Highveld Grassland community (Table 6.7), mares spent approximately 24.80 minutes feeding per hour in the morning while stallions fed for 22.07 minutes per hour. Foals spent the least time feeding in the morning with a mean of 20.76 minutes per hour. During midday mares of the Rocky Highveld Grassland vegetation type spent 33.14 minutes feeding per hour. Stallions fed for approximately 27.89 minutes per hour while foals spent 24.37 minutes feeding per hour. During the evenings a mean of 39.21, 35.48 and 31.50 minutes were spent feeding by the mares, stallions and foals respectively. Therefore, mares in the Rocky Highveld Grassland spent most time feeding per day, followed by stallions and lastly foals (Figure 6.7). These differences however, were non-significant ($p > 0.05$).

In the Mixed Grassland community mares spent approximately 22.91 minutes feeding in the morning while foals fed for 22.13 minutes. Stallions spent the least time feeding in the morning with an average of 21.54 minutes per hour. During midday stallions, mares and foals of the Mixed Grassland community spent 28.59, 28.30 and 26.04 minutes feeding per hour respectively. Mares fed for approximately 40.84 minutes, stallions for 38.33 minutes and foals for 36.09 minutes per hour during the evenings (Figure 6.8). As such, mares grazing in the Mixed Grassland vegetation type spent most time feeding per day, followed by stallions and lastly foals. These differences

Table 6.7. A summary of the daily feeding recordings that compares the data between the stallions, mares and foals of the Rocky Highveld Grassland and Mixed Grassland communities followed by the ANOVA results.

Rocky Highveld Grassland	Morning			Midday			Evenings		
	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV
Stallion	23	22.07	1.70	25	27.89	3.62	26	35.48	3.15
Mare	23	24.80	2.03	25	33.14	4.30	26	39.21	3.68
Foal	23	20.76	1.90	25	24.37	4.15	26	31.50	3.70

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	248.2964695	2	124.1482	9.64699217	0.013348	5.143253
Within Groups	77.2146795	6	12.86911			
Total	325.511149	8				

Mixed Grassland	Morning			Midday			Evenings		
	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV
Stallion	26	21.54	0.65	25	28.59	1.24	26	38.33	1.94
Mare	26	22.91	0.67	25	28.30	1.19	26	40.84	2.28
Foal	26	22.13	0.56	25	26.04	1.40	26	36.09	2.26

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	409.1898074	2	204.5949	76.064945	5.46E-05	5.143253
Within Groups	16.1384383	6	2.68974			
Total	425.3282457	8				

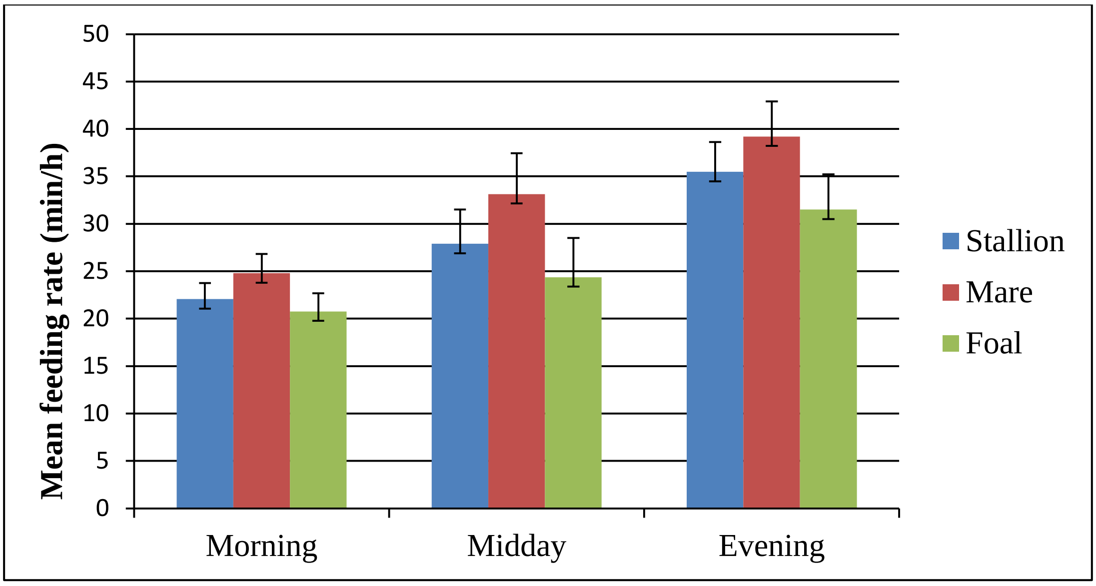

Figure 6.7. Mean daily feeding time of stallions, mares and foals in the Rocky Highveld Grassland community with standard deviation bars.

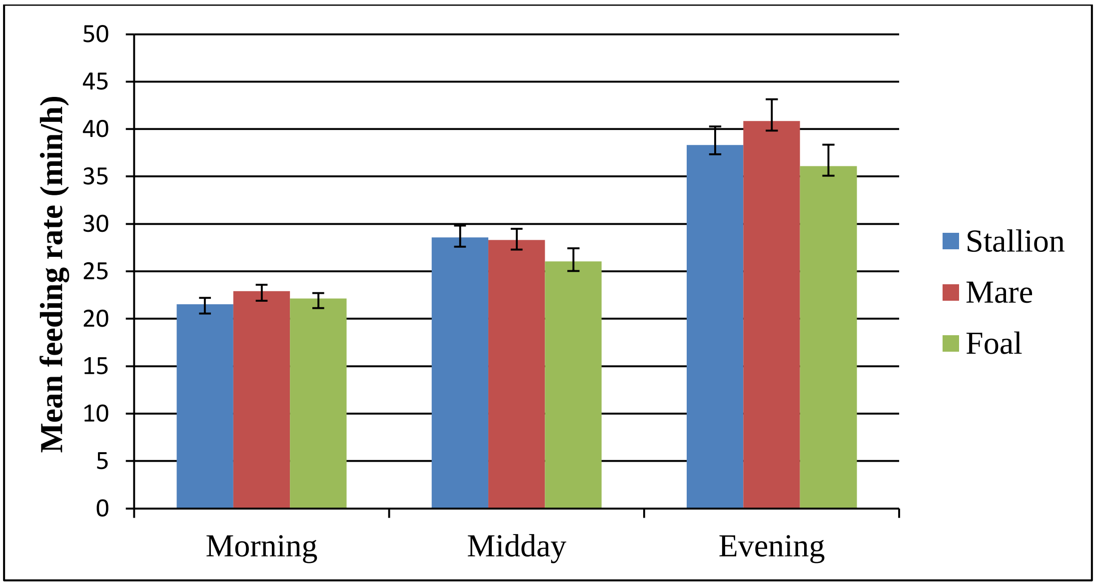

Figure 6.8. Mean daily feeding time of stallions, mares and foals in the Mixed Grassland community with standard deviation bars.

however, are also not significant ($p > 0.05$).

The yearly feeding rates are illustrated in figure 6.9. In the Rocky Highveld Grassland, zebras spent significantly different average times feeding throughout the year ($p = 0.044388$). In June the feeding rates between the different times of the day was non-significant ($p > 0.05$). The differences are also non-significant between the morning and midday, midday and evening and morning and evening. In July however, the difference between the feeding rates during the different times of the day is significant ($p = 0.000492$). There is also a significant difference between July's morning and midday feeding rates ($p = 0.002872$) and the midday and evening feeding rates ($p = 0.000856$). The differences between the morning and evening feeding rates are non-significant. In August the differences in mean time spent feeding is significant ($p = 0.032994$) with midday and evening ($p = 0.029749$) and morning and evening ($p = 0.0251790$) differing significantly. The difference in September is also significant ($p = 0.000586$). These significant differences are observable between the morning and midday ($p = 0.016662$), midday and evening ($p = 0.000535$) as well as in the morning and evening ($p = 0.025422$). There is no significant difference in the mean feeding rates for the sampling times in October or between the overall feeding rates for different times of the day during November. However, there is a significant difference between the morning and evening ($p = 0.010813$) feeding rates during November. In December the average feeding rates were not significantly different. During January, a significant difference ($p = 0.0020930$) was recorded. These significant differences are shared between the morning and midday ($p = 0.000215$) and morning and evening ($p = 0.024691$) as a result of no time spent feeding during the morning. In February, the difference is again significant with $p = 0.006007$. The midday and evening and morning and evening feeding rates differ significantly with $p = 0.0296233$ and $p = 0.004292$ respectively. In March the overall feeding rates between the different times of the day is significant ($p = 0.0172585$). The feeding rates between the morning and midday, midday and evening and morning and evening for March is non-significant. During April, the feeding rates were also non-significant. The mean time spent feeding during the sampling times differ significantly for May ($p = 0.001928$), with significant differences between mornings and midday ($p = 0.008463$) and morning and evenings ($p = 0.001238$).

The Mixed Grassland community's mean feeding rate data is summarized in table 6.9 and illustrated in figure 6.10. Mixed Grassland zebras has significantly different mean feeding rates throughout the year ($p = 0.00256$). Zebras feeding rates differ significantly in June between midday and evening feeding rates with $p = 0.001118$. The average time spent feeding in July is significant ($p = 0.001362$) with morning and midday ($p = 0.048523$), midday and evenings ($p = 0.001629$) as well as morning and evenings ($p = 0.01462$) differing significantly. In August a significant difference was recorded between the feeding rates in the morning and evening ($p = 0.007451$). The difference in September is also significant ($p = 0.017871$). These significant differences are observable between midday and evenings ($p = 0.024223$) and morning and evenings ($p = 0.029699$). As can be seen from figure 6.10, the difference in October is significant with $p = 0.0000814$. The low average time spent feeding during the mornings resulted in the significant difference between the morning and midday ($p = 0.000205$) and morning and evenings ($p = 0.000954$). There is no significant difference in the average feeding rates for the sampling times in November or December. A significant difference again occur between feeding times in January ($p = 0.0000893$). The significant difference between midday and evening feeding rates ($p = 0.001566$) are however lower than that of the significant difference between morning and evening ($p = 0.000155$). The average time spent feeding during the sampling times of February differ significantly ($p = 0.002587$), with significant differences between midday and evenings ($p = 0.013447$) and morning and evenings ($p = 0.000155$). In March the significant difference between feeding rates is the result of a high mean feeding rate during the evenings. The difference is however only significant between midday and evenings ($p = 0.002476$). As with March, April's average feeding rate during the evenings are high which results in a significant difference ($p = 0.00008$). These significant differences are observable between all sampling times being morning and midday ($p = 0.019188$), midday and evenings ($p = 0.00063$) as well as morning and evenings ($p = 0.00062$). No significant difference occurred when comparing specific sampling times in May, albeit the average feeding rates between the different sampling times differ significantly ($p = 0.039362$). The zebras in this vegetation community's average feeding rate during the mornings are somewhat similar throughout the year.

Table 6.8. A summary of the difference in morning, midday and evening feeding rates of the Rocky Highveld Grassland zebras throughout the year followed by the ANOVA results.

Rocky Highveld Grassland									
	Morning			**Midday**			**Evenings**		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
June	6	22.89	5.14	6	21.55	3.17	6	21.36	7.59
July	6	44.08	7.44	12	10.21	5.09	12	30.44	0.96
August	6	13.69	10.99	6	21.30	7.76	9	23.75	1.16
September	6	41.65	5.32	6	27.03	3.55	6	40.82	2.89
October	6	30.57	8.10	6	33.16	3.60	6	28.32	15.55
November	6	24.82	4.82	6	27.59	1.16	6	30.62	2.90
December	6	18.37	12.21	6	37.65	8.70	6	24.92	11.72
January	6	0.00		6	42.20	5.71	6	22.80	12.93
February	6	9.87	2.06	6	26.07	7.80	6	19.53	3.19
March	6	11.53	12.27	6	27.17	7.47	6	27.20	7.13
April	6	14.76	4.21	6	27.12	13.70	6	27.37	8.97
May	6	26.72	2.07	6	43.25	5.56	6	38.96	3.76
ANOVA									
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***			
Between Groups	897.5566888	2	448.7783	3.42820292	0.044388	3.284918			
Within Groups	4319.955885	33	130.9078						
Total	5217.512574	35							

Table 6.9. A summary of the difference in morning, midday and evening feeding rates of the Mixed Grassland zebras throughout the year followed by the ANOVA results.

Mixed Grassland									
	Morning			Midday			Evenings		
	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV
June	3	24.17	26.94	3	31.58	0.64	3	12.65	3.87
July	12	27.43	3.36	12	19.56	3.51	15	36.09	1.41
August	9	14.44	4.69	6	35.66	15.61	6	33.06	4.42
September	6	32.33	4.55	6	20.18	11.86	6	48.19	6.95
October	6	10.53	4.09	6	47.08	2.67	6	47.62	6.13
November	6	27.06	17.66	6	31.17	1.83	6	31.70	5.17
December	6	18.61	3.58	6	19.16	7.03	6	22.03	5.85
January	6	20.87	2.51	6	27.68	3.48	6	44.53	1.55
February	6	12.21	2.93	6	15.40	8.20	6	39.90	5.81
March	6	28.84	14.46	6	30.81	2.83	6	50.33	4.11
April	6	27.14	1.55	6	17.58	4.08	6	45.59	2.89
May	6	25.86	10.69	6	45.93	6.98	6	39.96	1.13
ANOVA									
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***			
Between Groups	1402.823749	2	701.4119	7.18980186	0.00256	3.284918			
Within Groups	3219.364358	33	97.5565						
Total	4622.188106	35							

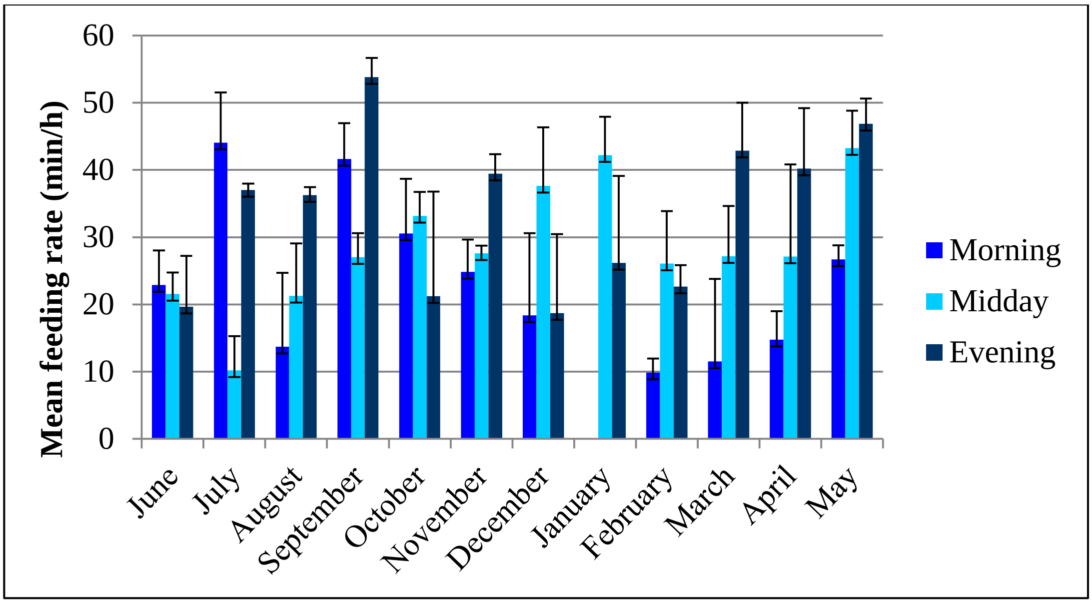

Figure 6.9. Mean feeding rate of zebras in the Rocky Highveld Grassland throughout the year with standard deviation bars.

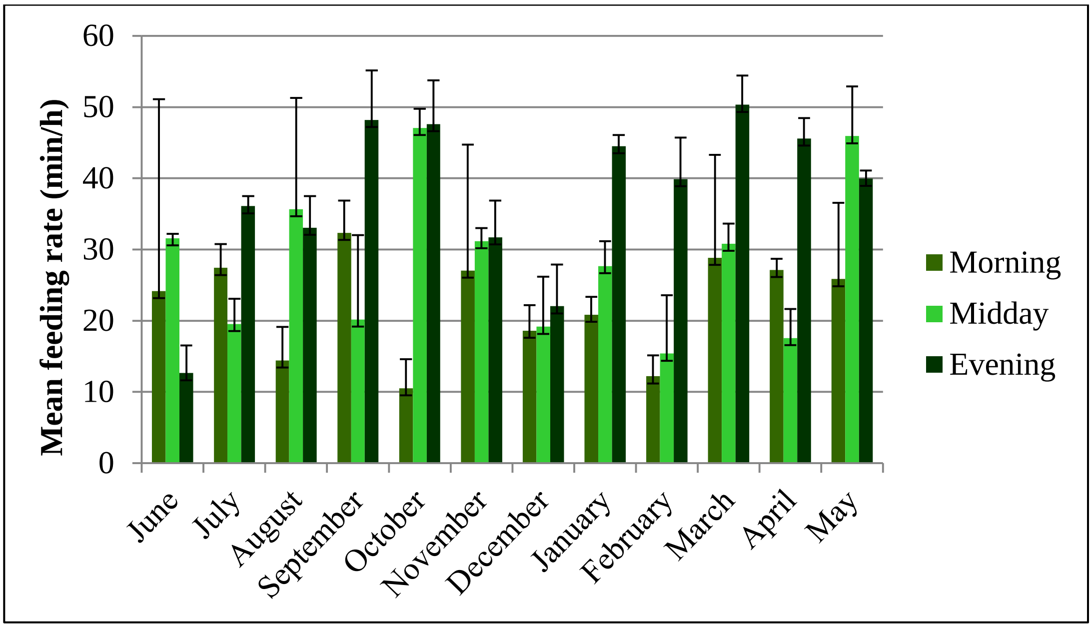

Figure 6.10. Mean feeding rate of zebras in the Mixed Grassland throughout the year with standard deviation bars.

6.2.3. Differences in stallion, mare and foal feeding behaviour

Mares of Telperion in eZemvelo Nature reserve spend most time feeding, followed by stallions and lastly foals (Table 6.10). The data is represented graphically in figure 6.11. The mean feeding rates were 31.53, 28.98 and 26.82 minutes per hour for mares, stallions and foals respectively. The differences are significant ($p = 0.0000451$).

As seen from table 6.11, the mean hourly feeding rate for stallions, mares and foals in the Rocky Highveld Grassland community (Figure 6.12), differ significantly ($p = 0.013348$). The difference in feeding rate between the stallions, mares and foals throughout the year is summarized in table 6.12 and presented in figure 6.13. Stallions spent the most time feeding during May with a mean value of 40.61 minutes per hour while mares and foals spent most time feeding per hour during September with a mean of 41.36 and 43.46 minutes per hour, respectively. The differences between the stallions, mares and foals for each month of the year were non-significant ($p > 0.05$). During January, the Rocky Highveld Grassland zebra group spent the mornings walking to other habitats of the game farm for grazing. From figure 6.13 one can see that a general trend exists for the stallions, mares and foals to spend a higher amount of time feeding to the end of winter and beginning of spring. During January to March the mean time spent feeding was low.

The difference in feeding rate between the stallions, mares and foals of the Mixed Grassland community is summarized in table 6.13. and presented in figure 6.14. There was no significant difference in mean feeding rate between the stallions, mares and foals throughout the year (Table 6.14.). Stallions of the Mixed Grassland community spent most time feeding during October with a mean of 37.66 minutes per hour. The highest mean feeding rates for mares were in May with a feeding rate of 40.57 minutes per hour. Foals on the other hand spent most time feeding during March with a mean feeding rate of 40.34 minutes per hour. Stallions and mares of the Mixed Grassland community show similar trends for mean feeding rates throughout the year (Figure 6.14). The trend for foals on the other hand is opposite. Foals tend to have high average hourly feeding rates in June and March with a low average feeding rate in October, November and again in May. The difference between the mean stallion and mare feeding rate in June is significant with $p = 0.014102$. The feeding rate of foals compared to that of stallions and mares in June and March is high. This difference is however non-significant ($p > 0.05$).

Table 6.10. A summary of the difference between stallion, mare and foal feeding rates in Telperion followed by the ANOVA results.

Telperion						
	Number of recordings	**Mean**	**STDEV**			
Stallions	151	28.98	6.84			
Mares	151	31.53	7.46			
Foals	151	26.82	5.89			
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	659.1964556	5	131.8393	16.94717	4.51E-05	3.105875
Within Groups	93.35311781	12	7.779426			
Total	752.5495734	17				

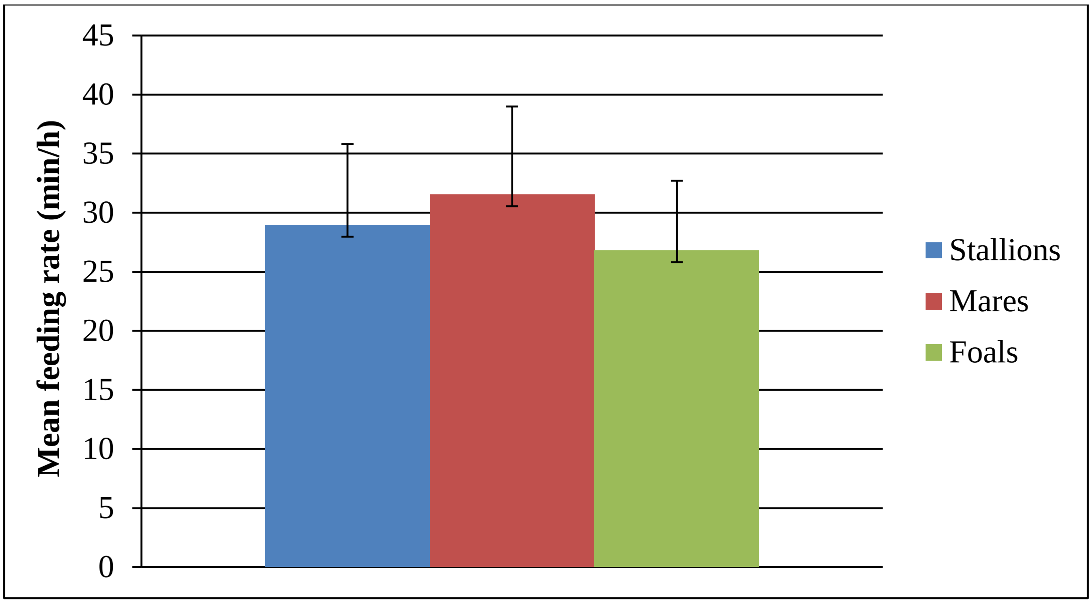

Figure 6.11. Mean feeding rate of zebras in Telperion with standard deviation bars.

Table 6.11. A summary of the difference between stallion, mare and foal feeding rates in the Rocky Highveld Grassland community followed by the ANOVA results.

Rocky Highveld Grassland						
	Number of recordings	**Mean**	**STDEV**			
Stallions	74	28.48	6.73			
Mares	74	32.38	7.23			
Foals	74	25.54	5.46			
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	248.2964695	2	124.1482	9.646992	0.013348	5.143253
Within Groups	77.2146795	6	12.86911			
Total	325.511149	8				

Table 6.12. A summary of the difference between stallion, mare and foal feeding rates in the Rocky Highveld Grassland community throughout the year followed by the ANOVA results.

Rocky Highveld Grassland	Stallions			Mares			Foals		
	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV
Total yearly recording:									
June	6	26.28	3.46	6	21.01	4.22	6	16.79	2.13
July	10	30.37	16.23	10	34.50	19.11	10	26.44	19.05
August	7	29.23	5.19	7	22.91	16.19	7	19.13	14.80
September	6	37.65	13.79	6	41.36	13.34	6	43.46	13.95
October	6	33.75	2.80	6	29.74	7.92	6	21.49	15.82
November	6	31.74	4.12	6	31.27	9.62	6	28.86	9.87
December	6	20.09	18.79	6	33.91	9.50	6	20.74	10.07
January	6	20.40	20.27	6	26.16	22.72	6	21.84	24.65
February	3	21.22	10.30	3	22.25	10.25	3	15.13	6.22
March	6	23.13	17.72	6	37.39	12.80	6	21.07	16.74
April	6	22.24	10.65	6	35.37	19.00	6	24.49	12.26
May	6	40.61	14.21	6	40.21	10.88	6	36.05	7.52
ANOVA									
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***			
Between Groups	270.5753409	2	135.2877	2.474631447	0.099684	3.284918			
Within Groups	1804.104255	33	54.66983						
Total	2074.679596	35							

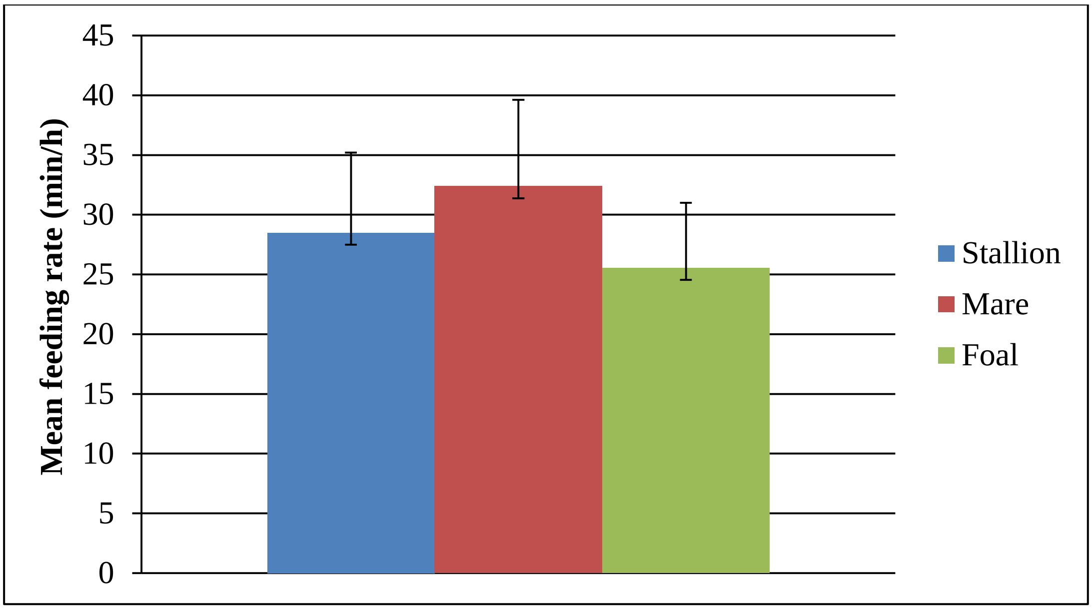

Figure 6.12. Mean feeding rate of zebras in the Rocky Highveld Grassland with standard deviation bars.

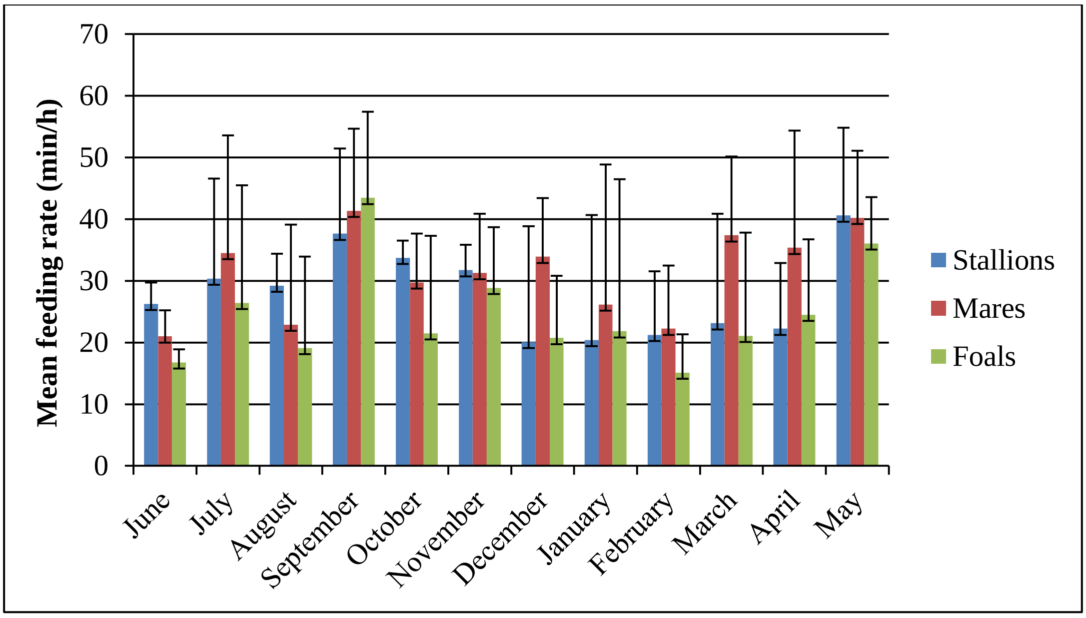

Figure 6.13. Mean feeding rate of stallions, mares and foals in the Rocky Highveld Grassland throughout the year with standard deviation bars.

Table 6.13. A summary of the difference between stallion, mare and foal feeding rates in the Mixed Grassland community followed by the ANOVA results.

Mixed Grassland						
	Number of recordings	**Mean**	**STDEV**			
Stallions	77	29.49	8.43			
Mares	77	30.69	9.20			
Foals	77	28.09	7.20			
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	409.1898074	2	204.5949	76.06495	5.46E-05	5.143253
Within Groups	16.1384383	6	2.68974			
Total	425.3282457	8				

Table 6.14. A summary of the difference between stallion, mare and foal feeding rates in the Mixed Grassland community throughout the year followed by the ANOVA results.

Mixed Grassland	**Stallions**			**Mares**			**Foals**		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Total yearly recording:									
June	3	15.96	14.85	3	21.34	9.50	3	31.11	22.95
July	13	27.09	10.46	13	30.15	6.40	13	25.84	8.10
August	7	29.85	12.98	7	31.59	20.06	7	21.72	5.75
September	6	33.55	6.83	6	33.00	22.62	6	34.15	15.56
October	6	37.66	19.41	6	35.23	23.63	6	32.34	21.47
November	6	31.73	1.99	6	36.76	4.63	6	21.45	12.38
December	6	14.21	1.78	6	21.83	4.64	6	23.77	2.29
January	6	29.38	14.17	6	31.66	12.81	6	32.03	9.74
February	6	28.07	16.54	6	19.88	13.71	6	19.56	16.34
March	6	35.23	16.59	6	34.40	16.45	6	40.34	8.99
April	6	30.93	12.27	6	30.72	17.07	6	28.65	13.74
May	6	36.99	3.41	6	40.57	9.56	6	34.19	18.69
ANOVA									
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***			
Between Groups	21.80907842	2	10.90454	0.239101876	0.788687	3.284918			
Within Groups	1505.006151	33	45.60625						
Total	1526.81523	35							

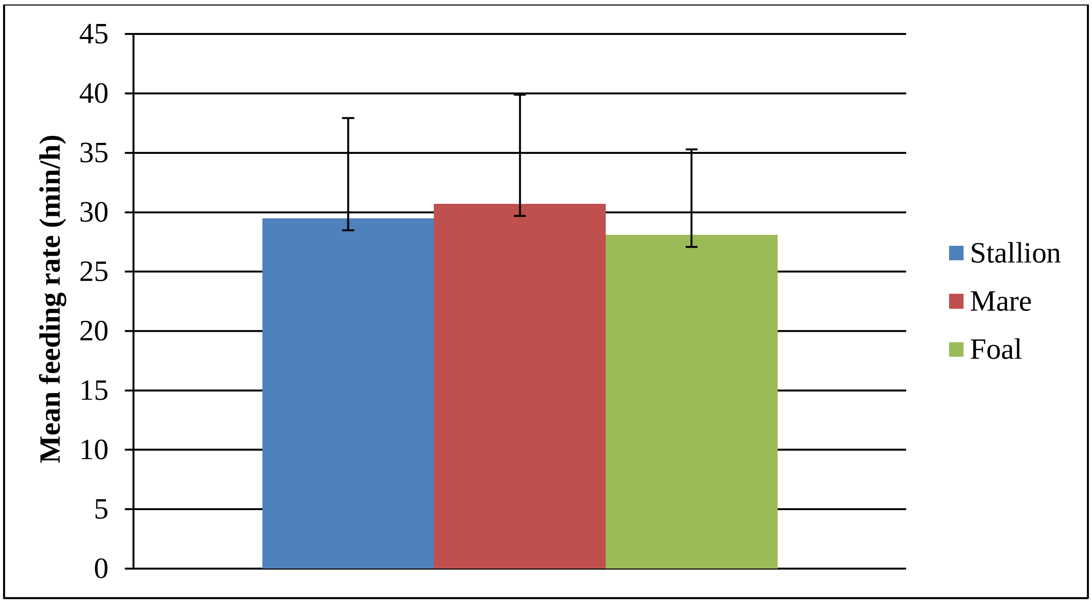

Figure 6.14. Mean feeding rate of zebras in the Mixed Grassland with standard deviation bars.

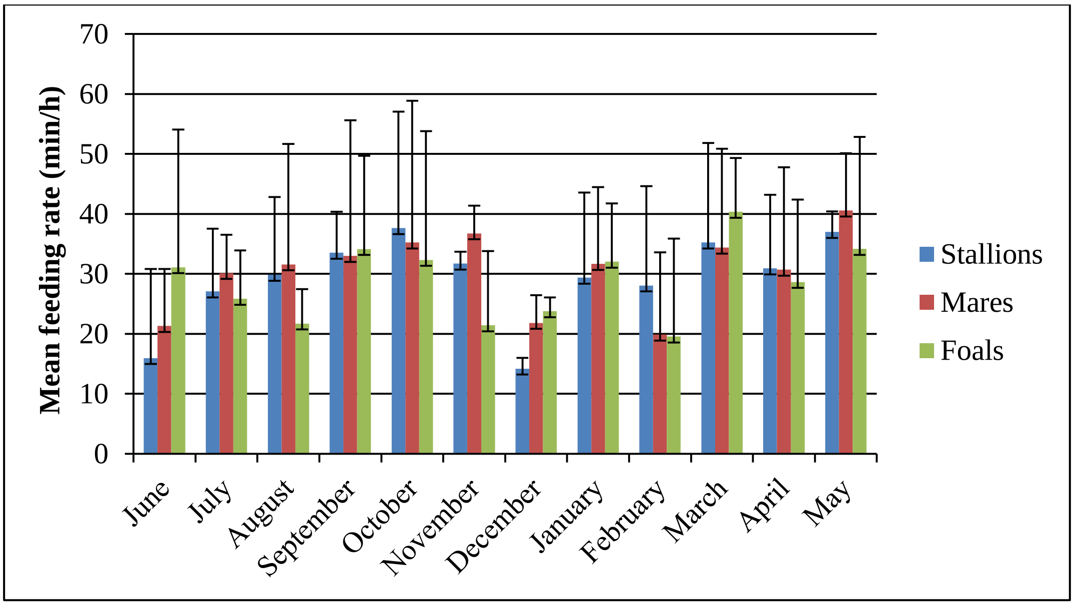

Figure 6.15. Mean feeding rate of stallions, mares and foals in the Mixed Grassland throughout the year with standard deviation bars.

6.2.4. Vigilance

Vigilance was measured counting the number of times a zebra lifts its head from the ground, high enough to see over their current grassy patch. The number of times that zebras in the Rocky Highveld Grassland lifted their heads compared to the number of times the Mixed Grassland zebras lifted their heads is non-significant as $p > 0.05$ (Table 6.15). Rocky Highveld Grassland and Mixed Grassland zebras lifted their heads a mean number of 19.91 and 22.99 times per hour respectively (Figure 6.16). The difference in vigilance between the Rocky Highveld Grassland and Mixed Grassland throughout the year was also non-significant ($p > 0.05$). The highest vigilance was observed in the Mixed Grassland community with mean number of head lifting's 33.78 times per hour (Table 6.16). The lowest frequency of head lifting in this community was 14.33 times per hour. In the Rocky Highveld Grassland, the maximum mean that zebras' lifted their heads were in June with a frequency of 28.50 times per hour. The lowest frequency of vigilance was in the Rocky Highveld Grassland with a value of 13.02 head lifting's per hour (Figure 6.17).

No significant difference ($p > 0.05$) occurs for vigilance between stallions, mares and foal (Table 6.17). Stallions were most vigilant, then mares and foals least vigilant with mean head lifting's of 25.30, 21.28 and 17.78 times per hour. This data is represented graphically in figure 6.18. The difference in vigilance between stallions, mares and foals is significant ($p = 0.000871$) when comparing the head lifting's throughout the year (Table 6.18). Stallions were most vigilant in July with a mean time lifting their heads of 33.05 per hour. Mares and foals were most vigilant in November with mean times lifting their heads of 32.42 and 27.50 per hour, respectively (Figure 6.19).

Zebras of the Rocky Highveld Grassland were most vigilant during evenings (Table 6.19). During mornings, midday's and evenings stallions lifted their heads the most frequently (Figure 6.20). Stallions' mean head lifting's per hour was 28.94 times during the evenings, 21.73 times in the midday's and 18.04 times in the mornings. Mares follow with a mean of 26.99 times, 17.19 times and 16.58 times in the evenings, midday's and mornings respectively. Foals lifted their heads the least with a mean of 21.40 times in the evening, 14.94 in the midday and 13.42 times in the morning. The differences are significant $p = 0.025$. The difference in the average time

Rocky Highveld Grassland zebras lifted their heads in the mornings and evenings are also significant ($p = 0.021$).

As with the Rocky Highveld Grassland zebras, plains zebras in the Mixed Grassland community were more vigilant in the evenings (Table 6.20). However, the difference in head lifting between the different sampling times is non-significant ($p > 0.05$). Stallions were also found to be the most vigilant followed by females and least vigilant being the foals. Stallions lifted their head an average of 35.94 times per hour during the evening. This is more frequent than stallions in the Rocky Highveld Grassland community. During mornings stallions lifted their heads 23.98 times per hour and midday's 23.15 times per hour. Mares lifted their heads a mean of 29.50, 19.69 and 17.73 times per hour during the evenings, midday's and mornings respectively. Foals were least vigilant with mean evening, midday and morning head lifting of 22.78, 17.21 and 16.95 times per hour respectively (Figure 6.21).

Table 6.15. A comparison between the mean frequency of head lifting between the Rocky Highveld Grassland and Mixed Grassland followed by the ANOVA results.

	Number of recordings	Mean	STDEV			
Rocky Highveld Grassland	222	19.91	3.17			
Mixed Grassland	231	22.99	4.39			
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	14.21334909	1	14.21335	0.9677978	0.380927	7.708647
Within Groups	58.7451186	4	14.68628			
Total	72.95846769	5				

Table 6.16. A comparison between the mean frequency of head lifting between the Rocky Highveld Grassland and Mixed Grassland throughout the year followed by the ANOVA results.

	Rocky Highveld Grassland			Mixed Grassland		
	Number of recordings	Mean	STDEV	Number of recordings	Mean	STDEV
Total yearly recordings:						
June	18	28.50	5.64	9	14.33	7.13
July	30	21.22	12.52	39	24.77	6.77
August	21	13.02	5.42	21	25.07	17.82
September	18	17.39	5.28	18	15.28	2.02
October	18	23.22	2.59	18	24.28	11.82
November	18	26.67	12.15	18	33.78	2.12
December	18	15.44	1.68	18	17.78	8.04
January	18	13.89	12.06	18	30.33	9.82
February	9	18.89	15.33	18	19.11	11.65
March	18	21.28	16.49	18	21.72	6.35
April	18	18.00	8.57	18	24.44	11.78
May	18	21.44	6.15	18	25.00	6.87
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	56.85339635	1	56.8534	2.03390046	0.167862	4.300949
Within Groups	614.9635857	22	27.95289			
Total	671.816982	23				

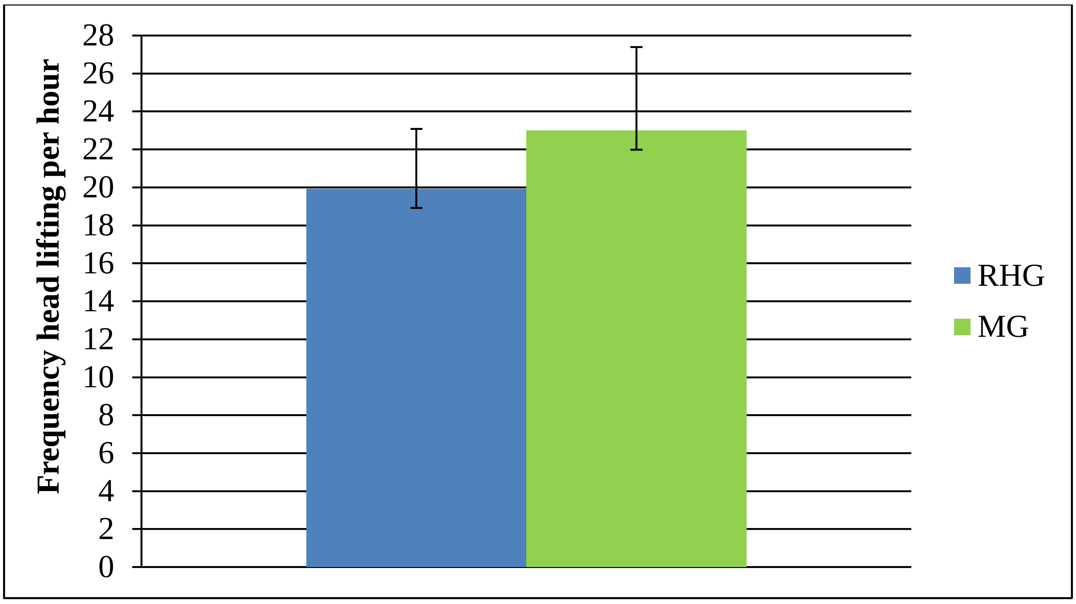

Figure 6.16. A comparison between the frequencies of head lifting's per hour between the Rocky Highveld Grassland (RHG) and Mixed Grassland (MG) with standard deviation bars.

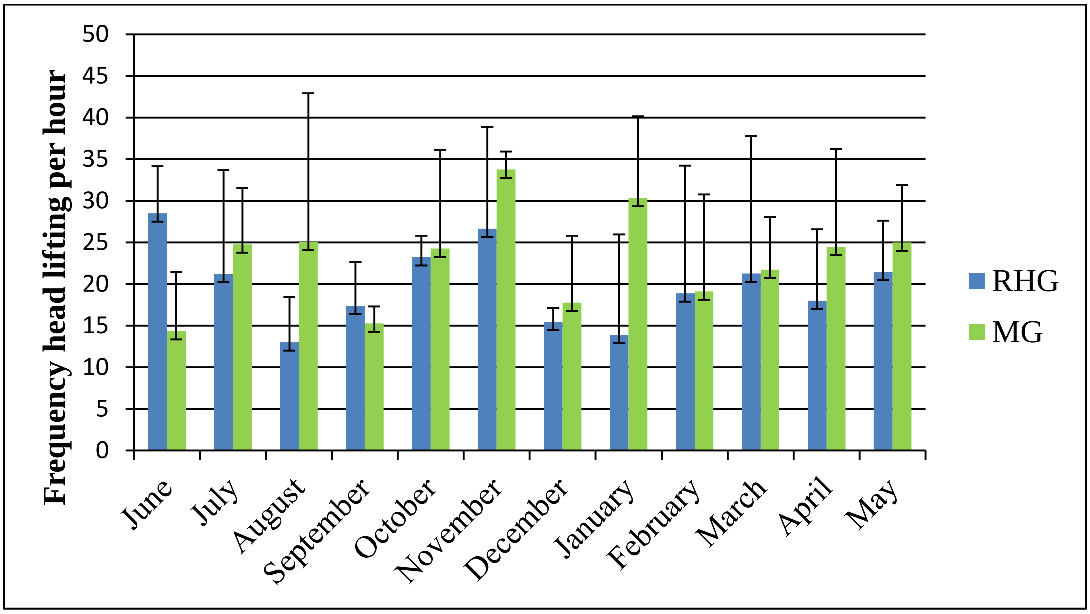

Figure 6.17. A comparison between the frequencies of head lifting's per hour between the Rocky Highveld Grassland (RHG) and Mixed Grassland (MG) throughout the year with standard deviation bars.

Table 6.17. A comparison between the mean frequency of head lifting between stallions, mares and foals followed by the ANOVA results.

	Number of recordings	Mean	STDEV			
Stallions	151	25.30	3.38			
Mares	151	21.28	1.45			
Foals	151	17.78	1.69			
ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	14.21334909	1	14.21335	0.9677978	0.380927	7.708647
Within Groups	58.7451186	4	14.68628			
Total	72.95846769	5				

Table 6.18. A comparison between the mean frequency of head lifting between stallions, mares and foals throughout the year followed by the ANOVA results.

	Stallions			**Mares**			**Foals**		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Total yearly recording:									
June	6	26.67	15.46	6	18.67	10.13	6	18.92	8.10
July	10	33.05	14.66	10	20.79	8.37	10	15.15	5.83
August	7	27.08	18.22	7	17.14	16.81	7	12.92	7.46
September	6	18.83	3.06	6	17.67	5.15	6	12.50	4.57
October	6	26.25	8.81	6	22.67	7.44	6	22.33	8.54
November	6	30.75	12.80	6	32.42	7.84	6	27.50	9.54
December	6	17.17	5.96	6	18.67	8.42	6	14.00	6.61
January	6	25.00	15.17	6	20.83	15.05	6	20.50	12.76
February	3	24.83	15.42	3	19.08	12.80	3	13.08	9.36
March	6	23.75	16.02	6	20.92	8.75	6	19.83	10.12
April	6	22.67	12.66	6	24.67	11.89	6	16.33	6.15
May	6	27.50	10.72	6	21.83	6.82	6	20.33	4.46
ANOVA									
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***			
Between Groups	339.1694372	2	169.5847	8.78985607	0.000871	3.284918			
Within Groups	636.6766043	33	19.29323						
Total	975.8460415	35							

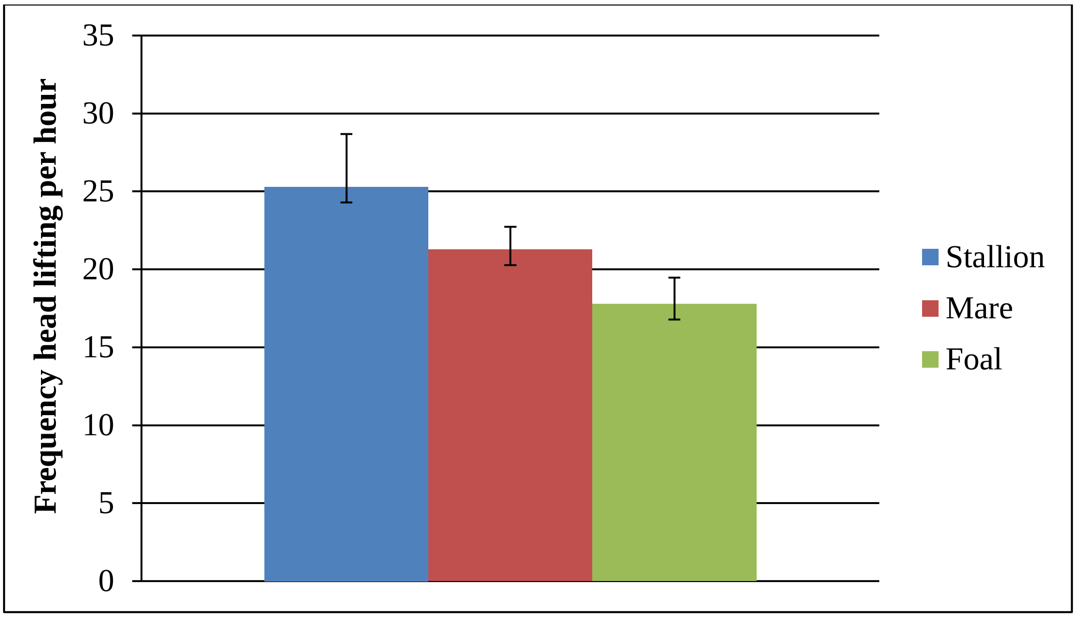

Figure 6.18. A comparison between the frequencies of head lifting's per hour for stallions, mares and foals with standard deviation bars.

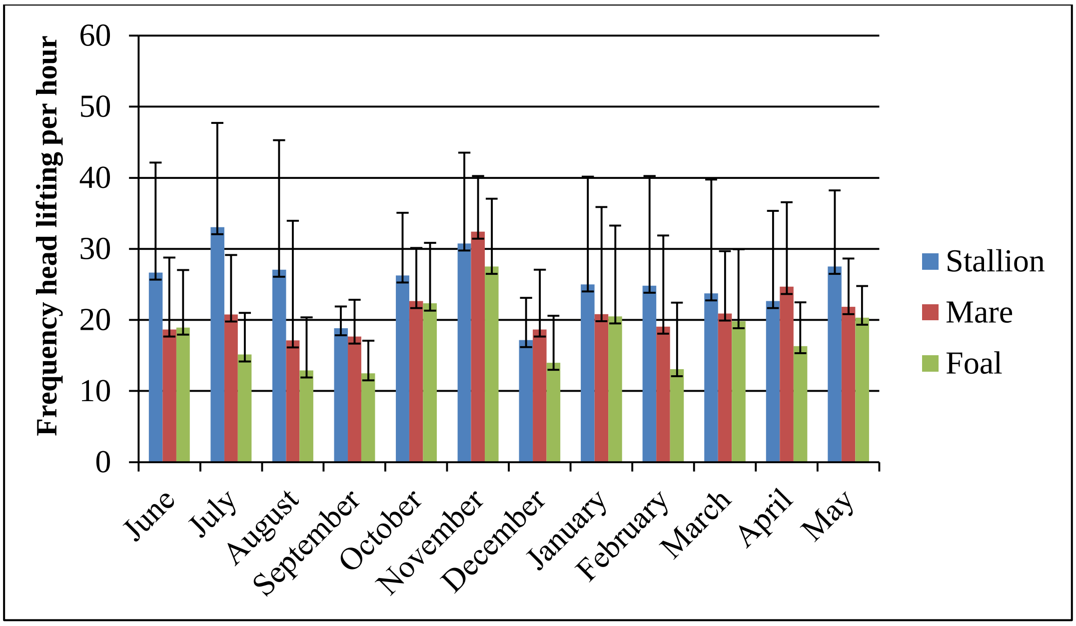

Figure 6.19. A comparison between the frequencies of head lifting's per hour for stallions, mares and foals throughout the year with standard deviation bars.

Table 6.19. A comparison between the mean frequency of head lifting between stallions, mares and foals during the mornings, midday and evenings in the Rocky Highveld Grassland followed by the ANOVA results.

Rocky Highveld Grassland									
	Morning			**Midday**			**Evenings**		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Stallions	23	18.0417	13.6423	25	21.7292	11.6431	26	28.9375	10.2614
Mare	23.00	16.5833	12.0865	25	17.1875	6.31838	26	26.9861	8.03133
Foal	23.00	13.4167	9.64561	25	14.9375	6.08661	26	21.4028	9.47683
ANOVA									
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***			
Between Groups	160.2583698	2	80.12918	7.3171888	0.024586	5.143253			
Within Groups	65.70489326	6	10.95082						
Total	225.963263	8							

Table 6.20. A comparison between the mean frequency of head lifting between stallions, mares and foals during the mornings, midday and evenings in the Mixed Grassland followed by the ANOVA results.

Mixed Grassland									
	Morning			**Midday**			**Evenings**		
	Number of recordings	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**	**Number of recordings**	**Mean**	**STDEV**
Stallions	26	23.98	12.51	25	23.15	9.16	26	35.94	13.31
Mare	26	17.73	7.88	25	19.69	10.04	26	29.50	11.08
Foal	26	16.95	7.60	25	17.21	9.24	26	22.78	7.21

ANOVA						
Source of Variation	***SS***	***df***	***MS***	***F***	***P-value***	***F crit***
Between Groups	185.5906331	2	92.79532	4.15328097	0.073765	5.143253
Within Groups	134.0559195	6	22.34265			
Total	319.6465526	8				

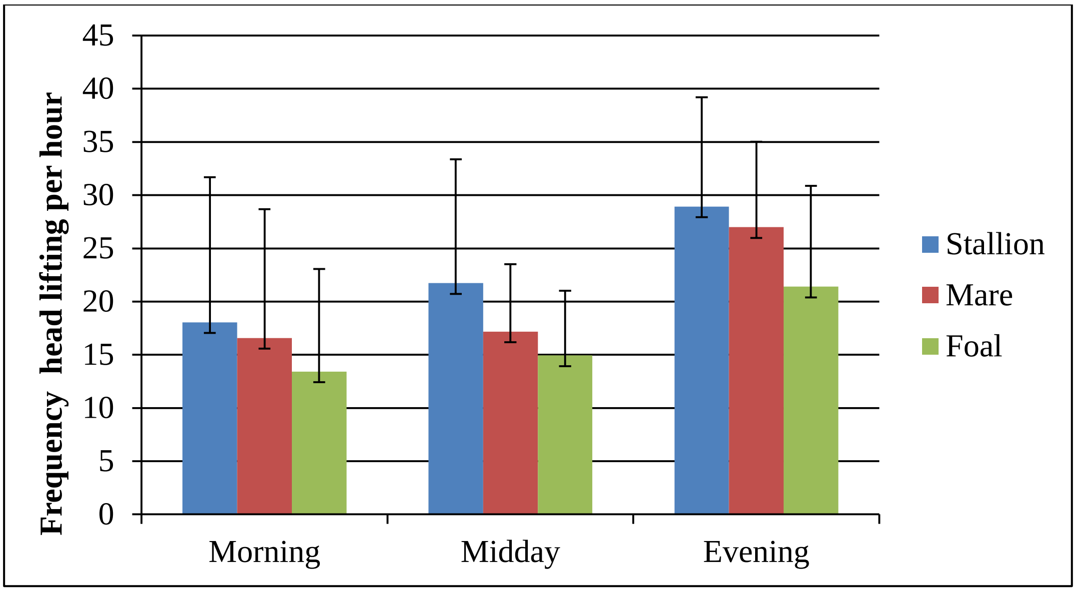

Figure 6.20. A comparison between the frequencies of head lifting's per hour for stallions, mares and foals during mornings, midday and evenings in the Rocky Highveld Grassland with standard deviation bars.

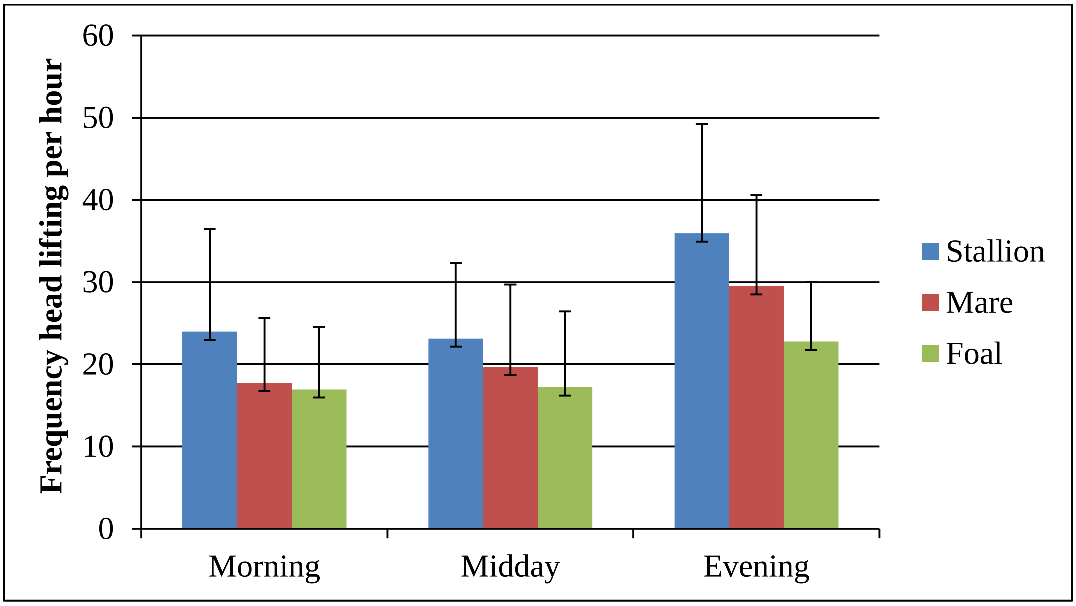

Figure 6.21. A comparison between the frequencies of head lifting's per hour for stallions, mares and foals during mornings, midday and evenings in the Mixed Grassland with standard deviation bars.

Table 6.21 compares the vigilance of the Rocky Highveld Grassland zebras during the mornings of the different months throughout the year with the total number of zebras present during the observation. From figure 6.22 it can be seen that when smaller numbers of zebras are present in a grazing area, the vigilance of the sample zebras was high relative to the number of zebras. During January, zebras were migrating to a grazing patch and vigilance was not recorded. Zebras of the Mixed Grassland community were mostly present in relatively small numbers during observations and therefore the vigilance remained high (Table 6.22). In January, however, the vigilance of the sampled zebras increased together with a higher number of zebras present (Figure 6.23). Perhaps vigilance here was related to competition and not predation.

During midday, the relationship between number of zebras present and vigilance is clearly seen (Table 6.23) in the Rocky Highveld Grassland. No vigilance was recorded for February because zebras were migrating. As the numbers of zebras increase, the vigilance of the sampled zebras decreases (Figure 6.24). However, the number of zebras present during midday in the Mixed Grassland community remained moderately constant with a high frequency in vigilance (Table 6.24). During December there is a sharp decrease in vigilance by the sampled zebras (Figure 6.25). This can be explained by pouring rain that limited visibility.

Table 6.25 shows the total numbers of zebras present during the evening observations in the Rocky Highveld Grassland community compared to the total number of times the sampled zebra group lifted their heads. This data is graphically represented in figure 6.26. In table 6.26 the data for the Mixed Grassland community group’s vigilance during the evenings is presented and it is illustrated in figure 6.27. In both these communities, the vigilance of the sample groups increased as the number of zebras present on the grazing patch increased.

Table 6.21. A comparison between the total number of zebras present and the sampled zebras' vigilance in the Rocky Highveld Grassland in the morning.

Mornings	Number of zebras	Vigilance
June	9	105
July	13	96
August	12	32
September	62	54
October	141	77
November	63	62
December	66	51
January	44	0
February	12	11
March	25	42
April	10	51
May	13	44

Table 6.22. A comparison between the total number of zebras present and the sampled zebras' vigilance in the Mixed Grassland in the morning.

Mornings	Number of zebras	Vigilance
June	10	26
July	7	92
August	9	31
September	15	39
October	10	75
November	11	94
December	37	68
January	44	149
February	5	31
March	10	69
April	12	79
May	9	67

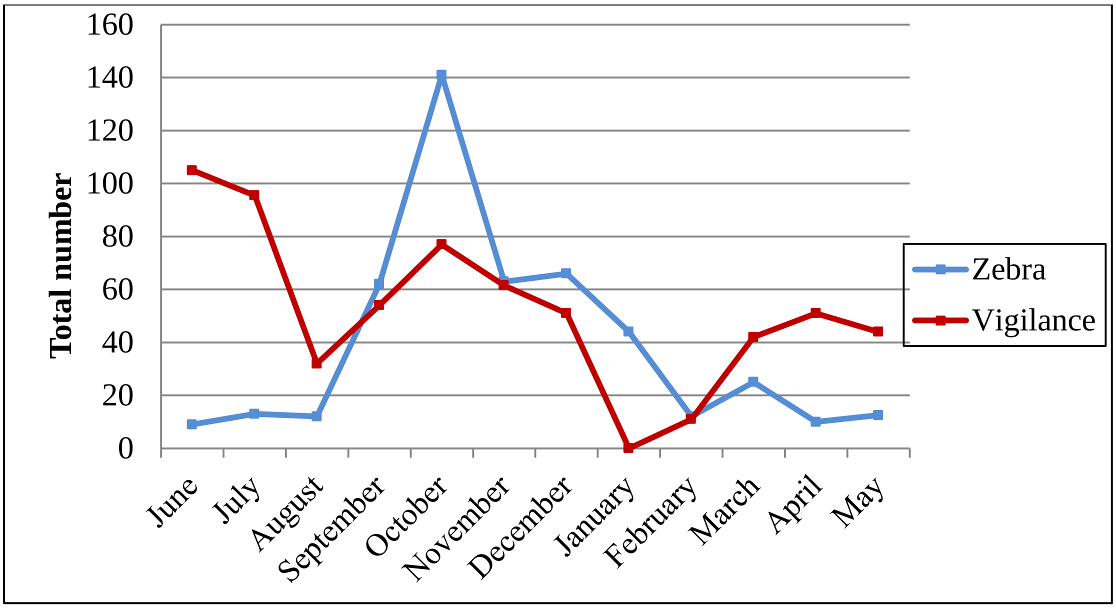

Figure 6.22. Line graph depicting the total number of zebras present during morning observations in the Rocky Highveld Grassland throughout the year compared to the number of times the zebras lift their heads (vigilance).

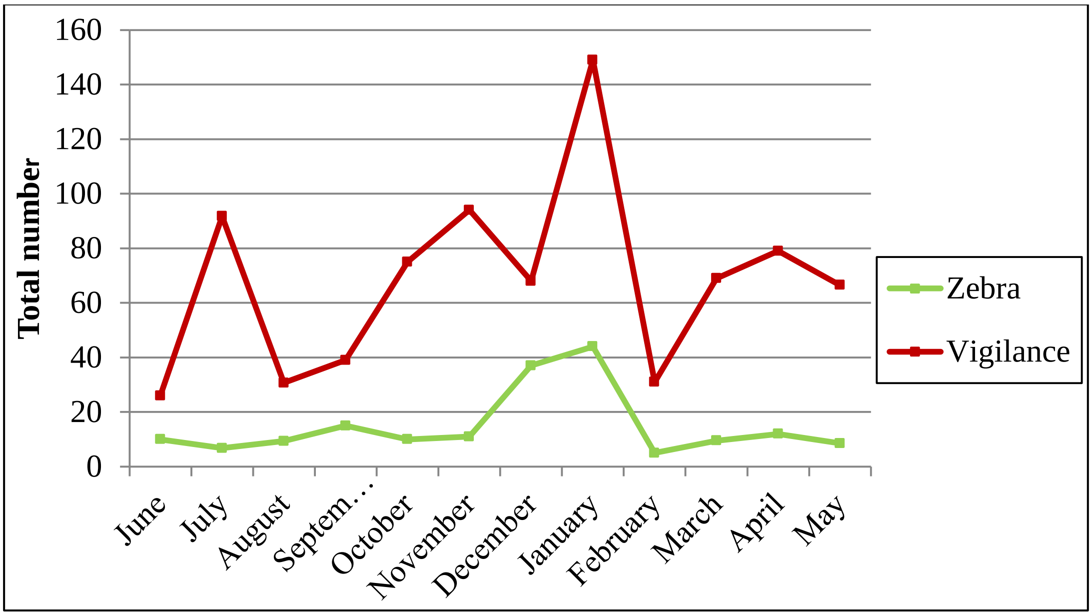

Figure 6.23. Line graph depicting the total number of zebras present during morning observations in the Mixed Grassland throughout the year compared to the number of times the zebras lift their heads (vigilance).

Table 6.23. A comparison between the total number of zebras present and the sampled zebras' vigilance in the Rocky Highveld Grassland during midday.

Midday	Number of zebras	Vigilance
June	16	77
July	15	22
August	4.5	28
September	78	36
October	39	82
November	60	57
December	76	41
January	41	65
March	14	53
April	13	61
May	23	80

Table 6.24. A comparison between the total number of zebras present and the sampled zebras' vigilance in the Mixed Grassland during midday.

Midday	Number of zebras	Vigilance
June	15	67
July	8	52
August	9	61
September	17	48
October	8	105
November	7	106
December	12	26
January	11	74
February	16	44
March	12	45
April	5	36
May	4	60

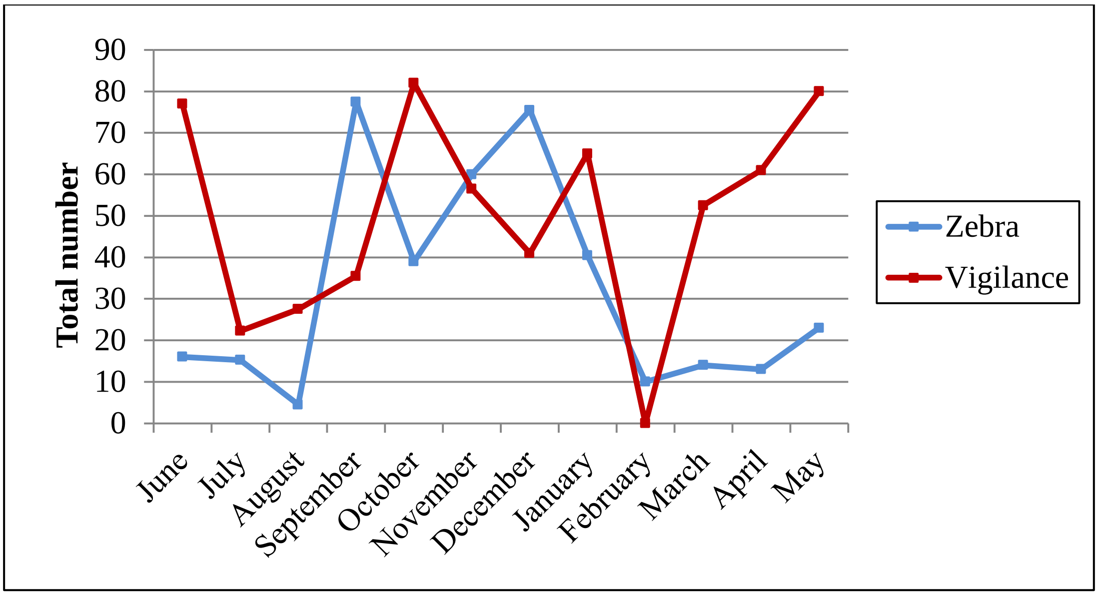

Figure 6.24. Line graph depicting the total number of zebras present during midday observations in the Rocky Highveld Grassland throughout the year compared to the number of times the zebras lift their heads (vigilance).

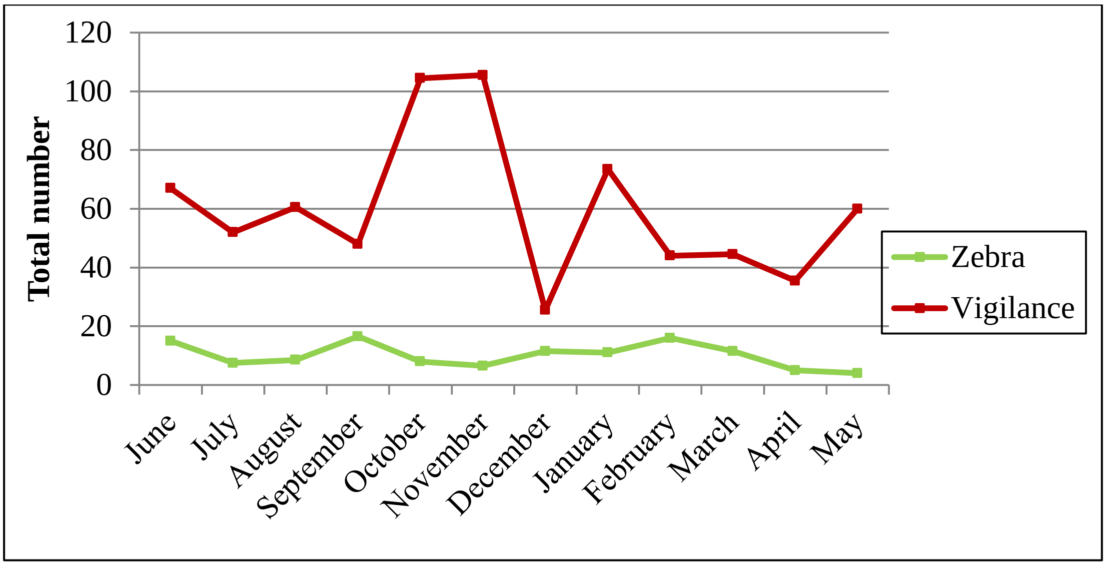

Figure 6.25. Line graph depicting the total number of zebras present during midday observations in the Mixed Grassland throughout the year compared to the number of times the zebras lift their heads (vigilance).

Table 6.25. A comparison between the total number of zebras present and the sampled zebras' vigilance in the Rocky Highveld Grassland in the evening.

Evening	Number of zebras	Vigilance
June	26	75
July	12	73
August	8	58
September	55	67
October	43	74
November	62	122
December	13	47
January	20	60
February	53	103
March	17	118
April	27	76
May	39	69

Table 6.26. A comparison between the total number of zebras present and the sampled zebras' vigilance in the Mixed Grassland in the evening.

Evening	Number of zebras	Vigilance
June	15	36
July	9	75
August	15	135
September	24	51
October	49	80
November	59	105
December	48	67
January	73	125
February	12	97
March	18	82
April	28	106
May	10	99

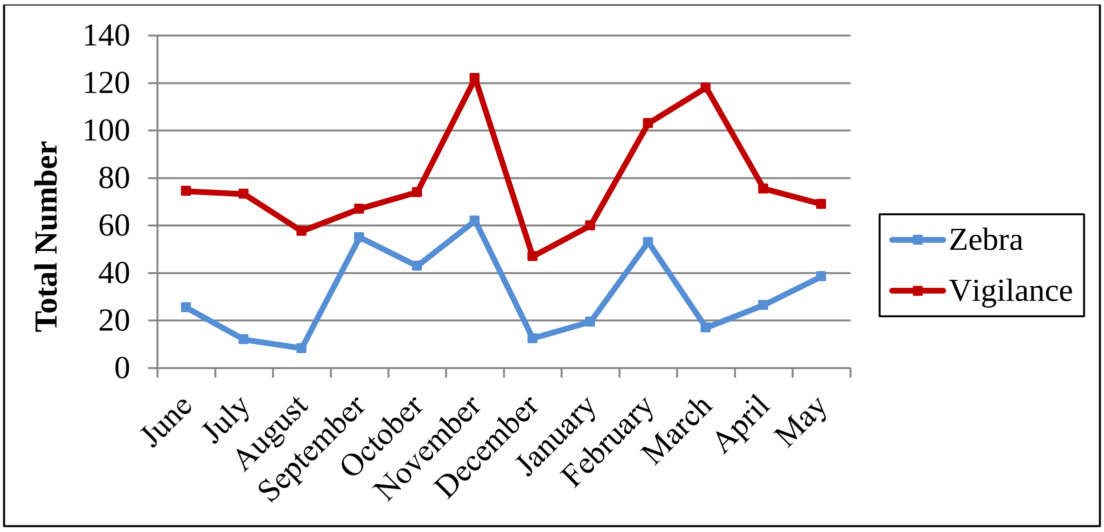

Figure 6.26. Line graph depicting the total number of zebras present during evening observations in the Rocky Highveld Grassland throughout the year compared to the number of times the zebras lift their heads (vigilance).

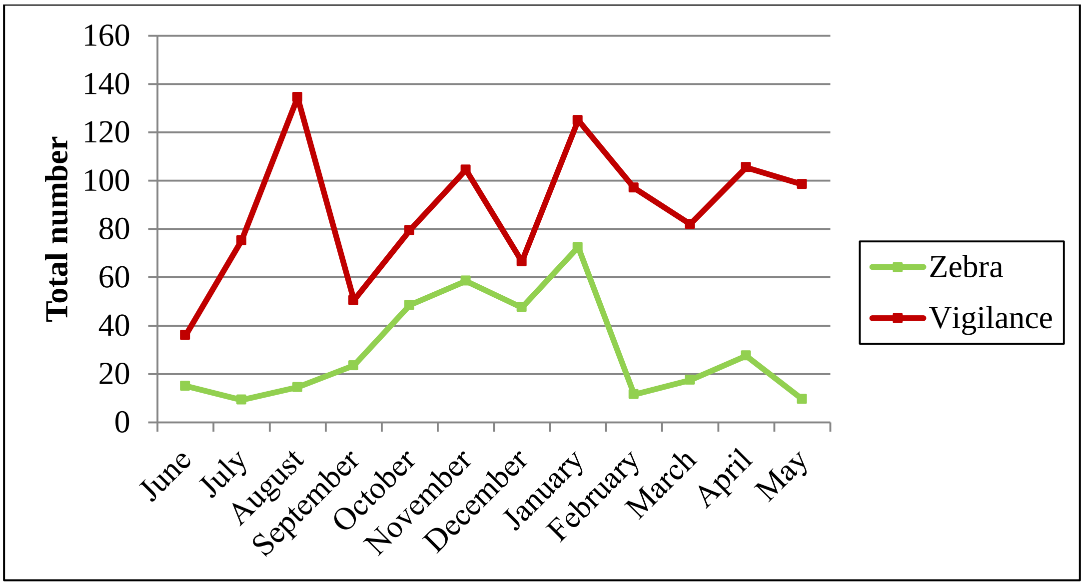

Figure 6.27. Line graph depicting the total number of zebras present during evening observations in the Mixed Grassland throughout the year compared to the number of times the zebras lift their heads (vigilance).

6.2.5. *Associated species*

During the observation of the plains zebra in Telperion, the presence of other species was also noted. A total of 18 associated species was recorded. This presence was noted even if these species just passed through the grazing area whilst plains zebra were present. Figure 6.28 shows the percentage times the associated species were present with that of the plains zebra. As expected, Blue Wildebeest was the most commonly associated species found at zebra grazing sites. They were found approximately 24% of the time during zebra observations. The common duiker was seen the least during the zebra observations.

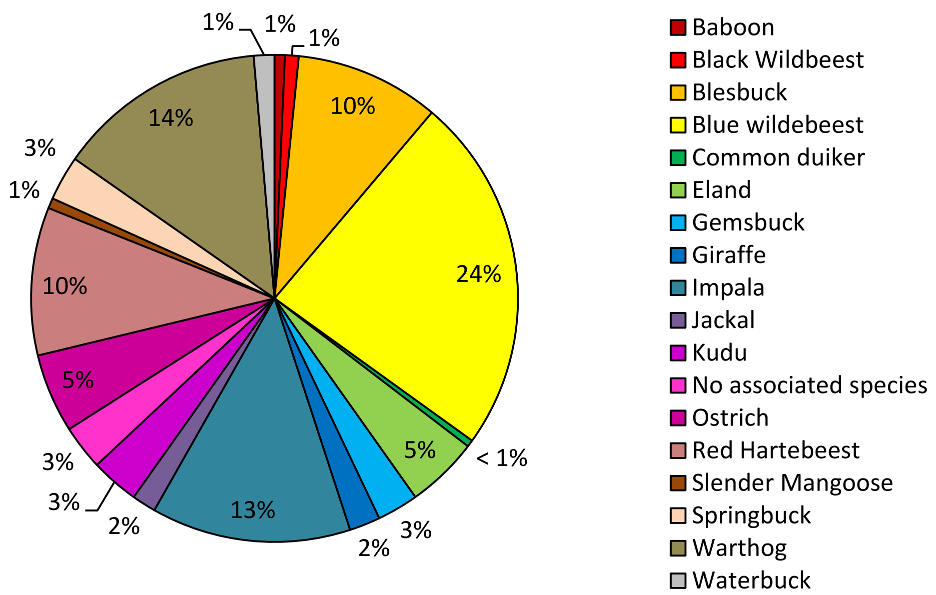

Figure 6.28. Pie chart showing the percentage times other species were present during zebra observation in Telperion.

6.3. Conclusion

In Telperion in the eZemvelo nature reserve no distinct differences were observed in the feeding rates between the two different habitat types or between stallions, mares and foals in the different habitat types. A general trend exists for an increase in feeding rates in both habitat types during spring and autumn. A definite trend was observed in feeding rates during different times of the day. Plains zebras in the Rocky Highveld Grassland and Mixed Grassland habitat types both spent least time feeding in the mornings and most during the evenings. In the comparison between stallions, mares and foals, mares in both the Rocky Highveld Grassland and the Mixed Grassland communities spent most time feeding. Stallions followed while foals spent least time feeding in both habitat types. In order to improve the above mentioned results, feeding observations should comprise of more than three individuals. Also, if individuals are properly identified the uncertainty of pregnant or non-pregnant mares will be eliminated and results can be adjusted according to this information. In addition, recording should take place more often a month for longer time periods. This will also solve the lack of data when zebras migrate or just stand due to heavy rain.

Even though no distinct pattern was observed for vigilance throughout the year for both the zebras of the Rocky Highveld Grassland and Mixed Grassland, individuals within the group tend to follow similar trends in the number of times of head lifting per month. Generally, stallions are most vigilant, followed by mares while foals are least vigilant. The study also clearly shows the relationship between the number of zebras present and the vigilance of the sampled zebras. Here, in Telperion where predators are few the increase in numbers of zebras showed that vigilance was related to competition rather than predation.

7. VEGETATION DESCRIPTION

7.1. Introduction

Vegetation data was collected in Telperion at preferred zebra grazing sites, not only in the two chosen vegetation types but also on the migration paths as recorded from the GPS. The plant species recorded were captured in the vegetation database TURBOVEG for Windows (Hennekens 1996; Hennekens & Schaminee 2001). The database was then exported into the working directory JUICE (Tichỳ 2002), as discussed in Methods.

7.2. Classification

Two major plant communities were identified from 52 relevés and a total of 196 species were recorded. Due to the homogenous nature of the grasslands, many abundant and dominant species are shared between these two communities. However, both of the two major communities can be divided into two sub-communities. One sub-community of each community can further be divided into variants. These communities are shown in the phytosociological table (Table 7.1).

The floristic analysis revealed the following communities:

1. *Parinari capensis–Themeda triandra* Grassland Community on shallow rocky soils.
    - 1.1 *Loudetia simplex–Elionurus muticus* Overgrazed Grassland Community.
    - 1.2 *Parinari capensis–Themeda triandra* Climax Grassland Community.
2. *Digitaria eriantha–Aristida stipitata* Grassland Community on deep sandy soils.
    - 2.1 *Aristida stipitata–Tephrosia lupinifolia* Overgrazed Grassland Community.
    - 2.2 *Digitaria eriantha–Aristida stipitata* Anthropogenic Grassland Community.

A hierarchical classification of the communities identified and their associated environmental factors are given in figure 7.1.

7.3. Plant community description

Species found in the communities are typical of the Bankenveld (Acock 1988), Rocky Highveld Grassland (Bredenkamp & Van Rooyen 1998) or Rand Highveld Grassland

Table 7.1. Phytosociological table of vegetation of preferred zebra grazing sites on Telperion.

Community	1																																			2															
Sub-community	**1.1**								**1.2**																												**2.1**					**2.2**										
Unique relevé number		1		1		4			1	1	2	2	3	3	3	2	2	2	2	2	3	3	3	4	4	4	4	3	4	4		5	4	5	4	3	2	4	1	3	3	1	1	2	2	1		1	5			1
	4	3	7	1	6	8	2	5	6	5	3	5	0	1	9	2	6	7	8	9	2	3	5	9	3	6	7	6	2	1	3	1	5	2	4	4	1	0	7	7	8	8	9	0	4	4	1	2	0	8	9	0
Species Group A																																																				
Aristida transvaalensis	+	.	.	+	+	.	.	.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	.	1	a	.	+	+	+	b	+	+	.	1	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Parinari capensis	+	+	a	.	.	.	.	.	+	+	1	+	1	a	1	+	1	1	1	1	+	+	1	+	a	+	.	.	.	1	+	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Themeda triandra	+	.	+	+	+	.	.	.	a	3	a	1	+	+	.	.	+	+	+	+	a	+	.	+	+	+	+	+	+	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.
Loudetia simplex	1	.	+	+	a	.	.	.	.	+	.	+	.	+	.	.	+	+	+	+	1	1	+	+	.	+	.	.	+	+	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Commelina africana	+	.	.	.	.	+	+	.	.	.	1	+	.	.	.	+	+	+	+	+	+	+	.	.	+	.	+	.	.	+	.	.	+	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Tristachya rehmannii	+	.	.	.	.	+	.	.	+	.	+	.	.	+	+	.	+	+	+	1	.	.	.	.	.	.	+	+	+	+	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Xerophyta retinervis	.	.	+	.	+	.	.	.	.	.	.	+	.	.	+	+	+	+	+	.	+	+	+	+	a	.	.	.	.	1	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elephantorrhiza elephantina	+	+	.	+	.	.	.	+	+	.	.	+	+	+	+	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	+	.	+	+	+	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pellaea calomelanos	.	.	+	+	.	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	+	.	.	.	+	.	+	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypoxis rigidula	.	.	+	.	.	+	.	.	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	+	+	+	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Elionurus muticus	b	.	+	+	b	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	+	1	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trichoneura grandiglumis	.	.	+	+	.	.	+	.	.	.	.	+	.	.	.	+	.	.	.	+	.	.	.	+	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.
Vernonia oligocephala	+	+	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tristachya biseriata	.	.	.	.	+	.	.	.	.	.	+	1	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bewsia biflora	.	.	+	+	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Protea welwitschii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Gladiolus elliotii	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Senecio venosus	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Cymbopogon plurinodis	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Ledebouria species	. . . .	. . . . + .	. . . + . .	. . . . .	. . . . .	. . .	. . .
Helichrysum species	. . . .	. . . . + . .	. . . . . +	. . . . .	. . . . .	. . .	. . .
Eragrostis nindensis	. . . . + . . .	. . . . + ...	+	. . . . .	. . . . .	. . .	. . .
Crabbea angustifolia	. . . . + . . .	. . . . + ...	. . . + . .	. . . . .	. . . . .	. . .	. . .
Zornia linearis	. + ...	. . . .	. + ...	. . . . .	. . . . .	. . .	. . .
Scabiosa columbaria	. . . . . + . .	. . . .	. . . . . +	. . . . .	. . . . .	. . .	. . .
Species Group B	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Chamaecrista mimosoide	. . . . + . a .	. . . . + . +	. . . . . .	. + . . .	. . . . .	1 . .	. + .
Kohautia virgata	+ 1	. . . .	. . . . + .	. . . . .	. . . . .	. . .	. . .
Urelytrum agropyroides	1	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Tristachya leucothrix	. + . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Dichapetalum cymosum	+ . . . . . . +	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Tephrosia longipes	+ . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Asparagus species	+ + + + + . . .	. . . .	+	. . . . .	. . . . .	. . .	. . .
Limeum viscosum	. . . . + . . +	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Bidens bipinnata	. . + . . + . +	. . . .	. . . . + .	. . . . .	. . . . .	. . .	. . .
Limeum species	. . + + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . +
Species Group C	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Trachypogon spicatus	. . . + ...	+ + . + ... + . . + + + + + + . . + +	. . . . . .	. . . . .	. . . . .	. . .	. . .
Asparagus suaveolens	. . . .	. . + . + . + + . . . + + + . . + . . + + +	. + ...	. . . . .	. . . . .	. . .	. . .
Searsia magalismontana	. + ...	. . . . + . + . . + + . + + + . . + +	. . . . . .	. . . . .	. . . . .	. . .	. . .
Felicia mossamedensis	. . . .	. + . + . + . . + . . + . . + + ...	. . . . . .	. . . . .	. . . . .	. . .	. . .
Hemizygia pretoriae	. . . .	. . . . + . + + + ...	. . . . . .	. . . . .	. . . . .	. . .	. . .
Elephantorrhiza burkei	. . . .	. . . . + + . . + + ...	. . + . . .	. . . . .	. . . . +	. . .	. . .
Kyllinga alba	. . . .	. . . . . + ... + . + ...	. . . . . .	. . . + .	. . . . .	. . .	. . .
Diheteropogon amplectens	. . + ...	. . . . + . + + ...	. . . . . .	. . . . +	. . . . .	. . .	. . .
Englerophytum magalismontanum	. . . .	. . . . + ... 1	. . . . . .	. . . . .	. . . . .	. . .	. . .
Dovyalis caffra	. . . .	. . . . 1	. . . . . .	. . . . .	. . . . .	. . .	. . .

Bulbostylis densa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hypoxis species	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hebenstretia comosa	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ipomoea crassipes	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Plantago lanceolata	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Felicia muricata	.	.	+	+	.	.	.	.	.	.	.	.	+	+	.	.	+	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Setaria sphacelata	.	.	.	+	.	.	.	b	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.
Andropogon schirensis	.	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	+	+	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Aristida congesta	.	.	+	+	+	.	1	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Sesamum triphyllum	.	.	+	+	.	.	+	.	.	.	.	.	.	+	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Ochna pulchra	.	.	.	1	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Indigofera species	.	.	+	+	.	.	+	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.
Gomphocarpus fruticosum	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
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Seriphium plumosum	+	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	1	+	+	.	1	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Wahlenbergia undulata	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.
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Digitaria eriantha	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	1	.	.	.	+	.	.	.	+	.	.	+	+	+
Gomphrena celosioides	.	+	.	.	.	+	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	+	.	+	+	+
Species Group G	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Chamaecrista comosa	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	+	.	.	.
Tephrosia lupinifolia	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	1	+	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Indigofera filipes	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
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Aristida stipitata	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	+	.	+	.	.	+	+	+	+	.	.	.	.	.
Hyparrhenia hirta	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+	.	.	.	+	+	.	.	.	.	.	.
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Cyperus esculentus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	3	+	.

Sporobolus africanus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	1	+	+
Eleusine coracana	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	+
Heteropogon contortus	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.
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Aristida congesta subsp. *Barbicollis*	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pseudognaphalium luteo-album	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	+	+	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	.
Solanum panduriforme	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
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Tagetes minuta	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	a	.	.	.	.	.	.	.	.	.	.	.	.	.	+
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Solanum sisymbrifolium	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	+	.	.	.	+	+	.	+	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.
Indigofera comosa	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	.	.	.	.	.
Conyza podocephala	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Datura stramonium	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Helichrysum rugulosum	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Species Group M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eragrostis chloromelas	.	.	b	b	.	a	b	a	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	1	.	.	.	1	.	.	.	.	.	.	.	.	.	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.
Cleome monophylla	.	.	+	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+	.	+	+	.	+	.	.	.	.	.	.	.	+	.	+	+	.	.	.	.	.	.	.	.	.	.	+
Leonotis ocymifolia var. *schinzii*	.	.	+	.	.	+	.	+	.	.	.	.	.	.	+	+	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.	+	+	+	.	.	.	.	.	.	.	+	.	.	.
Commelina livingstonii	.	.	.	.	+	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.
Verbena bonariensis	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
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Portulaca kermesina	.	.	.	.	.	.	.	.	.	.	.	+	+	+	+	.	.	.	.	.	+	.	.	+	.	.	.	+	+	.	.	.	.	.	.	+	+	1	+	+	+	.	a	+	.	+	.	.	.	.	.	.
Aristi congesta subsp. *Congesta*	.	.	.	.	.	+	.	.	.	.	+	+	+	.	.	+	.	.	.	+	+	.	+	.	+	.	.	+	+	.	.	+	+	+	+	+	.	+	+	+	+	.	+	.	+	1	.	.	+	.	.	.
Eragrostis plana	.	.	.	.	.	.	.	.	.	+	+	.	+	a	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	3	a	a	3	a	.	.	.	.	.	.
Hermannia depressa	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.
Species Group O	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Oldenlandia herbacea	1 . + + 1 + + +	1 . . + + + 1 + + + . + + + 1 1 + + . + 1 1	a b a + + b	. . . a .	. . + + +	. . .	. + .
Vernonia poskeana	. + b + + + . +	. + + + + + + + + . + + . . + + + + + + . +	+ + + + + +	+ + + + +	. + + + .	. . .	. . .
Phyllanthus parvulus	. . + + + . . +	. + + + + 1 + . + + + + ... + . . . + +	. . . + . .	. + + + +	. . + 1 .	. . +	. . .
Perotis patens	+ . . + + . + .	. 1 + . + + + ... + + + . + + + +	. + + + + +	+ + + + +	. + . 1 +	+ . +	. . .
Cleome maculata	. . + + . + + +	+ + + + . + + + + + + + + + + + . . . + + +	. . . . + +	. . + + +	+ + + + .	. . .	. . .
Pollichia campestris	. + . + . + + .	+ + + + + + + ... + . . . + + . . + . +	. . . . + .	+ + + . .	+ + + . .	+ . .	. . .
Bulbostylis hispidula	+ + + 1 + + + .	+ + + + + + a + 1 + 1 a a + 1 1 + + + + + +	. a b + 1 +	. . . . +	+ 1 + + +	. . .	. . +
Schizachyrium sanguineum	. + 1 . . + + .	. + + + . . + + . + + + + + + . + + + + + +	. . . . + +	. . . + +	. + . . .	. . .	. . .
Fadogia homblei	+ + . + . + . +	+ . . . + 1 . . . . + . . + ... + + +	+ . . . + .	. . + + +	. + + . .	. . .	. . .
Eragrostis gummiflua	+	. . . . + . . . + . + . . + 1 . + + +	1 a a 1 + 1	. + + + .	. . . + +	. . .	. . .
Commelina species	. . + ...	. . . .	. . . . . .	. . . . .	. . . . +	. . .	. . .
Cyperus species	. . . .	. . + ...	. . . . . .	. . . . .	. + . . .	. . .	. . .
Cyperus obtusiflorus	+	. . . .	. . . . + .	. . . + .	. . . + .	. . .	. . .
Sporobolus stapfianus	. + ...	. . . .	. . . . . .	. . + . .	. . . . .	. . .	. . .
Species Group P	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Melinis repens	. + + + + . + .	. + + + . + + + + + + + + + + + + + + + + +	+ . + + + +	+ . + + +	. + + + +	+ . +	. . .
Pogonarthria squarrosa	. . + + + + . +	. . . + + . + ... + +	. . . + + +	+ + . + +	. + . + +	+ . +	. . .
Eragrostis racemosa	. . . + ...	+ + . . + . + + . . + ... + . + + + + +	. . + . + +	. . . . .	. . . . +	+ + .	. . .
Species Group Q	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Cynodon dactylon	+ . . + . . 1 .	. . . . + . . . + . .	. 3 + 3 . .	. . + + .	. . . . .	3 4 3	1 3 a
Verbena brasiliensis	. . . .	. . . .	. . + . . .	. + . . .	. . . . .	. . .	+ . +
Species Group R	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Richardia brasiliensis	+ . + + . + + .	+ + . + + + ... + . . + . . . + . + .	. . . + + +	+ + + + +	+ + . . +	+ . .	+ . 1
Schkuhria pinnata	+ + b + . + 1 .	. . . . + . . + ... + ...	. . . . . .	. 1 + + .	. . . . .	a 4 b	+ . 1
Solanum incanum	. . + + + . + +	. . + . . . + ... + . . . + . . .	+ . + . . +	+ + . + +	. . + + .	+ + +	+ . .
Cleome rubella	+ + + + + + + .	+ + + . . + + + . . + + + + + + + . + + + .	. . . . + .	+ + + . .	+ + . . .	. + +	. . +
Hibiscus engleri	. . . + . + + .	. + ... + . + + . . . + . + . . .	. . . + . .	+ . 1 . +	+ + + . .	. + +	+ + +
Eragrostis curvula	. . . .	+ . . . . . + . + + ... + . 4 . . +	. . . + . .	. . . + +	. . . . .	. . +	+ + b
Eragrostis trichophora	. + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. + .

Commelina erecta	+ . . . . . + .	. . . .	. . . . . .	. . . . .	. . . . .	+ . .	. . .
Conyza albida	. . . + ...	. . . . +	. . + . . .	. . . . .	. . . . .	. . .	+ . +
Tricholaena monachne	. . + ...	. . . . + + +	. . . . . .	+ + . . .	. . . . .	. . .	+ . .
General Species	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Ceratotheca triloba	. + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Panicum natalense	+	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Schistostephium crataegifolium	+	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Searsia lancea	. . . . +	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Ipomoea ommaneyi	. . . . . . + .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Sesamum alatum	. . . . . . + .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Vernonia staehelinoides	. . . . . . + .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Eriosema salignum	. . . . . + . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Sida cordifolia	. . . . . + . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Dactyloctenium aegyptium	. . . . + . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Polygala hottentotta	. . . . + . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Searsia pyroides	. . . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Rhynchosia monophylla	. . . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Triumfetta sonderi	. . . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Striga elegans	. . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Stylochieton natalensis	. . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Conyza species	. . + ...	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Solanum mauritianum	. . . .	. . . . + . .	. . . . . .	. . . . .	. . . . .	. . .	. . .
Crassula species	. . . .	. . . . + ...	. . . . . .	. . . . .	. . . . .	. . .	. . .
Convolvulus sagittatus	. . . .	. . . . + ...	. . . . . .	. . . . .	. . . . .	. . .	. . .
Cyperus rupestris	. . . .	. . . . + ...	. . . . . .	. . . . .	. . . . .	. . .	. . .
Mundulea sericea	. . . .	. . . . + ...	. . . . . .	. . . . .	. . . . .	. . .	. . .
Monocymbium ceresiiforme	. . . .	. . + ...	. . . . . .	. . . . .	. . . . .	. . .	. . .
Aspalathus suaveolens	. . . .	+	. . . . . .	. . . . .	. . . . .	. . .	. . .

Conyza bonariensis	. . . .	. . . .	. . . . . +	. . . . .	. . . . .	. . .	. . .
Gladiolus species	. . . .	. . . .	. . . . . +	. . . . .	. . . . .	. . .	. . .
Helichrysum acutatum	. . . .	. . . .	. . . . + .	. . . . .	. . . . .	. . .	. . .
Asparagus burchellii	. . . .	. . . .	. . + . . .	. . . . .	. . . . .	. . .	. . .
Senecio species	. . . .	. . . .	. . + . . .	. . . . .	. . . . .	. . .	. . .
Oxalis obliquifolia	. . . .	. . . .	. . + . . .	. . + . .	. . . . .	. . .	. . .
Boophane disticha	. . . .	. . . .	+	. . . . .	. . . . .	. . .	. . .
Pentarrhinum insipidum	. . . .	. . . .	. . . . . .	. + . . .	. . . . .	. . .	. . .
Gladiolus sericea subsp. *calva*	. . . .	. . . .	. . . . . .	. . . . +	. . . . .	. . .	. . .
Indigofera filiformis	. . . .	. . . .	. . . . . .	. . . . +	. . . . .	. . .	. . .
Ipomoea crispa	. . . .	. . . .	. . . . . .	. . . . +	. . . . .	. . .	. . .
Manulea parviflora	. . . .	. . . .	. . . . . .	. . + . .	. . . . .	. . .	. . .
Panicum maximum	. . . .	. . . .	. . . . . .	. . . . .	. . . . +	. . .	. . .
Phyllanthus parvus	. . . .	. . . .	. . . . . .	. . . . .	. . . . +	. . .	. . .
Leonotis leonurus	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . +	. . .
Oenothera indecora	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	. + .
Chloris gayana	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	+ . .
Chloris virgata	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	+ . .
Cyperus rotundus	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	+ . .
Fuirena pubescens	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	+ . .
Lepidium species	. . . .	. . . .	. . . . . .	. . . . .	. . . . .	. . .	+ . .

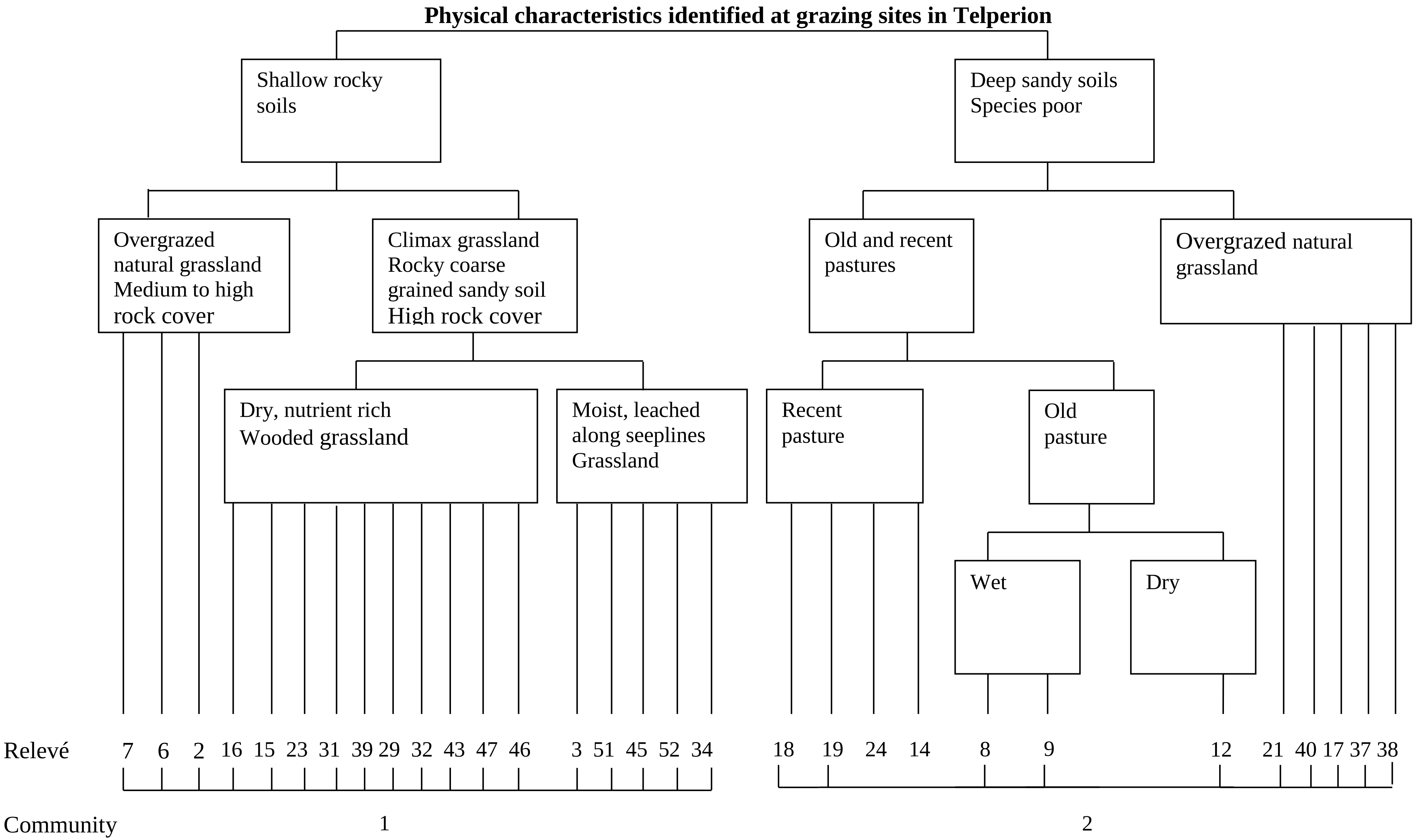

Figure 7.1. Dendrogram depicting the hierarchical classification of the vegetation communities.

(Mucina & Rutherford 2006). The graminoid layer in Telperion is dominated by *Cynodon dactylon*, *Eragrostis chloromelas*, *Eragrostis curvula* and *Eragrostis gummiflua*. Other conspicuous grass species are *Aristida stipitata*, *Elionurus muticus*, *Loudetia simplex*, *Schizachyrium sanguineum*, *Setaria sphacelata*, *Themeda triandra* and *Eragrostis plana* on abandoned sown pastures used for cattle grazing. *Burkea africana* were also found in the survey areas but were excluded from the data analysis as mentioned in Methods, because it skewed the results by concealing the true grassland community pattern by giving these woody species a high weighting value. Other woody species recorded were *Dovyalis caffra*, *Englerophytum magalismontanum* and *Searsia magalismontana.* The most dominant forbs present at the preferred zebra grazing sites were *Cleome maculata*, *Cyperus esculentus*, *Oldenlandia herbacea*, *Phyllanthus parvulus*, *Schkuhria pinata* and *Vernonia poskeana.* Other species include *Bulbostylis hispidula*, *Chamaecrista mimosoides*, *Parinari capensis*, *Pollichia campestris* and *Tagetes minuta.*

1. *Parinari capensis–Themeda triandra* Community on shallow rocky soils.

This community is found on shallow rocky soils and is typical of the Bankenveld (Acocks 1988) or Rocky Highveld Grassland (Bredenkamp & Van Rooyen 1998). It is similar to the Grassland communities as identified by Swanepoel (2006).

Species group A (Table 7.1) characterise this community. Typical diagnostic grass species are *Aristida transvaalensis*, *Loudetia simplex* and *Tristachya rehmannii. Elephantorrhiza elephantina*, *Parinari capensis*, *Pellaea calomelanos*, *Protea welwitschii* and *Xerophyta retinervis* are other diagnostic species recorded in this community.

1.1 *Loudetia simplex–Elionurus muticus* Overgrazed Grassland Community.

The vegetation in this sub-community is characterised by overgrazed natural grassland on shallow rocky soils (Figure 7.2). Here the surface rock cover is medium to high and the soils associated with this community have never been ploughed. It is represented by eight relevés. The dominant species are *Chamaecrista mimosoides*, *Kohautia virgata* and *Urelytrum agropyroides*. In this sub-community the grass species *Tristachya leucothrix* is diagnostic.

This vegetation is characterised by Species Group B but species from Groups A, D, M, O, P and R are strongly represented. The prominent shared species were grasses *Aristida congesta, Elionurus muticus, Eragrostis chloromelas, Loudetia simplex, Schizachyrium sanguineum, Setaria sphacelata* and *Themeda triandra.* Other shared species such as *Bulbostylis hispidula, Ochna pulchra, Oldenlandia herbacea, Parinari capensis, Schkuhria pinnata* and *Vernonia poskeana* were also recorded.

Figure 7.2. *Loudetia simplex–Elionurus muticus* Overgrazed Grassland Community.

1.2 *Parinari capensis–Themeda triandra* Climax Grassland Community

This sub-community consist of a climax grassland community found on shallow, rocky, coarse grained, sandy soils (Figure 7.3). The surface area covered with rock is high, much more than in Community 1.1. Diagnostic species include the woody species *Elephantorrhiza burkei*, *Englerophytum magalismontanum* and *Searsia magalismontana*, grass species *Diheteropogon amplectens*, *Trachypogon spicatus* and the forb species *Asparagus suaveolens.* This community is represented by 28 relevés.

Species Group C and E is characteristic of this sub-community. Dominant species found were woody species *Dovyalis caffra*, *Englerophytum magalismontanum* and other species like *Seriphium plumosum*. Prominent species shared with Species Group A and D are *Protea welwitschii*, graminoids like *Aristida transvaalensis*, *Loudetia simplex*, *Setaria sphacelata*, *Themeda triandra* and *Tristachya biseriata*. *Vernonia oligocephala* and *Xerophyta retinervis* were also recurrently recorded.

Sub-community 1.2 can further be divided into two variants. The first is that of a climax wooded grassland on relatively dry, nutrient rich sand. Here *Dovyalis caffra* and *Englerophytum magalismontanum* are diagnostic. The second variant is dominated by the diagnostic species *Seriphium plumosum*. This variant can be classified as Climax grassland on moist leached sand along seep lines.

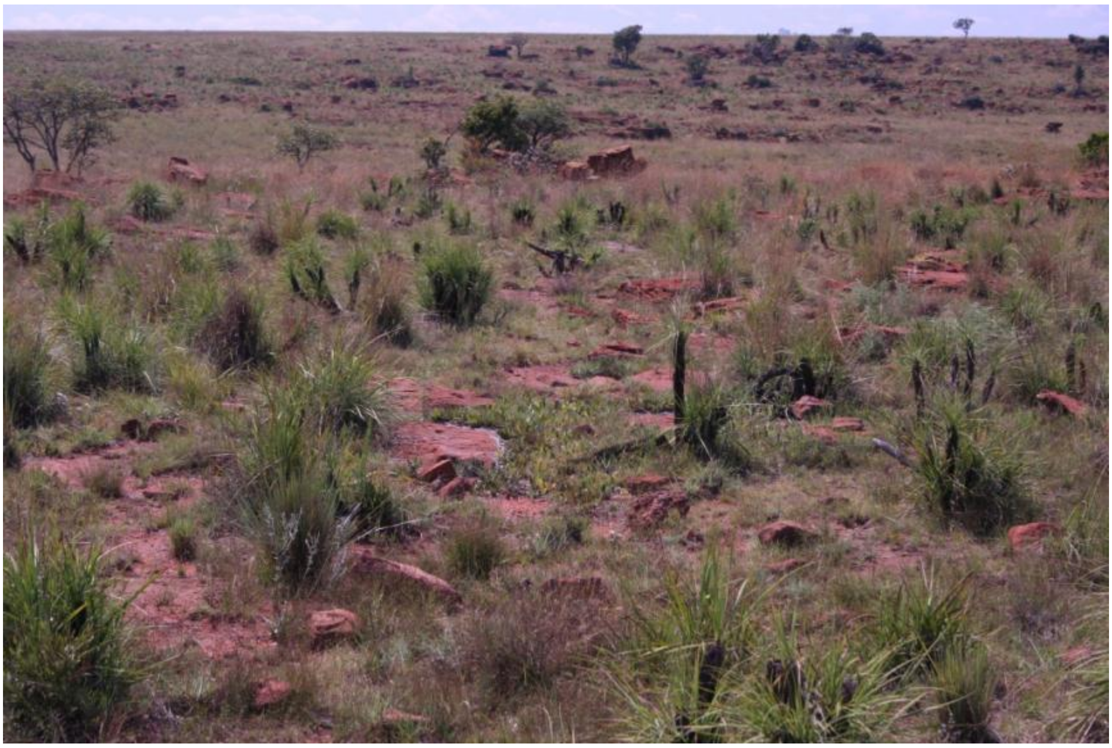

Figure 7.3. *Parinari capensis–Themeda triandra* Climax Grassland Community.

2. *Digitaria eriantha–Aristida stipitata* Community on deep sandy soils

This community is similar to the Grassland Community identified by Swanepoel (2006) and is found on deep, sandy soils and is relatively species poor. It is characterised by Species Group F and can be divided into two sub-communities:

2.1 *Aristida stipitata–Tephrosia lupinifolia* Overgrazed Grassland Community

The vegetation in this sub-community can be classified as overgrazed natural and semi-natural grasslands on deep soils (Figure 7.4). It is characterised by Species Group G (Table 7.1) but species from Species Group F and H were also recorded. The five relevés revealed that the grass species *Digitaria eriantha* and the forb species *Tephrosia lupinifolia* are dominant. *Aristida stipitata* and *Hyparrhenia hirta* are also well represented.

Figure 7.4. *Aristida stipitata–Tephrosia lupinifolia* Overgrazed Grassland Community.

2.2 *Digitaria eriantha–Aristida stipitata* Anthropogenic Grassland Community

This sub-community consists of old and recent pastures on deep sandy soils (Figure 7.5). It can be divided into two variants. The first is that of Recent Pastures. These relevés were all taken from the newest area added to Telperion and is represented by five relevés. *Eragrostis plana* is the dominant species but it is shared with the *Parinari capensis–Themeda triandra* Climax Grassland Community represented in

Species Group N. Other prominent species like *Bulbostylis hispidula*, *Perotis patens* and *Phyllanthus parvulus* are shared with Species Group O.

The second variant is that of old pastures. It can further be divided into a Wet and Dry variant each represented by three relevés. The dry variant is dominated by pioneer species *Cynodon dactylon*, *Schkuhria pinnata* shared with *Parinari capensis–Themeda triandra* Climax Grassland Community in Species Group Q and R respectively. The wet variant, on the other hand, is characterised by Species Group I with the most dominant species being *Cyperus esculentus*. Other prominent pioneer species include graminoids *Cynodon dactylon*, *Eragrostis curvula* and *Sporobolus africanus* as well as species such as *Schkuhria pinnata* shared with Species Groups Q and R.

Figure 7.5. *Digitaria eriantha–Aristida stipitata* Anthropogenic Grassland Community.

Homogenous nature of vegetation sampled

Numerous species are shared between the two major communities *Parinari capensis–Themeda triandra* Community on shallow rocky soils and *Digitaria eriantha–Aristida stipitata* Community on deep sandy soils as a result of the homogenous nature of the study areas. Graminoid species such as *Cynodon dactylon*, *Eragrostis chloromelas*, *Eragrostis gummiflua*, *Eragrostis plana* and other species like *Bulbostylis hispidula*, *Oldenlandia herbacea* and *Schkuhria pinnata* are dominant in both communities. Other species well represented in these communities are grass species *Perotis patens* and *Schizachyrium sanguineum* and other species such as *Cleome maculata*, *Pollichia campestris*, *Phyllanthus parvulus* and *Vernonia poskeana* of Species Group O. *Melinis repens* and *Pogonarthria squarrosa* of Species Group P also features commonly in both communities. Other species common between the two communities are *Cleome rubella*, *Richardia brasiliensis* and *Solanum incanum* of Species Group R (Table 7.1).

7.4. Ordination

In plant sciences, ordination refers to the arrangement of individual plant samples or species according to their similarities in species composition and/or the influence of environmental factors. It allows comparison of the distribution of individuals within different communities. Also, ordination forms part of gradient analysis. Here, differences in species composition are related to the differences in environmental factors. The ultimate goal of ordination is to reduce data, study the result and then form a hypothesis thereof (Barbour *et al*. 1999; Kent & Coker 1994).

Ordination is a procedure that graphically displays quadrates or species in one, two, three or multi-dimensional scales. Stands with similar species composition will be grouped together (Barbour *et al*. 1999). The results of DECORANA, using the programme PCOrd, as well as another study conducted in this reserve (Swanepoel 2006), supports the JUICE classification of these grassland communities and is depicted in Figure 7.6. The habitat data collected on site were used to interpret the results as obtained from the ordination.

According to the DECORANA ordination the preferred *Equus burchelli* grazing sites can be divided into five grassland communities:

1. *Cynodon dactylon–Schkuhria pinnata* Old pasture Community on deep sandy soils;
2. *Eragrostis plana* Recent pasture Community on deep sandy soils;

3. *Aristida stipitata–Tephrosia lupinifolia* Overgrazed grassland Community on deep sandy soils;
4. *Parinari capensis–Themeda triandra* Climax grassland Community on shallow rocky soils and
5. *Loudetia simplex–Elionurus muticus* Overgrazed grassland Community on shallow rocky soils.

Community 1, 2 and 3 of the DECORANA ordination is equivalent to JUICE Community 1 *Digitaria eriantha–Aristida stipitata* on deep sandy soils while Community 4 and 5 of DECORANA coincides with JUICE Community 2 *Parinari capensis–Themeda triandra* on shallow rocky soils. These grassland communities are represented by the five different clusters on the diagram (Figure 7.6).

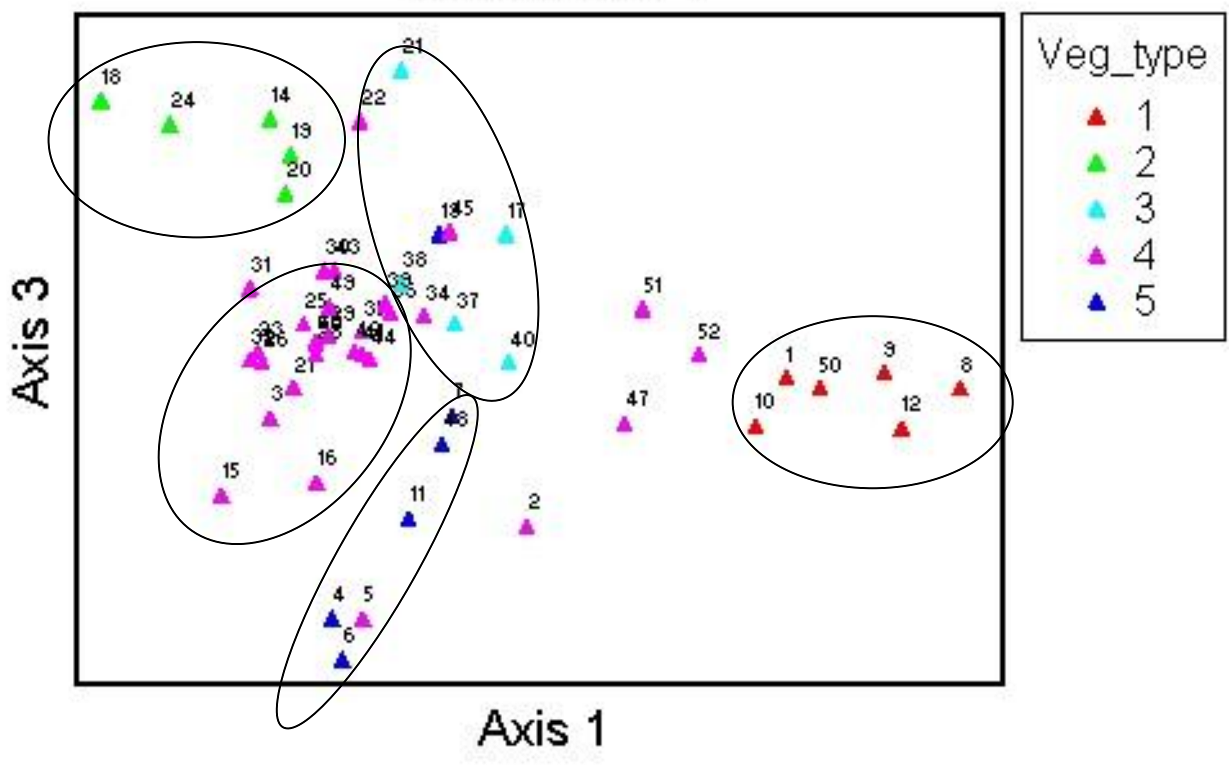

Figure 7.6. DECORANA ordination of the communities present at preferred zebra grazing sites.

7.5. References

ACOCKS, J.P.H. 1988. Veld Types of South Africa. *Memoirs of the Botanical Survey of South Africa* No. 57.

BARBOUR, M.G., BURK, J.H. & PITTS, W.D. 1999.*Terrestrial plant ecology*. Benjamin/Cummings Publishing Company, Inc. Canada.

BREDENKAMP, G.J. & VAN ROOYEN, N. 1996. Rocky Highveld Grassland. In: Low, A.B. & Rebelo, A.G. (eds). *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs and Tourism, Pretoria.

HENNEKENS, S.M. 1996. *TURBOVEG: A Software Package for Constructing Phytosociological Tables*. IDLO, Wageningen.

HENNEKENS, S.M. & SCHAMINEE, J.H.J. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. *Journal of Vegetation Science* 12:589–591.

KENT, M. & COKER, P. 1994. *Vegetation description and analysis: A practical approach.* John Wiley & Sons Inc. England.

MUCINA, L. & RUTHERFORD, M.C. (eds.) 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. South African Biodiversity Institute, Pretoria.

SWANEPOEL, B.A. 2006. *The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspruit, South Africa.* M.Sc. Dissertation (Botany), University of Pretoria, Pretoria.

TICHỲ, L. 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science* 13:451–453.

8. DISCUSSION

8.1. Introduction

Telperion consist of numerous vegetation types in a wide variety of habitats. It includes wetlands in floodplains and streams, woodland vegetation on slopes and rocky ridges and grasslands on plains (Swanepoel 2006). The link between vegetation and animals is their feeding behaviour (Owen-Smith 1999). Feeding behaviour nonetheless is more complex than first perceived, as it not only involves physically grazing a grassy patch but also migrating to find a suitable patch and being vigilant during the feeding bout.

This chapter explores the relationship between the vegetation found on preferred zebra grazing patches and feeding behaviour as well as pointers on the management of Telperion.

8.2. Vegetation interpretation

8.2.1. Classification

The dendrogram (Figure 7.1) indicates that the determining factor dividing the two major grassland communities is soil depth. The *Parinari capensis–Themeda triandra* Community (Community 1) was found on shallow rocky soils while the *Digitaria eriantha–Aristida stipitata* Community (Community 2) occurred on deep sandy soils. The latter was relatively species poor.

The secondary divisions of the two major communities was based on the condition of the grassland. In Community 1, the first sub-community *Loudetia simplex–Elionurus muticus* was found to be an overgrazed natural grassland while the second sub-community *Parinari capensis–Themeda triandra* is a climax grassland community. The former is further divided into a drier, nutrient rich soil and wetter, leached soil. In Community 2, the *Aristida stipitata–Tephrosia lupinifolia* Overgrazed Grassland Community is natural or semi-natural and can be separated from the *Digitaria eriantha–Aristida stipitata* Anthropogenic Grassland Community. The anthropogenic grassland is divided into old and recent pastures. In turn, old pastures are divided into wet and dry variants.

8.2.2. Ordination

Three of the clusters (Figure 8.1), Communities 3, 4 and 5, showed continuous but distinguishable clusters indicating biogeographical differences in the plant species compositions as well as the affiliation between grassland and bushveld communities present on the same geological substrate (Bredenkamp & Theron 1978; Bredenkamp & Brown 2003). The lack in clear division may be ascribed to gradients of soil depths, grazing pressure and intensity of disturbance. Represented on the bottom left of the diagram is the *Loudetia simplex–Elionurus muticus* Overgrazed grassland Community that occurs on shallow rocky soils. The adjacent cluster is *Parinari capensis–Themeda triandra* Climax grassland Community also on shallow rocky soils while the *Aristida stipitata–Tephrosia lupinifolia* Overgrazed grassland Community occurs on deep sandy soils.

Communities 1 and 2 are found as separated clusters representing the old and recent pastures respectively. On the ordination diagram (Figure 8.1) Community 1 is found to the right concurring with the soil depth gradient. Community 2 however, is positioned in the top left hand side of the diagram. The separation of these two clusters may be an indication of the artificial structure and composition of these communities.

8.3. Interpretation of *Equus burchelli* behaviour

8.3.1. Feeding

The main factor that determines rate of food intake is the bite rate. This is based on the assumption that male and female zebras are similar in size and that all bite volumes are equal (Neuhaus & Ruckstuhl 2002). From field observations, eZemvelo zebras are indeed similar in size thus comparing feeding rates between males and females where not biased toward a bigger sex. According to Neuhaus & Ruckstuhl (2002) similar feeding times between males and females indicate similar intake needs due to the similar body size or change in similar behaviours. This confirms results obtained by this study since the difference in feeding times between the stallions and mares were non-significant. In this study a random mare was chosen, therefore the higher intake of mares to the stallions may then be ascribed to the statement that lactating females takes more bites per minute than non-lactating females (Neuhaus &

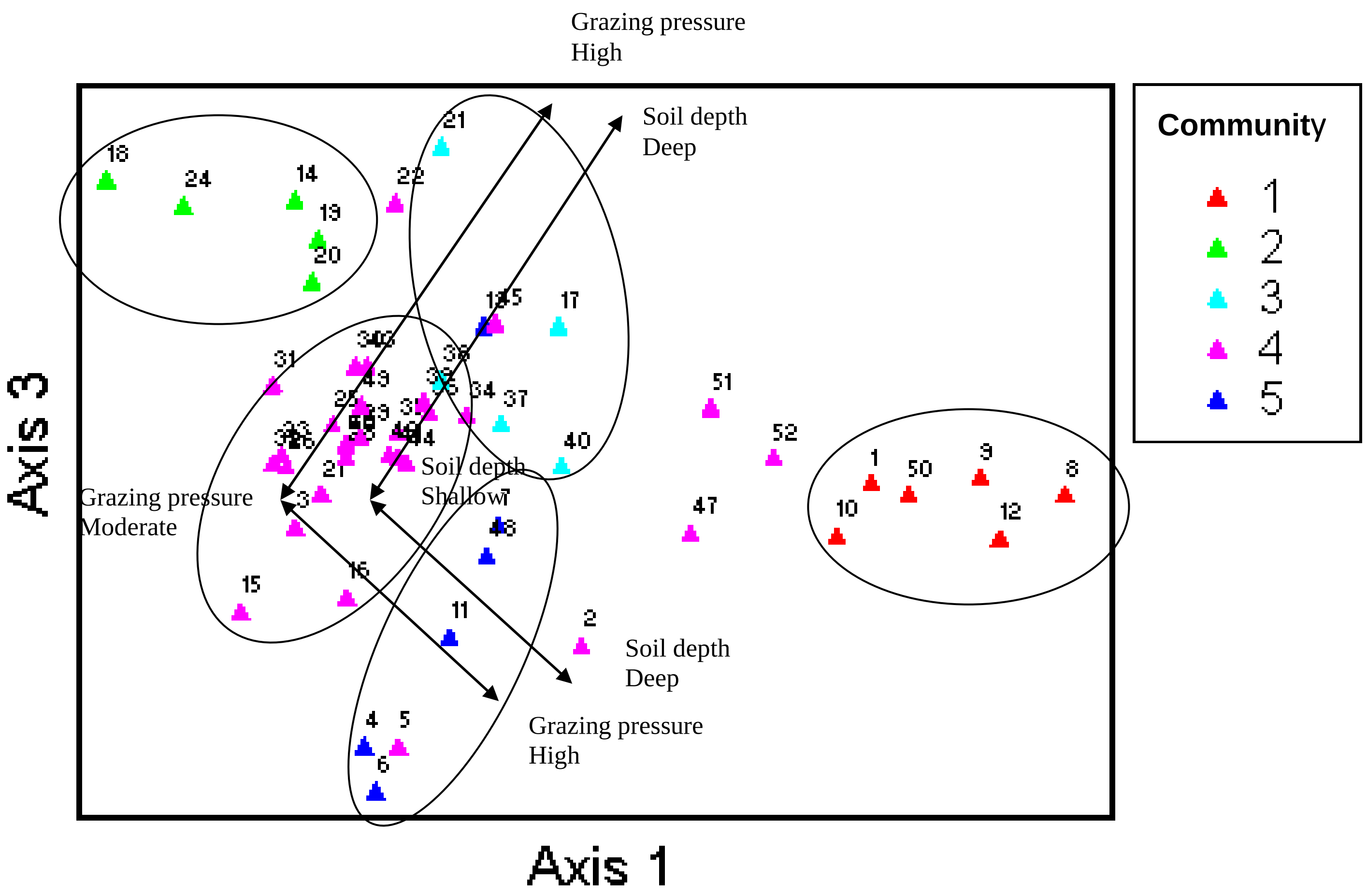

Figure 8.1. DECORANA ordination of the communities present at preferred zebra grazing sites showing gradients of grazing pressure and soil depth.

Ruckstuhl 2002). The comparison of feeding rates of foals with mares and stallions was however influenced by the foal's smaller bite-size, body size and behaviour.

As Rocky Highveld Grassland provides sheltered habitat from several crevices and rocks protruding from the ground, it is expected that a wider diversity of plant species may result in a more nutrient rich community than that of the Mixed Grassland habitat that contained little or no rocks. It was deliberated that due to the lower diversity in the grassland habitat, feeding rates would be higher to compensate for the lower nutrient intake. In Telperion, this is not the case (Figure 6.1). There was no significant difference between the two chosen habitat types.

A surprising result was the average time spent feeding during the different times of the day. Owen-Smith (1999) believes that ungulates spend less time feeding at night than during the day. During this study it was suspected that the highest rate would be during the mornings to reload on energy lost during the night keeping warm and vigilant. It was however found that the highest rate of feeding occurred during evenings, more so in the Mixed Grassland community than in the Rocky Highveld Grassland community. In contrast to results in this study, where the lowest feeding rates was found to be in the morning, followed by midday and evening feeding rates being the highest in Telperion zebras, Owen-Smith (1999) found that high feeding rates usually occurs in the morning and late afternoon whilst animals tend to rest during midday. The higher feeding rate of mares may be ascribed to the fact that most were lactating and the possibility of pregnancy. Neuhaus & Ruckstuhl (2002) found that lactating females took more bites per minute than non-lactating females. Wand *et al*. (2002) states that the growing cycle of South African grasses peak in the wet season, usually mid-summer and senesce when rainfall strongly decrease (late summer to autumn). Therefore, as anticipated, in both communities feeding rates were highest during spring and lowest during autumn.

8.3.2. Vigilance

Neuhaus & Ruckstuhl (2002) found no difference in vigilance between males, non-lactating or non-pregnant females and lactating or pregnant females. In Telperion however, stallions were most vigilant, and mares more vigilant than foals. This may be due to several reasons. One may be the protection of a filly in oestrous. Stallions of other herds may abduct a one and a half to two years old filly (Groves 1974, MacClintock 1976). Should a stallion be aware of an approaching stallion, he might be able to protect his fillies because he was not caught off guard. During this study plains zebras of Telperion were most vigilant during the evenings. Perhaps this result aids us in understanding the different vigilance patterns observed. This coincides with typical times zebras and other game fall prey to predators (MacClintock 1976). eZemvelo Reserve does not have lions, primary predators of zebra (Stahl 1971, MacClintock 1976, Fay & Greeff 2006, Grange & Duncan 2006) but leopards are well represented and evidence of leopard kill on blue wildebeest was observed during the study. Zebra foals have a small frame and may be an easy target to predation. As zebras gestation period is more than a year, and foals cannot be produced in successive seasons foals are available to predators throughout the year (Grange & Duncan 2006). Grange *et al.* (2004) found that zebra foals vulnerability to predation is high when zebra groups are fragmented, especially in wetter periods when grass cover is high. The reduced frequency of vigilance in the presence of numerous zebra groups grazing together may well support the predator theory (Scheel 1993).

8.3.3. Equus burchelli **migration through Telperion**

The position of a herd of zebras closest to each habitat was recorded with a Global Positioning System (GPS). It can be seen from figure 8.2 that they were largely found in the rocky ridges in winter. During spring (Figure 8.3), they start moving towards the open plains and plateaus which continues through summer (Figure 8.4). Only again in autumn do they retreat back to the rocky ridges (Figure 8.5). In addition, to aid in understanding of the behaviour of the plains zebra in Telperion, their daily migration was observed during this study and recorded. The GPS points were taken at the point where they were first observed as well as the final point. Smuts (1974) stated that zebra are migratory innately and travel to winter and summer grazing areas. It was found that the migration of zebras took largely place during summer. Sunrise they walked from the Rocky Highveld Grassland community to the rest of Telperion and back to the Rocky Highveld Grassland during sunset. In studies done by MacClintock (1976) and Brooks & Harris (2007) the same patterns where found, where zebras moved out from a central point and migrated to other parts of the natural landscape, as observed in Telperion (Figure 8.6). However, Brooks & Harris (2007) found migration largely to take place in winter whereas in Telperion, zebras merely walked to the closest rocky ridge and grazed there throughout the day. The observation that zebras were most often found on slopes during winter is confirmed by a study of Penzhorn & Novellie (1991) that zebras move away from plateaus and seek slopes as it provides more shelter from cold winds and low temperatures. Therefore, perhaps one should be careful to underestimate the importance of rocky areas and slopes during carrying capacity calculations as they support plains zebras during winter and autumn months in Telperion. Penzhorn & Novellie (1991) also stated that zebras tended to seek shelter in wooded ravines during sharp temperature drops. Telperion zebras however, were more often found in the *Burkea africana* woodland communities during the summer but their conclusion that temperature does not play a determining role in seasonal movement of zebras supports the observation that Telperion plains zebras did not seek shade during extremely hot days in the summer months.

In addition, when zebras in Telperion started to migrate, they would direct their movement in a specific direction and continue along this path to specific vegetation areas, the movement was not random. The start and end GPS points allow us to infer

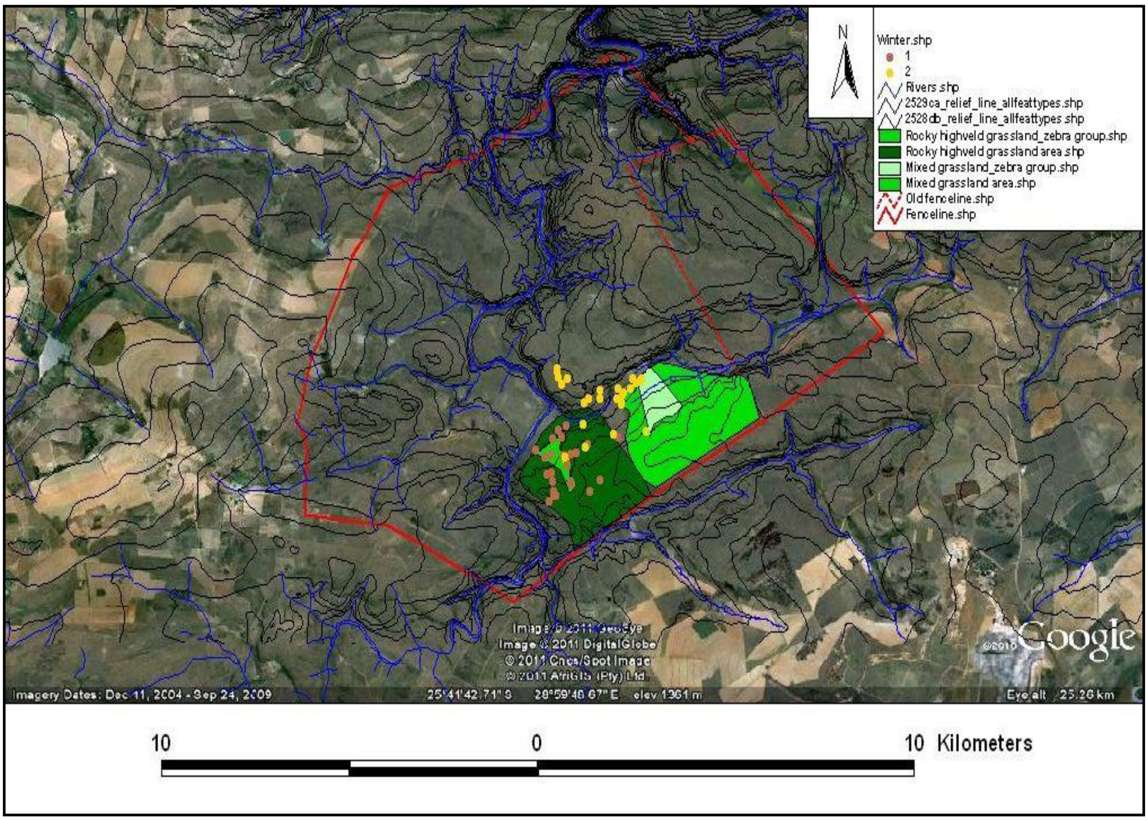

Figure 8.2. Position of plains zebra during winter.

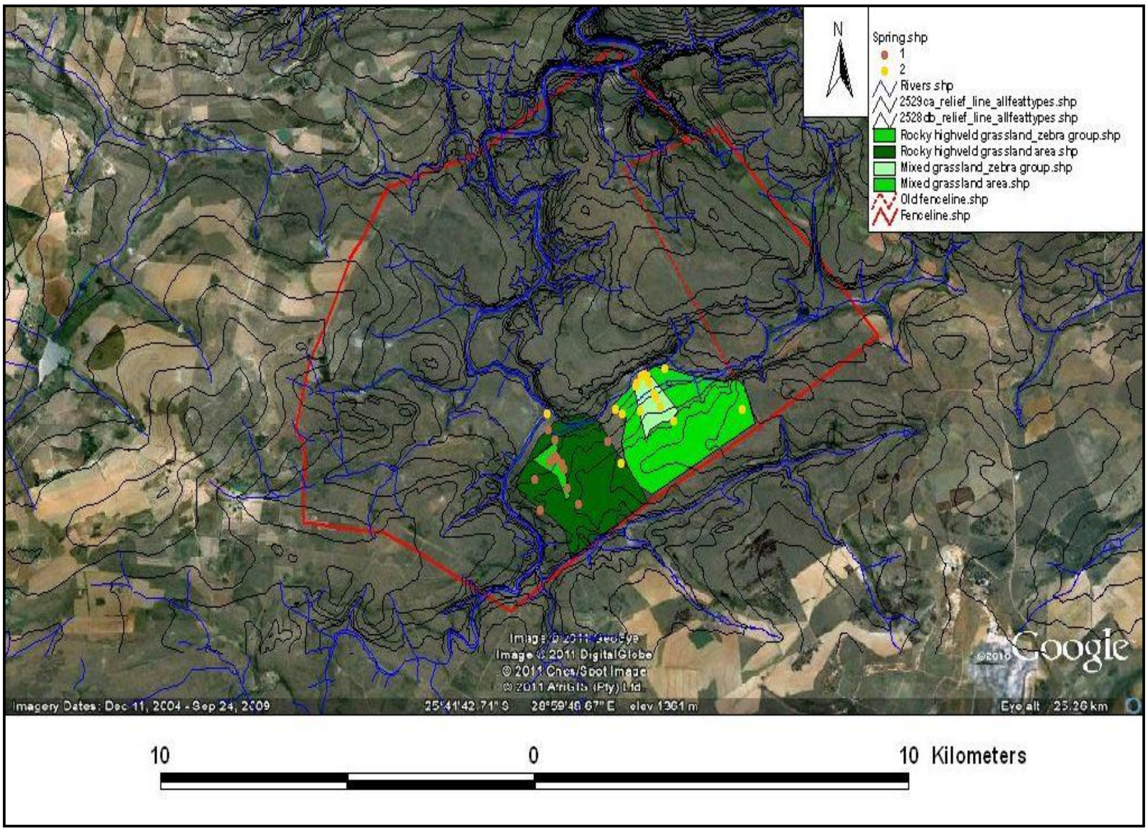

Figure 8.3. Position of plains zebra during spring.

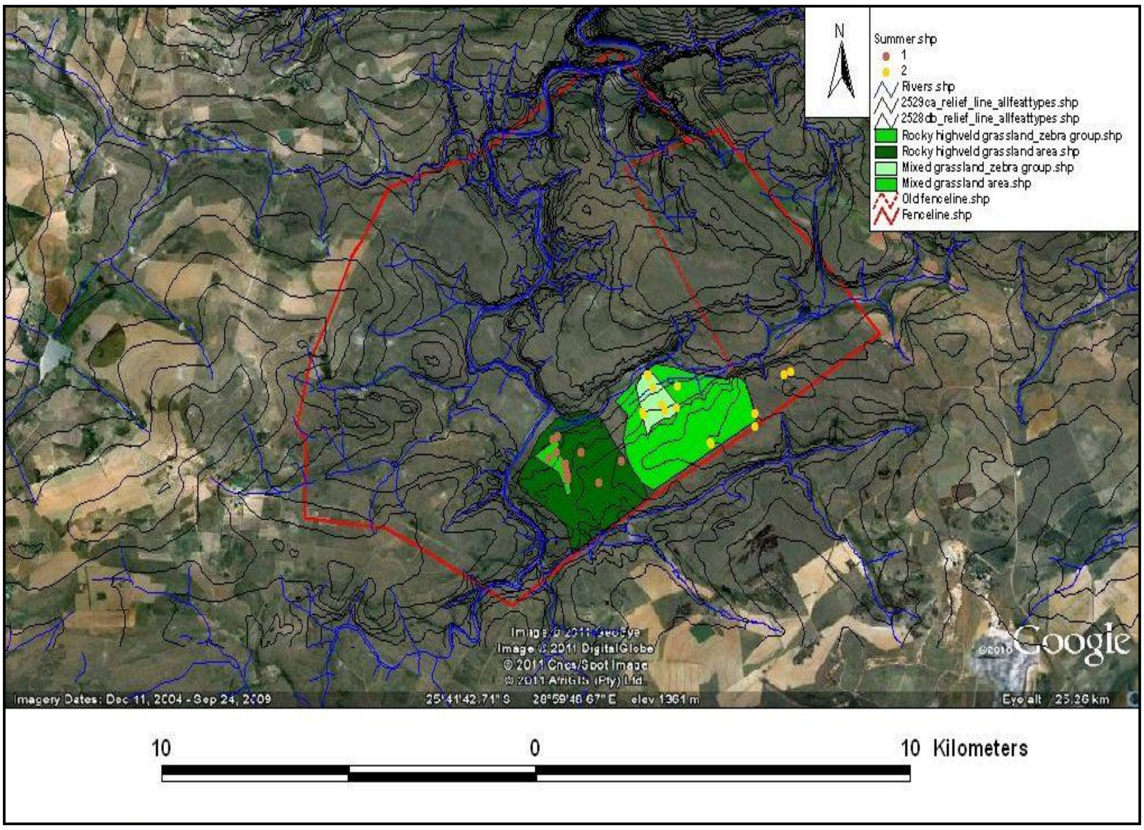

Figure 8.4. Position of plains zebra during summer.

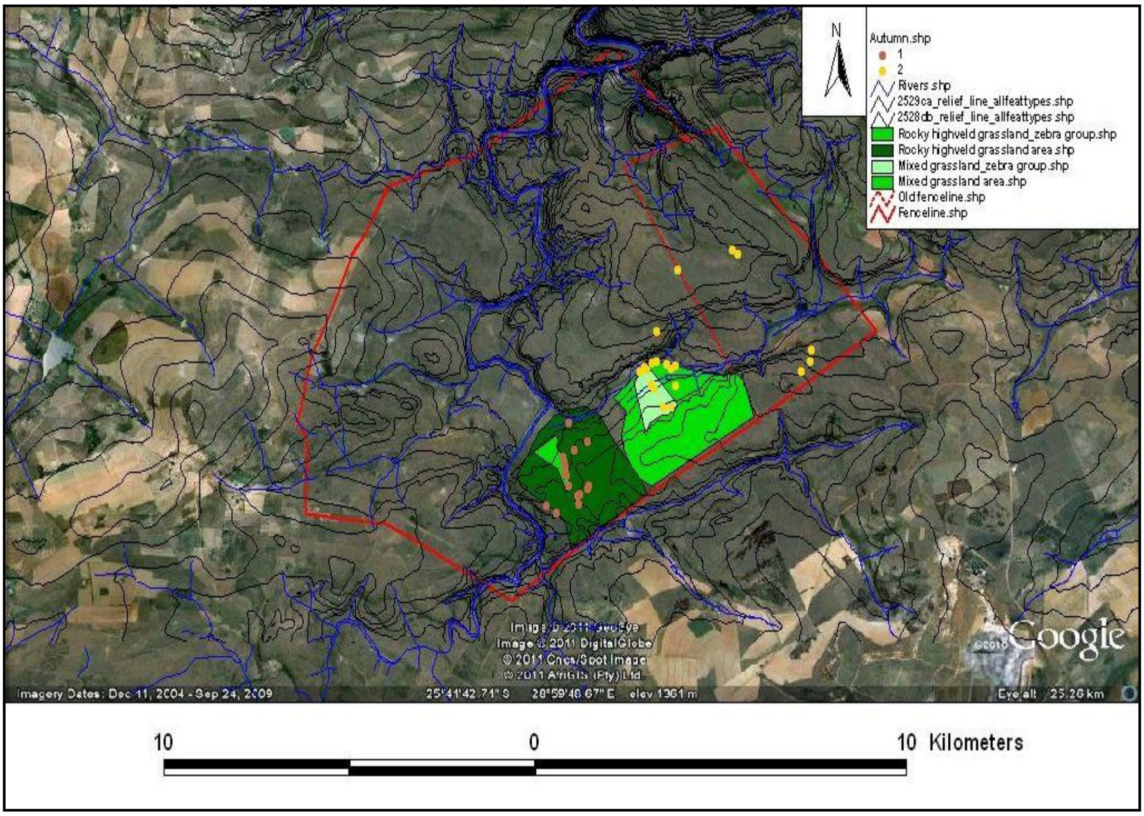

Figure 8.5. Position of plains zebra during autumn.

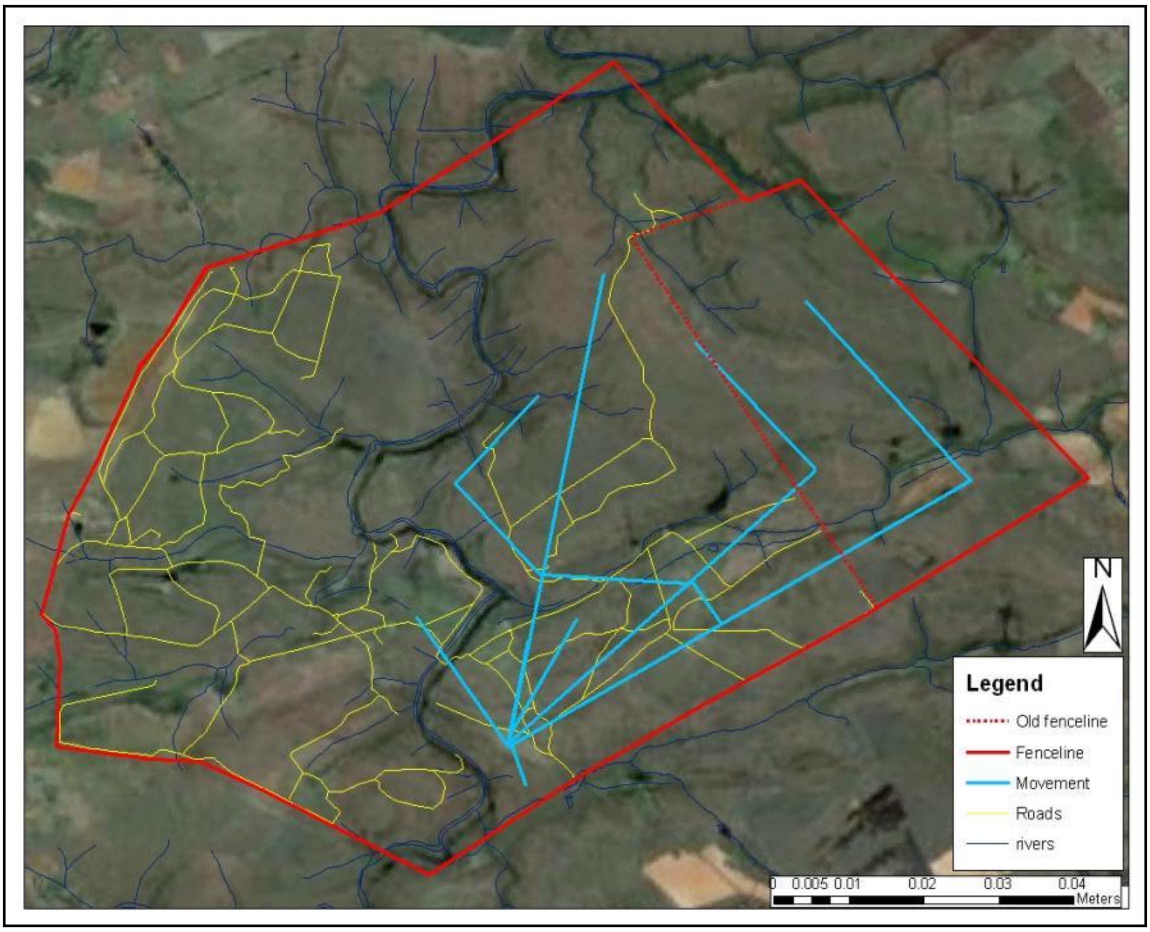

Figure 8.6. Migration of Telperion zebras in summer.

that they are spaciously aware of their surroundings allowing them to find suitable patches as these patches was much further than mere smell or sight. This behaviour is supported by the study done by Brooks and Harris (2007) where zebras also migrated in specific directions. They (Brooks & Harris 2007) found however that the movement was not aimed at specific patches and believes that the zebras use cues to migrate in a direction with known preferred patches.

An interesting observation was that during the tracking of the plains zebra, it became apparent that there was no discrete zebra group but numerous smaller groups intertwining, moving together and splitting apart in a random manner. Even though an area had for example twelve zebras grazing, a group of 3 individuals (stallion, mare and foal) would form their own entity and migrate away from the group at any given time. This may be the reason why no significant difference in feeding behaviour was found between the two plains zebra groups in their chosen habitat types – they were the same group moving between the mixed grassland and rocky grasslands. This is supported by a study done by Brooks & Harris (2007) that stated that foraging strategies for individual zebras is different and that zebra resource preference was based on the ability of the individual to remember where vegetation patches can be found.

8.4. Management of Telperion

In order to manage Telperion and the whole of eZemvelo, veld condition assessments can determine if a change in species composition or bush encroachment occurred etc. The result thereof will determine the management plan (Van Rooyen *et al.* 1996). A trend in veld condition can be established if the same site is surveyed annually at approximately the same time. In this case, no benchmark is necessary as the site is compared to itself (Van Rooyen *et al*. 1996; Tainton & Hardy 1999). The following paragraphs can be used to incorporate into such a management plan.

8.4.1. Alien weeds and invasive plant species.

Ecosystems around the world, including those found in Telperion, are threatened by invasion of alien weeds and invasive plant species (Browmilo 2001; Richardson & Van Wilgen 2004). The main cause for this phenomenon remains ignorance, lack of knowledge and carelessness. It is therefore of crucial importance that we recognise the problem and its causes and use the knowledge that we gained to manage it (Bromilow 2001).

A weed is defined as a plant that grows in an undesirable place at the wrong time. They have efficient methods of dispersal and reproduction can easily establish itself and grow rapidly. Normally they have a strong root system and are adaptable to various habitats and environmental conditions. They are fierce competitors and are difficult to eradicate (Browmilo 2001). In the case of Telperion, any plant that is an exotic invader and upsetting indigenous vegetation can be classified as a weed. Alien invasion may lead to the extinction of indigenous species in certain areas as these plants are pushed out of their natural habitat (Browmilo 2001; Henderson 2001). When indigenous plants start to disappear, the fauna relying on them also decrease. This causes an ecosystem to weaken and become unstable. It is these factors that increase the vulnerability of habitats to fires, floods and diseases (Browmilo 2001) as plant invaders modify biogeochemical cycles, trophic and physical resources such as food webs, habitat, light, sediment and water (Richardson & Van Wilgen 2004).

According to Richardson & Van Wilgen (2004) grasslands and savannas have been invaded widely but knowledge thereof is limited (Milton 2004; Richardson & Van Wilgen 2004). According to Milton (2004), the principle of invasion of grass species is simple. Stands of invasive grasses are unpalatable to herbivores and provide sufficient fuel for fires which allow these aliens to out-compete the indigenous species because they might not be adapted for fire or may be adapted to longer fire cycles (Milton 2004).

Milton (2004) believes re-seeding invaded areas with perennial plant and excluding fires and herbivores from that area may be the only way to reverse the invasion of annual grass invaders. It is important to understand that most annual invaders and some of the more serious perennial invaders are C_3 grasses (Milton 2004). In C_3 grasses the carbon-fixation pathway is most efficient at high altitudes and cool temperatures whereas C_4 grasses are most efficient in more tropical areas. Most Southern African grasses are C_4 grasses and are able to utilize nitrogen found in the soil efficiently because of low disturbance factors. With global warming the CO_2 concentration is increasing which may allow C_3 grasses to use nitrogen more efficiently and therefore ultimately becoming a greater threat to South African indigenous grasses (Milton 2004).

The control of invasive plant species is addressed under the Conservation of Agricultural Resources Act (CARA, Act No 43 of 1983). Regulation 15 (A) lists plants that are declared as weeds and Regulation 15 (B & C) list plants that are declared as invader plants. The categories are as follows:

Category 1 invaders: These species are prohibited and must be controlled or eradicated. They have no economical function and are harmful to humans, animals and/or the environment (Landcare South Africa 1983, Bromilow 2001).
Category 2 invaders: species proven to be invasive, but they have commercial value. They may also be soil stabilizers, animal fodder and woodlots but they must be controlled in demarcated areas and bio-control areas (Bromilow 2001). Category 2

plants may never occur within 30m of the 1:50 year floodline of any wetlands or watercourses (Landcare South Africa 1983).

Category 3 invaders: plants that are proven to have the potential of becoming invasive. These plants are however popular garden plants (ornamentals or shade trees). No trade or further planting of these species is allowed and the spread of current species must be prevented (Landcare South Africa 1983, Bromilow 2001).

The basic methods of control of weed and invasive alien species are Physical, Cultural, Biological or Chemical control. In Physical control, or also know as Mechanical control, it entails digging, cutting, bulldozing or hacking of the species. Cultural control includes the use of fire while Biological control is the use of biological agents such as diseases and insects that feed on the plant or seeds. Chemical control is the use of herbicides (Landcare South Africa 1983, Bromilow 2001).

Weed and invader species found at *Equus burchelli* grazing sites are tabulated in Table 8.1. (Van Wyk & Malan 1998; Van Oudtshoorn 2004; AGIS 2007). Please note that this list is not complete. A field investigation must be done to specifically identify all weeds and invasive species and deal with them accordingly, to allow indigenous species of Telperion, and the rest of eZemvelo, to prevail.

8.4.2. Medicinal plant species

Several species (Table 8.2) occurring on the site are known to have some medicinal value (Van Wyk *et al.* 2000; Van Wyk & Gericke 2003). During the field study, the farm workers and their families had several guests visiting. Should it become apparent that species are harvested for their medicinal value, a suitable management strategy may be to encourage them to harvest only the weed or invader species instead of banning it completely. In this way, both parties win.

Table 8.1. Weed and Invader species found at grazing sites.

Species name	Common Name	Invasive status
Chloris virgata	Feather-top Chloris	Not declared
Datura stramonium	Common Thorn Apple	Category 1: Declared weed and must be controlled
Eleusine coracana	Goose grass	Not declared
Heteropogon contortus	Spear grass	Not declared
Hyparrhenia hirta	Common Thatching grass	Not declared
Limeum viscosum	Klosaarbossie (Afrikaans)	Not declared
Loudetia simplex	Common Russet grass	Not declared
Monocymbium ceresiiforme	Boat grass	Not declared
Panicum maximum	Guinea Grass	Not declared
Panicum natalense	Natal Panicum	Not declared
Perotis patens	Cat’s Tail	Not declared
Solanum mauritianum	Bugweed	Category 1: Declared weed and must be controlled
Solanum sisymbrifolium	Wild Tomato	Category 1: Declared weed and must be controlled
Sporobolus africanus	Ratstail Dropseed	Not declared
Tagetes minuta	Khaki weed	Not declared
Trachypogon spicatus	Giant Spear grass	Not declared
Trichoneura grandiglumis	Small Rolling grass	Not declared
Tristachya leucothrix	Hairy Trident grass	Not declared
Verbena bonariensis	Wild Verbena	Not declared
Verbena brasiliensis		Not declared

Table 8.2. Medicinal species found at plains zebra grazing sites.

Species name	Common name	Use
Boophone disticha	Bushman poison bulb	Dry outer scales of the bulb used as a dressing after circumcision and are applied to boils and septic wounds. Decoctions of the bulb are taken orally or as enema for headaches, abdominal pain, weakness and eye conditions. Also used as a sedative. High doses induce hallucinations and can be fatal.
**Datura stramonium*	Common Thorn Apple	Potentially poisonous, added to beer to make it more intoxicating. Infusions and decoctions used to sedate hysterical and psychotic patients and as consciousness-altering snuff by diviners. Can cause mental confusion and hallucinations. Leaves of the plant are used to treat asthma, pain, hypnotics, aphrodisiac, rheumatism, gout, boils, abscesses, wounds, toothache, sore throat, tonsillitis, bronchitis, motion sickness, Parkinsonism and visceral spasms.
Elephantorrhiza elephantina	Elandsbean	The rhizomes are used for diarrhoea and dysentery, stomach disorders, haemorrhoids and perforated peptic ulcers. Also used for skin diseases and acne.
Hypoxis species	Inkomfe (Zulu)	Infusions of the corms are used as emetics to treat dizziness, bladder disorders and insanity. Decoctions are used as tonic and juices are applied to burns. Stems and leaves are mixed with other ingredients to treat prostate problems such as testicular tumours, prostate hypertrophy and urinary infections.
**Plantago lanceolata*	Ribwort	Some of its many uses are: as a vulnerary, as a bone healer, as an expectorant and as a decongestant. More uses are listed in the medicinal properties section. Herbal remedies are only prepared from the leaves.
**Sida cordifolia*	Flannel weed	Used for inflammation, asthma, bronchitis, and nasal congestion. Research suggest that it has hypoglycaemic (blood lowering properties), anti-inflammatory, and analgesic (pain relieving) properties. Because the leaves of Sida cordifolia contain small amounts of both ephedrine and pseudoephedrine many nutritional companies have included it as a weight loss product.

* *Tagetes minuta*	Khaki Weed	Treat nematode infestations and fleas on dogs
Vernonia oligocephala and various other *Vernonia* spp	Groenamara	Leaves, twigs and rarely roots used for abdominal pain, colic, rheumatism, dysentery, diabetes and ulcerative colitis.

* Weed or alien invader species

8.4.3. Management after burning

Various scientists believe that fire is catastrophic to vegetation but numerous ecologists however acknowledge it as a natural part of our environment (Tainton & Hardy 1999). South Africa commonly experiences unplanned fires during the dormant winter which may be man-induced or ignited by lightning (Snyman 2002; 2004). The effects thereof may be seen in the productivity even after the following season depending on the climatic condition (Snyman 2002). These fires remove accumulated litter (Snyman 2004). Botanical composition in South Africa is not influenced by fire (Snyman 2002; 2006) but the abundance of the species present change (Lunt 1990; O'Connor & Bredenkamp 1997; Snyman 2006).

A decrease in cover ensures sufficient light penetration needed for germination and growth (Morgan 2002; Ghebrehiwot *et al*. 2006) but leads to a decrease in soil water which only recovers in two growing seasons time (Snyman 2002). This results in an increase in evaporation (Snyman 2002). Burning also reduces organic soil matter which results in a reduction of soil fertility and may result in the breakdown of soil structure. This will lead to an increase in soil run-off and erosion. It was found however, that an increase in the pH and Ca, Mg, Na and K in the soil takes place. These concentrations continued to the middle of the second growing season (Snyman 2002). The effect of burning on soil moisture and nitrogen are important factors that influence the outcome of competition between species in the grassveld (Ghebrehiwot *et al*. 2006). In addition, fire also causes a decrease to the root biomass in the following season thus roots are more sensitive to fire than above-ground biomass. New growth is higher in minerals and nutrients only in the following season, thereafter there is little difference. If grazing occurs on these areas, recovery can be two years or even longer depending on the climatic conditions (Snyman 2002; 2004).

On 10 July 2007, the Rocky Highveld Grassland habitat was burnt down when a runaway fire occurred from a fire break. This is especially easy for grasses in the grassland biome as fires in this region are normally head-fires, intense and spread rapidly (Everson 1999). Initially this area was ignored by the animals but as the re-growth appeared large numbers of animals gathered to graze on this area. This led to severe overgrazing of this area. This is similar to statements made by Owen-Smith (1999). In order to prevent the detrimental effect of this overgrazing on vegetation in future, the area can be cordoned off, especially if it is such a small area.

Lunt (1990) and Everson (1999) describes fire as an appropriate management plan for grassland because it provides bare soil for seed germination and is less selective than grazing (Lunt 1990). The best time however to use fire as a management tool in grassland is late winter when grasses are still dormant. Should it not be possible to burn during this time, burning should be moved into winter rather than spring. The conventional method of using fire in management is burning areas in blocks equal in size and burnt in schedules (Everson 1999). It should be noted however that fire also promotes the establishment of weeds thus it should not be the only management tool applied (Lunt 1990).

8.6. References

AGIS, 2007. Agricultural Geo-Referenced Information System, accessed from www.agis.agric.za on July 2011

BREDENKAMP, G.J. & BROWN, L. 2003. A reappraisal of Acocks' Bankenveld: origin and diversity of vegetation types. *South African Journal of Botany* 69 (1): 7–26.

BREDENKAMP, G.J. & THERON, G.K. 1978. A synecological account of the Suikerbosrand Nature Reserve, Part II: The phytosociology of the Ventersdorp geological system. *Bothalia* 13: 199–216.

BROMILOW, C. 2001. *Problem Plants of South Africa.* Briza Publications CC, Pretoria.

BROOKS, C.J. & HARRIS, S. 2007. Directed movement and orientation across a large natural landscape by zebras, *Equus burchelli antiquorum. Animal Behaviour* 76: 277–285.

EVERSON, C.S. 1999. Veld burning in different vegetation types: Grassveld. In Tainton, N.M. (Ed.). *Veld Management in South Africa.* Natal University Press, Pietermaritzburg.

FAY, T.H. & GREEFF, J.C. 2006. Lion, Wildebeest and Zebra: A predator-prey model. *Ecological Modelling* 196: 237–244.

GHEBREHIWOT, H.M., FYNN, R.W.S., MORRIS, C.D. & KIRKMAN, K.P. 2006. Shoot and root biomass allocation and competitive hierarchies of four South African grass species on light, soil resources and cutting gradients. *African Journal of Range and Forage Science* 23(2):113-122.

GRANGE, S. & DUNCAN, P. 2006. Bottom-up and top-down processes in African ungulate communities' resources and predation acting on the relative abundance of zebra and grazing bovids. *Ecography* 29:899–907.

GRANGE, S., DUNCAN, P., GAILLARD, J., SINCLAIR, A.R.E., GOGAN, P.J.P, PACKER, C., HOFER, H. & EAST, M. 2004. What limits the Serengeti zebra population? *Oecologia* 140: 523–532.

GROVES, C.P. 1974. *Horses, asses and zebras in the wild*. David & Charles Newton Abbot, London.

LANDCARE SOUTH AFRICA. Brochure. CARA Legislation Made Easy. The Conservation of Agricultural Resources Act 1983 (Act No 43 of 1983) (CARA).

LUNT, I.D. 1990. Impact of an autumn fire on a long-grazed *Themeda triandra* (Kangaroo grass) grassland: implications for management of invaded, remnant vegetations. *Victorian Naturalist.* 107:45-51.

MACCLINTOCK, D. 1976. *A natural history of zebras*. Charles Scribner's Sons, New York.

MILTON, S. J. 2004. Grasses as invasive alien plants in South Africa. *South Africa Journal of Science* 100: 69–75.

MORGAN, J.W. 2001. Seedling recruitment patterns over 4 years in an Australian perennial grassland community with different fire histories. *Journal of Ecology* 89: 908-919.

NEUHAUS, P. & RUCKSTUHL, K.E. 2002. The link between sexual dimorphism, activity budgets, and group cohesion: the case of the plains zebra (*Equus burchelli*). *Canadian Journal of Zoology* 80: 1437–1441.

O'CONNOR, T.G., BREDENKAMP, G.J. 1997. Grassland. In: Cowling, R.M., Richardson, D.M., Pierce, S.M. (Eds.). *Vegetation of Southern Africa*. Cambridge University Press, Cambridge, pp. 615.

OWEN-SMITH, N.M. 1999. The animal factor in veld management. In: Tainton, N.M. (Ed.). *Veld Management in South Africa.* Natal University Press, Pietermaritzburg.

PENZHORN, B.L. & NOVELLIE, P.A. 1991. Some behavioural traits of Cape mountain zebras (*Equus zebra zebra*) and their implications for the management of a small conservation area. *Applied Animal Behavioural Science* 29: 293–299.

RICHARDSON, D.M. & VAN WILGEN, B.W. 2004. Invasive alien plants in South Africa: how well do we understand the ecological impacts? *South African Journal of Science* 100: 45–52.

SCHEEL, D. 1993. Watching for lions in the grass: the usefulness of scanning and its effects during hunts. *Animal Behaviour* 46: 695–704.

SMUTS, G.L. 1974. *Growth, reproduction and population characteristics of Burchell's zebra (Equus burchelli antiquorum, H. Smith, 1841) in the Kruger National Park.* Ph.D Thesis. University of Pretoria, Pretoria.

SNYMAN, H.A. 2002. Fire and the dynamics of a semi-arid grassland: influence on soil characteristics. *African Journal of Range and Forage Science* 19: 137-145.

SNYMAN, H.A. 2004. Short-term response in productivity following an unplanned fire in a semi-arid rangeland of South Africa. *Journal of Arid Environments* 56: 465-485.

SNYMAN, H.A. 2006 Short-term response of burnt-grassland to defoliation in a semi arid climate of South Africa. *African journal of Range and Forage Science* 23(1): 1-11.

STAHL, B. 1971. *The elusive zebra.* Addison-Wesley Publishing Company, Massachusetts.

SWANEPOEL, B.A. 2006. *The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspruit, South Africa.* M.Sc. Dissertation (Botany), University of Pretoria, Pretoria.

TAINTON, N.M. & HARDY, M.B. 1999. Introduction to the concepts of development of vegetation. In: Tainton, N.M. (Ed.). *Veld Management in South Africa.* University of Natal Press, Pietermaritzburg.

VAN OUDTSHOORN, F. 2004. *Guide to grasses of Southern Africa.* Briza Publishers, Pretoria.

VAN ROOYEN, N., BREDENKAMP, G.J. & THERON, G.K. 1996. Veld management. In: Bothma, J. du P. (Ed.). *Game ranch management*. J.L. van Schaik, Pretoria. Chapter 51, pp. 539–571.

VAN WYK, B-E. & GERICKE, N. 2003. *People's plants – A guide to useful plants of Southern Africa.* Briza Publications, Pretoria.

VAN WYK, B & MALAN, S. 1998. *Field guide to wild flowers of the Highveld.* Struik Publishers, Cape Town.

VAN WYK, B-E., VAN OUDTSHOORN, B. & GERICKE, N. 2000. *Medicinal Plants of South Africa.* Briza Publications, Arcadia.

WAND, S.J.E., MIDGLEY, G.F. & STOCK, W.D. 2002. Response to elevated CO_2 From a natural spring in a C_4-dominated grassland depends on seasonal phenology. *African Journal of Range & Forage Science* 19: 81–91.

9. CONCLUSION

In Telperion, there is a mosaic distribution of different vegetation types. One finds grasslands on the plains and plateaus, wetlands adjacent to streams and along floodplains and woodlands on the hills, ridges and occasionally fringing grasslands. As this reserve is positioned on geologically similar substrates, no clear separation between major vegetation types occurs. However, gradients were observed from one plant community to another. This feature results in a wide floristic diversity which requires unique veld management strategies for local conditions. It was established that numerous abundant and dominant plant species are shared among the two zebra grazing sites, underlining the transition between the communities. The vegetation at these preferred zebra grazing sites were identified and quantified. Combining the results obtained with the physical characteristics of the habitat, allowed the understanding of the migration that occurs during summer and winter, as well as the feeding and vigilant behaviour of the plains zebra. Therefore the objective of this study was accomplished to satisfaction. The list of medicinal species and alien and invader plant species can aid in management plans. However, this list should not be viewed as complete, as it only represents species found on grazing sites. A study specifically focussed on identification of such species is needed. It is crucial that information from this thesis assist in management plans of Telperion and that management remains a constant process in order the preserve the natural, increasingly fragmented habitat of the Bankenveld.

The natural environment is ever changing and cannot be controlled as if in a lab environment. In order to better understand the behaviour of plains zebras in Telperion, a more detailed study is required where all zebra groups are included, including those on eZemvelo and conditions are kept as constant as possible. This study faced difficulties when the Rocky Highveld Grassland habitat burnt down during a runaway fire from a fire break. After the fire this area was avoided by all animals affecting the locality where the behaviour of the Rocky Highveld Grassland zebras group was recorded. Thereafter, a large number of animals, including the plains zebras, gathered together to graze on the re-growth, once again changing the grazing pattern. In addition, fences were lifted to a newly acquired area resulting in large quantities of plains zebras migrating and gathering on the new area, once again affecting patterns that were observed previously. These difficulties however, pose unique information on the needs of the zebra population of Telperion, as well as veld management. Perhaps, the grass was greener on the other side.

10. REFERENCES

ACOCKS, J.P.H. 1988. Veld Types of South Africa. *Memoirs of the Botanical Survey of South Africa* No. 57.

AGIS, 2007. Agricultural Geo-Referenced Information System, accessed from www.agis.agric.za on July 2011

ANDERSEN, K.F. 1992a. Size, design and interspecific interactions as restrictors of natural behaviour in multi-species exhibits. 1. Activity and intraspecific interactions of Plains zebra (*Equus burchelli*). *Applied Animal Behaviour Science* 34: 157–174.

ANDERSEN, K.F. 1992b. Size, design and interspecific interactions as restrictors of natural behaviour in multi-species exhibits. 3. Interspecific interactions of Plains zebra (*Equus burchelli*) and Eland (*Tautotragus oryx*). *Applied Animal Behaviour Science* 34: 273–284.

BARBOUR, M.G., BURK, J.H. & PITTS, W.D. 1999.*Terrestrial plant ecology*. Benjamin/Cummings Publishing Company, Inc. Canada.

BODENSTEIN, V., MEISSNER, H.H. & VAN HOVEN, W. 2000. Food selection by Burchell's zebra and blue wildebeest in the Timbavati area of the Northern Province Lowveld. *South African Journal of Wildlife Research* 30: 63–72.

BOWLAND, A. E., BISHOP, K.S., TAYLOR, P.J., LAMB, J., VAN DER BANK, F.H., VAN WYK, E. & YORK, D. 2001. Estimation and management of genetic diversity in small populations of plains zebra (Equus quagga) in KwaZulu-Natal, South Africa. *Biochemical Systematics and Ecology* 29: 563–583.

BREDENKAMP, G.J. 1975. 'n Plantsosiologiese studie van die Suikerbosrand natuurreservaat. MSc Dissertation. University of Pretoria, Pretoria.

BREDENKAMP, G.J. 1982. *'n Plantekologiese studie van die Manyeleti*-*Wildtuin*. DSc Thesis, University of Pretoria, Pretoria.

BREDENKAMP, G.J. 1999. Grassland. In Knobel, J. *The magnificent natural heritage of South Africa.* Sunbird Publishing, Llandudno.

BREDENKAMP, G.J. 2001. Vegetation – more than just a species list! IAIA Newsletter 2001.

BREDENKAMP, G.J. & BROWN, L.R. 2001. Vegetation – A reliable ecological basis for environmental planning. Urban Greenfile, Nov/Dec 2001.

BREDENKAMP, G.J. & BROWN, L. 2003. A reappraisal of Acocks' Bankenveld: origin and diversity of vegetation types. *South African Journal of Botany* 69 (1): 7–26.

BREDENKAMP, G.J. & THERON, G.K. 1978. A synecological account of the Suikerbosrand Nature Reserve, Part II: The phytosociology of the Ventersdorp geological system. *Bothalia* 13: 199–216.

BREDENKAMP, G.J. & VAN ROOYEN, N. 1998. Rocky Highveld Grassland. In: Low, A.B. & Rebelo, A.G. (eds.). *Vegetation of South Africa, Lesotho and Swaziland*. Department of Environmental Affairs and Tourism, Pretoria.

BROMILOW, C. 2001. *Problem Plants of South Africa.* Briza Publications CC, Pretoria.

BROOKS, C.J. & HARRIS, S. 2007. Directed movement and orientation across a large natural landscape by zebras, *Equus burchelli antiquorum. Animal Behaviour* 76: 277–285.

COWLING, R.M., RICHARDSON, D. M. & PIERCE, S. M. 1997. *Vegetation of southern Africa.* Cambridge University Press. Cambridge.

EVERSON, C.S. 1999. Veld burning in different vegetation types: Grassveld. In Tainton, N.M. (Ed.). *Veld Management in South Africa.* Natal University Press, Pietermaritzburg.

FAY, T.H. & GREEFF, J.C. 2006. Lion, Wildebeest and Zebra: A predator-prey model. *Ecological Modelling* 196: 237–244.

GHEBREHIWOT, H.M., FYNN, R.W.S., MORRIS, C.D. & KIRKMAN, K.P. 2006. Shoot and root biomass allocation and competitive hierarchies of four South African grass species on light, soil resources and cutting gradients. *African Journal of Range and Forage Science* 23(2):113-122.

GRANGE, S. & DUNCAN, P. 2006. Bottom-up and top-down processes in African ungulate communities' resources and predation acting on the relative abundance of zebra and grazing bovids. *Ecography* 29:899–907.

GRANGE, S., DUNCAN, P., GAILLARD, J., SINCLAIR, A.R.E., GOGAN, P.J.P, PACKER, C., HOFER, H. & EAST, M. 2004. What limits the Serengeti zebra population? *Oecologia* 140: 523–532.

GROBLER, A. 1999. Phytosociology & Veld condition assessment of Ezemvelo Game Reserve. B.Sc (Hons). University of Pretoria, Pretoria.

GROVES, C.P. 1974. *Horses, asses and zebras in the wild*. David & Charles Newton Abbot, London.

GROVES, C.P. & BELL, C.H. 2004. New investigations on the taxonomy of the zebra genus Equus subgenus *Hippotigris*. *Mammalian Biology* 69:182–196.

HACK, M.A. & RUBENSTEIN, D.I. 1998. Zebra zones. *Natural History* 107 (2): 26–28.

HELM, C.V. 2006. *Ecological separation of the black and blue wildebeest at Ezemvelo Nature Reserve in the Central grasslands of South Africa.* M.Sc. Dissertation (Wildlife Management), University of Pretoria, Pretoria.

HENDERSON, L. 2001. *Alien weeds and invasive plants.* Agricultural Research Council, Pretoria.

HENNEKENS, S.M. 1996. *TURBOVEG: A Software Package for Constructing Phytosociological Tables*. IDLO, Wageningen.

HENNEKENS, S.M. & SCHAMINEE, J.H.J. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. *Journal of Vegetation Science* 12:589–591.

HURT, C.R. & BOSCH, O.J.H. 1991. A comparison of some range condition assessment techniques used in southern Africa grasslands. *Journal of the Grassland Society of South Africa.* 8: 131-136.

KENT, M. & COKER, P. 1994. *Vegetation description and analysis: A practical approach.* John Wiley & Sons Inc. England.

KROHNE, D.T. 2001. *General ecology.* Brook/Cole. A division of Thompson Learning, Inc, Pacific Grove.

LANDCARE SOUTH AFRICA. Brochure. CARA Legislation Made Easy. The Conservation of Agricultural Resources Act 1983 (Act No 43 of 1983) (CARA).

LAND TYPE SURVEY STAFF. 1987. Land types of the maps 2526 Rustenburg, 2528 Pretoria. Memoirs on the Agricultural Natural Resources of South Africa No. 8.

LOW, A. B. & REBELO, A. G. 1998. *Vegetation of South Africa, Lesotho and Swaziland.* Department of Environmental Affairs and Tourism, Pretoria.

LUNT, I.D. 1990. Impact of an autumn fire on a long-grazed *Themeda triandra* (Kangaroo grass) grassland: implications for management of invaded, remnant vegetations. *Victorian Naturalist.* 107:45-51.

LUNT, I.D. & MORGAN, J.W. 1999. Vegetation change after 10 years of grazing exclusion and intermittent burning in a *Themeda triandra* (Poaceae) grassland reserve in South-eastern Australia. *Australian Journal of Botany* 47: 537-552.

MACCLINTOCK, D. 1976. *A natural history of zebras*. Charles Scribner's Sons, New York.

McCUNE, B. & MEFFORD, M.J. 1999. *Multivariate analysis of ecological data.* Version 4.0.MjM Software, Gleneden Beach, Oregon, USA.

MILTON, S. J. 2004. Grasses as invasive alien plants in South Africa. *South Africa Journal of Science* 100: 69–75.

MORGAN, J.W. 2001. Seedling recruitment patterns over 4 years in an Australian perennial grassland community with different fire histories. *Journal of Ecology* 89: 908-919.

MUCINA, L. & RUTHERFORD, M.C. (eds.) 2006. The vegetation of South Africa, Lesotho and Swaziland. *Strelitzia* 19. South African Biodiversity Institute, Pretoria.

MUELLER-DOMBOIS, D. & ELLENBERG, H. 1974. *Aims and Methods of Vegetation Ecology*. Wiley, New York.

NEUHAUS, P. & RUCKSTUHL, K.E. 2002. The link between sexual dimorphism, activity budgets, and group cohesion: the case of the plains zebra (*Equus burchelli*). *Canadian Journal of Zoology* 80: 1437–1441.

O'CONNOR, T.G., BREDENKAMP, G.J. 1997. Grassland. In: Cowling, R.M., Richardson, D.M., Pierce, S.M. (Eds.). *Vegetation of Southern Africa*. Cambridge University Press, Cambridge, pp. 615.

OOSTHUIZEN, I.B. & SNYMAN, H.A. 2003. Impact of water stress on growth reserves and re-growth of *Themeda triandra* (Forssk.) following defoliation. *African Journal of Range & Forage Science* 20: 41-45.

OWEN-SMITH, N.M. 1999. The animal factor in veld management. In: Tainton, N.M. (Ed.). *Veld Management in South Africa.* Natal University Press, Pietermaritzburg.

PENZHORN, B.L. & NOVELLIE, P.A. 1991. Some behavioural traits of Cape mountain zebras (*Equus zebra zebra*) and their implications for the management of a small conservation area. *Applied Animal Behavioural Science* 29: 293–299.

PLUHAČEK, J. & BARTOŠ, L. 2000. Male infanticide in captive plains zebra, *Equus burchelli*. *Animal Behaviour* 59: 689–694.

PLUHAČEK, J., BARTOŠ, L. & ČULÍK, L. 2006. High ranking mares of captive plains zebras *Equus burchelli* have a greater reproductive success than low-ranking mares. *Applied Animal Behaviour Science* 99: 315–329.

PLUHAČEK, J., BARTOŠ, L., DOLEŽALOVA, M., BARTOŠ-VÍCHOVA, J. 2006. Sex of the foetus determines the time of weaning of the previous offspring of captive plains zebra (*Equus burchelli*). *Applied Animal Behaviour Science*, in press.

POOLEY, E. 1998. *A field guide to wild flowers of Kwa-Zulu Natal and the Eastern Region.* Natal Flora Publications Trust, Durban.

REYERS, B., FAIRBANKS, D.H.K., VAN JAARSVELD, A.S. & THOMPSON, M. 2001. Priority areas for the conservation of South African vegetation: A course filter approach. *Diversity and Distributions* 7:77–96.

RICHARDSON, D.M. & VAN WILGEN, B.W. 2004. Invasive alien plants in South Africa: how well do we understand the ecological impacts? *South African Journal of Science* 100: 45–52.

RUXTON, G. 2002. The possible fitness benefits of striped coat coloration for zebra. *Mammal Review* 32: 237–244.

SCHEEL, D. 1993. Watching for lions in the grass: the usefulness of scanning and its effects during hunts. *Animal Behaviour* 46: 695–704.

SCHILDER, M.B.H. & BOER, P.L. 1987. Etological investigations on a herd of Plains Zebra in a Safari Park: Time-Budgets, Reproduction and Food Competition. *Applied Animal Behaviour Science* 18: 45–56.

SKINNER, J.D. & CHIMIMBA, T.C. 2005. The Mammals of the Southern African Subregion. 3rd edition. Cambridge University Press, Cape Town.

SMUTS, G.L. 1974. *Growth, reproduction and population characteristics of Burchell's zebra (Equus burchelli antiquorum, H. Smith, 1841) in the Kruger National Park.* Ph.D Thesis. University of Pretoria, Pretoria.

SNYMAN, H.A. 1993. The effect of defoliation during wilting on the production of *Themeda triandra* and *Eragrostis lehmanniana* in semi-arid grassland. *African Journal of Range & Forage Science* 10(3): 113-117.

SNYMAN, H.A. 2002. Fire and the dynamics of a semi-arid grassland: influence on soil characteristics. *African Journal of Range and Forage Science* 19: 137-145.

SNYMAN, H.A. 2004. Short-term response in productivity following an unplanned fire in a semi-arid rangeland of South Africa. *Journal of Arid Environments* 56: 465-485.

SNYMAN, H.A. 2006 Short-term response of burnt-grassland to defoliation in a semi arid climate of South Africa. *African journal of Range and Forage Science* 23(1): 1-11.

SOUTH AFRICAN WEATHER SERVICES. 2008. Maximum and Minimum temperatures for Witbank Station 0515320 8 from 1993 to 2008.

SOUTH AFRICAN WEATHER SERVICES. 2008. Climate statistics for Witbank Station 0515320 8 from 1993 to 2006.

SOUTH AFRICAN WEATHER SERVICES. 2008. Monthly daily rain for Kungwini Local Municipality 051440 8 X from 1978-2008.

SOUTH AFRICAN WEATHER SERVICES. 2008. Monthly daily rainfall for Witbank Station 0515320 8 from 1993 to 2008.

STAHL, B. 1971. *The elusive zebra.* Addison-Wesley Publishing Company, Massachusetts.

SWANEPOEL, B.A. 2006. *The vegetation ecology of Ezemvelo Nature Reserve, Bronkhorstspruit, South Africa.* M.Sc. Dissertation (Botany), University of Pretoria, Pretoria.

TAINTON, N.M. & HARDY, M.B. 1999. Introduction to the concepts of development of vegetation. In: Tainton, N.M. (Ed.). *Veld Management in South Africa.* University of Natal Press, Pietermaritzburg.

THERON, A. 1991. *The behavioural ecology of two zebra species on game farms in the Waterberg, northern Transvaal*. M.Sc. Dissertation (Wildlife Management). University of Pretoria, Pretoria.

TICHỲ, L. 2002. JUICE, software for vegetation classification. *Journal of Vegetation Science* 13:451–453.

VAN OUDTSHOORN, F. 2004. *Guide to grasses of Southern Africa.* Briza Publishers, Pretoria.

VAN ROOYEN, N., BREDENKAMP, G.J. & THERON, G.K. 1996. Veld management. In: Bothma, J. du P. (Ed.). *Game ranch management*. J.L. van Schaik, Pretoria. Chapter 51, pp. 539–571.

VAN WYK, A.E. & SMITH, G.F. 2001. *Regions of Floristic Endemism in Southern Africa. A review with emphasis on Succulents.* Umdaus Press, South Africa.

VAN WYK, B-E. & GERICKE, N. 2003. *People's plants – A guide to useful plants of Southern Africa.* Briza Publications, Pretoria.

VAN WYK, B & MALAN, S. 1998. *Field guide to wild flowers of the Highveld.* Struik Publishers, Cape Town.

VAN WYK, B. & VAN WYK, P. 1997. *Field guide to the trees of southern Africa*. Struik Publishers, Cape Town.

VAN WYK, B-E., VAN OUDTSHOORN, B. & GERICKE, N. 2000. *Medicinal Plants of South Africa.* Briza Publications, Arcadia.

WAND, S.J.E., MIDGLEY, G.F. & STOCK, W.D. 2002. Response to elevated CO_2 From a natural spring in a C_4-dominated grassland depends on seasonal phenology. *African Journal of Range & Forage Science* 19: 81–91.

WERGER, M.J.A. 1974. On concepts and techniques applied in the Zürich-Montpellier method of vegetation survey. *Bothalia* 11:309–323.

WESTHOFF, V. & VAN DER MAAREL, E. 1973. The Braun-Blanquet approach. In: *R.H. Whittaker, Handbook of vegetation science.* The Hague: Junk.

SUMMARY

The effect of vegetation on the behaviour and movements of Burchell's Zebra (*Equus burchelli*) in the Telperion Nature Reserve, Mpumalanga, South Africa.

by

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Telperion is but a portion of the 13 000 ha eZemvelo Nature Reserve, located in Mpumalanga Province of South Africa. It falls within the Grassland biome of which 60-80 % is transformed by Agriculture, Industrialisation, Urbanisation and Mining. It is therefore of critical importance to manage the 2.3% grasslands currently conserved in reserves. The objective of this study was to determine the interaction of Telperion zebras with their vegetation habitats, the influence of vegetation on their movement and how it differs seasonally, focusing specifically on two groups in distinctly different habitat types.

Hourly zebra observations took place by distinguishing between stallions, mares and foals during different times of the day, throughout a year both in a Rocky Highveld Grassland community and a Mixed Grassland community. The bytes per hour were noted for each randomly chosen individual by means of a stop watch. Bytes were defined as the time a zebra's head is in the grass or on the ground. As soon as it lifted its head, the time was stopped and recorded. When a zebra resumed feeding, the watch was restarted. This was repeated per group several times during one hour, three times a day, two days every month for one year during June 2007 to May 2008. No distinct differences were observed in the

feeding rates between the two different habitat types. Mares spent the most time feeding followed by stallions and lastly foals in both vegetation habitats. In addition, zebras of these two communities spent the most time feeding during evenings. In both the Rocky Highveld Grassland and the Mixed Grassland communities the stallions were most vigilant and foals the least vigilant. Zebras were less vigilant during grazing when large numbers were gathered in the same area. Ultimately it was found that there were not two distinct zebra groups but numerous smaller groups that migrate between the two habitat types, essentially from a central point. During summer the zebras migrated to different parts of the reserve whilst in winter migration was to the closet rocky ridge. From these observations Zebra habitat was identified and vegetation surveys were conducted in each of these grazing sites.

Two major plant communities were identified according to the Braun-Blanquet vegetation sampling method from 52 relevés and a total of 196 species. Due to the homogenous nature of the grasslands, many abundant and dominant species are shared between these two communities. The plant species recorded for each sample plot were captured in the vegetation database TURBOVEG. The database was exported into the working directory JUICE. Using the ordination programme PCOrd, a Detrended Correspondence Analysis (DECORANA) ordination was applied to the data set. This was done to confirm the identity the plant communities. In addition, a vegetation gradient was identified, implying that zebras utilise both vegetation communities, as well as the transition between the communities.

The understanding of zebra behaviour contributes to management and mitigation for good veld conditions in Telperion.

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SPECIES LIST

This list contains only species found at vegetation sampling sites.

Pteridophyta

Pteridaceae

Pellaea calomelanos (Sw.) Link

Angiosperms

Acanthaceae

Crabbea angustifolia Nees

Amaranthaceae

Gomphrena celosioides Mart.

Guilleminea densa (Humb. & Bonpl. ex Schult.) Moq.

Amaryllidaceae

Boophane disticha (L.f) Herb.

Anacardiaceae

Lannea edulis (Sond.) Engl.

Searsia lancea L.f.

Searsia magalismontana Sond.

Searsia pyroides Burch.

Apocynaceae

Gomphocarpus fruticosus (L.) Aiton f.

Pentarrhinum insipidum E.Mey.

Araceae

Stylochieton natalensis Schott

Asparagaceae

Asparagus burchellii Baker

Asparagus species L.

Asparagus suaveolens Burch.

Asteraceae

Bidens bipinnata L.

Conyza albida Spreng.

Conyza bonariensis L.

Conyza podocephala DC

Conyza species

Dicoma anomala Sond.

Felicia mossambicensis Oliv.

Felicia muricata (Thunb.) Nees

Helichrysum acutatum DC

Helichrysum rugulosum Less.

Helichrysum species

Pseudognaphalium luteo-album (L.) Hilliard & Burtt

Schistostephium crataegifolium (DC) Fenzl ex Harv.

Schkuhria pinnata (Lam.) Cabrera

Senecio species

Senecio venosus Harv.

Seriphium plumosum (Herb Linn.)

Tagetes minuta L.

Vernonia oligocephala (DC.) Sch.Bip. ex Walp.

Vernonia poskeana Vatke & Hildebr.

Vernonia staehelinoides Harv.

Brassicaceae

Lepidium africanum (Brum.f.) DC.

Campanulaceae

Wahlenbergia undulata (L.f) A.DC.

Capparaceae

Cleome maculate (Sond.) Szyszyl.

Cleome monophylla L.

Cleome rubella Burch.

Caryophyllaceae

Pollichia campestris Aiton

Chrysobalanaceae

Parinari capensis Harv.

Commelinaceae

Commelina africana L.

Commelina erecta L.

Commelina livingstonii (C.B.Clarke) C.V.Morton

Commelina species L.

Convolvulaceae

Convolvulus sagittatus Thunb.

Ipomoea crassipes Hook.

Ipomoea crispa (Thunb.) Hallier f.

Ipomoea ommaneyi Rendle

Crassulaceae

Crassula species L.

Kalanchoe paniculata Harv.

Cucurbitaceae

Cucumis zeyheri Sond.

Cyperaceae

Bulbostylis densa (Wall.) Hand. -Mazz.

Bulbostylis hispidula (Vahl) R.W.Haines

Cyperus esculentus L.

Cyperus obtusiflorus Vahl

Cyperus rotundus L.

Cyperus rupestris Kunth

Cyperus species

Fuirena pubescens (Poir.) Kunth

Kyllinga alba Nees

Dichapetalaceae

Dichapetalum cymosum (Hook.) Engl.

Dipsacaceae

Scabiosa columbaria L.

Euphorbiaceae

Phyllanthus parvulus Sond.

Phyllanthus parvus Hutch.

Fabaceae

Aspalathus suaveolens Eckl. & Zeyh.

Burkea africana Hook.

Chamaecrista comosa E. Mey.

Chamaecrista mimosoides (L.) Greene

Elephantorrhiza burkei Benth.

Elephantorrhiza elephantina (Burch.) Skeels

Eriosema salignum E. Mey.

Indigofera comosa N.E.Br.

Indigofera filiformis L.f.

Indigofera filipes Benth. Ex Harv.

Indigofera species

Mundulea sericea (Willd.) A. Chev.

Rhynchosia monophylla Schltr.

Tephrosia longipes Meisn.

Tephrosia lupinifolia DC.

Zornia linearis E.Mey.

Flacourtiaceae

Dovyalis caffra (Hook. f. & Harv.) Hook. f.

Hyacinthaceae

Ledebouria species

Hypoxidaceae

Hypoxis rigidula

Hypoxis species Baker

Iridaceae

Gladiolus elliotii Baker

Gladiolus sericeovillosus Hook. f.

Gladiolus species

Lamiaceae

Hemizygia pretoriae (Gürke) M.Ashby

Leonotis leonurus (L.) R.Br.

Leonotis ocymifolia (Burm.f.) Iwarsson

Malvaceae

Hibiscus engleri K.Schum.

Sida cordifolia L.

Molluginaceae

Limeum species

Limeum viscosum (J. Gay) Fenzl

Ochnaceae

Ochna pulchra Hook.

Onagraceae

Oenothera indecora Cambess.

Orobanchaceae

Striga elegans Benth.

Oxalidaceae

Oxalis obliquifolia Steud. Ex Rich.

Pedaliaceae

Ceratotheca triloba (Beernh.) Hook.f.

Sesamum alatum Thonn.

Sesamum triphyllum Welw. Ex Asch.

Plantaginaceae

Plantago lanceolata L.

Poaceae

Andropogon schirensis A.Rich.

Aristida congesta Roem. & Schult. subspecies barbicollis (Trin. & Rupr.)

Aristida congesta Roem. & Schult. subspecies congesta

Aristida stipitata Hack.

Aristida transvaalensis Henrard

Bewsia biflora (Hack.) Gooss.

Chloris gayana Kunth.

Chloris virgata Sw.

Cymbopogon plurinodis (Stapf) Stapf ex Burtt Davy

Cynodon dactylon (L.) Pers.

Dactyloctenium aegyptium (L.) Willd.

Digitaria eriantha Steud.

Diheteropogon amplectens (Nees) Clayton

Eleusine coracana (L.) Gaertn.

Elionurus muticus (Spreng.) Kuntze

Eragrostis chloromelas Steud.

Eragrostis curvula (Schrad.) Nees

Eragrostis gummiflua Nees

Eragrostis nindensis Ficalho & Hiern

Eragrostis plana Nees.

Eragrostis racemosa (Thunb.) Steud.

Eragrostis trichophora Coss. & Durieu

Heteropogon contortus (L.) Roem. & Schult.

Hyparrhenia hirta (L.) Stapf

Loudetia simplex (Nees) C.E.Hubb

Melinis repens (Willd.) Zizka

Monocymbium ceresiiforme (Nees) Stapf

Panicum maximum Jacq.

Panicum natalense Hochst.

Perotis patens Gand.

Pogonarthria squarrosa (Roem. & Schult.) Pilg.

Schizachyrium sanguineum

Setaria sphacelata (Schumach.) Moss

Sporobolus africanus (Poir.) Robyns & Tournay

Sporobolus stapfianus Gand.

Themeda triandra Forssk.

Trachypogon spicatus (L.f) Kuntze

Tricholaena monachne (Trin.) Stapf & C.E.Hubb.

Trichoneura grandiglumis (Nees) Ekman

Tristachya biseriata Stapf

Tristachya leucothrix Nees

Tristachya rehmannii Hack.

Urelytrum agropyroides (Hack.) Hack.

Polygalaeae

Polygala hottentotta C.Presl.

Portulacaceae

Portulaca kermesina N.E. Br.

Proteaceae

Protea welwitschii Engl.

Rubiaceae

Fadogia homblei De Wild.

Kohautia virgata (Willd.) Bremek

Oldenlandia herbacea (L.) Roxb.

Richardia brasiliensis Gomes

Sapotaceae

Englerophytum magalismontanum (Sond.) T.D.Penn.

Scrophulariaceae

Hebenstretia comosa Hochst.

Manulea parviflora Benth.

Solanaceae

Datura stramonium L.

Solanum incanum L.

Solanum mauritianum Scop.

Solanum panduriforme E. Mey.

Solanum sisymbrifolium Lam.

Sterculiaceae

Hermannia depressa N.E.Br.

Tiliaceae

Triumfetta sonderi Ficalho & Hiern

Velloziaceae

Xerophyta retinervis Baker

Verbenaceae

Verbena bonariensis L.

Verbena brasiliensis Vell.