THE ECOLOGICAL PLANNING OF DOORNKLOOF NATURE RESERVE, NORTHERN CAPE PROVINCE

By

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Declaration

I, the undersigned, hereby declare the work contained in this dissertation, for the degree Master of Science (Wildlife Management) is my own original work and that I have not previously in its entirety or in part submitted it at any other University for a degree.

Signature..

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Chapter 1: Introduction

With the rapidly diminishing wildlife resources and biodiversity in Africa and the world as a whole, the conservation and proper management of our environment and wildlife resources have become a critical priority. According to the Endangered Wildlife Trust (2004), South Africa is regarded as the third most biological diverse country in the world that contains 10% of global plant, bird and freshwater fish diversity, and approximately 6% of mammal and reptile diversity, but contributes less than 1% of the global land surface. Therefore, it is a cause of great concern that formal conservation areas not only comprise a very small percentage of South Africa (6.1%), but are also endangered through ineffective management due to a lack of adequate resources to aid managers. The land area covered by conservancies in South Africa is also significantly lower than the world average of 12.7% for terrestrial land (Bertzkey *et al.,* 2012). Furthermore, these small areas covered by conservancies are facing increasing pressures and threats in the form of habitat loss, fragmentation, isolation, illegal exploitation, invasive species, inappropriate policies and a lack of capacity to implement policies (IUCN, 2004).

Since wildlife initially held no monetary value and was regarded as competition to livestock for resources, the numbers of wildlife diminished throughout Africa and particularly in South Africa. However, along with the gradual decrease in wildlife numbers, the economical value of wildlife increased exponentially. The increasing value of game has consequently resulted in more and more farmland being converted to game ranches (NAMC, 2006, Absa 2002). According to statistics from the NAMC (2006) there were approximately 9 000 game ranches in 2006, which included big, small, breeding, intensive and extensive farms in South Africa. In comparison to the small section comprised of formal conservation areas (6.1%), game ranches comprise 17.0 % of the country's total land area (NAMC, 2006). In 2006 South Africa had 22 national parks and about 100 provincial parks (NAMC, 2006).

In response to the diminishing wildlife numbers, government conservation agencies were instituted. These agencies established National Parks and Provincial Nature Reserves throughout South Africa with the main purpose of conserving our heritage. In 1926 the first National Parks Act was promulgated, while South Africa's first National Park, the Kruger National Park, was also established during this period. Another three national parks, namely the Addo-, the Bontebok- and the Kalahari Gemsbok National Park, were additionally established in 1931 (NAMC, 2006).

In South Africa, there are different kinds of protected areas that come in various forms that differ in their conservation objectives and consequently also their wildlife management programmes. Other forms of conservation areas in South Africa include Trans-Frontier Parks, Conservancies and World heritage sites (Du Toit, 2002). Protected areas are of great importance as they provide us with unique insight into the functioning of biotic communities and ecosystems in which human interference is very low (Arcese & Sinclair, 1997). Today the core challenges facing conservancies is preserving and conserving natural areas and reducing biodiversity loss (Rodriques *et al.,* 2004; Ehrlich & Pringle, 2008; Bertzkey *et al.,* 2012).

The PROTECTED AREAS ACT (2003), stipulates that the purposes of declaring areas as protected areas are: (i) to protect ecologically viable areas representative of South Africa's biological diversity, and its natural landscapes and seascapes in a system of protected areas; (ii) to preserve the ecological integrity of those areas; (iii) to conserve biodiversity in those areas; (iv) to protect areas representative of all ecosystems, habitats and species naturally; (v) to protect South Africa's threatened or rare species; (vi) to protect an area which is vulnerable or ecologically sensitive; (vii) to assist in ensuring the sustained supply of environmental goods and services; (viii) to provide for the sustainable use of natural and biological resources; (ix) to create or augment destinations for nature-based tourism; (x) to manage the interrelationship between natural environmental biodiversity, occurring in South Africa.

The NAMC (2006) defines wildlife ranching as the management of game in a system with minimal human interference in forms such as water provision, food provision, parasite control and health care. Wildlife ranching differs mainly from state conservancies by principally being an agricultural enterprise with the main aim of sustainable utilisation of valuable but vulnerable natural resources (NAMC, 2006). A wide range of non-consumptive activities and consumptive activities provided by the sector generates the income. Non-consumptive activities include activities such as tourism, wildlife sales, wildlife viewing and accommodation, while consumptive activities include recreational hunting, trophy hunting and meat production (NAMC, 2006).

More than 80 % of South Africa is land surface is predominantly under private ownership of which approximately 20.5 million ha falls under conservation (NAMC, 2006; Smit, 2007). With such a large area under private ownership, it is obvious that the private sector has an important role in the conservation of both plant and animal species and their ecosystems. However, Smit (2007) states that the conversion of a farming enterprise from livestock to game is not necessarily synonymous to conservation. The misconception exists that game ranching is “an easy farming system” as there are no camps and thus no grazing rotation system to be applied. The truth, however, is that game ranching is far more complex than generally anticipated (Smit, 2007). Since game ranching is a multi-species production system that utilizes a wide range of habitats, grazing/browsing strata and veld conditions, the number of variables that need to be taken into account is much higher. Therefore, a broad knowledge base and an active, rather than a passive approach to management is required. With the expansion of the game ranching industry and consequent increase in competition in this industry, the need of a sound scientific approach which include both ecological and economical principles, is paramount to ensure long-term success (Smit, 2007).

Wildlife ranching has been the fastest growing sector in agriculture over the past 30 years (NAMC, 2006). The fast growth of the game ranching industry, particularly over the past 10 years, is best indicated by the sales of wildlife and increase in game ranchers (Bothma, 2002; NAMC, 2006). From 1992 to 2005 the number of exempted game ranchers almost doubled from 3 357 to 6 330, representing an increase of approximately 6.4% per year (NAMC, 2006). During 1991 the sales of wildlife auctions amounted to R 9 million, of which 68.0 % were sold by various conservation authorities (Conroy, 1993). During 2002, the income of live animal sales escalated to R 105 million, with most of the animals sold by private owners (Eloff, 2006). In comparison to other facets of the game ranching industry, the live sales of wildlife contribute only a small percentage to the total gross income of the industry. According to rough estimates of NAMC (2006), the recreational hunting industry is the largest contributor (66%) to the industry, with a value of 3 100 million, followed by the translocation industry (16%, worth 750 million); trophy hunting industry (11%, worth 510 million); the taxidermist sector (4%, worth 200 million); live animal sales (2%, worth 94 million); and meat production (1%, worth 42 million) (Cloete, 2011).

There is growing concern among some conservationists regarding the over commercialisation of wildlife and the impact that this may have on conservation of species and ecosystems. Some concerns are (i) cross breeding of closely related species and sub-species, (ii) deliberate breeding of mutations, (iii) breeding of scarce and endangered species for trophy purposes by people without the necessary knowledge, and (iv) the impact of game on the habitat, especially game species that are introduced into areas and habitats where they did not occur naturally before.

Even though conservation and commercial game ranching differ in their objectives, certain management aspects are relevant to both. The introduction and sustainable management of game species in a constrained (fenced) area requires knowledge of a wide range of considerations, which all play an important role to ensure success. These considerations can broadly be classified into ecological, economical, conservation and regulatory considerations, which can all be subdivided into several sub-categories and topics. Consequently, the number of variables involved in the decision making process is large and complex. This is aggravated by a general lack of basic knowledge and experience of many land owners and managers of conservation areas as well as game ranches in particular.

The objectives of the study were:

1. To identify the vegetation communities and sub-communities present on Doornkloof Nature Reserve (DNR), to demarcate from data different management units and compile a vegetation map,

2. To determine the botanical composition, the veld condition, and grazing capacity of the herbaceous layer of the various management units described,

3. To quantify the density, species composition and above-ground biomass of woody plants within each management unit, and to calculate the browsing capacities of each management unit and of DNR as a whole,

4. To study food selection of the ungulate species of DNR during both the cold, dry season and warm, wet season as well as the group sizes, social structures and general trends in the population growth,

A final objective of this study is to develop a decision support system in the form of a suitability index that will consider all aspects that influence the suitability of a species in a specific region and also to provide recommendations for the best combination of species for different conservation purposes and game ranching enterprises.

Chapter 2: Study area

2.1 Geographical Location and History

The Doornkloof Nature Reserve (DNR) is situated in the south eastern corner of the Northern Cape Province, in South Africa and is situated approximately 45 km north-west of Colesberg which is the nearest town (Figure 2.1). The DNR borders along the Orange River and the banks of the southern most part of the Vanderkloof Dam that form the approximate 40 km north-eastern boundary of the reserve and is also the provincial boundary between the Northern Cape and Free State Provinces. Of special importance is the Zeekoei River (formerly known as Seacow River), the largest of the tributaries of the Orange River that flows into the Vanderkloof Dam. The Zeekoei River flows for 15 km through the DNR. The surface area of the DNR expands over an area of approximately 12 000 ha. However, excluding the aquatic area, only 9 906 ha is available habitat for game.

The DNR is a provincial Nature Reserve that is managed by the Northern Cape Department of Tourism, Environment and Conservation. DNR was proclaimed a provincial nature reserve under proclamation 276 of 1981 under section 6 (1) of the Nature and Environmental Conservation Ordinance of 1974 (Ordinance 19 of 1974) with the purpose to protect the biodiversity and ecological processes of the area, with particular emphasis on the Zeekoei River. The boundaries of the reserve were extended during 1991 to include sections of the farms Rietvalley and Elandskloof in proclamation 55 of 1991.

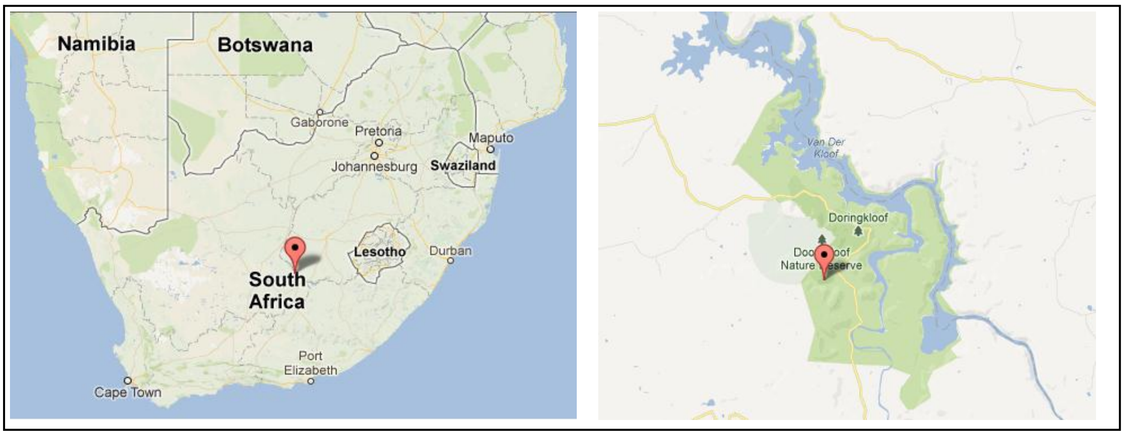


Figure 2.1 The geographical location of Doornkloof Nature Reserve (Maps afriGIS pty (lmt) @ 2013).

The terrain of DNR is characterised by mountains, hills and ridges with relatively low to moderate altitudes and often steep slopes. The relative altitude with different slope categories of the reserve is indicated in Figure 2.2. Due to the mountainous terrain, kloofs and drainage lines are abundant and consequently true plains are mostly absent, except for a small area in the northern and southern parts of the reserve. There are no artificial waterholes present on DNR.

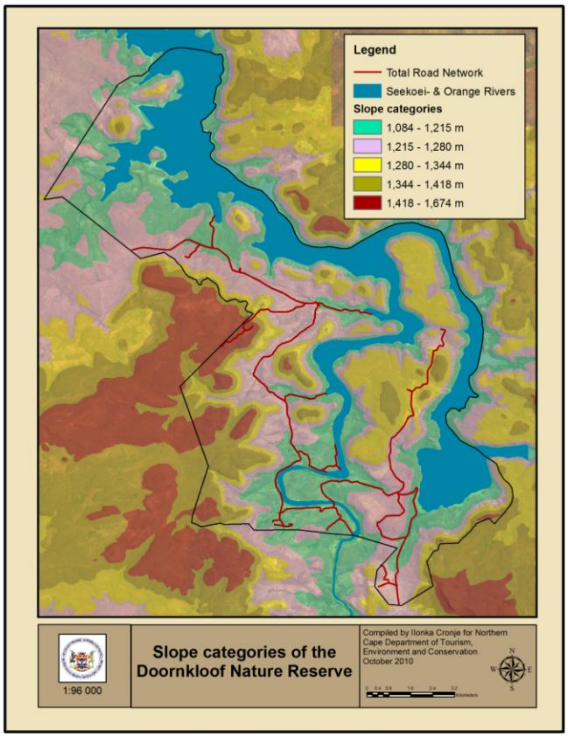


Figure 2.2 The slope categories and relative altitude of Doornkloof Nature Reserve (Northern Cape Department of Conservation and Tourism).

2.2 Climate

The climate of a specific region is regarded as one of the most important determinants of the geographical distribution of species and vegetation types. Under local conditions it is especially climate variables such as temperature, light, humidity and moisture that play an important role in production and survival of plants (Tainton & Hardy, 1999).

The DNR falls within the ecotone of the Nama Karoo and Grassland biomes but tends to have the weather characteristics associated with the Nama Karoo biome, which is an arid biome (Mucina & Rutherford, 2006). The climate within the Nama Karoo is essentially continental since the oceans play almost no climatic role (Mucina & Rutherford, 2006). Droughts occur frequently within this biome for a number of reasons that include the extremely variable seasonal rainfall, the relative low humidity of the atmosphere and also the unfavourable geographical position of the Karoo in relation to the general west-to-east patterns of air circulation over the country (Tainton, 1999).

2.2.1 Temperatures

The temperatures of DNR are affected by the relative high altitudes and vary considerably from season to season. The summer months are very hot with day temperatures that can reach a maximum of up to 41 °C with mean summer temperatures above 30 °C. The winter months are very cold, characterised by frost and occasional snowfall. Temperatures can drop as low as -8 °C during winter nights with mean winter temperatures close to 0 °C.

2.2.2 Rainfall

Rainfall is considered as the single most important factor that influences the distribution and productivity of plant communities in South Africa, as well as the potential productivity of these communities (Tainton & Hardy, 1999). The DNR falls within the summer rainfall region of South Africa (Wegner, 1980). Wegner (1980) mentions that long term trends of rainfall in the DNR area indicate that the rainfall fluctuates widely and also rapidly, with few periods of more than one or two years at a time clearly above or below the mean average, which is characteristic of the Nama Karoo region. The mean annual rainfall measured on DNR from 1981 to 2012 is 355 mm and it shows wide fluctuations between different years (Wegner, 1980) (Figure 2.3). The mean monthly rainfall for the same period shows that the most rainfall occurs during the months of February and March, mostly in the form of thunderstorms, while the lowest amount of rainfall occurs during the months of June and July (Figure 2.4).

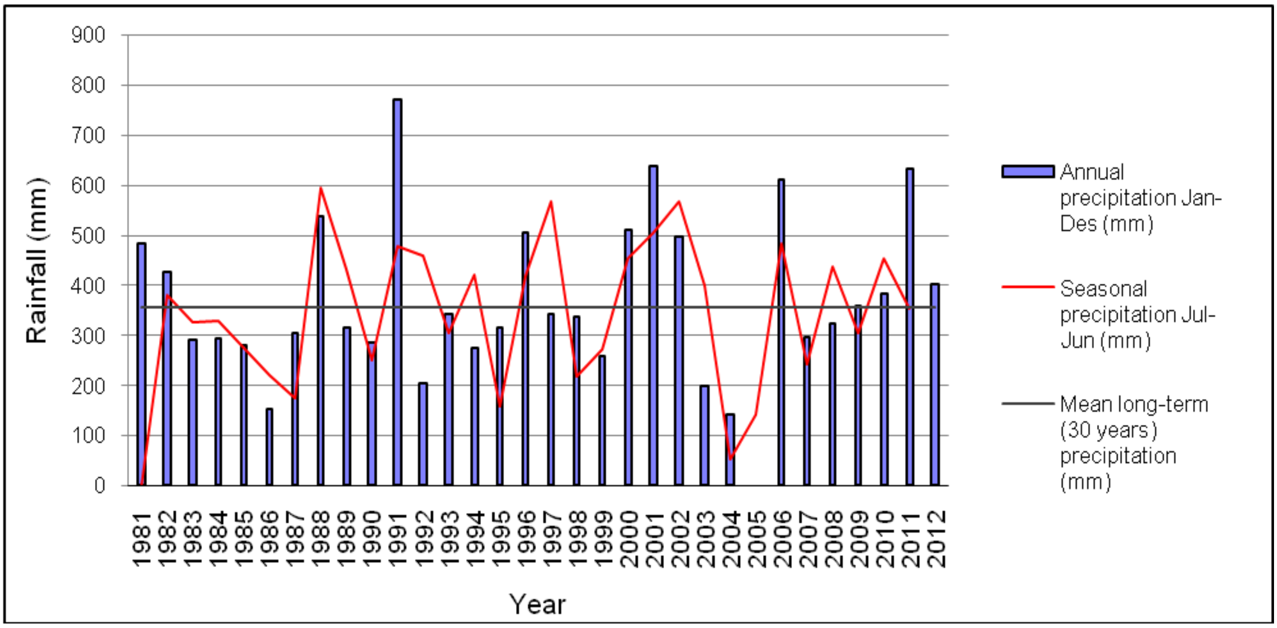


Figure 2.3 The average annual rainfall, average seasonal rainfall and mean long term rainfall for Doornkloof Nature Reserve for the period 1981 to 2012.

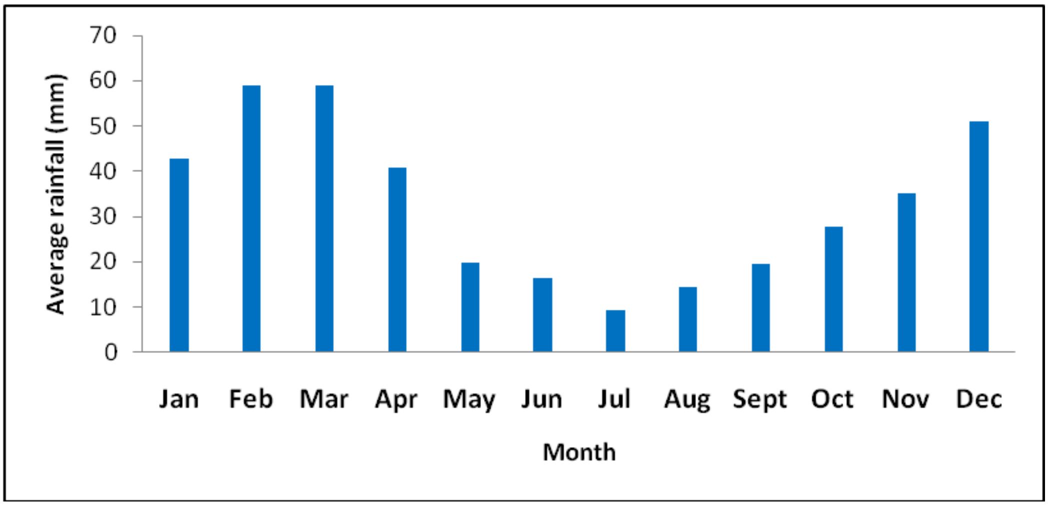


Figure 2.4 The mean average monthly precipitation for the period 1981 to 2012 for Doornkloof Nature Reserve.

2.3 Geology

The geology of the reserve belongs to the Karoo Supergroup that ranges in age from the late Carboniferous to middle Jurassic period (MacCarthy & Rubidge, 2005; Johnson *et al.,* 2006). The Karoo Supergroup covers almost 700 000 km² and forms a thick pile of dominantly sedimentary strata that were deposited in a sub-continental sized inland basin at the time when the super continent Gondwana existed (MacCarthy & Rubidge, 2005; Johnson *et al.,* 2006).

Due to decades of erosion, only the upper parts of the Ecca, the lowermost parts of the Beaufort Group, and the intrusions of dolerite dykes and sills are exposed in the DNR area (Macey & McDonald 2002; Mucina & Rutherford, 2006). The geomorphology of the region is largely defined by the resistant Karoo dolerites and Beaufort Group sandstones that occur together with mudstone (Macey & McDonald 2002; Mucina & Rutherford, 2006) (Figure 2.5).

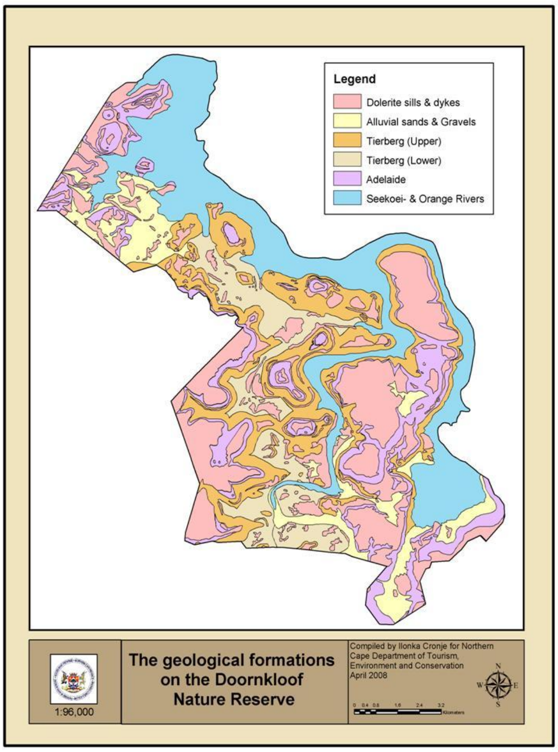


Figure 2.5 Map of the geology of Doornkloof Nature Reserve (Northern Cape department of Conservation and Tourism).

2.4 Floristic description

According to the biome boundaries as redefined by Mucina & Rutherford (2006), the DNR falls within the ecotone of the Nama Karoo biome and the Grassland biome. In previous classifications the DNR fell within the boundaries of the Nama Karoo biome that stretched into the southern Free State Province (Acocks, 1988; Low & Rebelo, 1996).

The veld type of DNR is described as the Besem Karee Koppies Shrubland (Mucina & Rutherford, 2006). According to older classifications, this veld type is described as the Eastern Mixed Nama Karoo veld type by Low & Rebelo (1996) and as the False Upper Karoo Veld by Acocks (1988). The vegetation within the Besem Karee Koppies shrubland veld type is characterized by slopes and koppies that are covered by a structurally two-layer karroid shrubland. The lower layer is dominated by dwarf karoo shrubs with a high abundance of grasses, while the second layer is dominated by higher shrubs such as *Searsia erosa, Searsia burchellii* and *Olea europaea* subsp. *europaea*. (Mucina & Rutherford, 2006). According to Acocks (1988) the region surrounding the Zeekoei River was originally grassveld but has been transformed to Karoo veld. This was mainly caused by the introduction of Merino sheep into the Colesberg division in the middle of the last century and the consequent overgrazing of the veld which enabled the establishment of karoo pioneer species (Acocks, 1988).

DNR, being situated in the transitional zone between the Nama Karoo and the Grassland biome, its vegetation displays characteristics of both biomes. The slopes and plateaus of the DNR display characteristics of the Grassland biome with perennial grasses such as *Themeda triandra, Heteropogon contortus* and *Cenchrus ciliaris* and shrubs such as *Searsia burchellii* and *Searsia cilliata* dominant. This is consistent with the description by Acocks (1988) of the False Upper Karoo Veld that the hills are still essentially a grassveld type. The flats show more characteristics of the Nama Karoo biome where a wide variety of karoo dwarf shrubs, such as *Pentzia spp*. *Eriocephalus ericoides* and *Selago spp.* occur. The kloofs and parts of the Zeekoei River bank are characterised by a high tree density with dominance of species such as *Acacia karroo, Searsia lancea*, *Olea europaea* subsp. *europaea* and *Diospyros lycioides*. A full description of the vegetation types and a vegetation map is presented in Chapter 3.

2.5 Fauna description

The DNR has a relatively low herbivore diversity compared to private game ranches in the region. Currently it has only nine large herbivore species, which are Cape buffalo, eland, mountain reedbuck, kudu, gemsbok, red hartebeest, steenbok, grey duiker and warthog. Only the species that were known to have occurred in the region historically are present on DNR. “Exotic species” such as red lechwe, bushbuck, waterbuck and impala, that are kept for hunting purposes on the bordering Hunters Moon game ranch, often cross the boundary fence into DNR and are regularly spotted in the southern section of the reserve.

The first group of Cape buffalo, which consisted of four individuals, were introduced into the reserve during 2000. The group was relocated from the Willem Pretorious Nature Reserve in the Free State province. During 2002 a second group of Buffalo from the Camdeboo National Park (formerly Karoo National Park) near Graaff-Reinet in the Eastern Cape consisting of six cows and four bulls were introduced (Venter, 2006). Other species that were later introduced to the reserve are eland, red hartebeest and kudu, while the remaining species all occur naturally (Venter, 2006).

During 2004 and 2009 aerial surveys were conducted to determine the numbers of each species and indicated population growth within all populations. The numbers obtained from the aerial counts are presented in Table 2.1 and also include estimates of the size of the populations at the time of study. Despite the culling of Eland and Warthog during 2009, the population has grown significantly.

Table 2.1 The average numbers, previous and current, of large herbivore species present in Doornkloof Nature Reserve.

Species	***Scientific name***	***Approximate numbers***		
		2004	*2009*	*2011-2012*
Buffalo	*Cyncerus caffer*	***19***	***55***	***80***
Eland	*Tragelaphus oryx*	***243***	***327***	***>450***
Gemsbok	*Oryx gazella*	***26***	***40***	***55***
Grey duiker	*Sylvicapra grimmia*	***46***	***77***	***100***
Kudu	*Tragelaphus strepsiceros*	***80***	***160***	***>230***
Mountain Reedbuck	*Redunca fulvorufula*	***315***	***389***	***300***
Red hartebeest	*Alcelaphus buselaphus*	***28***	***53***	***110***
Steenbok	*Raphicerus campestris*	***36***	***50***	***50***
Warthog	*Phacochoerus africanus*	***9***	***130***	***>200***

Other prominent mammal species found in DNR are predators such as black-backed jackal and caracal, which are the reserve's top predators and still very common in the entire region. aardwolf, erdvark, porcupine, Cape foxes and bat-eared foxes are all species that occur within the boundaries of the reserve. Although elusive, the reserve also boasts a healthy greater Cape otter population.

Apart from the main herbivore species DNR is also host to a large diversity of other animals. A total of 48 mammal species, 172 bird species and 28 reptile species have been recorded within the reserve. The Orange River system also supports many aquatic species.

Chapter 3: Identification and Description of Vegetation units

3.1 Introduction

Vegetation ecology is best described as the study of plant communities and their relationship to the environment (Van der Maarel, 2012). Vegetation, the collective term for plant communities, forms the cornerstone of vegetation ecology and is defined as a system of largely spontaneously growing plants that can be seen as the most physical representation of the biotic environment (Kent, 2012; Van der Maarel, 2012; Brown *et al.,* 2013). Thus, plant communities are regarded as types of vegetation recognised by their floristic composition which is composed of plant species that grow together in the same location and show a definite association or affinity with each other (Westhoff & Van der Maarel, 1978; Kent & Coker, 1992).

Part of the plant community concept is the idea that certain plant species populations grow together in certain locations and environments more frequently than would be expected by chance since they can tolerate the same environmental conditions and have similar environmental requirements to survive (Kent and Coker, 1992; Kent, 2012). Kent (2012) states that the presence or absence of particular species is of great importance within plant communities and after this the abundance of each species present also become significant.

A sound knowledge and understanding of the vegetation ecology of a region is of great importance for the establishment of efficient wildlife and environmental management programs and the compilation of conservation policies (Bredenkamp & Theron, 1978; Van Rooyen *et al*., 1981; Bredenkamp *et al*., 1993; Bezuidenhout, 1996; Brown *et al*., 2013). Brown *et al.* (2013) states that by identifying different plant communities, different ecosystems are also identified and described. Different ecosystems react differently to specific management practices, such as fire and grazing (Bredenkamp & Theron, 1976). Furthermore, the vegetation is the single most important characteristic of the habitat of animals and can reveal vital information on its various aspects. Animals prefer and select those habitats that provide not only palatable food plant species, but also a preferred density and cover for shelter (Van Rooyen, 2002). It is therefore essential to classify, describe and map the different vegetation types. Brown *et al.* (2013) further states that detailed vegetation classification, mapping and description are invaluable for making informed and scientifically defendable decisions with regards to infrastructure development of an area.

The main objectives of the vegetation classification were to identify the vegetation communities and sub-communities of DNR and use the data to demarcate different management units and compile a vegetation map. Several environmental variables, like soil type, topography and climate can lead to a variation in vegetation composition and growth and thus also habitat suitability and food provision to the different herbivore species. Therefore a vegetation map, indicating the various vegetation units is essential for this study. It was decided to combine similar vegetation units and sub-communities into management units which are more practical in terms of management and planning. This data will also assist in the long-term monitoring of the different ecosystems as well as for compiling a management plan.

3.2 Methodology

To determine the different plant communities of DNR, the Braun-Blanquet phytosociological method (Braun-Blanquet, 1932, Kent, 2012), which is associated with the Zurich-Montpellier school of phytosociology, was used. The Braun-Blanquet method is used world wide for the classification of vegetation communities. Numerous local studies have found the Braun-Blanquet method to be the most efficient phytosociological method available and it is commonly used in South Africa (Werger, 1980; Bezuidenhout, 1994; Malan *et al*., 2001; De Klerk *et al*., 2003; Bezuidenthout & Brown, 2009).

The Braun-Blanquet method consists of two phases, namely the analytical and the synthetic phase.

3.2.1 Analytical phase (botanical phase)

The analytical phase involved the acquisition of all relative vegetation data represented in the relevés, using the Braun-Blanquet method (Kent & Coker, 1992). After a reconnaissance and study of a 1: 50 000 aerial photograph of the region, the study area was stratified into homogenous physiognomic and physiographic units. A total number of 204 relevés were sampled and randomly placed within each homogenous unit identified. The number of relevés within each homogenous unit was determined by the size of the unit, with more relevés being allocated to larger units. Transitional and marginal zones as well as areas that showed clear signs of overgrazing were avoided for sampling. Relevés for mountain slopes where generally placed mid-slope, while sampling of the crests was avoided.

The plot sizes were fixed at 10 x 10 m (100m²) for most of the vegetation units sampled, except for grassland areas that had a low tree and shrub density, where plot sizes were fixed at 4 x 4 m (16 m²)(Bredenkamp & Theron, 1978). Field surveys were undertaken during April and May 2011 and again in March 2012. During the surveys, the modified/new Braun-Blanquet cover-abundance scale (Mueller-Dombois & Ellenberg, 1974) (Table 3.1) was used to record the abundance of each species within the relevés. Average height and canopy cover of tree, shrub and herbaceous strata were estimated and the data were used in the description of the plant communities. Herbarium samples of unknown species were taken for identification in the Geo Potts herbarium (BLFU). The positioning of each relevé was also determined and recorded by means of a GPS.

Further environmental data that assisted with the refinement and description of the different plant communities were also recorded and included aspect, slope, exposure to sunlight, the size of the rocks present, altitude, locality, geology, the percentage of area covered by rock, topography, the degree of surface erosion, drainage, soil depth, as well as total percentage canopy cover.

Erosion was estimated with a three-scale numerical system, where 1 = no erosion, 2 = moderate and 3 = high. Grazing pressure was similarly estimated, where 1 = no grazing, 2 = low grazing pressure, 3 = moderate grazing pressure and 4 = high grazing pressure. Slope was estimated in degrees of the following scale: 0 to 3° = flat, 3 to 8° = gradual, 8 to 16° = moderate, 16 to 26° = steep, 26 to >45° = very steep. Soil depths were measured with a probe graded for 5 cm intervals to a maximum depth of 40 cm.

Table 3.1 The modified/new Braun-Blanquet cover-abundance scale used to record the cover of each species present within the sampling plots.

Cover Values	Description
r	One or few individuals, rare occurrence
+	Cover less than 1%
1	Cover less than 5%
2a*	Cover between 5 - 12.5%
2b*	Cover between 12.5 - 25%
3	Cover between 25 - 50%
4	Cover between 50 - 75%
5	Cover between 75 - 100%

3.2.2 Synthetic phase (data analysis)

The botanical data collected during the analytical phase was first captured within the program TURBOVEG (Hennekens, 1996b) and then exported to the program JUICE (Tichý & Holt, 2006). A first approximation of the main plant communities was determined by means of divisive clustering. The modified two-way indicator species analysis (modified TWINSPAN, Roleček *et al*., 2009) which is contained within JUICE (Tichý & Holt, 2006), was applied to the floristic data set. The modified TWINSPAN differs from the original version by not enforcing a dichotomy of classification, but instead, at each step, divides only the most heterogeneous cluster of the previous hierarchical level (Roleček *et al*., 2009). Thus, the application of the modified TWINSPAN algorithm results in vegetation units of similar internal heterogeneity. Pseudospecies cut levels that were used for classification were set to “0 15 25 50 75”. Further division of clusters to determine sub-communities, was done using the original TWINSPAN (Hill 1979). Final refinement of the classification was achieved by applying Braun-Blanquet procedures.

An ordination algorithm, DECORANA (Hill 1979b), was applied to the floristic data in order to illustrate floristic relationships between plant communities and to detect possible habitat gradients and/or disturbance gradients associated with vegetation gradients. Using the final phytosociological table and habitat information collected during sampling in the field, different plant communities were identified, described and ecologically interpreted.

Plant community names were assigned according to the same guidelines as presented in the International Code of Phytosociological Nomenclature (Weber *et al.,* 2000). In accordance to these guidelines the first name was given to either a diagnostic or co-dominant species. The second name was given to the dominant plant species or the species that dominates the vegetation structure. The sub-community name starts with the community name followed by a characteristic or dominant species for that sub-community. Preference was given to using perennial species rather than of annual species in names where possible. Taxon names conform to those of Germishuizen & Meyer (2003).

3.3 Results and Discussion

3.3.1 Identification of plant communities

Six major plant communities that can be grouped into 14 sub-communities, were identified from the classification. The result of the classification can be seen within the phytosociological and synoptic table presented in Appendix Ai and Appendix Aii. Two relevés (relevé 13 and 16) were deleted from the final table as they did not fit into any plant community and was thus incorrectly sampled. A total number of 128 plant species were identified during the field surveys. The plant communities are indicated in Figure 2.1 and are as follows:

1. *Eragrostis chloromelas-Chloris virgata* Grassland

    1.1 *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland

    1.2 *Eragrostis chloromelas-Chloris virgata-Searsia burchellii* Shrubby grassland

2. *Melianthus comosus-Acacia karroo* River thicket

    2.1 *Melianthus comosus-Acacia karroo-Lycium hirsutum* River thicket

    2.2 *Meliathus comosus-Acacia karroo-Searsia lancea* River thicket

3. *Hyparrhenia hirta-Olea europaea* subsp. *africana* Drainage lines

4. *Olea europaea* subsp. *africana-Searsia burchellii* Shrubland

    4.1 *Olea europaea* subsp. *africana-Searsia burchellii-Tarchonanthus camphoratus* Shrubland

    4.2 *Olea europaea* subsp. *africana-Searsia burchellii-Melinis repens* Shrubland

    4.3 *Olea europaea* subsp. *africana-Searsia burchellii-Aristida diffusa* Shrubland

    4.4 *Aristida adscensionis-Eragrostis lehmanniana* -Ziziphus *muricata* Shrubland

5. *Pentzia globosa-Eragrostis lehmanniana* Grasslands

    5.1 *Pentzia globosa-Eragrostis lehmanniana-Aristida adscensionis* Grasslands

    5.2 *Pentzia globosa-Eragrostis lehmanniana-Searsia ciliata* Grasslands

    5.3 *Pentzia globosa-Eragrostis lehmanniana-Eriocephalus spinescens* Grassland

6. *Themeda triandra-Searsia burchellii* Randjie veld

    6.1 *Themeda triandra-Searsia burchellii-Boophane distica* Randjie veld

    6.2 *Themeda triandra-Searsia burchellii-Sporobolus fimbriatis Rantjie veld*

    6.3 *Themeda triandra-Searsia burchellii-Melolobium microphyllum Rantjie veld*

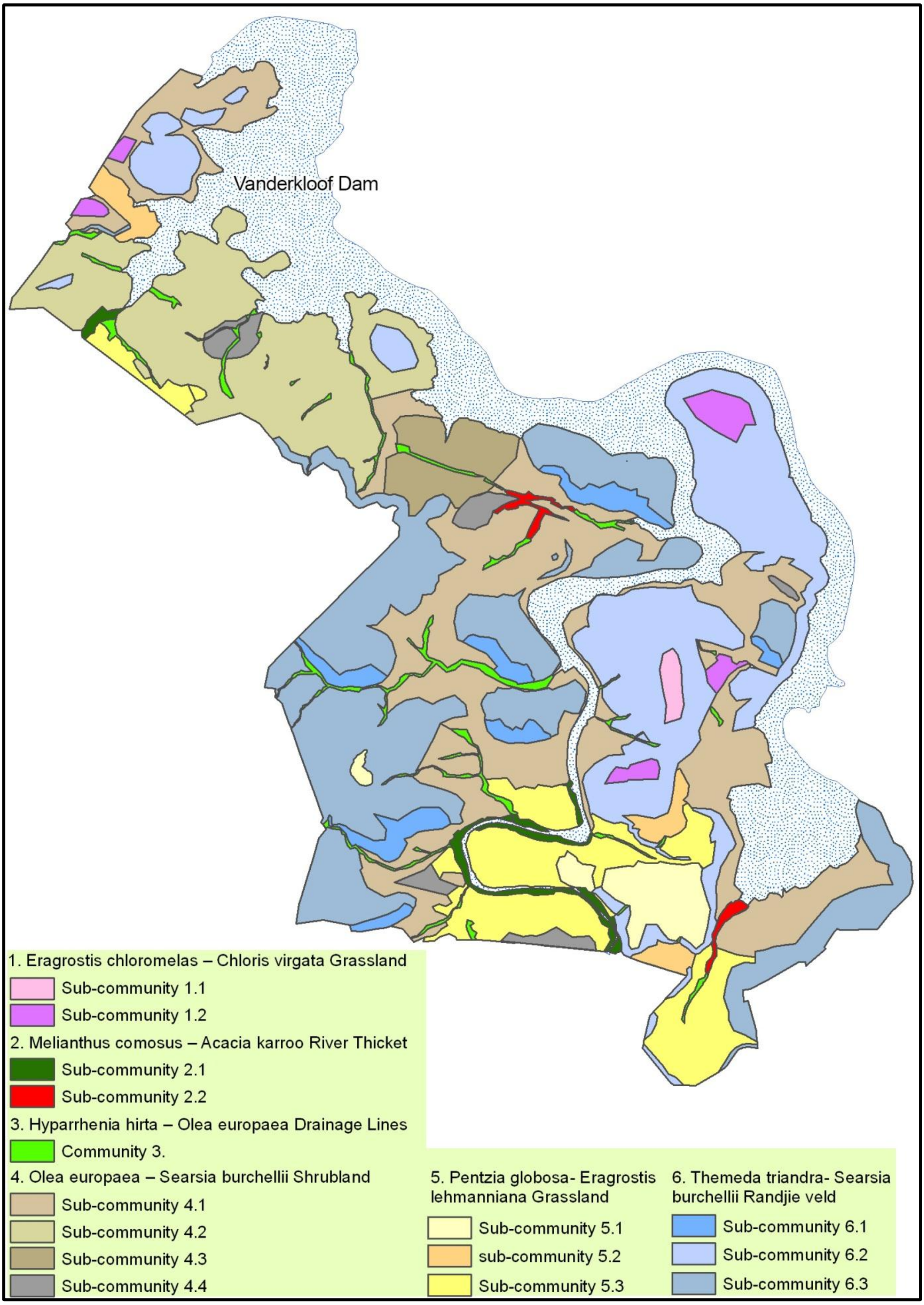


Figure 3.1 Plant communities of DNR.

3.3.2 Description and discussion of communities

1. *Eragrostis chloromelas-Chloris virgata* Grassland (Table 3.1, Appendix Ai)

The *Eragrostis chloromelas-Chloris virgata* Grassland is a small plant community that is located in isolated patches on low lying plateaus and flat ridges. These plateaus and ridges lie predominantly between the Zeekoei and Orange Rivers but also include areas in the far northern section of the reserve (Figure 3.1). This is the smallest plant community on the reserve that covers a total area of only 135 ha. The terrain is characterized by very flat plains that consist of deep darkish clayey soils with few rocks covering the surface. Grazing and animal trampling vary from low to very high in parts of this community. Very little indication of any soil erosion was visible.

Diagnostic species, with also a high fidelity, are the species of Species group A and include the grasses *Aristida adscensionis*, *Eragrostis chloromelas* and *Chloris virgata*. These grasses are the dominant species, while the karroid shrub *Pentzia incana* (Species group Y) is also dominant. The geophyte *Moraea pallida* and the forb *Oxalis depressa* (Species group Z) occur frequently within this community. The species diversity of this community is low with only 42 different species recorded at an average of 9 species per relevé. The herbaceous layer is well developed with a high canopy cover.

This community can be grouped into two sub-communities, namely the *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland and the *Eragrostis chloromelas-Chloris virgata-Searsia burchellii* Shrubby grassland

1.1 *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland (Table 3.1, Appendix Ai)

Covering an area of 100 ha, this grassland comprises the largest area of the *Eragrostis chloromelas-Chloris virgata* Grassland community. The terrain is very flat with almost no rocks visible on the soil surface. Rock cover varies from 0-10% with an average of 3.4%. Soils from this grassland have a high clay content and are very deep with a soil depth of 30-40+ cm. Grazing pressure and trampling tend to be low to moderate, while there is no indication of soil erosion.

The karroid shrubs *Felicia muricata* subsp*. cinerascens* and *Salsola glabrescens* as well as the grass *Eragrostis obtusa* of Species group B are diagnostic species. This sub-community is further characterized by the presence of dominant species of Species group A, which include the annual grasses *Aristida adscensionis* and *Chloris virgata* and the perennial grass *Eragrostis chloromelas. Eragrostis chloromelas* forms large tufts in this vegetation unit. All three these dominant grasses are associated with growing on disturbed areas, while *Chloris virgata* grows particularly in disturbed areas on heavier, deep soils (Van Oudtshoorn, 2004). Other dominant species are the grass *Eragrostis obtusa* (Species group B) as well as the karroid shrubs *Felicia muricata* subsp*. cinerascens* (Species group B), *Pentzia incana* (Species group Y) and *Chrysocoma ciliata* (Species group Z). Species that are prominent in this grass sub-community are those of Species group Y and Z of which the most conspicuous species are the low growing shrublet *Hermannia coccocarpa*, the dome shaped karroid shrub *Pentzia globosa*, the small erect geophyte *Moraea pallida*, the perennial grass *Heteropogon contortus* and seasonal forb *Oxalis depressa*.

The vegetation is dominated by herbaceous species, especially grasses and no woody layer (Figure 3.2). However, canopy cover of grasses in this sub-community is greatly influenced by seasonal rainfall as indicated in Figure 3.3. During the period the field surveys were conducted, the vegetation was in a post-succession state due to the exceptionally high rainfall of that season (See Chapter 2). Therefore, this sub-community, can be expected to mainly occur in a lower successional state during seasons of average and below average rainfall. During this state, the vegetation is dominated by karroid shrubs with sparsely distributed grasses with a low canopy cover. The canopy cover of the herbaceous layer varies between 65-90% of the area with an average of 81.6%.

This *Eragrostis lehmanniana-Chloris virgata-Felicia muricata* sub-community is comparable to the Grassland described by Bezuidenhout (1994) in the former Vaalbos National Park (now reproclaimed), Northern Cape. Both communities are found on clayey soils, while species such as *Chloris virgata*, *Aristida adscensionis*, *Eragrostis obtusa* and *Felicia muricata* are also prominent in both communities. The main differences between the sub-communities include the absence of the grasses *Eragrostis porosa* and *Urochloa panicoides* and of the forb *Vahlia capensis* from the *Eragrostis lehmanniana-Chloris virgata-Felicia muricata* sub-community, which are diagnostic species for the Grassland described by Bezuidenhout (1994). The occurrence of *Salsola glabrescens* in this sub-community is substituted by *Salsola rabieana* in the *Eragrostis* species-*Chloris virgata* Grassland community described by Bezuidenhout (1994).

Figure 3.2 The vegetation of *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland.

Figure 3.3 A view of the same area indicating the influence of rainfall on biomass production

1.2 *Eragrostis chloromelas-Chloris virgata-Searsia burchellii* Grassy Shrubland (Table 3.1, Appendix Ai)

This grassy shrubland covers a flat mountain plateau that is located in the middle section of the mountain range between the Zeekoei and Orange River as indicated in Figure 3.1. This sub-community is very small, covering an area of only 35 ha. At an average of 14% the rock cover in this area is higher than in the the *Eragrostis chloromelas-Chloris virgata Felicia muricata* Grassland (Sub-community 1.1), while the soil depth is similar (31-40cm). The largest area of this community is severely overgrazed, most notably by Gemsbok (Figure 3.4).

This sub-community is characterized and distinguished from the previous sub-community by its well-developed, evenly spaced shrub layer that has a canopy height between 1 m to 3 m (Figure 3.4). This shrub layer is dominated by the tall, multi-branched *Searsia burchellii* (Species group X), which is a differential species for this sub-community. The only other prominent shrub is *Diospyros austro-africana* (Species group X) that occurs scattered throughout the community. The herbaceous layer is very similar to the *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland (Sub-community 1.1), with the same dominant grass species of Species group A. The herbaceous layer of this sub-community only differ by the absence of species from Species group B as well as certain species of Species group Y and Z that include the karroid shrub *Chrysocoma ciliata* and small shrublet *Hermannia coccocarpa*. The karroid shrubs *Pentzia incana* (Species group Y) and *Pentzia globosa* (Species group N) are also far more dominant within this variant. Other significant species are those of Species group Z, namely the geophyte *Moraea pallida*, the inconsistent shrublet *Asparagus suaveolens*, the perennial grass *Heteropogon contortus* and seasonal forb *Oxalis depressa*.

In this sub-community the changes in plant species composition caused by overgrazing are important to be noted from a management point of view. In this sub-community the species composition has been dramatically altered with almost all characteristic grass species being absent (Figure 3.4). The abundance of the mat-forming grass, *Cynodon hirsutus* is a further indication of the negative impact of the overgrazing on this sub-community. The average canopy cover of the woody layer is 20% that varies between 10-30%, while the canopy of the herbaceous layer covers an average of 74% of the ground that varies between 70-80%.

Figure 3.4 The vegetation of the *Searsia burchellii-Eragrostis chloromelas* Grassy shrubland sub-community also demonstrates the impact of overgrazing within this sub-community on the right where species such as *Cynodon hirsutus* and *Urochloa panicoides* have replaced the dominant grass species.

2. *Melianthus comosus-Acacia karroo* River thicket (Table 3.1, Appendix Ai)

The distribution of the *Melianthus comosus-Acacia karroo* River thicket community is mainly restricted to the lower river banks of the Zeekoei River and along larger drainage lines (Figure 3.1). This small riparian plant community covers a total area of 144 ha. The very deep soils that have mainly been formed by sedimentary deposits are sandy and light of colour. The soil often remains moist for long periods after rainstorms, mainly due to the relatively cool and shaded conditions created by the dense shrub layer. Almost no rocks occur on the ground. Overgrazing and trampling are very high within large areas of this community.

The vegetation is structurally dominated by a woody layer of which a tree and shrub stratum is very prominent. In many areas the height of the tree canopy is over 10 m. The diagnostic species are those from Species group C and include the creeping grass *Cynodon hirsutus* and the shrubs *Melianthus comosus, Lycium cinereum, Urtica dioica*, *Hibiscus pusillus,* and also *Salvia disermas*. Most of these species throughout their distribution are associated with riverine plant communities (Sheaning & Van Heerden, 1994). The dominant woody species are tree species that include *Acacia karroo*, *Searsia lancea, Diospyros lycioides* subsp. *lycioides* of Species groups E and to a lesser extent *Ziziphus mucronata* (Species group H). The herbaceous layer is dominated by the creeping grass species *Cynodon hirsutus* (Species group C). The species of Species groups C and D have high fidelity for this dense shrub community. Due to the mat-forming growth form of *Cynodon hirsutus*, it is the main contributor to the relative high canopy cover of the herbaceous layer. Species diversity is relatively low with 42 species recorded at an average of 13 species per relevé.

Werger (1973, 1980) classified the river communities of the upper Orange River as the *Diospyrion lyciodis* alliance with four distinct riverine communities (associations and sub-associations) grouped under this alliance. The Thicket community of DNR falls under the Zizipho- Acacietum karroo association described by Werger (1980), but also shows definite characteristics of the Rhoo- Diospyretum acacietosum karroo sub-association. Characteristic species of the Rhoo-Diospyretum acacietosum karroo sub-association that are also prominent in the *Meliathus comosus- Acacia karroo* River thicket community is the grass species *Melica decumbens* and the shrubs *Asparagus suaveolens* and *Melianthus comosus*. This is probably due to the fact that DRN is located on the western boundary of the Rhoo-Diospyretum acacietosum karroo sub-association where the riverine community changes to the Zizipho-Acacietum karroo association (Werger, 1980).

The entire *Diospyrion lyciodis* alliance falls within the *Acacia karroo* Riparian Thicket phytociosiolocigal class that was described for the Free State Province by Du Preez & Bredenkamp (1991). Malan *et al*. (2001) also described many of the drainage lines found throughout the south western Free State, which also forms part of the *Acacia karroo* Riparian Thicket. The results of Malan *et al*. (2001) closely resemble the species composition found for this Thicket community. The similarity between these two communities is mainly due to the close proximity of DNR to that of the study area of Malan *et al*. (2001).

The *Setaria verticillata-Acacia karroo* sub-community described in the Kareefontein Private Game Reserve by Botha (2003) is also very similar to the *Melianthus comosus-Acacia karroo* River Thicket community. The *Setaria sphacelata-Acacia karroo* and to a lesser degree the *Diospyros lyciodes-Rhus pyriodes* communities from the central Free State are also comparable to this Thicket (Muller, 2002). Other similar communities are the *Searsia pyroides-Acacia karroo* Shrub sub-community and *Ziziphus mucronata-Asparagus africanus* Shrub sub-communities found along the Vet River, Free State Province (Van Aardt, 2010). This community forms part of the inland Azonal vegetation described by Rutherford & Mucina (2006), where species composition is determined and charactarized by the precence of permanent bodies of water such as rivers, drainage lines and dams.

This community can be grouped into two sub-communities namely the *Meliathus comosus-Acacia karroo-Lycium hirsutum* Thicket and the *Melianthus comosus-Acacia karroo-Searsia lancea* Thicket

2.1 *Melianthus comosus-Acacia karroo-Lycium hirsutum* Thicket (Table 3.1, Appendix Ai)

The distribution of this thicket is mainly along the southern river banks of the Zeekoei River where the river forms a horseshoe bend, as well as along one of the larger drainage lines in the northern section of the reserve (Figure 3.1). This sub-community covers an area of 97 ha. The river banks are generally flat although sections form steep banks that slope downwards towards the river. The ground cover is semi-shaded by the dense tree and shrub layers allowing moist soil conditions to often persist. The light coloured sandy soils that predominantly consists of Augrabies and Oakleaf soil forms, are very deep with no rock cover on the surface. Overgrazing is especially high within this thicket sub-community and is almost entirely caused by buffalo (see chapter 6). Sections of the Zeekoei River banks have been eroded away by fluctuating water levels of seasonal floods.

The vegetation structure is characterized by dense stands of woody species that consist of a shrub and medium to high tree layer (Figure 3.5). Diagnostic species of this sub-community belong to Species group D and are the annual grass *Setaria verticillata*, the large multi-stemmed shrub *Lycium hirsutum* and perennial grass *Melicia decumbens*. Both the grasses *Melicia decumbens* and *Setaria verticillata* often grow under trees in semi-shaded areas (Van Oudtshoorn, 2004), while the shrub *Lycium hirsutum* typically grows along larger watercourses (Palgrave, 2002). The perennial grass *Melica decumbens* is seldom grazed, which partly explains its high occurrence in comparison to the other palatable perennial grasses which are mostly absent from this thicket. The occurrence of *Setaria verticillata* is often an indication of a disturbance such as overgrazing (Van Oudtshoorn, 2004). Dominant species include the medium high to high deciduous tree *Acacia karroo* (Species group E), the small to medium sized ever-green tree *Searsia lancea* (Species group E), the creeping perennial grass *Cynodon hirsutus* (Species group C), the perennial grass *Setaria verticillata* (Species group D), the shrub *Lycium cinereum* (Species group C), the shrub *Melianthus comosus* (Species group C), and to a lesser extent the exotic shrub *Urtica dioica* (Species group C). The tree *Acacia karroo* is mostly restricted to water courses in drier parts of the country (Palgrave, 2002). Other species with significant occurrence are the shrub to medium sized deciduous tree *Ziziphus mucronata* (Species group H), the tree *Diospyros lycioides* subsp. *lycioides* (Species group E), the erratic small shrub *Asparagus suaveolens* (Species group X), and the forb *Salvia verbenaca* (Species group C).

The woody layer cover is very dense and the canopy cover varies from 70-100% with an average of 92%. The canopy cover of the herbaceous layer varies from 40-80% with an average of 60% and is mostly influenced by the level of abundance of the creeping grass *Cynodon hirsutus*. The high canopy covers of both the annual grasses *Cynodon hirsutus* and *Setaria verticillata* is largely the result of the above average rainfall received during 2011. During years of normal and below average rainfall, it is expected that larger areas of bare ground will occur. This was already evident during 2012 (which was drier) when point surveys were conducted (see Chapter 4).

The species composition of the *Melianthus comosus-Acacia karroo-Lycium hirsutum* Thicket sub-community is similar to that of the *Diospyros lycioides-Acacia karroo* Woodland community described by Bezuidenthout (2009) in the Rooipoort Nature Reserve, Northern Cape. The canopy cover of the woody layer of the *Diospyros lycioides-Acacia karroo* Woodland, which is of approximately the same stratum height, is significantly lower.

Figure 3.5 The vegetation of the *Melianthus comosus-Acacia karroo-Lycium hirsutum* Thicket.

2.2 *Melianthus comosus-Acacia karroo-Searsia lancea* Thicket (Table 3.1, Appendix Ai)

This sub-community which covers an area of 47 ha along larger drainage lines in the central, as well as southern section of the reserve. This thicket is most notably in areas where the drainage lines flow on flat open terrain and. The environmental conditions and terrain is very similar to the previous thicket sub-community. However, while grazing and trampling by animals were also high in this thicket, it was not as severe as in the previous thicket. Various areas have moderate levels of surface erosion caused by high water discharge, especially where the herbaceous cover is low.

The vegetation structure is very similar to the previous sub-community. It also has a dense woody layer consisting mostly of a high shrub and tree layer (Figure 3.6). This thicket sub-community can be differentiated from the previous thicket community by the presence of the shrub *Salvia namaensis* (Species group F) and by the predominantly absence of species of Species group D. The woody tree species *Diospyros lycioides* subsp. *lycioides* and *Searsia lancea* of Species group E are also more dominant within this sub-community than the previous community. The tree *Searsia lancea* grows in a wide variety of habitats that include river and stream banks (Palgrave, 2002; Van Wyk *et al.,* 2008). Dominant species are the creeping grass *Cynodon hirsutus* (Species group C), the evergreen tree *Searsia lancea* (Species group E), the deciduous tree *Acacia karroo* (Species group E), the shrub to small tree *Diospyros lycioides* subsp. *lycioides* (Species group E), the multi-stemmed shrub *Salvia namaensis* (Species group F) and the exotic forb *Urtica dioica* (Species group C). Other notable species are the shrub *Melianthus comosus* (Species group C), the perennial grass *Digitaria eriantha* (Species group S) and the forb *Oxalis depressa* (Species group Z).

The canopy cover of the woody layer varies between 60-100% with an average of 79.2%. The herbaceous layer varies between 5-80% with an average of 55%. The same trends concerning the variation in cover abundance of the grass *Cynodon hirsutus* from one rainfall season to another, as discussed in above-mentioned sub-community descriptions, is also applicable to this sub-community.

Figure 3.6 The vegetation of the *Melianthus comosus-Acacia karroo-Searsia lancea* Thicket.

3. *Hyparrhenia hirta-Olea europaea* subsp. *africana* Drainage lines (Table 3.1, Appendix Ai)

This community is associated with the numerous drainage lines and tributaries found across the reserve and in total covers an area of 222 ha. The soils are deep and sandy with soil depths between 30-50cm. The surface has little rock cover that varies from 0-25% (average 9.3%). Many locations have moist soil conditions because water infiltration from the drainage lines containing water. The ground cover is also semi shaded by a generally thick and often high tree canopy cover, similarly to that found in the *Melianthus comosus-Acacia karroo* River thicket community, large areas are overgrazed mainly by buffalo. Some drainage lines have very high soil erosion, while others have none and are mainly influenced by the amount of herbaceous cover and amount of water discharge.

The vegetation is dominated by the woody layer, which mainly consists of a medium high to high tree stratum that varies from 3 to 6 m or more in height (Figure 3.7). The diagnostic species for this community are the perennial grasses *Hyparrhenia hirta* and *Panicum coloratum* var. *coloratum* of Species group G. The distribution of the highly palatable grass *Panicum coloratum* var. *coloratum* was mainly restricted to areas where it is protected from grazing. The grass *Hyparrhenia hirta,* although an indicator of previous disturbances, plays an important role in stabilizing and protecting bare soil against erosion (Van Oudtshoorn, 2004) and is also present in many of the drainage lines of the reserve. As expected, the most dominant species are predominantly tree species which include the small to medium sized evergreen *Olea europaea* subsp. *africana* (Species group H), *Searsia lancea* (Species group E) and deciduous *Acacia karroo* (Species group E), which are far more abundant in the lower reaches than upper reaches of the drainage lines. All three these species are known to occur along watercourses throughout their distribution (Palgrave, 2002; Van Wyk *et al.,* 2008). Other dominant species of the herbaceous layer are the grass *Hyparrhenia hirta* (Species group G) and shrub *Salvia namaensis* (Species group F). Other prominent species include the shrub *Searsia burchellii* (Species group X), the small trees *Ziziphus* *mucronata* subsp. *mucronata* (Species group H), *Diospyros lycioides* subsp. *lycioides* (Species group E), and the shrub *Diospyros austro-africanum* var. *microphylla* (Species group X).

The *Acacia karroo-Diospyros lycioides* sub-community described by Muller (2002) found throughout the central Free State Province shows a close similarity to the *Hyparrhenia hirta-Olea europaea* subsp. *africana* Drainage lines community. The woody layer in particular displays a very close resemblance, while the herbaceous layer is less similar to each other. The *Acacia karroo-Diospyros lycioides* sub-community is also typically found along drainage lines, ravines and foot slopes of hills.

The canopy cover of the woody layer is between 80-100% with an average cover of 89.3%. The cover of the herbaceous layer is between 40-70% with an average of 47.9%.

Figure 3.7 The vegetation of the *Hyparrhenia hirta-Olea europaea* subsp. *africana* Drainage Lines.

4. *Olea europaea* subsp. *africana-Searsia burchellii* Shrubland (Table 3.1, Appendix Ai)

This shrubland community is the second largest of all the plant communities, covering a total land area of 3 239 ha. The landscape varies from flat to undulating plains with numerous scattered ridges and small hills. The largest part of this community is covered by very rocky terrain with very shallow soils. Soils from lower regions are generally sandy and often also gravely while soils from higher areas tend to have a higher loam content. Rock cover varies from 0-60% (average 27.3) and soil depth from 3-40 cm. Large areas within this community, particularly lower and flat areas, are heavily overgrazed and trampled. In large areas sheet erosion has removed most of the top soil.

The characteristic species for this community are the woody species of Species group H and are the small to medium high trees *Olea europaea* subsp. *africana* and *Ziziphus mucronata* subsp. *mucronata* as well as the perennial grass *Heteropogon contortus* (Species group X). The characteristic species are also dominant and occur consistently throughout this community. The tree *Olea europaea* subsp. *africana* usually occurs near water such as riverine fringes but also grows in mountain ravines and on rocky terrain (Palgrave, 2002; Van Wyk *et al.* 2008). Other dominant species include several species from Species groups Q, R, X, Y and Z. Common species are mostly species from Species groups L, M, P,X and Z. A total of 107 species out of the 128 different species were recorded in this community at an average of 17 species per sample plot. The woody layer is well defined and is made up by a shrub and low to medium high tree layer. The plant cover of the herbaceous layer is in many instances sparse and patchy with large areas of bare soil.

The shrubland communities of the False Upper Karoo (Acocks 1988) was classified under the order Rhoetalia cilliato - erosae and the shrublands of the western upper Orange River valley under the association Pentzietea incanae by Werger (1980). It is unclear under which of these two orders the shrubland community of DNR exactly falls, but is most probably a form of the Zizipho-Rhigozetum associations of the Pentzietea incanae order. The *Olea europaea* subsp. *africana-Searsia burchellii* Shrubland displays definite floristic and environmental similarities to the Osteospermetum leptolobi and Stachyo-Rhoetum associations of the order Rhoetalia cilliato- erosae as well as the Zizipho-Rhigozetum association of the class Pentzietea incanae. All three the above mentioned communities are also in the same region as DNR, which further complicates distinction.

The environmental conditions of the Osteospermum leptolobi community have the closest resemblance to the *Olea europaea* subsp. *africana-Searsia burchellii* Shrubland community. Werger (1980) also noted that this community occurs on undulating terrain with shallow sandy soils, which often has a high occurrence of gravel. However, within the O. leptolobi community, shrubs are mostly absent and are dominated by karroid shrubs. Many of the characteristic species of the Stachyo-Rhoetum association are also very prominent in the *Olea europaea* subsp. *africana-Searsia burchellii* Shrubland and include species such as *Aristida diffusa* subsp. *burkei*, *Heteropogon contortus* and *Limeum aethiopicum*. Despite the similarity in floristic composition, the Stachyo- Rhoetum is found on steeper slopes of mountainous terrain which is more characteristic of the environment of the *Themeda triandra-Searsia burchellii* Randjie veld. Similarly, the Zizipho-Rhigozetum occurs on larger mountains and steep river valleys that are not typically associated with the shrublands of DNR, but it is largely similar in floristic characteristics, especially in regards to shrub species.

The *Olea europaea* subsp. *africana-Searsia burchellii* Shrubland community also falls under the *Rhus erosa* shrubland phytosociological class described by Du Preez & Bredenkamp

(1991). Similar shrubland communities from other regions nearby are the *Aristida diffusa-Olea europaea* sub-community from Kareefontein Private Nature Reserve, Central Free State Province (Botha, 2003) and the *Searsia burchellii-Hermannia vestita* community from Groenrivier, Northern Cape (Van Rensburg, 2013).

This community can be grouped into four different sub-communities, namely the *Olea europaea* subsp. *africana-Searsia burchellii-Tarchonanthus camphoratus* Shrubland, the *Olea europaea* subsp. *africana-Searsia burchellii-Melinis repens* Shrubland, the *Olea europaea* subsp. *africana- Searsia burchellii-Enneapogon scoparious* Shrubland, and the *Olea europaea* subsp. *africana- Searsia burchellii-Stipagrostis ciliata* Shrubland.

4.1 *Olea europaea* subsp. *africana- Searsia burchellii-Tarchonanthus camphoratus* Shrubland (Table 3.1, Appendix Ai)

This small sub-community (338 ha) covers two small low lying areas in the central region of the reserve. The slightly undulating terrain is characterized by shallow to moderately deep grey, gritty soils covered by gravel and small rocks. Soil depth is between 11-30 cm, while rock cover varies between 10-30% (average 21.25%). Almost all areas show moderate signs of sheet and gully soil erosion as well as grazing and trampling.

The species of Species group I are diagnostic of this community and are the shrubs *Tarchonanthus camphorates* and karroid shrub *Solanum lichtensteinii*. Dominant species are the tall shrub *Searsia burchellii* (Species group X), the grasses *Aristida congesta* subsp. *barbicollis* (Species group Q), *Aristida diffusa* subsp. *burkei* (Species group X), *Eragrostis lehmanniana* var. *lehmanniana* (Species group R), and *Fingerhuthia africana* (Species group R), and the karroid shrubs *Monechma incanum, Eriocephalus ericoides* (Species group Q) and *Pentzia incana* (Species group Y). All these dominant grass species prefer disturbed areas such as overgrazed rocky and sandy soils (Van Oudtshoorn, 2004) while the rigid karroid shrub *Monechma incanum* also prefers stony and rocky soils and often grows in colonies (Le Roux *et al.* 1994). Other common species include the karroid shrub *Chrysocoma ciliata* (Species group Z), the tree *Acacia karroo* (Species group E), the grasses *Heteropogon contortus* (Species group Z), *Setaria verticillata* (Species group D) and *Enneapogon scoparius* (Species group X) that typically grow on stony terrain and prefer shallow soils (Van Oudtshoorn, 2004). Conspicuous species of this shrubland are species of Species group X and Z.

The cover of the herbaceous layer is generally patchy, especially in lower regions (Figure 3.8). Canopy cover of the woody layer varies between 10-45% with an average cover of

27.14 %, while the herbaceous layer varies between 25-50% with an average cover of 40.9%

Figure 3.8 The vegetation of the *Olea europaea* subsp. *africana-Searsia burchellii-Tarchonanthus camphoratus* Shrubland indicating patchy ground cover.

4.2 *Olea europaea* subsp. *africana-Searsia burchellii-Melinis repens* Shrubland (Table 3.1, Appendix Ai)

This shrubland covers a large area of 1 155 ha in the northern section of the reserve. This region is characterized by a landscape of small to medium high ridges and hills with uneven rocky terrain and very shallow sandy soils (Figure 3.9). Rock cover varies from 20-60%, while soil depth is always less than 20 cm. Many areas were overgrazed and trampled by mostly eland and red hartebeest.

The species of Species group J are diagnostic for this shrubland and are the weak perennial grass *Melinis repens*, the annual grass *Enneapogon scaber*, the rigid woody shrub *Rhigozum obovatum*, and the forbs *Limeum aethiopicum*, *Barleria rigida* and *Jamesbrittenia albiflora*. These shrub and forb species are often found growing on hills and ridges, while the highly palatable *Limeum aethiopicum,* especially, prefers rocky and disturbed soils (Le Roux *et al*., 1994). Dominant species of the woody layer are the trees *Searsia burchellii* (Species group X)*, Olea europaea* subsp. *africana* (Species group H) and *Ziziphus mucronata* subsp. *mucronata* (Species group H). The herbaceous layer is mostly dominated by grass species that include *Aristida diffusa* subsp. *burkei* (Species group X), *Aristida congesta* subsp. *barbicolis* (Species group Q), *Heteropogon contortus* (Species group Z), *Fingerhuthia africana* (Species group R) and *Eragrostis lehmanniana* var. *lehmanniana* (Species group R). Both the grasses *Aristida diffusa* and *Heteropogon contortus* often grow on rocky terrain, while *Aristida diffusa* is especially common on shallow overgrazed soils with rocky cover (Van Oudsthoorn, 2004). A large number of dwarf shrubs species of predominantly Species groups J, L, M, P, X and Z are abundant in this community, although with a low canopy cover. The most notable of these dwarf shrub species are *Chrysocoma ciliata*, *Selago geniculata*, *Eriocephalus ericoides*, *Eriocephalus spinescens* and *Indigofera nigromontana*. Other conspicuous species are the tree *Acacia karroo* (Species group E), the grass *Enneapogon scaber* (Species group J), and the shrub *Asparagus suaveolens* (Species group Z).

In comparison to other communities and sub-communities, this shrubland has high species richness with 89 of the 128 known species recorded within this sub-community at an average of 19 species per sample plot. Canopy cover of the woody layer varies between 10-35% with an average of 22.5%. The canopy cover of the herbaceous layer varies between 20-60% with an average of 43.4%

Figure 3.9 The vegetation of the *Olea europaea* subsp. *africana-Searsia burchellii-Melinis repens* Shrubland indicating the typically rocky terrain with relatively shallow soils associated with the community.

4.3 *Olea europaea* subsp. *africana-Searsia burchellii-Enneapogon scoparious* Shrubland (Table 3.1, Appendix Ai)

The *Olea europaea* subsp. *africana-Searsia burchellii-Enneapogon scoparious* Shrubland is the largest of the four sub-communities, encompassing a total area of 1 595 ha and is distributed throughout the reserve. The northern and western regions of this community cover mostly small hills and foot slopes of larger mountains. The central and southern areas also cover the bottom reaches of valleys and low lying open, uneven terrain with small ridges. Throughout the sub-community, soil depth is very shallow, being rarely ever deeper than 20 cm. Soils of lower lying areas varies from sandy to gravelly, while soils of hills and other higher areas can also often be loamy. The degree of rockiness differs considerably from one region to another with hilly areas tending to have higher rock cover. The rock cover varies between 10-50% with an average of 26.4%. Many areas are overgrazed and trampled, especially on low lying areas of the sub-communities range.

This shrubland is characterized by the presence of the annual grass *Enneapogon scoparius* (Species group X) although this species has a low fidelity. Dominant species of the woody layer are the trees of Species group H and the shrubs *Searsia burchellii* and *Searsia ciliata* of Species group X. Dominant species of the herbaceous layer include the grasses *Aristida diffusa* subsp. *burkei (*Species group *X)*, *Aristida congesta* subsp. *barbicolis* (Species group Q), *Heteropogon contortus* (Species group Z), *Fingerhuthia africana* (Species group R) and *Eragrostis lehmanniana* var. *lehmanniana* (Species group R), as well as the karroid shrubs *Eriocephalus ericoides* and *Monechma incanum* of Species group Q. Both structurally and in species composition, the vegetation closely resembles those of sub-communities 4.1 and 4.2. This sub-community is mainly differentiated from the other sub-communities by the absence of species of diagnostic Species groups I and J, while the large multi-stemmed shrub *Searsia ciliata* is more dominant in this community than in the other sub-communities. Other common species are species of Species group L, M, P and Z.

The vegetation is especially patchy within this shrubland (Figure 3.10). The woody canopy cover varies from 10-35% with an average of 20.5%. The herbaceous canopy cover varies from 10-50% with an average of 39.2%

Figure 3.10 The vegetation of the *Olea europaea* subsp. *africana-Searsia burchellii-Enneapogon scoparious* Shrubland.

4.4 *Olea europaea* subsp. *africana-Searsia burchellii-Stipagrostis ciliata* Shrubland (Table 3.1, Appendix Ai)

This sub-community comprises of numerous small, low lying areas found across the reserve. The terrain for this shrubland is typically very flat (Figure 3.11). This small sub-community covers an area of 159 ha. The moderately deep soils are sandy and characteristically deeper than those in the other sub-communities. Soil depth varies between 11-30 cm. Rock cover can differ considerably from one location to another varying, between 0-40% with an average of 15%. Grazing pressure is low to moderate, while there is little indication of soil erosion.

Diagnostic species are the perennial grass *Stipagrostis ciliata* var. *capensis* and forb *Dicoma capensis* of Species group K. The annual grass *Aristida adscensionis* (Species group A) is also characteristic. Dominant species are the tree species of Species group H as well as the shrub *Searsia burchellii* (Species group X) and grasses *Eragrostis lehmanniana* var. *lehmanniana* (Species group R), *Aristida adscensionis* (Species group A) and *Aristida diffusa* subsp. *burkei* (Species group X). Numerous karroid shrub and forb species are prominent, which include *Chrysocoma ciliata* (Species group Z), *Plinthus karooicus* (Species group P), *Selago geniculata* (Species group P) and forbs such as *Indigofera alternans* (Species group P)*, Salvia verbenaca* (Species group C) and *Dicoma capensis* (Species group K).

Canopy cover of the woody layer was consistently between 15-25% with an average of 20.7%, while the canopy cover of the herbaceous layer as a whole was high and varied between 25-60% with an average of 52.8%

Figure 3.11 The vegetation of the *Olea europaea* subsp. *africana-Searsia burchellii-Stipagrostis ciliata* var*. capensis* Shrubland.

5. *Pentzia globosa-Eragrostis lehmanniana* Grassland (Table 3.1, Appendix Ai)

This community is the closest representation of true plains on DNR and covers areas in the south and north of the reserve. These plains consist of alluvial flats that surround the Zeekoei River as well as flat low hills. In total this grassland encompass an area of 1 421 ha. Rock cover varies from 0-30% (average 9%). Soil depth is between 11-30 cm and of sedimentary and sandy soil type. Lower lying regions of this community, most notably areas around the Zeekoei River, tend to have deeper soils with less rock cover than areas covering hills. Sheet erosion and moderate to high levels of overgrazing and trampling were observed in most areas.

This community is characterized by the occurrence of less abundant karroid shrub species of Species group N. These karroid shrub species are *Pentzia globosa*, *Aptosimum marlothii*, *Gnidia polycephala*, *Phymaspermum parvifolium*, *Helichrysum zeyheri* and *Pteronia glauca. Gnidia polycephala* is a plains species that prefers sandy and limestone-rich soil (Le Roux *et al*., 1994). The dominant species are the grasses *Eragrostis lehmanniana* var. *lehmanniana* (Species group R) and *Aristida diffusa* subsp. *burkei* (Species group X), and the karroid shrubs *Pentzia incana* (Species group Y), *Pentzia globosa* (Species group N). The high abundance of the grass *Eragrostis lehmanniana* var. *lehmanniana* is an indication of overgrazing as it is documented that this species, which prefers sandy soils, increases where disturbances have occurred in the past (Van Oudtshoorn, 2004). Species diversity was generally low with an average of 11 species recorded per relevé. Many of the common species in this community are also abundant in the *Olea europaea* community and are almost entirely associated with overgrazing.

Werger (1973, 1980) grouped the communities the False Upper Karoo plains (Pentzio-Chrysocomion prov.) under one association, namely the Hermannio coccocarpae-Nestleretum confertae. The *Pentzia globosa- Eragrostis lehmanniana* Grassland community present on DNR is a representation of the Aptosimetosum marlothii, which is a sub-association of the Hermannio coccocarpae- Nestleretum confertae. The location of the grassland communities of DNR is slightly further west than the boundaries defined by Werger (1980) for the Aptosimetosum marlotti sub-association, although he mentioned the possibility of this community occurring outside the mentioned distribution range.

The Hermannio coccocarpae-Nestleretum confertae association is also grouped under the *Eragrostis obtusa-Eragrostis lehmanniana* Dry Grassland Phytosociological class as described by Du Preez & Bredenkamp (1991). The vegetation of these plains are characterized by typical karoo veld with grasses and karroid shrubs being the dominant species. The woody layer is not always clearly represented and shrubs and trees often scattered or occur in clumps throughout the community. One other *Eragrostis obtusa-Eragrostis lehmanniana* Dry Grassland community that is similar to the *Pentzia globosa-Eragrostis lehmanniana* Grassland is the *Aristida diffusa-Aristida congesta* community of the Central Free State province (Muller, 2002).

Other very similar plant communities have also been described in the Mountain Zebra National Park which include the *Aristida congesta* subsp. *barbicollis* Grasslands from the Du Rust section (Brown & Bezuidenthout, 2000), both the *Pentzia globosa-Enneapogon scoparius* and *Aristida adscensionis-Pentzia globosa* Grasslands from the Doornhoek section (Bezuidenhout & Brown, 2008), the *Eragrostis obtusa-Pentzia globosa* sub-community of the Ebenaeser section (De Klerk *et al*., 2003) and the *Eragrostis obtusa-Pentzia globosa* Shrubland on the farms Ingleside and Welgedacht (Brown & Bezuidenhout, 2005). While the *Stipagrostis obtusa-Eragrostis lehmanniana* community from the Groenrivier catchment, Northern Cape is another community similar to the Karoo region (Van Rensburg, 2013).

Three different sub-communities can be differentiated, namely the *Pentzia globosa-Eragrostis lehmanniana-Aristida adscensionis* Grasslands, the *Pentzia globosa-Eragrostis lehmanniana-Arisitda diffusa* Grasslands and the *Pentzia globosa-Eragrostis lehmanniana-Eriocephalus spinescens* Grassland.

5.1 *Pentzia globosa-Eragrostis lehmanniana-Aristida adscensionis* Grasslands (Table 3.1, Appendix Ai)

This sub-community mainly covers the low flat hills in the southern sector of the reserve. The reddish and light coloured sandy soils of this grassland are moderately deep with little rock cover. This sub-community covers a total area of 250 ha. Soil depth varies between 11-40 cm while rock cover varies between 10-25% (average 10%). Overgrazing was especially high and mostly caused by the destructive feeding behaviour of warthog as indicated in Figure 3.13.

No Species group is diagnostic of this community. This community is mainly differentiated from the other sub-communities by the occurrence of the annual grass *Aristida adscensionis* (Species group A) and of Species group L as well as its higher dominance of the woody shrubs *Searsia burchellii* and *Searsia ciliata* of Species group X (Figure 3.12). Dominant species of the herbaceous layer are the grasses *Aristida congesta* subsp. *barbicollis* (Species group Q), *Eragrostis lehmanniana* (Species group R), *Aristida adscensionis* (Species group A) and *Aristida diffusa* subsp. *burkei* (Species group X), as well as the karroid shrubs *Eriocephalus ericoides* (Species group Q), *Chrysocoma ciliata* (Species group Z) and *Pentzia incana* (Species group Y). Conspicuous species for this sub-community are mostly grasses and karroid shrubs of Species groups N, P and Z.

Especially the high abundance of the grasses *Aristida congesta* subsp. *barbicollis, Aristida adscensionis* and *Aristida diffusa* subsp. *burkei* can be seen as clear indication of long term overgrazing within this sub-community. Woody species within this grassland were more evenly distributed than in the other grassland sub-communities with also a higher canopy cover that varies between 10-25% with an average of 17.2%. The cover of the herbaceous layer varies between 35-60% at an average of 49.4%.

Figure 3.12 The vegetation of the *Pentzia globosa-Eragrostis lehmanniana-Aristida adscensionis* indicating a higher shrub density in comparison to the other grassland sub-communities.

Figure 3.13 Indication of the damage caused by warthog. The warthog tend to concentrate on regions where deeper reddish sands occur.

5.2 *Pentzia globosa-Eragrostis lehmanniana-Aristida diffusa* Grasslands (Table 3.1, Appendix Ai)

This sub-community is restricted to a small area in the far southern section of the reserve and covers an area of only 161 ha on top of an elevated ridge with a flat surface (Figure 3.14). Rock cover varies between 10-30% (average 24.4%). Soils are sandy and moderately deep with depths between 15-30cm. Grazing pressure and animal trampling was moderate, while indication of soil erosion was evident.

No plant species are diagnostic of this sub-community, which can be distinguished from the other two sub-communities by the absence of the grass *Aristida adscensionis* and species of Species group O. Furthermore, species from Species group Q are also less abundant than in the other sub-communities. The only dominant woody species is the multi-stemmed shrub *Searsia ciliata* (Species group X). Dominant species of the herbaceous layer are the perennial grasses *Eragrostis lehmanniana* (Species group R) and *Aristida diffusa* subsp. *burkei* (Species group X), and the karroid shrubs *Pentzia incana* (Species group Y), *Pentzia globosa* (Species group N) and *Chrysocoma ciliata* (Species group Z). Both *Pentzia incana* and *Pentzia globosa* are very common dwarf shrub species throughout their distribution in the Karoo and grow on plains, depressions and ridges (Le Roux *et al*. 1994). Significant species are the annual grass *Aristida congesta* subsp. *barbicollis* (Species group Q) and shrub *Searsia burchellii* (Species group X). Other abundant species are the karroid shrub *Nenax microphylla* (Species group P) and species of Species group N.

The canopy cover of the woody layer varies from 0-20 % with an average of 10.5%. The cover of the herbaceous layer varies from 40-70% with an average of 54.6%

Figure 3.14 The vegetation of the *Pentzia globosa-Eragrostis lehmanniana-Aristida diffusa* Grasslands that covers a small flat hill.

5.3 *Pentzia globosa-Eragrostis lehmanniana-Eriocephalus spinescens* Grassland (Table 3.1, Appendix Ai)

This sub-community represents the largest area of the major community (1010 ha) and covers areas in both the northern and southern sections of the reserve (Figure 3.15). The soils are sandy and of a sedimentary soil type. Areas on the lower areas around the Zeekoei River and the northern section of the reserve tend to have no rock cover, while areas west of the Zeekoei River, where the community stretches over hills, are more rocky. Rock cover varies from 0-10% on the low lying areas and from 10-30% on the higher reaches. Large areas most notably areas surrounding the Zeekoei River, are overgrazed and trampled, especially by large herds of eland.

Diagnostic species of this sub-community are the species of Species group O and are the woody karroid shrub *Eriocephalus spinescens*, the perennial grasses *Stipagrostis uniplumis* var. *neesii* and *Stipagrostis obtusa,* and the annual grass *Aristida congesta* subsp. *congesta*. Both *Stipagrostis* species are highly palatable grass species that often grows on sandy soil and plays an important role in stabilizing soil (Van Oudtshoorn, 2004). Dominant species are the perennial grasses *Eragrostis lehmanniana* (Species group R) and *Aristida diffusa* subsp. *burkei* (Species group X), the annual grass *Aristida congesta* subsp. *barbicollis* (Species group Q) and the karroid shrubs *Pentzia incana* (Species group Y), *Pentzia globosa* (Species group N), *Eriocephalus ericoides* (Species group Q), *Eriocephalus spinescens* (Species group O) and *Chrysocoma cilliata* (Species group Z). The high abundance of the unpalatable *Pentzia globosa* is of particular interest as it is often an indication of karoo invasion of grassland (Le Roux *et al*. 1994). Both *Eriocephalus* species are common karroid species throughout their distribution (Le Roux *et al*. 1994). Other common species are karroid species from Species groups N and P.

The vegetation of this sub-community is comparable to that of the previous sub-community, both in structure and species composition. Apart from the diagnostic species of Species group O, this sub-community can be further differentiated from the other sub-communities by the higher dominance of the karroid shrubs *Eriocephalus ericoides* and *Pentzia incana*, which are less prominent in the other sub-community (5.1).

The abundance of grasses in this grassland seems to fluctuate seasonally depending on the rainfall, although not nearly as dramatic as in the *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland (sub-community 1.1). Therefore, the veld may change from grass dominance (grassland) to karroid shrub dominance (typical bossieveld) and *vice versa* from one season to another depending on rainfall. The canopy cover of the woody layer varies from 0-25% with an average of 8.5%.The cover of the herbaceous layer varies from 35-50% with an average of 43.8%

This grassland is comparable to the *Selago geniculata-Eragrostis obtusa* Grassland sub-community described by Brown & Bezuidenthout (2000) in the De Rust section of the Mountain Zebra National Park, Eastern Cape. Dominant and prominent species in both grasslands are the grasses *Eragrostis lehmanniana*, *Aristida congesta* subsp*. barbicolis* and the dwarf shrubs *Pentzia globosa* and *Eriocephalus ericoides*.

Figure 3.15 The vegetation of the *Pentzia globosa-Eragrostis lehmanniana-Eriocephalus spinescens* Grassland.

6. *Themeda triandra-Searsia burchellii* Randjie veld (Table 3.1, Appendix Ai)

All the higher and larger hills of the reserve form part of this community and it covers an area of 3 880 ha, making it the largest plant community. The bedrock of these hills consists largely of dolerite sills and dykes. The terrain varies from very steep slopes (25° and higher) to flat plateaus that are characterized by very deep brown loamy soils. The soil is both covered and embedded by large rocks and boulders. Except for a few localities on steep slopes, no indication of soil erosion is evident. There are no evidence indicating grazing and trampling on the mountain slopes in general, while low levels of grazing and trampling are evident in various areas on the mountain plateaus, with a few isolated grazing-lawns occurring within the community, mostly caused by herds of red hartebeest (see Chapter 6).

Diagnostic species of this community are the species of Species group S and are the perennial grasses *Themeda triandra* and *Digitaria eriantha*, the tall shrub *Euclea crispa* subsp. *ovata*, and the dwarf shrub *Stachys linearis* and ferns *Cheilanthes hirta* and *Pellaea calomelanos* var*. calomelanos*. The large shrub *Euclea crispa* subsp. *ovata* typically occur in mountainous terrain throughout its distribution in the Karoo region (Van Wyk *et al*. 2008). The diagnostic species of Species group Q are also dominant species for this community, apart from the fern species, while other dominant species are the shrubs *Searsia burchellii* and *Searsia ciliata* of Species group X. The vegetation is characterized by a dense herbaceous layer that is dominated by perennial grasses with a definite woody layer also distinguishable.

The woody layer varies from low to medium canopy cover density and consists of large shrub and small trees stratum usually under 2 m high. The herbaceous layer is particularly dominated by the diagnostic perennial grass *Themeda triandra* that in some instances constitutes almost 100% of the herbaceous layer cover. *Themeda triandra* occurs in all veld types over its distribution range but is especially common in undisturbed climax grassland on loamy soils at altitudes between 1300-3000 m (Van Oudsthoorn, 2004, Snyman *et al*., 2013). The abundance of both perennial grasses *Themeda triandra* and *Digitaria eriantha* is an indication that the veld is in very good condition. Species diversity of for this community is especially low with only 55 different species recorded in a total of 61 relevés at an average of 8 species per sample plot.

As with the *Olea europaea* subsp. *africana-Searsia burchellii* Shrubland, this Randjie veld is one of the Rhoetia- cilliato-erosae orders and is most likely a representation of the Stachyo-Rhoetum-hermannietosum vistidae and the Stachyo-Rhoetum variant Salvia namaensis associations. However, the Randjie veld community differs floristically vastly from the communities described by Werger (1980), but occurs on the same type of dolerite hills from the same region that Werger (1980) described for the communities. In none of Werger's communities is the grass *Themeda triandra* a prominent or common species were it is dominating the Randjie veld vegetation.

This community can be divided into three sub-communities, namely the *Themeda triandra-Searsia burchellii-Boophane disticha* Randjie veld, the *Themeda triandra-Searsia burchellii-Sporobolus fimbriatus* Slope vegetations and the *Themeda triandra-Searsia burchellii-Melolobium microphyllum* Randjie veld

6.1 *Themeda triandra-Searsia burchellii-Boophane disticha* Randjie veld (Table 3.1, Appendix Ai)

This sub-community covers the highest mountains of DNR with plateaus peaking between altitudes of 1400 m and 1 600 m. These mountains are largely situated in the central and southern sections of the reserve (Figure 3.1). This Randjie veld covers both the slopes, which are often very steep, and the usually flat plateaus (Figure 3.17). In total this sub-community covers an area of 2 011 ha. The darkish brown coloured loamy soils are deep and are covered and embedded by very large rocks. The rock covers varies between 10-40% of the ground surface with an average of 30.9%. The rock cover is generally higher on the slopes than on the plateaus. The slopes are steep with a slope degree between 12.5-20°. Grazing pressure and trampling were low with no evident soil erosion.

The geophyte *Boophane disticha* (Species group T) is the only diagnostic species although with a low fidelity. This geophyte species are more commonly encountered on the flat plateaus and less frequently on the slopes. This community is further characterized by differential species, which are the grasses *Heteropogon contortus* (Species group Z), *Aristida diffusa* subsp. *burkei* (Species group X) and *Enneapogon scoparius* (Species group X). The herbaceous layer is dominated by the grasses *Themeda triandra* (Species group S), *Heteropogon contortus* (Species group X) and to a lesser extent by the grasses *Digitaria eriantha* (Species group S), *Aristida diffusa* subsp. *burkei* (Species group X) and *Enneapogon scoparious* (Species group X). The woody layer is dominated by the shrubs *Searsia ciliata*, *Searsia burchellii* and *Euclea crispa* subsp. *ovata*. Other significant species are the forb *Stachys linearis*, the grasses *Fingerhuthia africana* and *Eragrostis lehmanniana* var. *lehmanniana* as well as the karroid shrub *Pentzia globosa*.

The vegetation of this sub-community is dominated by a dense stance of grasses and a distinguishable woody layer with a low canopy cover consisting of high shrubs between 1-2 m in height (Figure 3.16). The woody canopy cover of this sub-community is lower than for the other two sub-communities and it varies between 0-20% with an average of 10.5%. The canopy cover of the herbaceous layer varies between 40- 70 with an average of 56.9%.

Figure 3.16 The vegetation of the *Themeda triandra-Searsia burchellii-Boophane disticha* Randjie veld illustrating the abundance of the grass *Themeda triandra* throughout this community.

6.2 *Themeda triandra-Searsia burchellii-Sporobolus fimbriatus* Southern slopes (Table 3.1, Appendix Ai)

This sub-community covers many of southern facing slopes of the larger mountains and comprises a total area of 297 ha (Figure 3.17). The slopes vary from moderate to very steep with very rocky terrain consisting of both embedded and submerged rocks and boulders.

These slopes are generally cooler, moister and are longer shaded from the sun than slopes facing other directions. The darkish loamy soil is very deep with depths above 35 cm.

The grasses *Sporobolus fimbriatus* and *Cymbopogon pospischilii* of Species group U are diagnostic of this sub-community. This community is further characterized by the relative high occurrence of the shrubs *Salvia namaensis* (Species group F), which typically grow between large boulders, and *Diospyros austro-africanum* var. *microphylla* (Species group X). The dominant shrubs species representing the woody layer are *Searsia cilliata*, *Searsia burchellii* and *Diospyros austro-africanum* var. *microphylla* of Species group X, as well as *Euclea crispa* subsp. *ovata* of Species group S. Both *Euclea crispa* and *Diospyros austro-africana* generally grow on mountain slopes, which explains the higher occurrence of these species in this sub-community compared to the other two sub-communities (Sheaning & Van Heerden, 1994; Van Wyk *et al.* 2008). The herbaceous layer is dominated by the grasses of Species group S, such as the grass species *Themeda triandra* and *Digitaria eriantha*. Other notable species are mainly species of Species group Z.

The woody layer, consisting of a high shrub layer that is between 1- 2 m high, is often denser in this sub- community than in the other two mountain grassland communities. The cover of the woody layer varies between 10-40% with an average of 21.4%. The herbaceous layer varies between 55-70% with an average of 57.5%

This sub-community is most probably the same Stachyo- Rhoetum hermannietosum Salvia namaensis variant described by Werger (1980) that occurs on steep southern facing dolerite slopes.

Figure 3.17 The vegetation of the *Themeda triandra-Searsia burchellii-Sporobolus fimbriatis* Southern slopes typically associated with steep southern facing slopes.

6.3 *Themeda triandra-Searsia burchellii-Melolobium microphyllum* Randjie veld (Table 3.1, Appendix Ai)

The largest areas covered by this sub-community are the mountains between the Zeekoei and Orange River and in total it covers an area of 1 572 ha. The terrain and environmental conditions of this sub-community are comparable to sub-community 6.1. However, the mountain ranges covered by this grassland are lower than those in sub-community 6.1 with plateau altitudes between 1 200 m and 1350 m.

The only diagnostic species of this sub-community is the small shrub *Melolobium microphyllum* (Species group V). This unpalatable shrub grows on hills and ridges and prefers rocky soils (Le Roux *et al.* 1994). Dominant species of the woody layer are the shrubs *Searsia burchellii* (Species group X), *Searsia ciliata* (Species group X), and *Euclea crispa* subsp.*ovata* (Species group S). The herbaceous layer is dominated by the grasses *Themeda triandra* (Species group S) and *Digitaria eriantha* (Species group S). In terms of species composition this community very closely resembles those of sub-communities 6.1 and 6.2. The main differences include the predominantly absence of the species of Species group W, while the grass *Themeda triandra* (Species group S) and woody large shrub *Searsia burchellii* (Species group X) are even more dominant within this community (Figure 3.18). The dwarf shrubs *Chrysocoma ciliata* and *Asparagus suaveolens* of Species group Z also occur more frequently. The high occurrence of *Themeda triandra* is an indication of the veld being in good condition. Common species with a low cover value are the shrub *Asparagus suaveolens* the forb *Oxalis depressa* of Species group Z.

The height of the woody layer tends to be higher in this grassland compared to the other two grasslands with heights varying between 1.5-3 m. The canopy cover of the woody layer varies from 5-25% with an average of 17.5% while the cover of the herbaceous layer varies from 40-70% with an average of 59.8%.

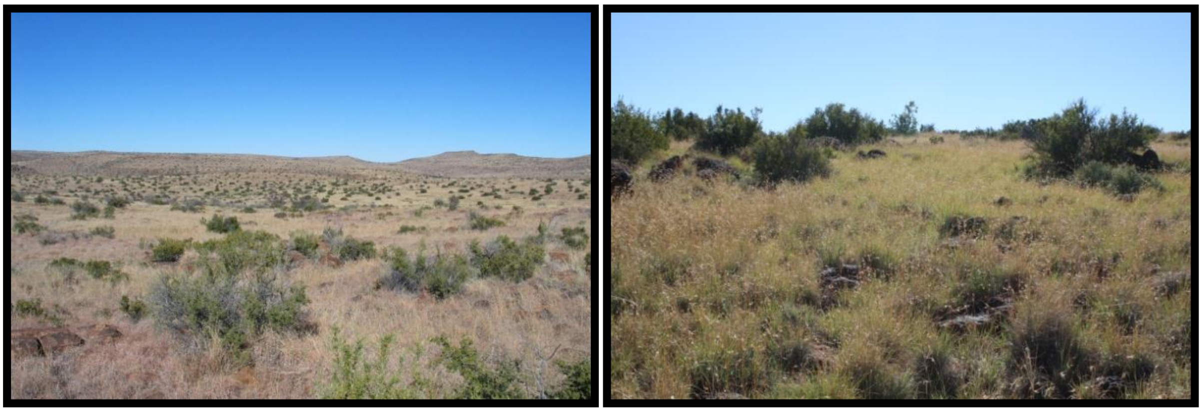


Figure 3.18 The vegetation of the *Themeda triandra-Searsia burchellii-Melolobium microphyllum* community covering the mountain plateaus between the Zeekoei River.

3.4 Ordination

Indirect ordination methods were used for the ordination by applying a Canonical Correspondence Analyses (CCA) to the vegetation data. A Detrended Correspondence Analysis (DCA) was also applied to the data to determine the heterogeneity of the species data and indicated that a unimodel model best fitted species response (‘length of gradient value’ >4) and was consequently used as the logarithmic model.

The Monte Carlo permutation test was applied to the CCA-ordinations to indicate the statistical significance of the species-environment variables measured in explaining dataset heterogeneity. Both the non-significant and ($p<0,05$) collinear environmental variables were removed for the final calculations during the forward selection process.

A CA (non-linear method) was also applied to the data and compared to the CCA (before exclusion of collinear and non-significant environmental variables) results. The results indicated that the most important environmental variables to explain heterogeneity were not measured. One such important variable not measured was likely the soil type.

The ordination indicated that communities from the plains (community 4 and 5) shared similar environmental conditions, such as soil dept, rock cover and size of rocks, although differing slightly from each other (Figure 3.19) Community 6 showed distinct environmental differences to the other communities by differing in higher rock cover, soil depth, and rock size. Both azonal communities (communities 2 and 3) were differentiated from the other communities by the semi-shaded conditions associated with the communities.

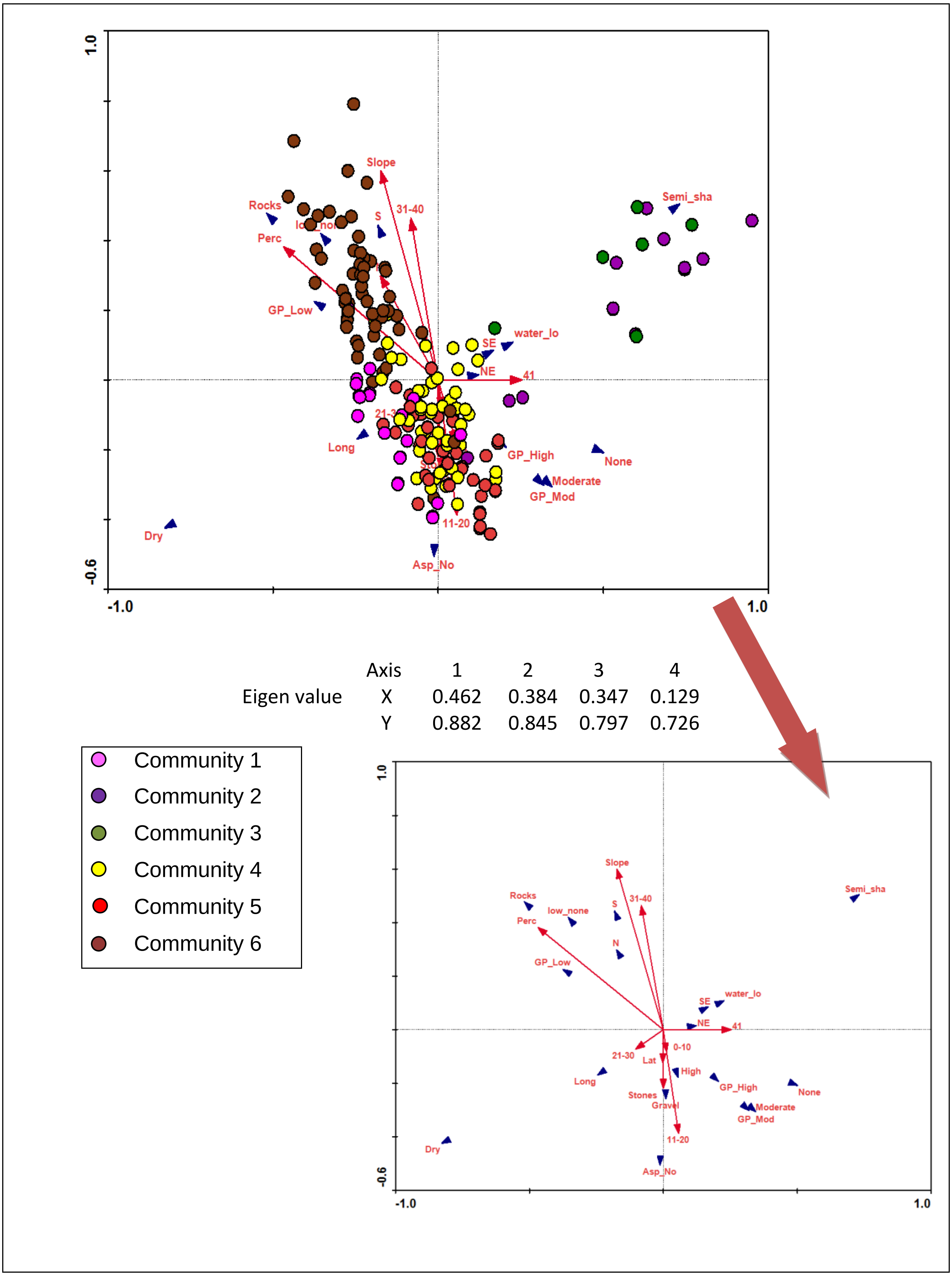


Figure 3.19 The Canonical Correspondence Analyses (CCA) of the species-environment data.

3.5 Allocation of management units

Usually the plant communities occurring in an area do not necessarily represent separate ecological management units that can be used in a practical management plan for a reserve, since many of these plant communities have similarities regarding species composition and habitat, and may have a complex mosaic distribution pattern. However, there are definite distinctions within the plant communities of DNR with regards to floristic and environmental differences to justify the separation of each plant community as a management unit of its own, as each of these units also requires its own monitoring and management policies. With regards to plant community one (*Eragrostis chloromelas-Chloris virgata* Grassland), it was decided to treat the two sub-communities as separate management units. This was done because one sub-community has a definite woody component that consists of large shrubs, while the other is pure grassland. As a result these two sub-communities vary in terms of browsing availability for game species, ultimately also influencing habitat selection of species and thus requiring different management considerations. The allocations of management units is given in Table 3.2 and are also indicated in Figure 3.20

Table 3.2 The management units of DNR.

Management unit (Habitat unit)	Plant community	Short description
Management unit 1: ***Eragrostis chloromelas* grasslands**	Sub-community 1.1: *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland	Grasslands with no shrub or tree layer. On flat terrain with deep loamy soils
Management unit 2: **Grassy shrublands**	Sub-community1.2: *Eragrostis chloromelas- Chloris virgata-Searsia burchellii* Grassy shrubland	Grasslands with low density shrubs. On deep loamy soils with little rock
Management unit 3: **Drainage lines**	Community 2: *Melianthus comosus-Acacia karroo* River thicket	Dense shrub and tree layer associated with drainage lines. On deep sandy soils
Management unit 4: **Riverine thicket**	Community 3: *Hyparrhenia hirta-Olea europaea* subsp. *africana*	Dense woodlands restricted to larger watercourses. soils sandy and deep

Management unit (Habitat unit)	Plant community	Short description
Management unit 6: ***Eragrostis lehmanniana* grasslands**	Community 5: *Pentzia globosa*-*Eragrostis lehmanniana* Grasslands	Grasslands with high abundance of dwarf shrubs and few shrubs and trees. On flattish terrain with sandy soils
Management unit 7: **Randjie veld**	Community 6: *Themeda triandra*-*Searsia burchellii* Randjie veld	Dense grassland with distinguishable short shrub layer covering larger hills. Terrain rocky with deep loamy soils

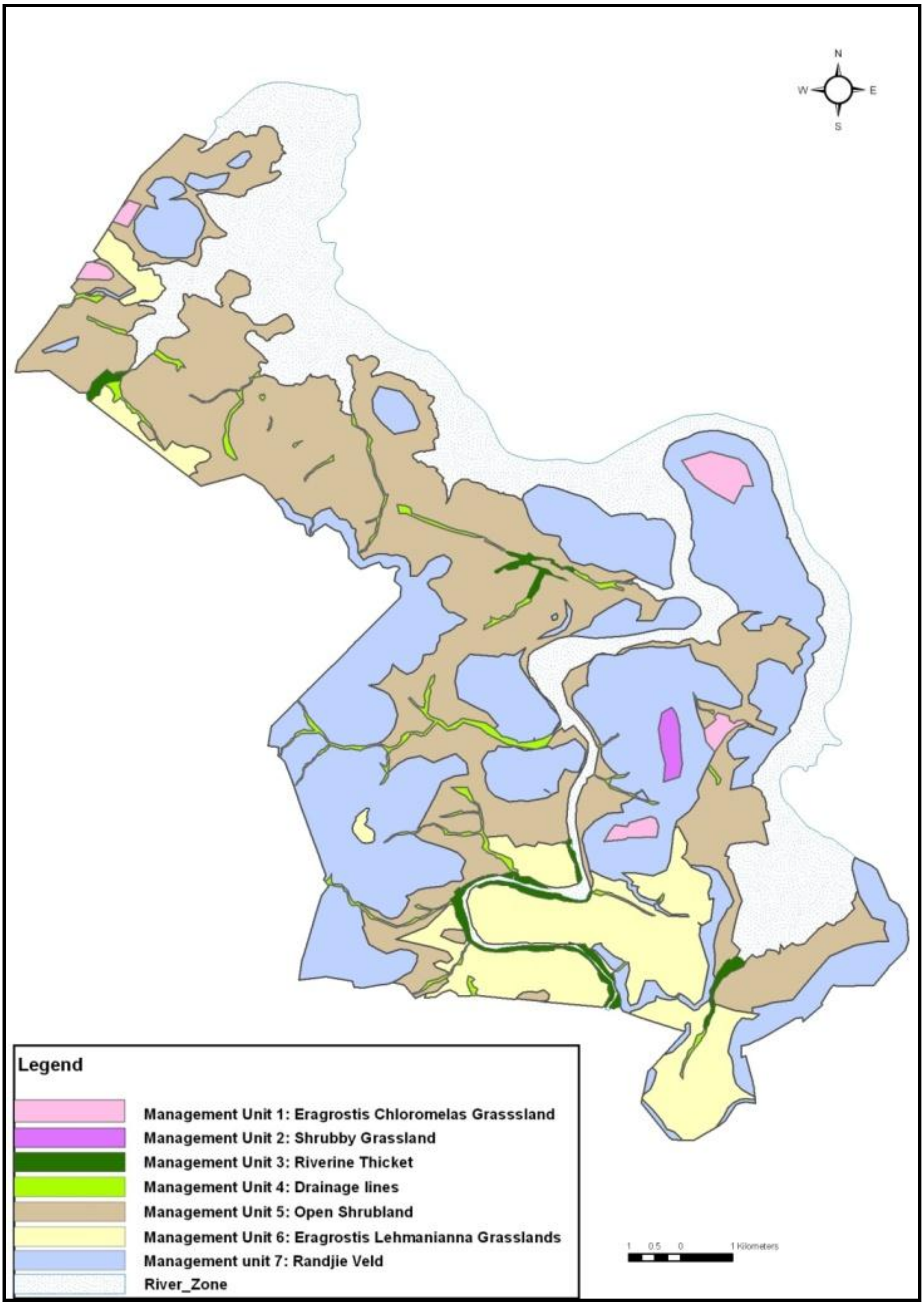


Figure 3.20 The Management Units of DNR.

3.6 Conclusion

The Braun-Blanquet vegetation classification technique proved to be an accurate and effective method for determining the different plant communities and management units. The determined plant communities and management units, together with the first vegetation map for the reserve, will be invaluable for developing long-term management policies and they enable long-term monitoring of the vegetation. Information gathered from this study forms the basis for further plant studies and assist in providing further insight into the vegetation dynamics of this region.

Due to the heterogeneous landscape of the Reserve the vegetation of DNR is relatively diverse consisting of grasslands, shrublands and riverine communities. This heterogeneity in terrain and vegetation creates a large variety of habitats that, in turn, promotes diversity in both fauna and flora species. Although all the communities are a function of their physical environment, it is in particular evident from this study that the floristic composition and characteristics are significantly influenced by the seasonal rainfall and overgrazing, both in the past and present.

The effect of rainfall on the vegetation is well known, and is more profound in drier regions. In the dry karoo region, the amount of rainfall has a great impact on the vegetation. During wet years karoo veld has high levels of production levels of annual and short-lived perennials (O'Conner & Roux's, 1995). Esler *et al.* (2006) also states that the level of grassiness in the karoo varies from year to year depending on the timing and quantity of rainfall. These rapid changes in vegetation are due to the ability of annual plants to grow rapidly after rainfall and thus quickly covering bare ground (Esler *et al.,* 2006).

Just prior to the field surveys of this study, DNR received an above average amount of rainfall for the months of January and February 2011. Within this two month, a total of 355 mm of rain fell, which is almost equal to the average annual rainfall figure of the region. The large amount of rainfall significantly influenced the floristic composition and canopy cover of the plant communities described. The effects were most clearly visible in the *Eragrostis chloromelas-Chloris virgata-Felicia muricata* Grassland and the *Pentzia globosa-Eragrostis lehmanniana* Grasslands and also to a lesser degree the Thicket community. In these communities the dominant grasses such as *Aristida adscensionis, Chloris virgata*, *Setaria verticillata* and *Eragrostis lehmanniana* either completely disappeared or decreased dramatically in abundance during the two years after these communities were described. During this two year period DNR received below average rainfall that occurred mostly later than normal within the rainy season.

Apart from rainfall, it was also evident that secondary factors such as grazing have influenced the vegetation of DNR. Numerous authors have referred to the effect of sheep farming on the vegetation of this region (Werger, 1980; Acocks, 1988; Du Preez & Bredenkamp, 1991; Le Roux *et al*., 1994;). Acocks (1988) named the region between Aliwal North and the Van der Kloof Dam the False Upper Karoo. He called the region “false” karoo veld as this region had previously been grassland, but was encroached by karroid invader species as a result of long-term overgrazing. He further states that the development of this veld type is the most spectacular change in vegetation of all the veld types in South Africa. Werger (1980) stated that the plains of the False Upper Karoo resemble those of the Central Upper Karoo, but were in a poorer state because of the abundance of less desired grazing grasses such as *Aristida adscensionis*, *Aristida congesta* and *Eragrostis lehmanniana*. Results from this study indicate that the floristic characteristics of the communities of the plains and lower lying regions of DNR have remained largely unchanged over the forty year period since Werger (1973, 1980) described the communities of this region. In this regard, especially the *Eragrostis lehmaniana-Pentzia globosa* and *Olea europaea-Searsia burchellii* community still bear the effects of overgrazing from the past. It also seems that overgrazing is the one major binding factor between the *Eragrostis lehmanniana-Pentzia globosa* community and other similar communities of other regions, such as those of the Mountain Zebra National Park. In many of these communities heavy overgrazing has occurred in the past and present that resulted in the increase of pioneer species. Species such as *Aristida congesta*, *Aristida adscensionis*, *Eragrostis lehmanniana* and *Pentzia globosa* are some of the most prominent species in most of these communities and are typically associated with overgrazing.

Interestingly, however, results from this study also indicate that the *Themeda triandra-Searsia burchellii* randjie veld that covers the higher hill and mountain regions might have changed, from a lower successional stage to a climax succession state. None of the communities described by Werger (1980) back in 1973 that cover these higher dolerite hill regions, truly reflect the floristic composition of these hills at the time of the study. In these communities of Werger (1980), various pioneer grasses and dwarf shrub species were prominent and characteristic, while climatic grasses such as *Themeda triandra* were rarely encountered. The canopy cover of these communities is also generally low. Currently, many of those pioneer grasses and dwarf shrub species are absent, while *Themeda traindra* completely dominates the vegetation and creates a far denser canopy cover. Werger (1980) and Du Preez & Bredenkamp (1991) mention that the grass *Themeda triandra* is a relic species of the former grassland communities of the region. Therefore, the abundance of this grass species within the randjie veld community can be seen as a strong indication of the community returning to its true climatic grassland state.

Many scientists are of the opinion that the invasion of karoo veld in this region is a function of rainfall and that drought periods result in an increase in karoo elements. During wet cycles the veld reverts to a grassland dominated state (Low & Rebello, 1996). Although it is possible that rainfall might have contributed to the changes in this community, it seems unlikely since over a long period prior to the high rainfall of 2011, DNR received below average or slightly above average rainfall. Apart from the short period from 2000-2002, no wet cycle has occurred in the past thirty years (Figure 2.3, chapter 2.). Therefore, this change is most probably due to the change in land use and subsequent change in grazing pressure when DNR was established. Sheep were replaced by game species of which many are browsers and mix feeders. This resulted in a reduced grazing pressure which enabled the veld to recover through plant succession to a state close to its former one. These vegetation changes of the higher regions have most probably not occurred in the lower lying communities, since game species still concentrate on the lower regions, thus maintaining the grazing pressure (see Chapter 6). It might also be possible that the changes brought about by sheep farming in these communities are irreversible. Acocks (1988) and Werger (1980) also state that many of the hills within the False Upper Karoo are still of a grassland type, especially in protected areas, and if probably strengthens the idea that the change in land use have assisted this community.

Chapter 4: Quantification of the herbaceous layer

4.1 Introduction

Successful wildlife management is greatly dependant on proper veld management which is based on a thorough knowledge of the diversity of the plant communities present, their seasonal variation, the quality and quantity of the available forage and also the grazing potential of the plants (Barnes, 1976, Erasmus *et al.,* 1978; Van Rooyen, 2002). Vegetation is typically heterogenous and comprises a mixture of species of varying acceptability to animals. According to Trollope (1990) the species composition of the grass sward serves as a good indicator of the intrinsic ability of the veld to produce forage for grazing ungulates. Veld condition refers to the condition of the vegetation in relation to some functional characteristics, normally sustained forage production and resistance to soil erosion (Trollope, 1988).

Determining current veld condition has proven to be very valuable for monitoring the effect of management practices and formulating new practises. The productivity, health and stability of veld are indicators of the current veld condition in relation to the maximum potential of it for the area in question (Van der Westhuizen, 2003; Ngwenya, 2012). Veld condition assessments also provide a means of comparing veld types, a way to determine quantity and quality, and to observe spatial and temporal changes within a plant community or vegetation type (Hardy *et al*., 1999). It is a known fact that vegetation is not static but constantly changing. These changes can be successive or retrogressive and are known as plant succession (Van der Westhuizen, 1994; Van der Westhuizen, 2003).

The term plant succession describes the process by which the vegetation of an area changes over time and is a process that occurs with or without human interference. The two main factors, outside man's control that predominantly control plant growth, are rainfall and soil type (Van Rooyen, 2002; Vetter, 2005, Bashari *et al*., 2008; Buitenwerf *et al*., 2011). Grazing management and fire practices are factors controlled by human intervention that impact on the habitat by modifying both the speed and direction of changes within the vegetation (Tainton, 1999; Van Rooyen, 2002; Vetter, 2005; Bashari *et al*., 2008; Buitenwerf *et al*., 2011). According to Van Rooyen (2002) the understanding and application of veld management depend heavily on the principles of plant succession, indicator plants and ecosystem dynamics. In general plant succession refers to the progression of different plant communities from a pioneer stage on bare or disturbed soils, through various transition stages to the final, stable or climax stage. Progressive succession occurs when veld condition has improved as a result of succession changes, while veld deterioration that can be caused by various influences, is known as retrogressive succession. Veld in a pioneer stage is unstable and of low grazing capacity, while climax veld represents a stable, healthy veld (Van Rooyen, 2002).

Apart from veld condition, the availability of forage that can support different species is considered to be the most important factor influencing habitat selection by large herbivores (Smit, 2006; Fynn, 2012). Furthermore the improvement, or ultimately the optimization of animal production systems in southern Africa, can only be realized if reliable production estimates are available for the specific area (Grossman, 1982). The appropriate stocking rates, determined by veld condition and forage availability, are important elements in determining the sustainability of any game ranching enterprise (Trollope, 1990). Therefore, veld condition assessment and determination of grazing capacity are important for the sustainable use and proper management of the vegetation.

The objectives of this study were to determine:
(i) the botanical composition,
(iii) the veld condition, and
(iv) the grazing capacity of the herbaceous layer in the various management units

4.2 Methodology

4.2.1 Botanical composition

The species composition of the herbaceous layer of each management units was determined for, based on the frequency of occurrence according to the nearest plant method (Everson & Clark 1987; Smit & Rethman 1999). Two hundred point-observations per survey plot were recorded. The number of survey plots per vegetation unit was determined by the size of the vegetation unit and varied from two to six survey plots per vegetation unit. Surveys were done in line transects on both sides of the main transect and points were spaced 1 m apart. Survey plots were placed to cover as much of the variation in species composition within each management unit as possible. The location of each survey plot is given in Figure 4.1.

An ordination was done by applying a non linear Detrended Correspondence Analysis (DCA) to the species composition data. The DCA indicated the relative homogeneity of the survey plots within each management units as well as the relative heterogeneity in species composition between different management units. This was done to determine if survey plots were correctly selected and was representative of the management unit. A second DCA ordination was done to determine if survey sites from similar management units adequately differed from each other to justify separation.

The plant nearest to the point was recorded. Herbaceous plants belonging to the family Poaceae (grasses), dwarf karoo shrubs and forbs were identified on a species basis. Unidentifiable forbs and other non-grasses (mainly annual forbs) were grouped together. In all the readings ‘bare ground’ was recorded when no herbaceous plants occurred within a radius of 30 cm from the point. In the same way rocks (thus areas where plants cannot grow) were also recorded as ‘bare ground’. Herbarium samples of plants were taken for identification verification at the Geo Potts herbarium of the Dept. of Botany of the University of the Free State, as required.

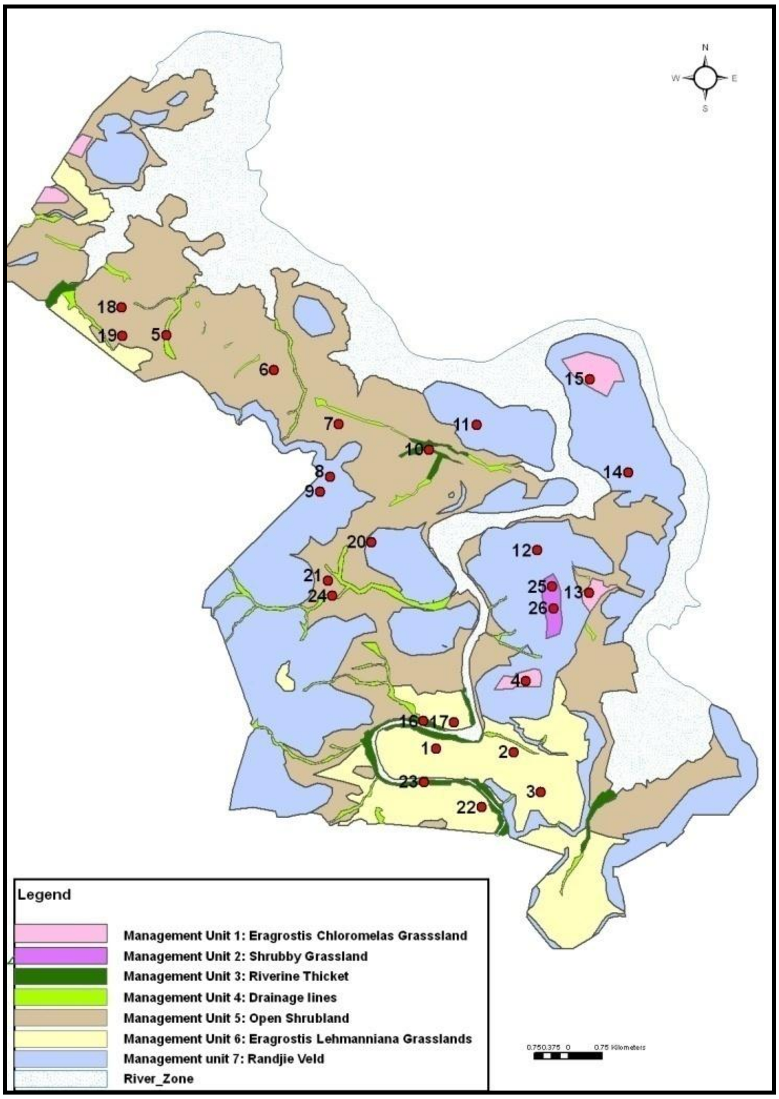


Figure 4.1 Location of Survey plots 1-26 with the different management units.

4.2.2 Veld condition assessment

A veld condition assessment was done according to the Ecological Index Method (EIM) of Vorster (1982), as revised by Tainton *et al.* (undated) and described by Heard *et al.* (1986). Besides providing the current condition of the veld, it can also serve as a reference to which subsequent assessments can be compared to determine trends in relation to specific environmental conditions, grazing impact of wildlife and management interventions.

For the purpose of the veld condition assessment, the different herbaceous species (grasses, dwarf karoo shrubs and annual forbs) recorded in the experimental plots were divided into the following ecological groups; Decreasers, Increaser Ia, Increaser IIa, IIb and IIc (Tainton *et al*., 1980):

Decreasers*:* Decreaser species are those which dominate in veld in good/excellent condition, i.e. that community which is considered to be the most productive for that site and one which is stable if well managed. They decrease in abundance when veld is under- or over-utilised. Most of the climax grasses are classified into this group.

Increaser Ia*:* These species increase in abundance with moderate under-utilisation. These grasses are usually unpalatable climax species that can grow without any defoliation.

Increaser IIa*:* Species in this group are rare in veld in excellent condition, but increase when veld is moderately overgrazed in the long term. Their relative frequency usually increases when that of Decreaser species declines. The subclimax and disclimax grasses, as well as the more palatable karoo bushes and taller shrubs, belong to this group. When these species dominate, the veld may be agro-ecologically classified as being in a good to fair condition.

Increaser IIb*:* Members of this group are rare in veld in excellent condition, but increase when veld has been heavily over-grazed over an extended period. An increase in their relative abundance is coupled with a decrease of the species of the Increaser IIa category. Species which belong to this group are some pioneer grasses and the less palatable forbs and karoo shrubs. Dominance of this group is generally a sign of veld in a fair to poor condition.

Increaser IIc*:* Members of this group are rare in veld in excellent condition and increase when veld is heavily overgrazed for an extended period. Their numbers increase when the abundance of Increaser IIb species declines. This group is represented mainly by rain-dependent annual grasses, ephemerals, hardy unpalatable forbs and karoo shrubs, as well as a number of poisonous plants. Dominance of this group signifies that the veld is in a poor to very poor condition.

The percentage contribution of herbaceous species in the same ecological group, was calculated and an index value was assigned to each group. A factor of 10 was used for Decreasers species, 7 for increaser Ia and IIa species, 4 for Increaser IIb species and 1 for Increaser IIc species (Vorster, 1982). The veld condition score of a particular survey plot was subsequently calculated as the sum of the product of the proportion contributed to the different ecological groups, multiplied with the relative index values assigned to each group. The maximum score is 1 000 (100% Decreaser species) and the minimum is 100 (100% Increaser IIc species) (Tainton, 1982).

The classification of plant species into the correct ecological groups is the most important principle on which the EIM rests. Allocation of species to the wrong ecological groups can lead to incorrect estimates of the productivity and ecological status of the veld (Stuart-Hill & Hobson, 1991; Tainton, 1999). Many of the plants in the region have already been allocated to ecological groups since the method was developed in the same region. Small reassessments were done of species where deemed necessary. Species not already grouped into ecological groups were placed in groups containing similar species. The allocation of ecological groups to each species is presented in Appendix Bi.

To asses the prevailing veld condition, the method requires the identification of veld benchmark sites against which veld condition scores can be compared. A veld benchmark is considered as an area in excellent condition and the Ecological Index Score of such an area is used as the benchmark score. Since each topographical unit differs in soil type, depth, topography and soil-moisture conditions, a veld benchmark must be identified for each topographical unit. Based on environmental conditions and species composition, management units 1 and 2, management units 3 and 4, management units 5 and 6, and management unit 7 were considered to occur in similar topographical units. The highest Ecological Index scores calculated for plots falling in each of these units, were used as the benchmark score for the respective management units in those topographical units. The veld condition score and condition rating of each survey plot is presented in Appendix Bii.

A regression analysis was done to determine the effects of increases and decrease in the percentage composition of each ecological group has on the veld condition.

4.2.3 Calculation of grazing capacity

Many researchers are of the opinion that veld condition is the best basis whereby to determine grazing capacity (Kruger, 1983; Van der Westhuizen 1994; Van der Westhuizen, 2003). The use of veld condition estimates as a method to rapidly calculate the grazing potential of vegetation is also growing in popularity (Ngwenya, 2012). However, grazing capacity determined on the basis of veld condition should only serve as a guideline for the maximum grazing capacity. Only by keeping detailed records of the veld condition over seasons can a more accurate grazing capacity be calculated (Van der Westhuizen, 2003). The grazing capacity was calculated on the veld condition scores determined with the EIM. Two separate methods were used to compare the accuracy of the calculation of the grazing capacity. The result of each method was converted from Large Stock Unit ha/ LSU to Grazer Unit ha/ GU. Dekker (1997) defined a grazer unit (GU) as the metabolic equivalent of a blue wildebeest (100% grazer) with a mean mass of 180 kg.

The first method used was the model of Dankwerts (1989) that combines rainfall data and veld condition scores to determine grazing capacity. The model is based on the following equation:

$$GC = \{(-0.03 + 0.00289)(X1)\} + \{(X2 – 419.7)(0.000633)\}$$

where GC = Grazing capacity in ha/ LSU

X1 = Percentage veld condtion index, which is the sample veld condition index

expressed as a percentage of the determined benchmark veld condition score

X2 = Mean annual rainfall in millimetres

Instead of using the benchmark scores of each management unit individually, the highest benchmark score calculated from all the management units was used as the benchmark score for all the management units. Two different rainfall values were also used. The first rainfall figure (380 mm), which is the rainfall value of the preceding 12 months before sampling started was used to determine the current grazing capacity of DNR. The second rainfall value (355 mm), which is the mean long term annual rainfall figure of DNR, was used to calculate mean long term grazing capacities.

The second method used was the Grazer Index Method (GIM) that was developed in the karoo region by Du Toit (1995) and is currently used by grassland scientists in the region to determine current carrying capacities (Esler *et al.* 2006). The model is as follows:

$$GC = (\text{Benchmark value } (500) \div \text{Veld condition index total}) \times 7.14$$

where GC = ha/LSU

Benchmark value = 500, which is considered as the benchmark score of the eastern karoo region

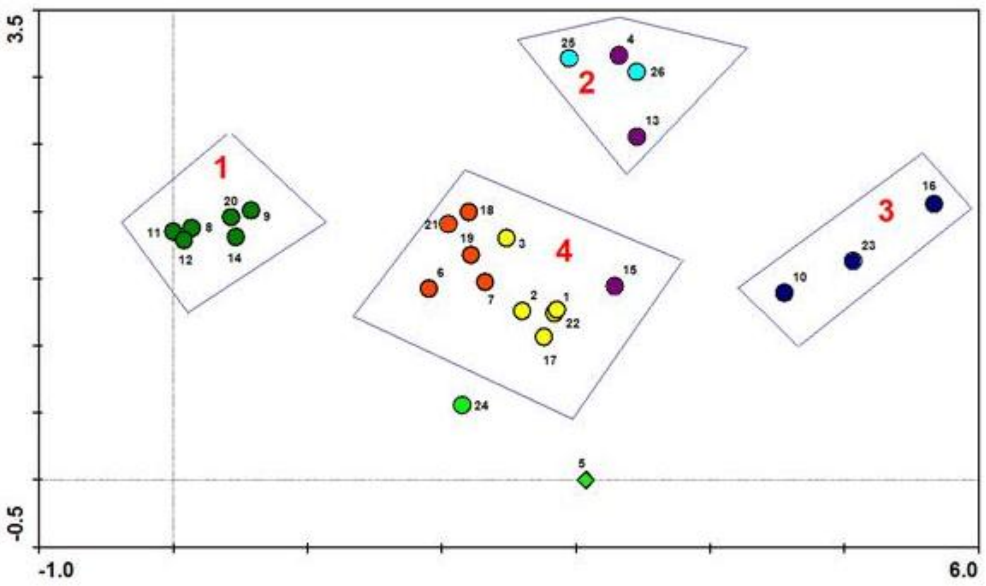
VCI total = ∑ (percentage cover of species x grazing index value of species)

The grazing index value of each species is a value calculated by the Department of Agriculture for most karoo plant species (Esler *et al*., 2006). The grazing index value is the sum of the scores obtained by assessing the following four different criterias of each plant: (1) forage production in and out of growing season, (2) accessibility to the grazing animal, (3) perenniality and (4) ability to protect soil. The average score for these attributes is between 1 and 10 (Esler *et al.* 2006).

4.3 Results

4.3.1 Botanical composition

A total of 50 species, excluding forbs, of which 18 species were perennial grasses, 11 species annual grasses and 21 species dwarf shrubs (non grasses) (Appendix Bi) were recorded in all the survey plots. Of these 50 species, 11 species occurred in only 1 of the survey plots, while 19 species occurred in 3 or fewer of the survey plots. Only 5 species occurred in more than 50% of survey plots. The results indicate that some species occurred in very specific plant communities, while several others have a general low occurrence over all plant communities. A detailed table of the occurrence of all the plant species in the herbaceous layer of each experimental plot is presented in Appendix Bii. The percentage contribution of grasses in different succession classes, as well as non-grass (Karoo bushes and forbs) in each of the vegetation units, excluding bare patches and rocks, is presented in Table 5.1. The classification of the grass species into the different succession classes is presented in Appendix Bi.



Eigen values: X-axis = 0.808
Y-axis = 0.409

- MU 1: *E. chloromelas* grassland
- MU 2: Shrubby grassland
- MU 3: Riverine thickets
- MU 4: Draniage lines
- MU 5: Open shrubland
- MU 6: *E. lehmanniana* grassland
- MU 7: Randjie veld

Figure 4.2 The DCA ordination of the survey plots.

The high eigen value of the x-axis showed clear separation between management units on the basis of species composition heterogeneity, while eigen value of the y-axis indicated differences between management units were less distinct on the y-axis. The first DCA ordination indicated that four groups could be distinguished. The close spacing of the survey points of management 7 (randjie veld) indicated that the different survey plots within this unit were very homogenous in species composition. The survey plots of the drainage line unit did not fit within the dataset and could be attributed to the large differences in species composition from one site to another. As expected, management unit 1 and 2 (*E. chloromelas* and shrubby grassland units) were very similar to each other in species composition and collectively formed group 2. The survey plots of management units 5 and 6 indicated that survey plots within each of these units were similar to one another. However, both management unit 5 and 6 also showed similarities between each other and collectively formed group 4. A second DCA ordination was done on group 4 and 2 subset to determine the difference between these groups.

The second DCA ordination indicated that survey sites from management units 5 and 6 differed enough from each other to justify them being grouped separately, although indicating some similarities to a small degree. As stated, management units 1 and 2 where very similar based on the herbaceous composition and could be grouped together on that basis. However, these similarities in the herbaceous layer composition were expected and it was the distinct difference in the woody layer that dictated that these two management units still be kept separately (see Chapter 3).

The results from the DCA ordination also clearly illustrated that survey sites where correctly selected for each management unit, although some similarities between units existed.

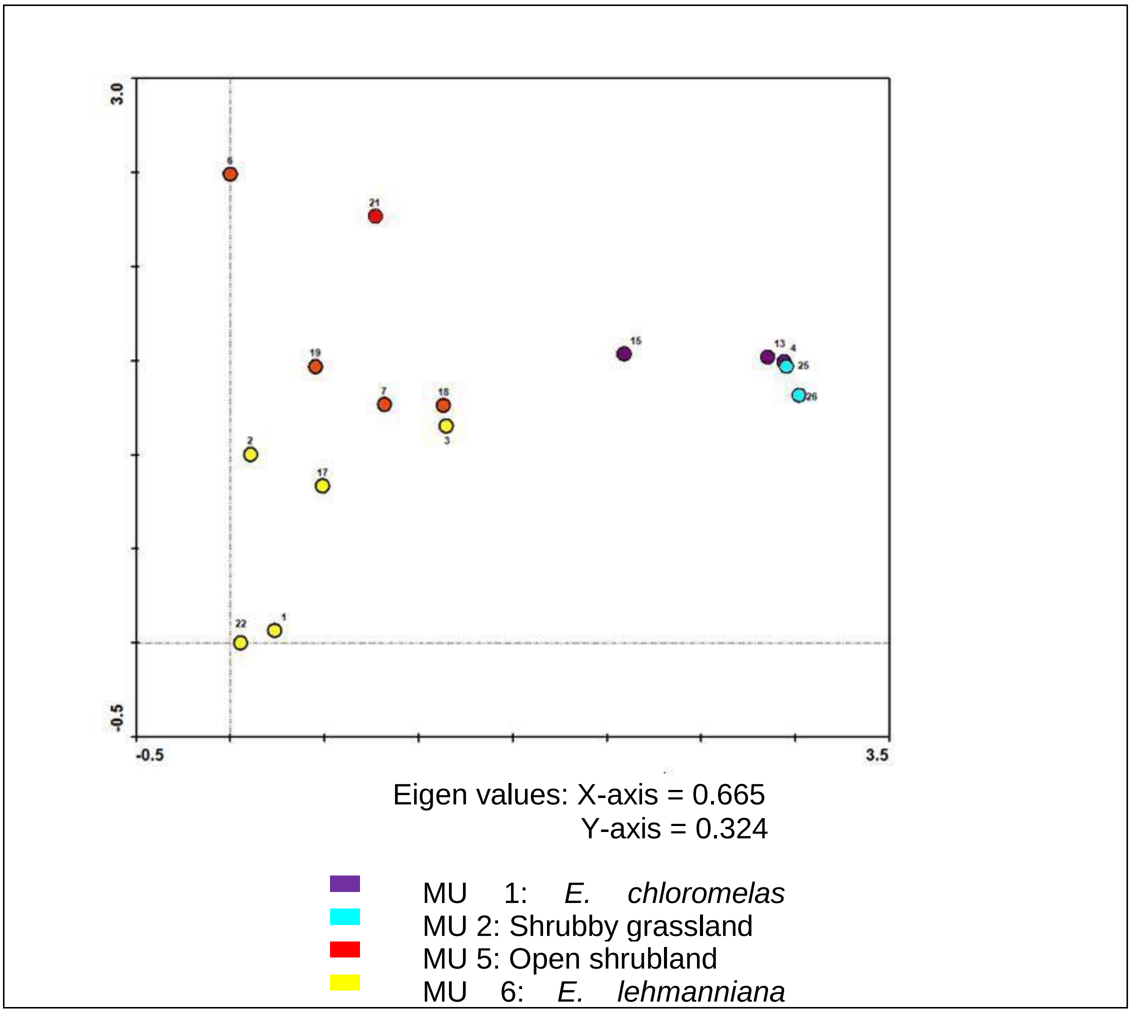


Figure 4.3 The DCA ordination of the grasslands, shrubby grassland and open short shrubland management unit.

4.3.1.1 Management unit 1

With only 13 species recorded, this management unit had the second lowest species diversity of all the management units (Figure 4.4). The dominant species were the perennial grass *Eragrostis chloromelas* (37.3%), the annual grass *Aristida congesta* subsp. *barbicollis* (23.17%) and dwarf shrub *Felicia muricata* (14.17%). Forbs and climax grasses were absent within this unit (Table 4.2). Furthermore, the co-dominance of sub-climax and pioneer grasses indicate that the vegetation was in a transitional succession state between pioneer and sub-climatic vegetation as discussed in Chapter 3.

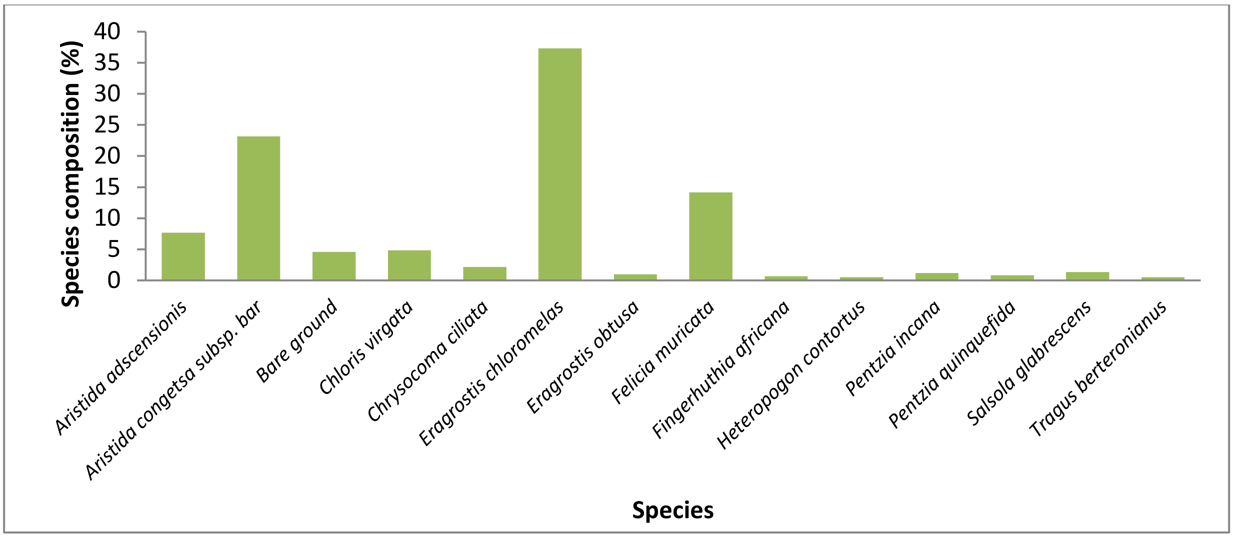


Figure 4.4 The herbaceous species composition of management unit 1.

4.3.1.2 Management unit 2

A total of 15 species were recorded within this management unit (Figure 4.5). The dominant species was the perennial grass *Eragrostis chloromelas* that contributed more than half to the total species composition (54.25%). The only other notable species was the dwarf shrub *Pentzia incana* (13.75%). The remaining species occurrence was significantly less with more than half of the species that contributed less than 2% to total species composition (Figure 4.5). The especially high dominance of sub-climax grasses was an indication that vegetation was in a sub-climax state (Table 4.1).

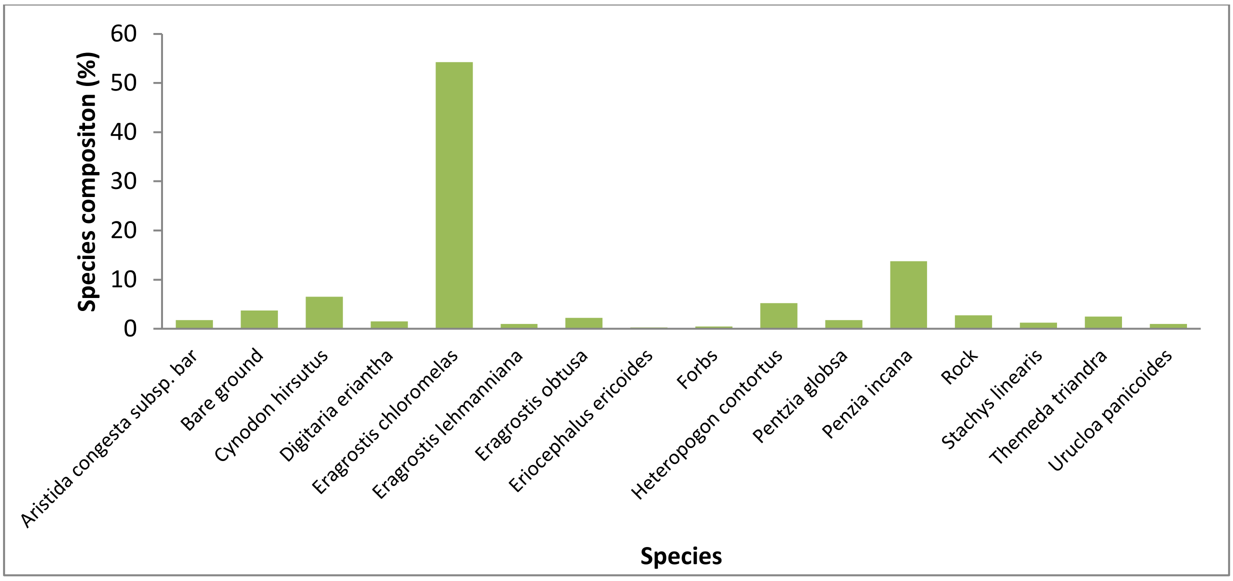


Figure 4.5 The herbaceous species composition of management unit 2.

<u>4.3.1.3 Management unit 3</u>

This riverine unit had the lowest species diversity of all the management units with only 11 herbaceous species recorded (Figure 4.6). However, it should be noted that forb species that were recorded were grouped together and this contributed to the lower species diversity. The floristic composition was dominated by the pioneer grasses *Cynodon hirsutus* (42.5%) and *Setaria veticilllata* (20.33%) and also forbs (11.17%). The high dominance of pioneer grasses, combined with the low occurrence of climax and sub-climax grasses indicated that the vegetation was in a predominantly pioneer stage. Compared to other management units, bare ground patches were also prominent in this unit, and comprised 12.5% of the point observations.

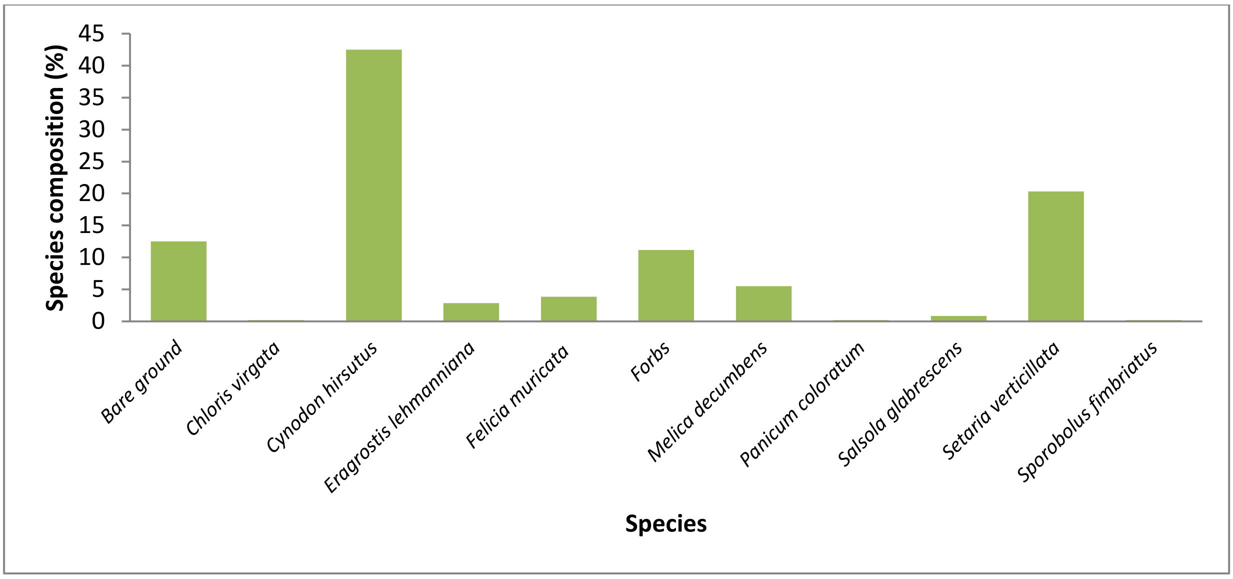


Figure 4.6 The herbaceous species composition of management unit 3.

4.3.1.4 Management unit 4

A total of 16 herbaceous species, excluding forbs, were recorded in this management unit (Figure 4.7). The plant cover was sparse within the drainage lines and it was reflected in the results by the large areas of bare ground (42.25%). The only true dominant species was the perennial grass *Hyparrhenia hirta* (17.25%). The only other species that contributed more than 5% to the species composition, were the perennial grasses *Panicum coloratum* and *Fingerhuthia africana*. The grasses *Hyparrhenia hirta* and *Panicum coloratum* were also diagnostic species to this unit as discussed in Chapter 3. Interestingly, despite the high occurrence of bare patches, the floristic composition was dominated by climax grass species, while pioneer grasses and forbs contributed very little (Table 4.1).

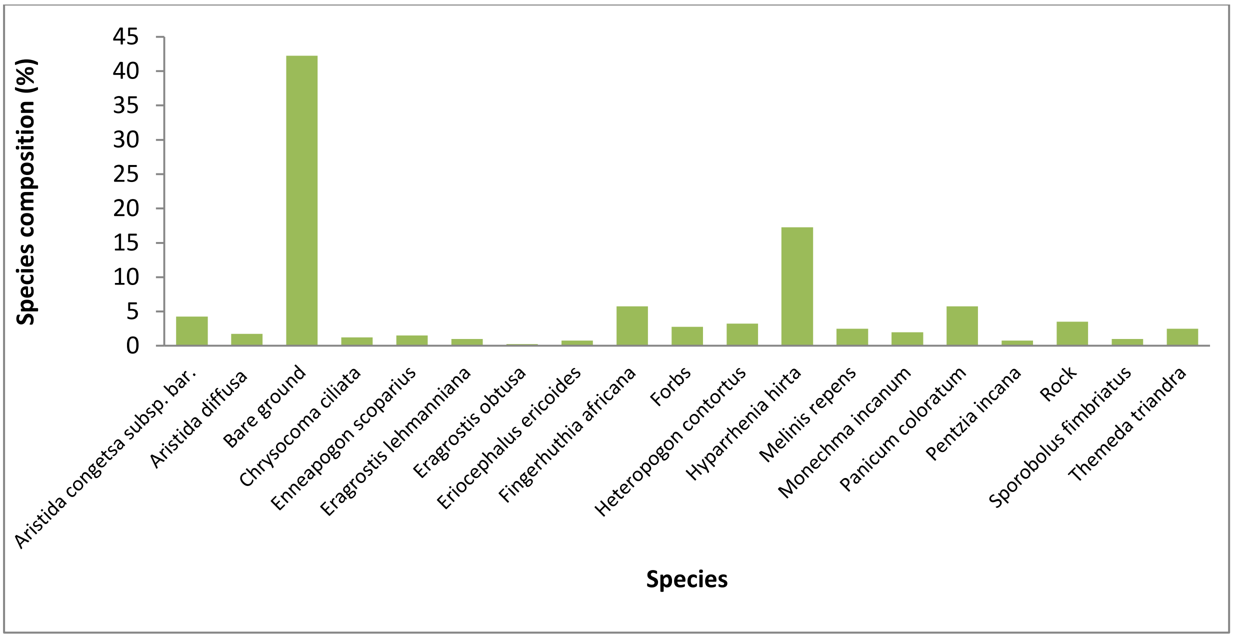


Figure 4.7 The herbaceous species composition of management unit 4.

4.3.1.5 Management unit 5

This management unit had the highest herbaceous species diversity of all the units as was also determined with the Braun-Blanquet study (Chapter 3), with a total of 28 species recorded (Figure 4.8). The dominant species were the grasses *Aristida congesta* subsp. *barbicollis* (20%), *Aristida diffusa* (14.7%), *Eragrostis lehmanniana* (13.3%) and to a lesser extent the grass *Heteropogon contortus* (10.6%) and dwarf shrub *Chrysocoma cilliata* (9.8%). Although almost half of the species recorded were dwarf shrub species (13 species), they only contributed 18.5% to the total floristic composition. All three vegetation successional classes were well represented within this unit (Table 4.1)

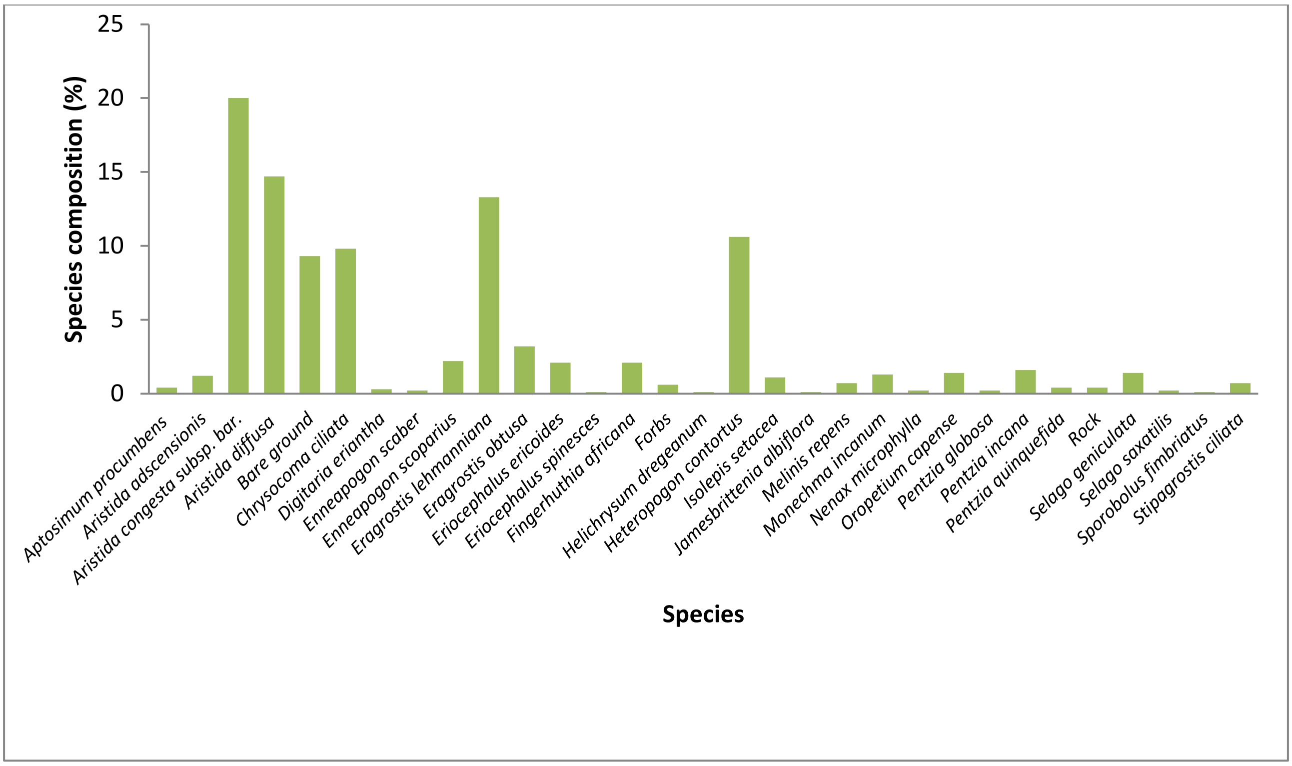


Figure 4.8 The herbaceous species composition of management unit 5.

4.3.1.6 Management unit 6

This management unit had the second highest species diversity of all the units with a total of 25 herbaceous species recorded (Figure 4.9). The perennial grass *Eragrostis lehmanniana* (31.8%) and annual pioneer grass *Aristida congesta* subsp. *barbicollis* (15%) were the dominant species. Karoo dwarf shrubs were especially abundant within this unit, as half of all the species recorded was dwarf shrubs (12) and contributed more than a third to the total botanical composition (34.4%) (Table 4.1). Of the Karoo dwarf shrub species, the most prominent species were *Chrysocoma cilliata* (9%), *Eriocephalus ericoides* (8.6%), *Pentzia incana* (4.8%) and *Pentzia globosa* (4.2%). The high occurrence of sub-climax grasses and pioneer grasses, combined with the low abundance of climax grasses, was an indication of the veld being in a sub-climax succession state (Table 4.1).

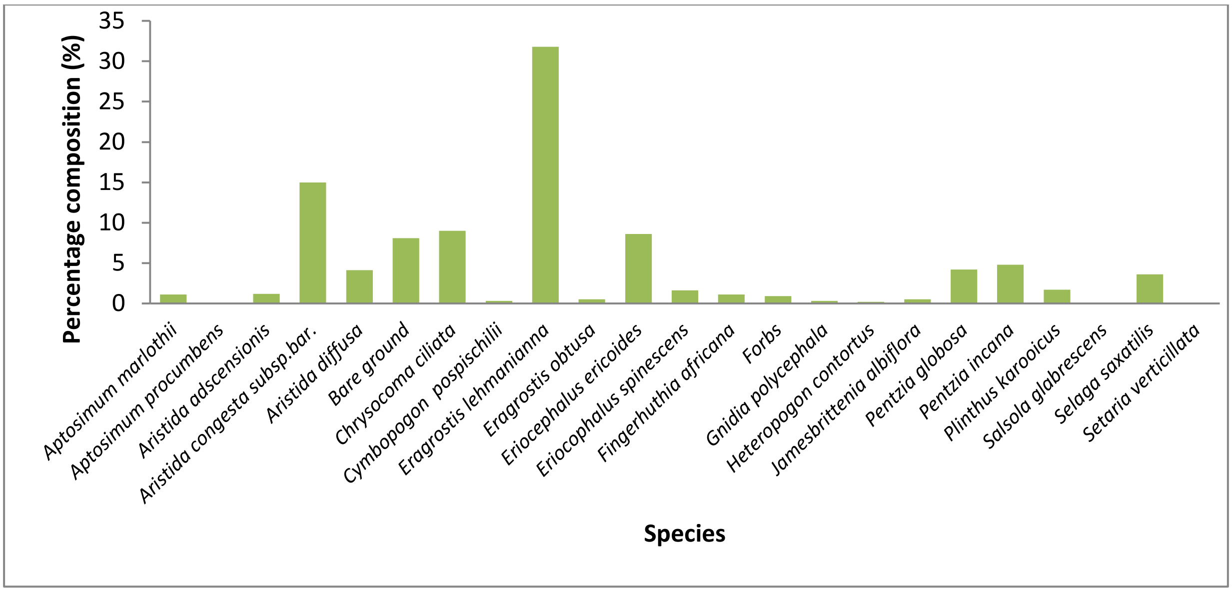


Figure 4.9 The herbaceous species composition of management unit 6.

<u>4.3.1.7 Management unit 7</u>

A total of 18 herbaceous species were recorded within this mountainous management unit (Figure 4.10). The dominant species was the climax grass *Themeda triandra* that comprised 66.92% of the botanical composition. The only other species with an occurrence higher than 10%, was the perennial grass *Heteropogon contortus* (11.25%), while 15 of the 18 species had an occurrence of less than 2%. Non-grasses (forbs and karoo dwarf shrubs) had a low occurrence within this veld type and contributed just over 3% of the total botanical composition (Table 4.1). The dominance of *Themeda triandra* together with the very low occurrence of pioneer grasses was an indication that the vegetation was in a climax succession stage.

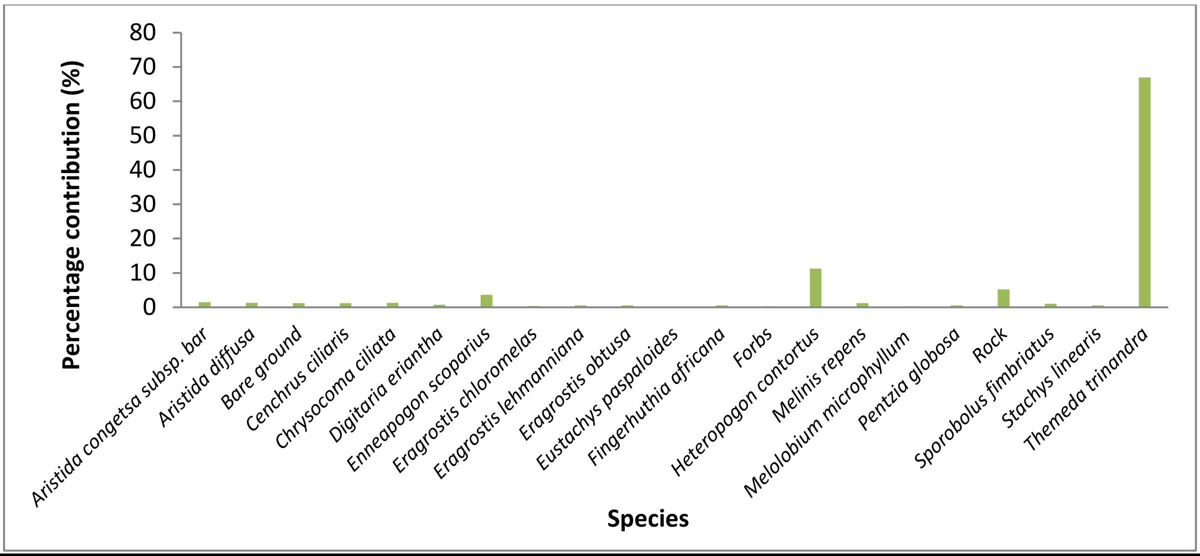


Figure 4.10 The herbaceous species composition of management unit 7.

Table 4.1 Percentage contribution of grasses in different succession classes, as well as non-grasses (Karoo bushes and forbs) in each management unit, excluding bare patches and rocks. The number of species of each group is in parenthesis.

Management unit	**% Contribution to species composition (number of species)**					
	Species recorded	Climax grasses	Sub-climax grasses	Pioneer grasses	Dwarf shrubs	Forbs
1	13	0 (0)	39.5 (4)	36.14 (4)	19.67 (5)	0
2	13	4 (2)	62.75 (4)	9.25 (3)	17 (4)	0.5
3	11	5.84 (3)	2.83 (1)	63 (3)	4.66 (2)	11.17
4	16	29.75 (6)	12.75 (5)	4.25 (1)	4.75 (4)	2.75
5	28	18.2 (6)	29.9 (5)	22.6 (3)	17.9 (13)	1.7
6	25	4.8 (4)	33.8 (5)	16.8 (4)	35.6 (12)	0.9
7	18	74.84 (7)	4.4 (6)	1.5 (1)	2.66 (4)	0.25

4.3.2 Veld condition assessment

The results of the veld condition assessment of each management unit are presented in Tables 4.2 – 4.8. A comparison between the veld condition scores are presented in Figure 4.11. The results of the regression analysis results of the relationship between each ecological group and veld condition score, is presented in Figures 4.12 – 4.16. The veld condition score of each survey plot is presented in Appendix Bii.

Table 4.2 The veld condition of management unit1.

Management unit 1 EIV:	**422.96**
Benchmark Score:	**598.5**
State:	**Good**
Veld Condition	**EIV**
Very good	481 - 600
Good	361 - 480
Fair	241- 360
Poor	121 - 240
Very poor	0 - 120

Table 4.3 The veld condition of management unit 2.

Management unit 2 EIV:	**566**
Benchmark Score:	**598.5**
State:	**Very good**
Veld Condition	**EIV**
Very good	481 - 600
Good	361 - 480
Fair	241- 360
Poor	121 - 240
Very poor	0 - 120

Table 4.4 The veld condition of management unit 3.

Management unit 3 EIV:	**273.32**
Benchmark Score:	**464**
State:	**fair**
Veld Condition	**EIV**
Very good	401 - 500
Good	301 – 400
Fair	201- 300
Poor	101 – 200
Very poor	0 – 100

Table 4.5 The veld condition of management unit 4.

Management unit 4 EIV:	**343.35**
Benchmark Score:	**464**
State:	**Good**
Veld Condition	**EIV**
Very good	401 - 500
Good	301 – 400
Fair	201- 300
Poor	101 – 200
Very poor	0 – 100

Table 4.6 The veld condition of management unit 5.

Management unit 5 EIV:	**401.61**
Benchmark Score:	**541**
State:	**Good**
Veld Condition	**EIV**
Very good	441 - 550
Good	331 – 440
Fair	221- 330
Poor	111 – 220
Very poor	0 – 110

Table 4.7 The veld condition of management unit 6.

Management unit 6 EIV:	**391.3**
Benchmark Score:	**541**
State:	**Good**
Veld Condition	**EIV**
Very good	401 - 500
Good	301 – 400
Fair	201- 300
Poor	101 – 200
Very poor	0 – 100

Table 4.8 The veld condition of management unit 7.

Management unit 5 EIV:	**830.75**
Benchmark Score:	**965**
State:	**Very good**
Veld Condition	**EIV**
Very good	801 - 1000
Good	601 – 800
Fair	401 - 600
Poor	201 – 400
Very poor	0 – 200

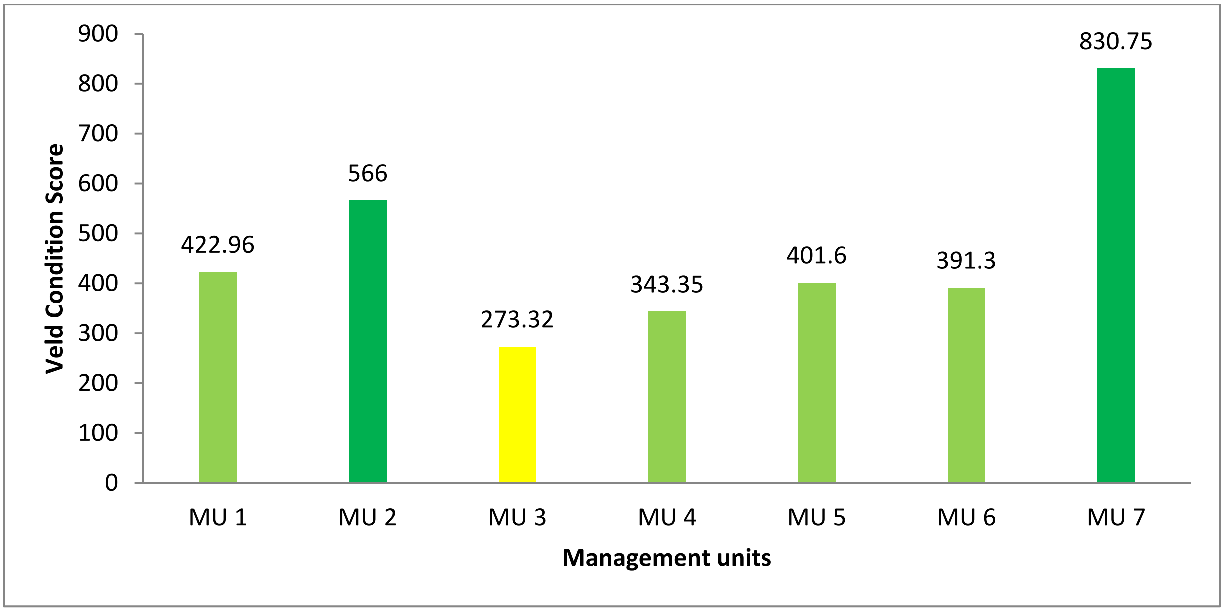


Figure 4.11 Comparison of Veld Condition Scores for different management units. Yellow indicates vegetation in fair condition, light green vegetation in good condition and dark green vegetation in very good condition.

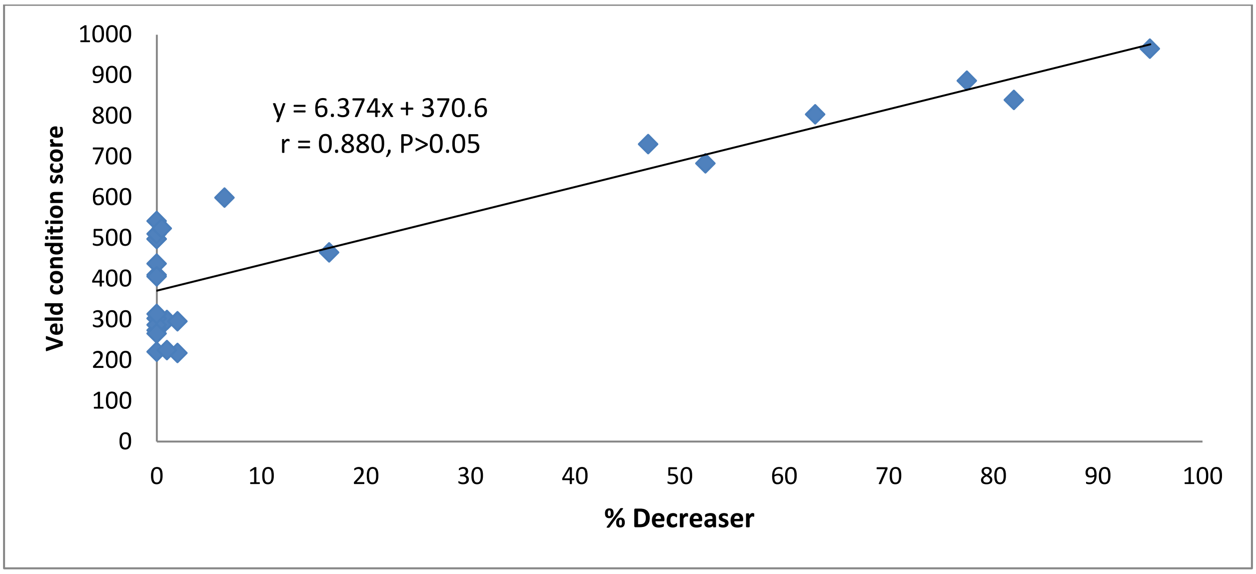


Figure 4.12 Regression analysis of the relationship between % Decreasers (independent variable) and Veld Condition Score (dependant variable).

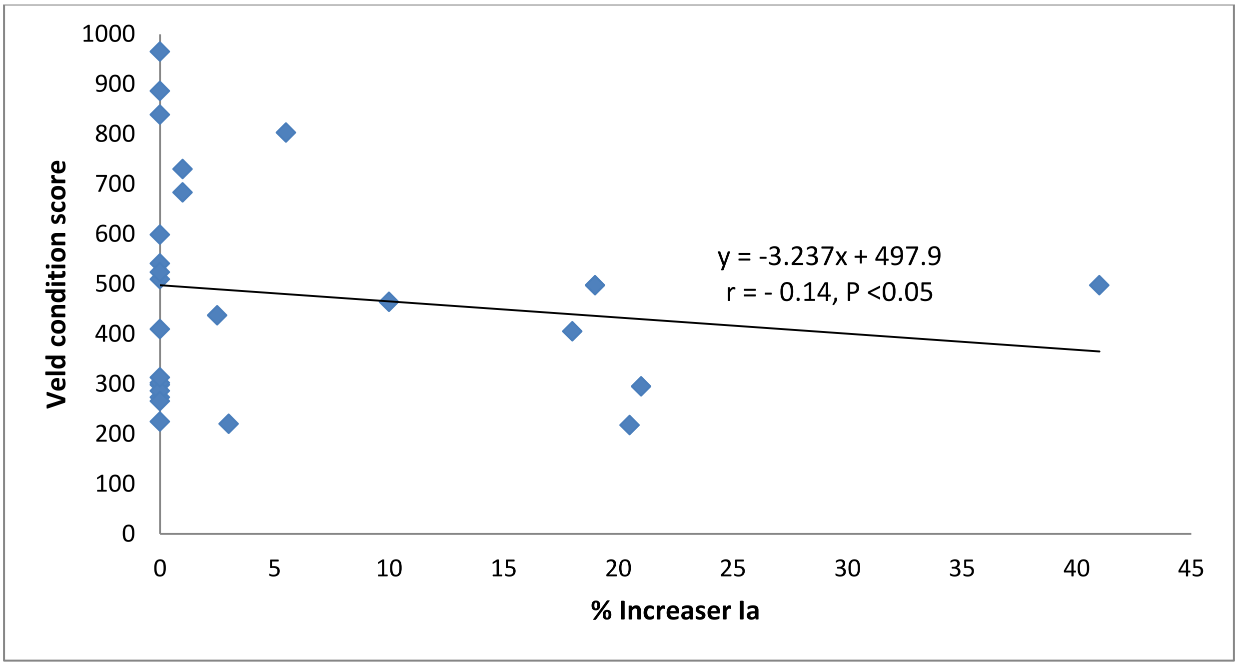


Figure 4.13 Regression analysis of the relationship between % Increaser Ia (independent variable) and Veld Condition Score (dependant variable).

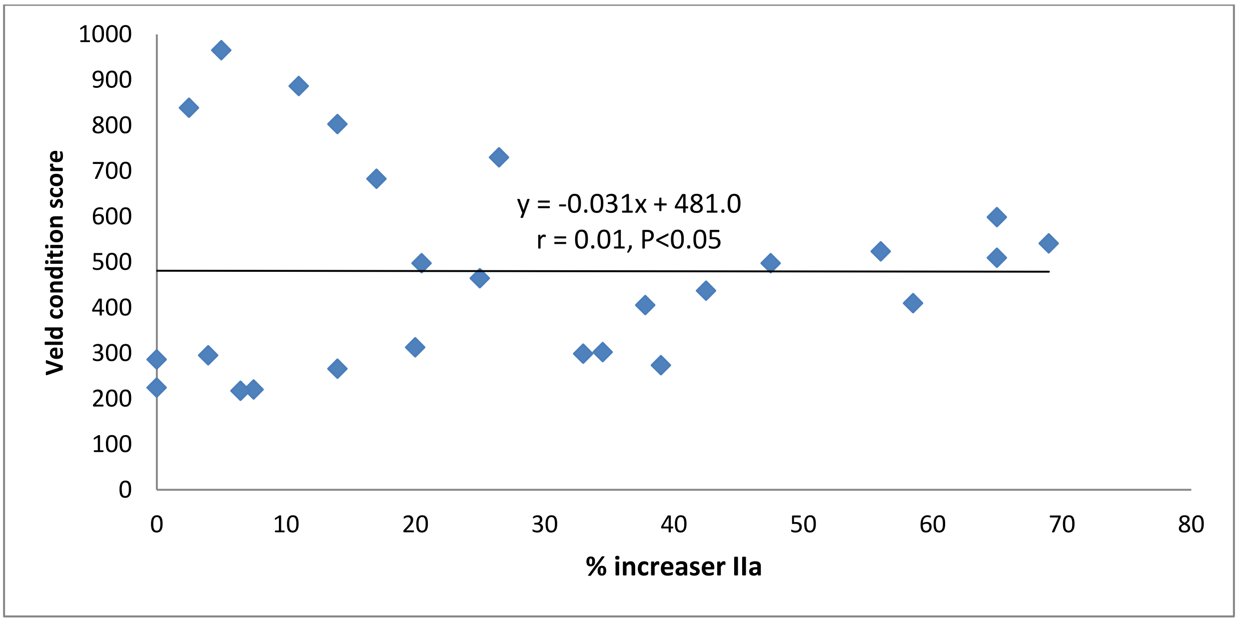


Figure 4.14 Regression analysis of the relationship between % Increaser IIa (independent variable) and Veld Condition Score (dependant variable).

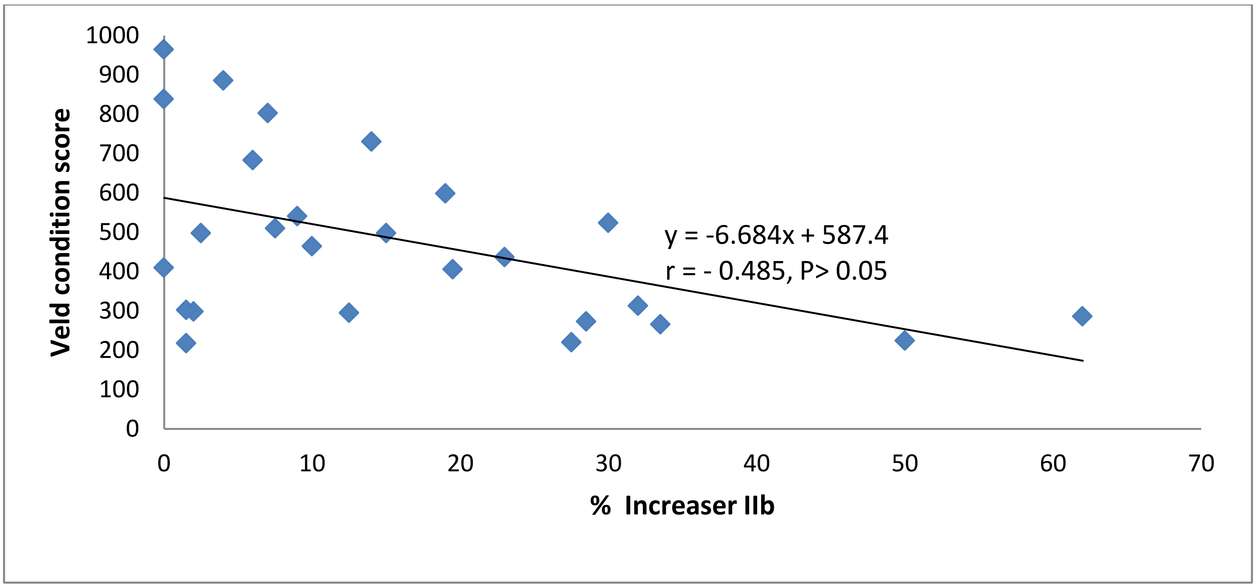


Figure 4.15 Regression analysis of the relationship between % Increaser IIb (independent variable) and Veld Condition Score (dependant variable).

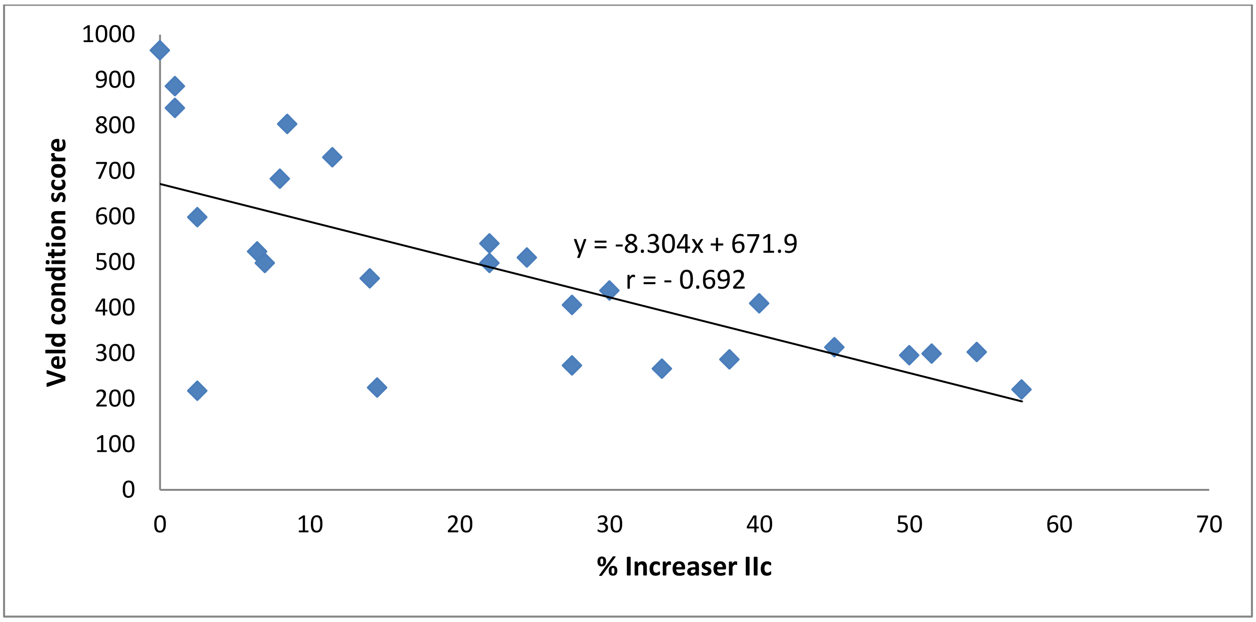


Figure 4.16 Regression analysis of the relationship between % Increaser IIc (independent variable) and Veld Condition Score (dependant variable).

4.3.3 Grazing capacities

The results of the grazing capacities and number of grazer units able to be supported by each management unit are presented in Tables 4.9 and 4.10 respectively.

Table 4.9 The grazing capacity of each management unit (ha/ GU) according to the Grazing Index method and Danckwerts Method.

Management unit	**Grazing Index Method (ha/ GU)**	**Danckwerts Method (ha/ GU)**	
		380 mm	**355 mm**
1. *E. chloromelas* grassland	6.21	5.58	7.12
2. Shrubby grassland	4.78	3.49	4.06
3. Riverine thicket	9.07	14.87	37.04
4. Drainage lines	7.22	8.36	12.54
5. Short open shrubland	6.14	6.13	8.12
6. *E. lehmanniana* grassland	6.60	6.44	8.66
7. Randjie veld	2.58	2.06	2.25

Table 4.10 The number of Grazer Units (GU) each of the management units can support according to the Grazer Index Method and Danckwerts Method.

Management units	**Size (ha)**	**Grazer Units total**		
		Grazer index method	Dankwerts method 380 mm	Dankwerts method 355 mm
E. chloromelas grassland	100	16	18	14
Shrubby grassland	35	7	10	9
Riverine Thicket	144	16	10	4
Drainage lines	222	31	27	19
Short open Shrubland	3 239	528	528	399
E. lehmanniana grassland	1 421	215	221	164
Randjie veld	3 880	1504	1 884	1724
Total	**9 041**	**2 316**	**2 696**	**2 331**

4.4 Discussion

The development of vegetation in any given area through the gradual changes in species composition of plant communities, is known as plant succession (Hardy & Tainton, 1999). Natural vegetation can be in one of three succession stages, or in transition between stages that include: pioneer, sub-climax and climax stage (Hardy & Tainton, 1999, Van Rooyen, 2002. Plant succession continues through primary or secondary regression until the community reaches a climatic climax condition, which is in dynamic balance with the environment. When disturbances, such as overgrazing or drought occur, retrogressive succession takes place (Hardy & Tainton, 1999). However, some scientists have challenged the conventional idea of plant succession because changes in vegetation in response to grazing have often been found neither to be continuous, nor reversible or consistent. They argue furthermore that vegetation changes are mainly a function of changing environmental conditions such as variability in rainfall, while factors such as grazing and fire play a small to no role in changes (Ellis & Swift, 1988; Tainton *et al*., 1999; Van Rooyen, 2002, Vetter, 2005). As a consequence, the terms equilibrium and non-equilibrium evolved. Some scientists are of the opinion that consumers (herbivores) reach densities that degrade environments from a previous condition of equilibrium, while others are of the opinion that the dynamics of pastoral systems are non-equilibrial and primarily dictated by variability in rainfall (Ellis & Swift, 1988; Vetter, 2005). Many authors further state that some ecosystems can display both equilibrial and non-equilibrial trends (Smit, 2004; Vetter, 2005; Bashari *et al*., 2008). In this regard the degree of aridity is important, where arid environments are less stable (non-equilibrial), while mesic ecosystems are often more stable (equilibrial) (Smit, 2004, Vetter, 2005).

An important concept is the so called state-and-transition model that is used to demonstrate that changes in vegetation are discontinuous and unpredictable. Accordingly, transition changes between various succession stages occur periodically as a result of episodic natural events such as rainfall (Van Rooyen, 2002). Each plant community has a critical threshold of resilience. If such a community is subjected to a level of pressure of a particular environmental factor that exceeds the critical threshold or range, it will change to a new stable configuration or domain of lower production. It is therefore unable to revert back to the original plant composition, even after that particular level of pressure from the environmental factor is removed. Indications from this study was that both grazing and rainfall influenced the species composition and production to a large extent and therefore they displayed both equilibrial and non-equilibrial characteristics. Numerous authors have stated that rainfall and herbivory, together with other factors such as soil nutrients and soil moisture, are the most important factors influencing the growth and sustainability of the herbaceous layer in semi-arid environments (Edroma, 1981; Grossman & Grunow, 1981; Dye & Spear, 1982; Stuart-Hill & Mentis, 1982; Du Toit & Aucamp, 1985, Hardy & Tainton, 1999, Smit, 2004, Vetter, 2005; Buitenwert *et al*. 2012).

Apart from influencing the species composition, rainfall was also the main factor that determined the direction of plant succession of the *E. chloromelas* grassland management unit (Management unit 1). As discussed in Chapter 3, the sub-climax grass *Eragrostis chloromelas* increases in dominance during periods of high rainfall, to become the most dominant species, while pioneer grasses such as *Aristida adscensionis* and *Chloris virgata* are also very prominent. However, during periods of lower rainfall, the abundance of *Eragrostis chloromelas* decreases sharply, while the pioneer grass *Aristida congesta* increases in abundance. Both *Eragrostis choromelas* and *Aristida adscensionis* are indicator species of long term overgrazing (Van Oudshoorn, 2004). Overgrazing caused by overstocking of animals in semi-arid environments is widely known to cause changes in soil nutrients, vegetation structure, production, composition, productivity and is one of the main causes of vegetation and soil degradation by means of trampling, reduced water infiltration and soil-erosion (Fourie *et al,.* 1985; Nsinamwa *et al.,* 2005). Even after these grazing pressures are lifted from degraded vegetation, the species composition and canopy cover may never recover to its former state (Visser *et al*. 2007). It may well be that long-term grazing pressures have exceeded the critical threshold value for such a long period that succession to its former state is almost impossible. The absence of any climax grass species presents further evidence of such a permanent altercation. However, despite the absence of climax grasses, the veld condition of this management unit was still considered good and this was mainly due to the high ground cover of the sub-climax grass *Eragrostis chloromelas* (Decreaser IIb ecological group) that increased substantially in abundance after receving above average rainfall. Regression analyses of the relationship between veld condition and cover of each ecological group indicated that veld condition deteriorates when Increaser IIc species increase in cover and Increaser IIb species decrease in cover (Figures 4.13 and 4.16). Therefore, this management unit could be expected to be in a poorer condition than what the veld condition indicated and emphasises the need for continuous monitoring.

The effect of grazing was also evident in the shrubby grassland unit. This small unit was dominated by *Eragrostis chloromelas* and apart from being known to occur where overgrazing prevailed for long periods, it also often replaces *Themeda triandra* on heavier soils. Regarding the fact that this management unit is a small “isolated island”, which is surrounded by the *Themeda traindra* dominated randjie veld unit, it may very well be that this unit once formed part of the randjie veld unit.

Both the *Eragrostis lehmanniana* and short open shrubland units seem more resilient to environmental changes, such as variations in rainfall. In both instances rainfall predominantly influences plant production only and not so much the species composition. Both units were dominated by sub–climax grass species which indicated the vegetation to be in a predominantly sub-climax successional state. The large proportion of pioneers and low abundance of climax grasses indicated that the vegetation can easily regress to a pioneer state under continuous grazing pressure or prolonged drought periods. The randjie veld unit was the only management unit in a stable climatic climax succession stage. As was discussed in Chapter 3, this unit may not always have been in a climax condition and possibly only progressed to a climax state when reduced continuous grazing pressures were experienced during periods the region was used for sheep farming.

The veld condition of vegetation refers to the relative "health" of the veld in terms of its ecological status, resistance to soil erosion and its potential for producing forage for sustained optimum animal production (Trollope *et al.*, 1990). The veld condition scores of the majority of the management units were generally in good condition to very good condition with only the riverine thicket in a fair condition. However, the true condition of the vegetation was likely worse than was indicated by the veld condition assessments due to the lack of proper benchmark sites and the effects of the above average rainfall. Many of the benchmark values may be considered lower than can be expected of veld in excellent condition for those specific topographical units. The occurrence of overgrazing of management units 3 to 6 imply that at the time of the surveys an ideal benchmark site most likely did not exist in either of these units. The benchmark sites that were chosen for the above mentioned management units were, however, still in above average condition. The above average rainfall increased the grass cover of all Increaser grass species, particularly in management units 1, 2, 3, 5 and 6. Therefore the veld condition scores of all the survey plots within these units would have been higher than the true condition.

The veld condition scores of the riverine thicket and drainage lines communities were, as expected, low, mainly due to two reasons: (i) the suppressive effects of woody plants on the herbaceous layer and (ii) overgrazing of the herbaceous layer. Both these units have a very high woody plant density (see Chapter 5), which is natural for riverine thicket communities. The suppressive effects of a dense woody layer on the herbaceous layer are well documented (Van Vegten, 1983; Belsky *et al*., 1989; Teague and Smit, 1992; Smit *et al*., 1996; Doughil *et al*, 1999; Smit & Rethman, 1999; Richter *et al*., 2001; Smit, 2001; De Klerk, 2004). Low tree and shrub densities, particularly of larger trees, are often beneficial to herbaceous production underneath their canopies by decreasing solar radiation, reducing evapotranspiration, reducing soil temperatures and by soil enrichment of the soil (Stuart-Hill *et al.,* 1987; Belsky *et al*., 1989; Smit, 2003; Hagos & Smit, 2005; Treydte *et al.,* 2007). However, beyond a critical tree density they are detrimental to the productivity of the herbaceous layer. Both woody plants and herbaceous species compete with each other for resources, most notably soil water (Doughil *et al.*,1999; Smit & Rethman, 1999). Many woody plants have well adapted and extensive roots systems that enable them to intercept a large proportion of the available soil water in the upper layers and out compete herbaceous species at high tree densities (Teague and Smit, 1992; Doughil *et al.*,1999; Richter *et al*., 2001; Balfour & Midgley, 2008; Buitenwerf *et al*., 2011; Puttick *et al*., 2011). *Acacia karroo*, which was the dominant plant species in the riverine thicket unit and prominent in the drainage lines unit, is one of the woody plant species that can suppress herbaceous plant production (Stuart-Hill & Tainton, 1988; Balfour & Midgley, 2008, Puttick *et al*., 2011).

The overgrazing of the herbaceous layer, which was particularly evident in the riverine thicket community, also decreased the herbaceous cover. In the drainage lines community desired perennial grasses still occurred, but they occurred in low numbers with very large bare patches present in this unit. In the riverine thicket unit the species composition was entirely dominated by short lived annuals of low grazing and ecological value (Decreaser IIc species). The only perennial grass species present was the poisonous and unpalatable *Melica decumbens*. The absence of palatable grass species in the riverine thicket and the numerous bare patches in the drainage line units are mainly the results of overgrazing by buffalo that highly favoured these units (see Chapter 6). A study done by Puttick *et al*. (2011) reported similar results in the Eastern Cape Province, where dense thornveld and encroached vegetation, that were particularly dominated by *Acacia karroo*, had the lowest veld condition scores of all vegetation types in the study area.

The randjie veld community was in excellent condition in general and was predominantly due to the high cover density of the Decreaser species *Themeda traindra*. As the regression analysis indicates (Figure 5.10), an increase in the percentage cover of Decreaser species rapidly improves the veld condition. One of the factors that enabled this grass to dominate is the low utilization of this unit by grazers (see Chapter 6). This species is not adapted to uninterrupted unselective grazing and decreases under intense grazing, and its decline is usually coupled with a decline in veld condition (Snyman *et al*., 2013). However, Novellie & Kraaij (2010) state that apart from intense grazing, the abundance of *Themeda triandra* may also decline as a result of very low grazing pressure in association with infrequent burning. *Themeda triandra* is known to thrive when it is frequently burned as it is well adapted to fire (Raitt, 2005; Everson *et al*. 2009; Novellie & Kraaij, 2010; Snyman *et al*., 2013). The hills and mountains of DNR are prone to natural veld fires and burn on a regular basis. It is therefore likely that the regular burning of the randjie veld units was a vital factor that enabled the continued dominance of *Themeda traindra* under the low grazing pressure that persisted in the unit at the time. Ironically this unit, which is from an ecological point of view in the best veld condition, was also the least favoured by animals. The deep loamy top soil, which is characteristic of this unit, was another important factor that enabled grasses to flourish. In comparison, the shallow to moderately deep soils of the *E. lehmanniana* grassland and short open shrubland is an important factor that inhibits large volumes of herbaceous production and also tends to favour the establishment of short lived annual species. Overgrazing was also a defining factor that influenced species composition and hence also decreased veld condition and grazing capacity.

The overall grazing capacity of DNR was very high for the region and mainly was due to the large size of the randjie veld community that has a high grazing capacity. However, as stated previously and also illustrated in Chapter 6, this unit is not generally favoured by game species. Furthermore, large areas of this unit are inaccessible to game species due to the topography of the unit. Other factors that play a definite role when considering stocking densities, are animal behaviour and feeding patterns of game compared to livestock. Many species are territorial and/or require minimum home ranges. Furthermore, game species tend to be more selective feeders than livestock due to the free roaming nature of game that can’t be controlled by a camp or grazing rotation system.

The above average rainfall also increased the grazing capacity of each management unit due to the subsequent increase in grass production, as was also illustrated in the veld condition scores. A study done by Smit *et al*. (2013) in the semi-arid savanna region of the Northern Cape, which receives approximately the same amount of annual rainfall as DNR, showed remarkable differences in the grazing capacity from one rainy season to another. In their study Smit *et al.* (2013) reported that the grazing capacity can differ as much as 40% from one season to another. In another study done in the central Free State, Janecke (2010) reported that the grazing capacity of a disturbed vegetation type decreased from 5 ha/BU during the above average wet season of 2006 to 12 ha/BU the next season (2007) and further decreased to 15 ha/BU the following season (2008), with both 2007 and 2008 receiving less rain than 2006. This emphasizes the need for annual grazing capacity calculations and subsequent re-adjustments to stocking densities to avoid further deterioration. The grazing capacity of management units with abundant sub-climax and annual pioneer species will differ even more from one season to another, based upon the rainfall of the season. The importance of adjusting stocking rates to changing conditions was emphasized in a study done by Peel *et al.* (1991) who measured the veld condition of vegetation in the semi-arid bushveld district of Thabazimbi, Limpopo Province. They found that the veld condition of game ranches in the region were generally poor due to the overstocking of the game ranches. They further stated that rainfall variation from season to season, together with overgrazing, played a major role in the deterioration of the veld. They thus concluded that an adaptive management approach should be implemented in which stocking rate is manipulated according to recent-, past and prevailing rainfall and vegetation conditions. In DNR, the management units that will exhibit the largest seasonal variation in grazing capacity and require regular monitoring, are management units 1, 2, 3 and 6.

4.5 Conclusion

The general absence of exclusion plots to serve as benchmark sites for veld condition assessments and the above average rainfall during the time of the study, made it difficult to assess the true state of degradation of the vegetation due to overgrazing. It was, however, clear that the state of the vegetation of particularly the *Eragrostis chloromelas* grassland and riverine thickets management units, were generally worse than what the veld condition scores indicated and was solely due to the abundance of annual grasses following the tremendous rain received during the rainy season. The randjie veld management unit was the only management unit of which the vegetation could with confidence be regarded as in a good condition due to the dominance of climax grasses, particularly *Themeda triandra.*

Despite the problems encountered with evaluating the true condition of the veld, both the veld condition assessment and subsequent grazing capacities still proved to be effective tools to measure the effects of grazing. This enabled the identification of areas and management units that were worst affected and will greatly benefit the implementation of management policies.

Although the grazing capacity of DNR was exceptionally high, the Reserve should not be stocked to these capacities for the following reasons: The the above average rainfall received during the study period drastically increased grass biomass production and cover, and subsequently increased the grazing capacity. This furthermore illustrates the importance of calculating grazing capacities on an annual basis and adjusting animal numbers accordingly. The second reason why stocking densities should be lower than the calculated grazing capacity, is because the randjie veld management unit, which was the biggest management unit and had the highest grazing capacity, was also the least favoured habitat type by game species and consequently supported the lowest densities of game (Chapter 6). This was mainly due to the steep sloping topography of the terrain that made this management unit unsuitable for many of the game species in DNR.

Chapter 5: Quantification of the woody layer

5.1 Introduction

The availability and structure of both grazing and browsing material is one of several habitat factors that determine the distribution and habitat selection of many herbivore species (Dörgeloh, 2001). The ability to accurately estimate aboveground biomass of woody plants is invaluable for any study involving aspects such as savanna structure, productivity and land use practises (Smit, 2014). The growing need for a scientific approach to wildlife management of wildlife populations in conservancies and wildlife ranches has further increased the need for accurate browsing calculations (Van Rooyen, 2002). In this regard a distinction must be made between total browse and available browse. Browse refers to the total sum of woody plant material that is edible to any specific species in a specific area. However, not all of this material is available to species due to height restrictions. That fraction of the material that can be utilized by any specific species, is referred to as the available browse. On average, impala browse at a height of up to 1.5 m (Dayton, 1978), eland and kudu up to 2 m and giraffe up to 5 m (Wentzel, 1990). The browsing capacity of a given area refers to the ecological potential of the region to sustain and carry a specific number of browsers in a good productive and reproductive condition over a prolonged period (Van Rooyen, 2002). The browsing capacity is expressed as the amount of hectares required to sustain one browser unit (ha/BU). A browser unit is the equivalent of a kudu with a weight of 140kg.

However, the availability of browse does not necessarily equate to utilization. Godwa (1997) stated that the nutritional value and accessibility of material is regarded as important variables that influence the consumption of leaf tissue by herbivores. Regarding nutritional value, the concept of food preference is of importance. Petrides (1975) classified two important food preference categories, namely preferred food species and principal food species. Grunow (1980) defined a 'preferred food species' as one which is proportionally more frequently in the diet of an animal than it is available in the environment, and 'food preference' as the extent to which food is consumed in relation to its availability. A 'principal food species' is being defined as one making a large contribution to the diet. Other categories distinguishing between the acceptability of woody plant species were also made by Owen-Smith & Cooper (1987), who categorised the acceptability of woody plant species as: (i) species favoured year round; and (ii) species generally rejected, except during certain periods. Barnes (1976) concluded that a proper understanding of animal-plant relationships in terms of intake will depend on knowledge of the diet of the animals, the number of plant species present and their distribution and availability. Therefore, the main objectives of this study were to:

I. Quantify the plant densities, species composition and above-ground biomass of the woody plants of each management unit, and

II. Calculate the browsing capacities of each management unit and of DNR as a whole

5.2 Methodology

5.2.1 Survey of the woody layer

Quantification of the above-ground biomass of the woody plants was done for each of the identified Management units. The 26 transects allocated for the point surveys were also simultaneously used for the survey of the woody layer (See Chapter 4). Some of the survey plots in the grassland communities had no measurable shrub or tree species. During the surveys at each survey site, the dimensions of all rooted, live trees were measured in belt transects demarcated in each vegetation unit as described in Chapter 3 (Figure 3.2). These measurements include the following (Figure 4.1)(Smit, 1989a; Smit 1989b; Smit, 1996):

(A) maximum tree height,
(B) height where the maximum canopy diameter occurs,
(C) height of first leaves or potential leaf bearing stems,
(D) maximum canopy diameter, and
(E) base diameter of the foliage at the height of the first leaves.

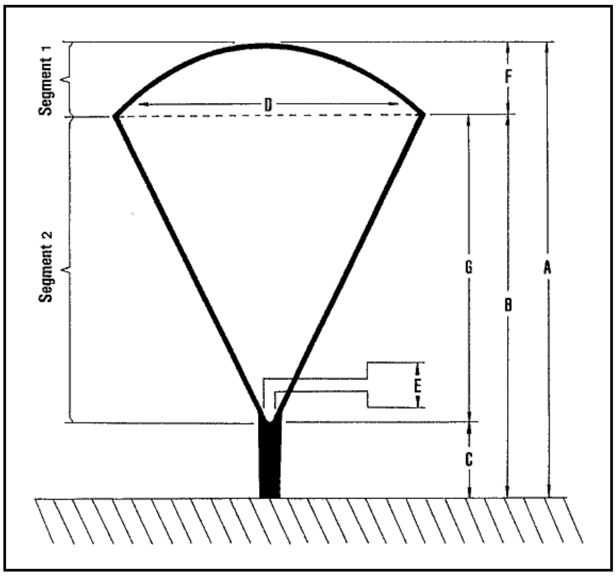


Figure 5.1 Different measurements taken of each woody species for the BECVOL-model as indicated on the ideal shape of a tree (from Smit 1989a).

5.2.1 Calculations

The tree density (plants/ha), Evapotranspiration Tree Equivalents (ETTE) (Smit 1989a) and dry mass estimates of the plants were calculated using the BECVOL-model (Smit 1994, 1996, 2014), which is based on the quantitative description technique proposed by Smit (1989a, 1989b). It includes regression equations, developed from harvested trees, which relate the spatial canopy volume (independent variable) to the actual leaf volume and various plant dry mass fractions (dependant variables). Values that were calculated with the BECVOL-model (Smit, 2014) are:

(i) Tree density (plants/ha),
(ii) Canopy cover (%),
(iii) Evapotranspiration Tree Equivalents (ETTE)/ha - an ETTE is defined as the leaf volume equivalent of a 1.5m tree = 500 cm^3,
(iv) Leaf biomass (kg dry mass ha^{-1}),
(v) New season's shoots less than 0.5 cm in diameter (kg dry mass ha^{-1}),
(vi) Stems>0.5-20 cm in diameter (kg dry mass ha^{-1}),
(vii) Wood >20 cm diameter (kg dry mass ha^{-1}),
(viii) Total tree biomass (leaves and wood combined) (kg dry mass ha^{-1}),
(ix) Total browsable material <1.5 m (kg dry mass ha^{-1}),
(x) Total browsable material <2.0 m (kg dry mass ha^{-1}), and
(xi) Total browsable material <5.0 m (kg dry mass ha^{-1})

The calculations of the ETTE and DM fractions are based on the relationship between the spatial canopy volume of a tree and its true volume, leaf mass and woody mass respectively. Regression models were developed for these calculations, based on the harvesting of complete plants of important species (Smit, 2014). The description of an ideal tree provides the basis for the calculation of the spatial canopy volume of any tree, regardless its shape and size. An ideal tree is a single stemmed tree with a canopy consisting of a dome-shaped crown and cone-shaped base.

In the new BECVOL3 version, the importance of shoots and stems as browsable material is also factored in the calculations of available browsing material. The previous model only estimated leaf DM values. In the new model shoots less than 0.5 cm in diameter are also estimated to provide a far more accurate estimate of the true browsable material available (Smit, 2014).

In addition to the total leaf and shoot DM/ha, stratified estimates of the leaf and shoot DM ha-1 below 1.5 m, 2.0 m and 5.0 m, respectively, were also calculated, using the BECVOL-model. The height of 1.5 m represents the mean browsing height of the impala (*Aepyceros melampus*) (Dayton 1978), while 2.0 m and 5.0 m represent the mean browsing heights of the kudu (*Tragelaphus strepciseros*) (Wentzel, 1990) and giraffe (*Giraffa camelopardalis*) (Skinner & Smithers 1990), respectively. These browsing heights are mean heights and not maximum browsing heights. It is known that large individuals are able to reach higher than these mean heights, e.g. 2.5 m and 5.5 m for kudu and giraffe respectively (Dayton, 1978), while breaking of branches may enable some browsers to utilize browse at even higher stratums (Rutherford, 1979; Styles, 1993)

From the leaf and shoot (<0.5 cm diameter) estimations per hectare the browsing capacity of each vegetation unit was calculated, according the formula used by Smit (2006) for the calculation of the grazing capacity:

y = d ÷ [(DM1 x f1 x p1) + (DM2 x f2x p2) + (DM3 x f3 x p3) ……]/r

y = browsing capacity (ha BU-1)
BU = metabolic equivalent of a kudu with an average body mass of 140 kg
d = number of days in a year (365)
DM1 = tree leaf and shoot DM yield ha-1 of species 1
DM2 = tree leaf and shoot DM yield ha-1 of species 2
DM3 = tree leaf and shoot DM yield ha-1 of species 3
…

f1 = utilization factor for species 1

f2 = utilization factor for species 2

f3 = utilization factor for species 3

…

p1 = leaf phenology of species 1

p2 = leaf phenology of species 2

p3 = leaf phenology of species 3

…

r = daily fodder DM required per Browser (BU) (2.5 % of body mass of 140 kg) = 3.5 kg/day).

The utilization factor, expressed as a decimal value, represents that part of the available leaf and shoot material that can be consumed. Actual consumption is limited by browsing preferences of the animals. Limited scientific information currently exists on which to base the utilization factor (f), but indications are that it is very low. In the case of black Rhinoceros it can be as low as 8 % (f = 0.08), and up to about 20 % or more (f = 0.20) for other browsers. The estimated percentage leaf presence (p = phenology) of the various plant groups can theoretically vary from 100 % (p = 1.0) in the case of evergreens, to 0 % (p = 0.0) during winter for the early deciduous group. However, there are indications that browsers may utilize the tips of shoots and twigs, even when no leaves are present. This implies that the value of p will always be above 0 (Smit, 1996).

5.3 Results

A total of 13 woody species were recorded in the survey of the woody layer. A list of these woody plants with indication of the utilisation factors of the leaves and shoots respectively used during the calculation of the browsing capacity is presented in Appendix Ci.

5.3.1 Species composition, density, ETTE and biomass

The results of the BECVOL-survey (species composition, tree density, Evapotranspiration Tree Equivalents and biomass) of the woody layer of the 18 survey plots within the six survey zones, are presented in Tables 5.1 - 5.7.

Table 5.1 Results of survey of woody layer of Management Unit 1: *Eragrostis curvula* Grassland.

SPECIES	PL_HA	ETTE	LMAS	LM_15	LM_20	LM_50	WM_5_15	WM_5_20	WM_5_50
Searsia burchellii	13	27	6	5	6	6	8	9	9
Searsia ciliata	27	105	23	23	23	23	37	37	37
Totals	**40**	**131**	**29**	**29**	**29**	**29**	**45**	**46**	**46**

PL_HA - Plants/ha
ETTE - Evapotranspiration Tree Equivalents/ha
LMAS - Leaf Dry Mass/ha (kg)
LM_15 - Leaf Dry Mass/ha below a browsing height of 1.5 m (kg)
LM_20 - Leaf Dry Mass/ha below a browsing height of 2.0 m (kg)
LM_50 - Leaf Dry Mass/ha below a browsing height of 5.0 m (kg)
WM_5_15 - Total shoots dry mass/ha of shoots <0.5 cm and below 1.5 m (kg)
WM_5_20 - Total shoots dry mass/ha of shoots <0.5 cm and below 2.0 m (kg)
WM_5_50 - Total shoots dry mass/ha of shoots <0.5 cm and below 5.0 m (kg)

Table 5.2 Results of woody survey of Management Unit 2: Shrubby Grassland.

SPECIES	PL_HA	ETTE	LMAS	LM_15	LM_20	LM_50	WM_5_15	WM_5_20	WM_5_50
Searsia burchellii	120	565	124	53	94	124	45	81	108
Searsia ciliata	100	38	8	8	8	8	6	6	6
Totals	**220**	**603**	**133**	**61**	**102**	**133**	**52**	**87**	**114**

PL_HA - Plants/ha
ETTE - Evapotranspiration Tree Equivalents/ha
LMAS - Leaf Dry Mass/ha (kg)
LM_15 - Leaf Dry Mass/ha below a browsing height of 1.5 m (kg)
LM_20 - Leaf Dry Mass/ha below a browsing height of 2.0 m (kg)
LM_50 - Leaf Dry Mass/ha below a browsing height of 5.0 m (kg)
WM_5_15 - Total shoots dry mass/ha of shoots <0.5 cm and below 1.5 m (kg)
WM_5_20 - Total shoots dry mass/ha of shoots <0.5 cm and below 2.0 m (kg)
WM_5_50 - Total shoots dry mass/ha of shoots <0.5 cm and below 5.0 m (kg)

Table 5.3 Results of woody survey of Management Unit 3: Riverine thicket.

SPECIES	PL_HA	ETTE	LMAS	LM_15	LM_20	LM_50	WM_5_15	WM_5_20	WM_5_50
Acacia karroo	533	6940	1756	214	420	1487	255	507	2062
Diospyros lycioides	133	499	110	17	40	110	14	34	94
Lycium cinereum	80	30	7	7	7	7	3	3	3
Lycium hirsutum	213	627	144	89	125	144	84	122	143
Searsia lancea	80	459	101	6	28	101	5	24	87
Totals	**1 040**	**8 554**	**2 118**	**332**	**620**	**1 849**	**361**	**690**	**2 390**

PL_HA - Plants/ha
ETTE - Evapotranspiration Tree Equivalents/ha
LMAS - Leaf Dry Mass/ha (kg)
LM_15 - Leaf Dry Mass/ha below a browsing height of 1.5 m (kg)
LM_20 - Leaf Dry Mass/ha below a browsing height of 2.0 m (kg)
LM_50 - Leaf Dry Mass/ha below a browsing height of 5.0 m (kg)
WM_5_15 - Total shoots dry mass/ha of shoots <0.5 cm and below 1.5 m (kg)
WM_5_20 - Total shoots dry mass/ha of shoots <0.5 cm and below 2.0 m (kg)
WM_5_50 - Total shoots dry mass/ha of shoots <0.5 cm and below 5.0 m (kg)

Table 5.4 Results of woody survey of Management Unit 4: Drainage Lines.

SPECIES	PL_HA	ETTE	LMAS	LM_15	LM_20	LM_50	WM_5_15	WM_5_20	WM_5_50
Acacia karroo	253	2 414	601	41	105	585	47	112	718
Diospyros austro-africanum	120	118	27	24	27	27	17	19	19
Diospyros lycioides	133	420	92	8	26	92	9	22	79
Lycium hirsutum	13	35	8	8	8	8	6	6	6
Searsia burchellii	173	520	118	50	87	118	45	80	112
Olea europaea	227	1 730	391	84	132	369	94	133	390
Searsia lancea	93	1 718	380	3	8	242	9	29	219
Tarchonanthus camphoratus	13	29	6	5	6	6	4	5	5
Ziziphus mucronata	93	406	89	17	32	89	15	27	77
Totals	**1**	**7 390**	**1**	**240**	**431**	**1 537**	**246**	**434**	**1625**

PL_HA - Plants/ha
ETTE - Evapotranspiration Tree Equivalents/ha
LMAS - Leaf Dry Mass/ha (kg)
LM_15 - Leaf Dry Mass/ha below a browsing height of 1.5 m (kg)
LM_20 - Leaf Dry Mass/ha below a browsing height of 2.0 m (kg)
LM_50 - Leaf Dry Mass/ha below a browsing height of 5.0 m (kg)

WM_5_15 - Total shoots dry mass/ha of shoots <0.5 cm and below 1.5 m (kg)
WM_5_20 - Total shoots dry mass/ha of shoots <0.5 cm and below 2.0 m (kg)
WM_5_50 - Total shoots dry mass/ha of shoots <0.5 cm and below 5.0 m (kg)

Table 5.5 Results of woody survey of Management Unit 5: Short scrubland.

SPECIES	PL_HA	ETTE	LMAS	LM_15	LM_20	LM_50	WM_5_15	WM_5_20	WM_5_50
Acacia karroo	16	211	53	7	20	53	9	25	65
Diospyros austro-africanum	32	31	7	6	7	7	5	6	6
Euclea crispa	24	13	3	1	1	3	1	1	2
Searsia burchelli	168	652	144	69	108	144	59	93	124
Searsia ciliata	16	86	19	17	19	19	14	16	16
Olea europeae	80	195	44	28	38	44	26	36	41
Tarchonanthus camphoratus	8	4	1	1	1	1	1	1	1
Ziziphus mucronata	72	107	24	16	21	24	13	18	19
Totals	**416**	**1**	**294**	**144**	**215**	**294**	**127**	**195**	**275**

PL_HA - Plants/ha
ETTE - Evapotranspiration Tree Equivalents/ha
LMAS - Leaf Dry Mass/ha (kg)
LM_15 - Leaf Dry Mass/ha below a browsing height of 1.5 m (kg)
LM_20 - Leaf Dry Mass/ha below a browsing height of 2.0 m (kg)
LM_50 - Leaf Dry Mass/ha below a browsing height of 5.0 m (kg)

WM_5_15 - Total shoots dry mass/ha of shoots <0.5 cm and below 1.5 m (kg)
WM_5_20 - Total shoots dry mass/ha of shoots <0.5 cm and below 2.0 m (kg)
WM_5_50 - Total shoots dry mass/ha of shoots <0.5 cm and below 5.0 m (kg)

Table 5.6 Results of woody survey of Management Unit: *Eragrostis lemanniana* grassland.

SPECIES	PL_HA	ETTE	LMAS	LM_15	LM_20	LM_50	WM_5_15	WM_5_20	WM_5_50
Ehretia rigida	10	3	1	1	1	1	0	1	1
Lycium cinereum	10	1	0	0	0	0	0	0	0
Searsia burchellii	30	160	35	17	27	35	14	23	30
Searsia ciliata	30	83	18	14	17	18	11	14	15
Searsia lancea	10	11	2	1	2	2	1	2	2
Ziziphus mucronata	10	126	28	7	15	28	6	14	25
Totals	**100**	**384**	**85**	**38**	**62**	**85**	**33**	**53**	**73**

PL_HA - Plants/ha
ETTE - Evapotranspiration Tree Equivalents/ha
LMAS - Leaf Dry Mass/ha (kg)
LM_15 - Leaf Dry Mass/ha below a browsing height of 1.5 m (kg)
LM_20 - Leaf Dry Mass/ha below a browsing height of 2.0 m (kg)
LM_50 - Leaf Dry Mass/ha below a browsing height of 5.0 m (kg)
WM_5_15 - Total shoots dry mass/ha of shoots <0.5 cm and below 1.5 m (kg)
WM_5_20 - Total shoots dry mass/ha of shoots <0.5 cm and below 2.0 m (kg)
WM_5_50 - Total shoots dry mass/ha of shoots <0.5 cm and below 5.0 m (kg)

Table 5.7 Results of woody survey of Management Unit 7: Randjie Veld.

SPECIES	PL_HA	ETTE	LMAS	LM_15	LM_20	LM_50	WM_5_15	WM_5_20	WM_5_50
Diospyros austro-africanum	36	34	7	7	7	7	6	6	6
Ehretia rigida	7	11	2	1	2	2	1	2	2
Euclea crispa	47	20	4	4	4	4	3	3	3
Searsia burchelli	95	165	36	28	35	36	23	29	30
Searsia ciliata	69	57	12	12	12	12	9	9	9
Tarchonanthus camphoratus	4	8	2	2	2	2	1	1	1
Ziziphus mucronata	11	41	9	5	8	9	4	6	8
Totals	**269**	**335**	**74**	**59**	**70**	**74**	**47**	**57**	**60**

PL_HA - Plants/ha
ETTE - Evapotranspiration Tree Equivalents/ha
LMAS - Leaf Dry Mass/ha (kg)
LM_15 - Leaf Dry Mass/ha below a browsing height of 1.5 m (kg)
LM_20 - Leaf Dry Mass/ha below a browsing height of 2.0 m (kg)
LM_50 - Leaf Dry Mass/ha below a browsing height of 5.0 m (kg)
WM_5_15 - Total shoots dry mass/ha of shoots <0.5 cm and below 1.5 m (kg)
WM_5_20 - Total shoots dry mass/ha of shoots <0.5 cm and below 2.0 m (kg)
WM_5_50 - Total shoots dry mass/ha of shoots <0.5 cm and below 5.0 m (kg)

5.3.2 Browsing capacities

The calculated browsing capacities of the seven Management Units are presented in Tables 5.8-5.15 and summarised in Table 5.1.

Table 5.8 Browsing capacity and number of browser units that can be supported by management unit 1: *E. chloromelas* Grassland.

MONTH	Browsing capacity (ha/BU)			Browser units total		
	BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
January	162.7	157.7	157.7	0.61	0.63	0.63
February	162.7	157.7	157.7	0.61	0.63	0.63
March	162.7	157.7	157.7	0.61	0.63	0.63
April	162.7	157.7	157.7	0.61	0.63	0.63
May	162.7	157.7	157.7	0.61	0.63	0.63
June	162.7	157.7	157.7	0.61	0.63	0.63
July	162.7	157.7	157.7	0.61	0.63	0.63
August	162.7	157.7	157.7	0.61	0.63	0.63
September	162.7	157.7	157.7	0.61	0.63	0.63
October	162.7	157.7	157.7	0.61	0.63	0.63
November	162.7	157.7	157.7	0.61	0.63	0.63
December	162.7	157.7	157.7	0.61	0.63	0.63

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m
BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m
BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

Table 5.9 Browsing capacity and number of browser units that can be supported by Management unit 2: Shrubby Grassland.

MONTH	Browsing capacity (ha/BU)			Browser units total		
	BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
January	86.6	51.6	39.8	0.4	0.68	0.88
February	86.6	51.6	39.8	0.4	0.68	0.88
March	86.6	51.6	39.8	0.4	0.68	0.88
April	86.6	51.6	39.8	0.4	0.68	0.88
May	86.6	51.6	39.8	0.4	0.68	0.88
June	86.6	51.6	39.8	0.4	0.68	0.88
July	86.6	51.6	39.8	0.4	0.68	0.88
August	86.6	51.6	39.8	0.4	0.68	0.88
September	86.6	51.6	39.8	0.4	0.68	0.88
October	86.6	51.6	39.8	0.4	0.68	0.88
November	86.6	51.6	39.8	0.4	0.68	0.88
December	86.6	51.6	39.8	0.4	0.68	0.88

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m
BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m
BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

Table 5.10 Browsing capacity and number of browser units that can be supported by Management unit 3: Riverine Thicket.

MONTH	Browsing capacity (ha/BU)			Browser units total		
	BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
January	8.3	4.3	1.3	17	33	110
February	8.3	4.3	1.3	17	33	110
March	8.3	4.3	1.3	17	33	110
April	8.3	4.3	1.3	17	33	110
May	9.6	5.0	1.5	15	29	96
June	12.2	6.3	1.9	12	23	75
July	13.9	7.2	2.1	10	20	68
August	20.7	10.6	3.0	7	14	48
September	19.1	10.0	2.9	8	14	49
October	10.3	5.3	1.6	14	27	90
November	8.8	4.6	1.4	16	31	103
December	8.3	4.3	1.3	17	33	111

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m
BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m
BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

Table 5.11 Browsing capacity and number of browser units that can be supported by Management unit 4: drainage Lines.

MONTH	Browsing capacity (ha/BU)			Browser units total (BU)		
	BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
January	10.7	6.1	1.6	20	36	139
February	10.7	6.1	1.6	20	36	139
March	10.7	6.1	1.6	20	36	139
April	10.8	6.1	1.6	20	36	139
May	11.3	6.5	1.7	19	34	139
June	12.3	7.2	2.0	18	31	111
July	12.9	7.5	2.1	17	30	106
August	14.0	8.5	2.4	16	26	93
September	13.9	8.4	2.4	16	26	93
October	11.6	6.7	1.8	19	33	123
November	11.0	6.2	1.7	20	36	130
December	10.7	6.1	1.6	21	36	138

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m

BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m

BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

Table 5.12 Browsing capacity and number of browser units that can be supported by Management unit 5: Short open Shrublands.

	Browsing capacity (ha/BU)			Browser units total (BU)		
MONTH	BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
January	23.3	15.5	11.0	139	209	294
February	23.3	15.5	11.0	139	209	294
March	23.3	15.5	11.0	139	209	294
April	23.6	15.6	11.1	137	208	292
May	24.2	16.2	11.7	134	200	277
June	25.7	17.3	12.8	126	187	253
July	26.4	17.9	13.2	123	181	245
August	28.1	19.2	14.7	115	169	220
September	28.1	19.2	14.7	115	169	220
October	24.7	16.5	12.0	131	196	270
November	23.7	15.8	11.3	137	205	287
December	23.3	15.5	11.0	139	209	294

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m
BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m
BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

Table 5.13 Browsing capacity and number of browser units that can be supported by Management unit 6: *Eragrostis lehmanniana* Grassland.

	Browsing capacity (ha/BU)			Browser units total		
MONTH	BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
January	108.3	64.5	44.3	13	22.	32
February	108.3	64.5	44.3	13	22	32
March	108.3	64.5	44.3	13	22	32
April	111.2	66.6	46.1	13	21	31
May	114.3	68.9	48.1	12	21	29
June	124.6	76.7	55.3	11	18	26
July	128.5	79.7	58.2	11	18	24
August	141.8	90.4	69.1	10	16	21
September	141.8	90.4	69.1	10	16	21
October	117.5	71.3	50.3	12	20	28
November	111.2	66.6	46.1	13	21	31
December	108.3	64.5	44.3	13	22	32

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m
BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m
BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

Table 5.14 Browsing capacity and number of browser units that can be supported by Management unit 7.

	Browsing capacity (ha/BU)			Browser units total		
MONTH	BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
January	81.6	66.5	63.4	48	58	61
February	81.6	66.5	63.4	48	58	61
March	81.6	66.5	63.4	48	58	61
April	82.8	67.9	64.7	47	57	60
May	85.7	70.3	67.1	45	55	58
June	91.6	76.3	73.0	42	51	53
July	97.1	80.9	77.4	40	48	50
August	103.7	88.0	84.5	37	44	46
September	103.7	88.0	84.5	37	44	46
October	87.0	71.9	68.6	45	53	57
November	82.8	67.9	64.7	47	57	60
December	81.6	66.5	63.4	48	58	61

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m
BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m
BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

Table 5.15 Browsing capacity and number of browser units that can be supported by all management units for January and Aug/Sept (minimum).

Management units	Size (ha)	Browser units total January			Browser units total Aug/Sept (lowest)		
		BC_15	BC_20	BC_50	BC_15	BC_20	BC_50
*E.*chloromelas grassland	100	1	1	1	1	1	1
Shrubby grassland	35	0	1	1	0	1	1
Riverine Thicket	144	17	33	111	7	14	48
Drainage lines	222	21	36	139	16	26	93
Short open Shrubland	3 239	139	209	294	115	169	220
E. lehmanniana grassland	1 421	13	22.	32	10	16	21
Randjie veld	3 880	47	58	61	37	44	46
Total	**9 041**	**239**	**361**	**639**	**187**	**270**	**429**

BC_15 – Browsing capacity and Browser units up to a browsing height of 1.5 m
BC_20 – Browsing capacity and Browser units up to a browsing height of 2 m
BC_50 – Browsing capacity and Browser units up to a browsing height of 5 m

5.4 Discussion

The *Eragrostis chloromelas* grassland had the lowest number of trees per hectare and subsequently the lowest browsing capacity of all management units. The unit also had the lowest shrub diversity, with only *Searsia burchellii* and *Searsia cilliata* recorded (Table 5.1). The few isolated shrubs were mostly located on the boundary fringes of the unit, indicating intrusion from the bordering management units. The shrubs were also small in size, seldom exceeding 1.5 m in height, which further contributed to the low ETTE/ha value. Due to the small size and low tree density of this unit, its contribution to the browsing capacity was negligible (Table 5.15).

The grassy shrubland management unit had the same woody species than the *Eragrostis chloromelas* grassland, with *Searsia burchellii* and *Searsia cilliata* being the only species recorded. However, shrubs were more established in this unit and also larger in size. Compared to other units, the number of trees per hectare was relatively low. Due to the small size of this unit, its contribution to the total browsing capacity of the reserve was insignificant. Both *Searsia cilliata* and *Searsia burchellii* are considered unpalatable food species in most of the karoo region (Esler *et al*. 2006) and further contributed to the unattractiveness of this unit to browser species (see Chapter 6).

The riverine and drainage line management units had a high tree density (Table 5.3). Not surprisingly, *Acacia karroo* was the most abundant species of the riverine thicket management unit (Table 5.3), as was also demonstrated with the Braun-Blanquet surveys, while it was less abundant in the drainage line management unit (Chapter 3). This is because in semi-arid environments, *Acacia karroo* is often restricted to water courses and prefers sandy soils, such as are found in the riverine thicket management unit.

The ETTE/ha value of the riverine thicket unit (8 554) was the highest of all units, while the drainage line unit had the second highest ETTE/ha value (7 390). These values were significantly higher than those of the other management units. Smit *et al*., (2013) stated that an ETTE/ha value higher than the annual rainfall figure multiplied by ten could be considered as a sign of bush encroachment in the region (In DNR that value is 355 mm x 10 = 3 550 ETTE/ha threshold value). Bush encroachment is defined as the invasion and/or thickening of aggressive undesired woody species, which suppress palatable grass and forb species, resulting in an imbalance of the grass- bush ratio; a decrease in biodiversity; and a decrease in carrying capacity (De Klerk, 2004; Ward, 2005; Balfour & Midgey, 2008). Although our understanding of what causes bush encroachment still remains somewhat unclear, a few factors have been attributed to causing bush encroachment (Ward, 2005). Some of these causes of bush encroachment are believed to be overgrazing, fire and droughts (Van

Vegten, 1983; Teage & Smit, 1992, Smit *et al*. 1996; De Klerk, 2004; Joubert *et al*., 2013). The occurrence of bush encroachment is often associated with heavily-grazed areas where grass competitiveness has been reduced (Van Vegten, 1983; Teage & Smit 1992; Smit *et al*. 1996; De Klerk, 2004; Smit, 2004). Therefore, the ETTE/ha of both the riverine thicket and drainage line management units were more than twice as high as the ETTE/ha threshold value of 3 550 ETTE/ha for DNR. However, in these instances, the high tree density is a natural phenomenon associated with riparian communities and not an indication of bush thickening.

Despite the relative small size of the riverine thicket and drainage line units (144 and 222 ha respectively), they were important habitat types for browsers as they contributed substantially to the total browsing capacity during the summer months. The abundance of *Acacia karroo* further emphasises the importance of the riverine thicket unit to browsers, since *Acacia karroo* is regarded as a palatable and productive tree species in the karoo region (Esler *et al.* 2006). On the negative side, *Acacia karroo* is winter deciduous, which is the main reason why the browsing capacity decreases dramatically from summer to late winter (Janecke, 2010, Janecke & Smit, 2011) (Table 5.15). The drainage lines unit had the highest tree density of all management units and also the highest woody species diversity. This unit can be considered as the most important unit for browsers, making it a critical resource area. As mentioned, this unit had the largest diversity of edible woody plant species. Furthermore, many of the dominant species, such as *Olea europaea* subsp. *africana*, *Searsia burchellii* and *Searsia lancea* are evergreen species, which are the main food species during the critical winter periods for browsers (Table 5.4). In this regard, *Olea europaea* subsp. *africana* is an important food species during the dry season as this evergreen species is both palatable and productive (Esler *et al*. 2006; Janecke & Smit, 2011). The high preference showed by browser for this unit, such as kudu, further illustrated the importance of this unit and made this unit a critical recourse area for browsers, enabling them to survive critical periods during late winter when browse shortages occur (see Chapter 6). The abundance of evergreen species was also the main reason why the browsing capacity of this management unit did not decrease dramatically from the wet to the dry period.

The open short shrubland unit also boasts a rich diversity of shrub species (Table 5.5). The large size of the unit and its abundance of shrubs enabled it to support the largest number of browser units (more than 50% of the total BU). Together with the drainage line and riverine thicket unit, the open short shrubland unit was also considered an important unit for browsers despite the fact that the dominant woody species was *Searsia burchellii,* which is regarded as relatively unpalatable.

As with the *E. chloromelas* grassland, the *E. lehmanniana* grassland had a low density of woody plants per hectare. The distribution of shrubs was also erratic and more abundant in transitional zones that surrounded the riverine thickets. Although the woody density was low, the species diversity was surprisingly high with many of the species regarded as palatable to browsers. The low tree density resulted in a low browsing capacity of this unit. The woody species were relatively large and the main reason for the slightly higher than expected ETTE/ha value.

Due to the low density and small size of woody species in the randjie veld, the ETTE/ha value was very low. Although, the tree density/ha in this unit was more than double of that recorded in the *E. lehmanniana* grassland, had a lower ETTE/ha value. As discussed in Chapter 3, the woody density was much higher in the western sections of this unit than in the eastern sections, where large areas had almost no shrubs. Due to the large area this unit covered, it could support the second largest amount of browser units, but at a considerably lower browser carrying capacity per unit area. In addition are the dominant woody species of the randjie veld unpalatable.

This study concluded that bush encroachment was not a problem in DNR, despite its large overgrazed area. The absence of the woody increases species *Acacia mellifera*, which has encroached large areas within the region, was probably the main reason why bush encroachment was not a problem on DNR. *Acacia mellifera* is regarded as one of the most serious woody increasers species because of its greater ability to compete for resources (Joubert *et al*., 2013). The establishment of *Acacia melliferia* therefore should be prevented at all costs in the future management of DNR. The only areas that showed indications of bush encroachment were a few small, isolated areas within the short open shrubland management unit, these areas encroached by the shrub *Rhigozum trichotomum*, a species known to be an aggressive invader that displace more valuable plant and sometimes form dense stands (Le Roux *et al*., 1994; Wakeling & Bond, 2007). It is therefore important that these areas are monitored and managed on a regular basis to prevent the expansion of these areas.

5.5 Conclusion

In general, three habitat units were identified as important browsing units, based on the species diversity, palatability of species and browsing capacity of the units. Similarly, three of the units were regarded as insignificant in terms of importance to browsers. The total browsing capacity of the reserve could be regarded as high for the region and it does not decrease substantially from the wet to dry season (22 - 25% decrease), which indicates the abundance of evergreen species. However, the current browser unit total on DNR exceeds the browsing capacity and is further discussed in Chapter 7. Despite the high stocking density, the negative effect of herbivory on woody plants was not regularly observed. Bush densification, which is a major problem in large parts of southern Africa, was not evident in this study.

Chapter 6: Habitat selection of game species of DNR

6.1 Introduction

Knowledge of habitat preferences and other ecological requirements of specific game species is a basic requirement for any proper management program. It is also a prerequisite for understanding the abundance and distribution of game species and to evaluate the suitability of species introduction to any specific region for (Grunow, 1980, Dekker *et al.* 1996). South Africa has a rich diversity of ungulate species which have all evolved and adapted to utilize a wide variety of different habitats available to them (Dekker *et al*,. 1996). Nell (2010) describes the habitat of an animal as the area it occurs in by choice and it is composed of geomorphological features such as topography, geological formations, soil types and vegetation. Nell (2010) further states that these areas selected by choice must also fulfil the life necessities of the species. Therefore, different parts of the environment represents habitat of varying quality in terms of opportunities such as food and risks such as predators and subsequently affect an individual's ability to survive and reproduce (Melton, 1987, Dekker *et al.*, 1996).

Habitat features and requirements of herbivores may change with time and space. Main determinants of local movements are forage availability, forage quality in terms of mineral nutrition, water availability (Ben-Shahar & Coe 1992; Grant *et al*., 2009; Smit, 2011; Hayward & Hayward, 2012) and certain landscape features such as topography, soil types, vegetation composition and structure (Ben-Shahar, 1995). Seasonal migration of animals may be attributed to climatic conditions, the seasonal phenological development of forage and fire (Dörgeloh, 1998). Rainfall is a central climatic factor governing herbivore population dynamics in African savannas (Owen-Smith, 1990; Ogutu & Owen-Smith, 2006; Ogutu *et al.,* 2008).

The following seven ungulate species were included in the habitat studies: Cape buffalo (*Syncerus caffer*), greater kudu (*Tragelaphus strepsiceros*), red hartebeest (*Alcelaphus buselaphus*), eland (*Tragelaphus oryx*), gemsbok (*Oryx gazella*), mountain reedbuck (*Redunca fulvorufula*) and warthog (*Phacochoerus africanus*). The objectives of this study were to determine: (I) the habitat selection of the ungulate species in both the cold, dry season and the warm, wet season, (II) group sizes, social structures and general population growth trends.

6.2 Methodology

6.2.1 Data collection

Animal sightings were recorded by means of a GPS using the CyberTracker icon interface program. The CyberTracker software is regarded as an efficient method of GPS field data collection. Different routes were travelled daily during which all sightings of the main ungulate species were recorded. Each predetermined sighting route and the regularity of travel were carefully planned to ensure equal sampling of the entire study area, thus avoiding over- or under sampling of any area. Buffalo and common rheebuck sightings were recorded whenever encountered, due to the rarity of these sightings. The routes were travelled by vehicle and on foot during the early mornings, starting from sunrise until 11 am in the dry season and 10 am in the wet season and also late afternoons from 3 pm until sunset when animal foraging activity was at its peak. Sightings were not generally recorded during the midday periods when animal activity was at its lowest. In addition, Estes (1997) mentions that feeding behaviour of ungulates peaks during the early morning and late afternoon while resting behaviour predominantly occurs during the hotter midday periods of the day. The data recorded with each sighting included the number of animals, distinguishing were possible between the number of adult males and females, sub-adults of each gender and juveniles. Notes were also taken in regard to the veld type and true position of each sighting to enable later readjustment within the Cybertracker map editor software. Animal sightings were recorded from July to September 2011 for the cold dry season, which occurs from June to September and from January to April 2012 for the warm wet season, which occurs from December to May. According to the long-term rainfall data the height of the dry season occurs from July to September and the wet season reaches its peak from January to April.

6.2.2 Data analysis

<u>6.2.2.1 Habitat selection</u>

A chi-square goodness-of-fit test was used to determine if there were significant differences ($P<0.05$) between the expected habitat selection and the actual habitat selection of each ungulate species (Neu *et al.* 1974, Byers & Steinhorst, 1984). Therefore, the null hypothesis (Ho1): is that habitat usage was in proportion to its availability and is not random selection. For the proportional usage, the availability of each habitat was determined by subtracting the areas from the total available area of each management unit that was inaccessible for any reason (ex. topography, fencing) as well as the areas where observations could not be made. This test was applied on condition that the expected use of each habitat was >5 (Roscoe & Byars, 1971). To meet this requirement, similar habitats had to be combined and dry and wet season data for buffalo, gemsbok, red hartebeest and mountain reedbuck also needed to be combined. If the Ho1 hypothesis that habitat selection was proportionate to its availability was rejected ($P < 0.05$) a second Ho2 was tested using the Bonferroni Z-statistic, that usage occurs in proportion to availability, considering each habitat type separately. The Bonferroni method, where 95% confidence intervals were calculated, therefore indicated if habitats were positively selected or avoided (Byers & Steinhorst, 1984)

6.2.2.2 Group sizes and population growth trends

Data collected of group sizes were pooled for each season and used to determine mean group sizes for each social organisation group, such as mixed groups and bachelor groups. The data was used to determine the proportion the sightings of each group made up of the total of observations and to determine seasonal changes. Survey figures of 2004 and 2009 as well as estimates of latest numbers were used to determine population growth figures (See Chapter 2). Culling programs were assimilated into the calculations.

6.2.2.3 Mapping

The GPS positions of the sightings recorded with Cybertracker were spatially adjusted to their true position within the Cybertracker program to their true positions. After correction, the spatial data was exported to the ArcGIS 10 program with which all spatial analyses and mapping of data were done. The spatial data was organised using the vector organisation system. The vector or point organisation of data was used to visually indicate the position of each sighting and the herd size of each of these animals sighting. The vector data was overlayed over the map of the management units.

For each of the seven species, graduated symbols were used to provide a visual presentation of herd size. Map legends were adjusted to appropriate densities for each of the species. Differentiation was also made between the wet and dry seasons by using a lighter colour for the wet season and a darker colour for dry season.

6.3 Results

6.3.1 Global habitat preferences

The chi-square test analysis for habitat selection was significant (P<0.05) for all ungulate species in the study (Tables 6.1 and 6.2), and thus rejected the null hypothesis that ungulate species were using the habitat in proportion to its availability. Subsequently, Bonferroni confidence (95% cl) intervals were calculated for all species and are presented in Tables 6.3 and 6.4.

Table 6.1 The chi-square test results of the combined seasons for buffalo, red hartebeest, gemsbok and mountain reedbuck at 95% confidence levels (*P* < 0.05).

Species	X^2 (a)	DF (b)	*P* value (c)	H_0 hyp. (d)
Buffalo	827.86	3	P < 0.001	rejected
Red hartebeest	18.3	3	P < 0.001	rejected
Gemsbok	30.74	3	P < 0.001	rejected
Mountain reedbuck	38.45	3	P < 0.001	rejected

(a) Chi-square test value

(b) Degrees of freedom (n -1)

(c) Probability value of significance

(d) Ho hypothesis is rejected or accepted

Table 6.2 The chi-square test results of the dry and wet season for eland, kudu, and warthog at 95% confidence levels (*P* < 0.05).

		Dry season			Wet season		
Species	**DF (a)**	**X^2 (b)**	***P* value (c)**	**H0 hyp. (d)**	**X^2 (b)**	***P* value (c)**	**H0 hyp. (d)**
Eland	3	49.51	P < 0.001	rejected	17.28	P < 0.001	rejected
Kudu	3	708.51	P < 0.001	rejected	897.44	P < 0.001	rejected
Warthog	3	80.29	P < 0.001	rejected	87.75	P < 0.001	rejected

a) Degrees of freedom (n -1)

(b) Chi-square test value

(c) Probability value of significance

(d) Ho hypothesis is rejected or accepted

Table 6.3 Bonferronni confidence intervals of buffalo, red hartebeest, gemsbok and mountain reedbuck.

Veld type	P_{io} (a)	P_{ie} (b)	Confidence intervals (95% CL) (c)	Pref (d)
Buffalo	Dry and Wet season combined (n = 109)			
Drainage lines + River thicket	0.67	0.053	0.557 ≤ *P* ≤ 0.783	+
Eragrostis spp Grasslands	0.11	0.202	0.035 ≤ *P* ≤ 0.184	-
Short open Shrublands	0.147	0.340	0.062 ≤ *P* ≤ 0.232	-
Randjie veld + Shrubby grassland	0.073	0.405	0.011 ≤ *P* ≤ 0.135	-
Red Hartebeest	Dry and Wet season combined (n = 145)			
Drainage lines + River thicket	0.007	0.053	0.000 ≤ *P* ≤ 0.024	-
Eragrostis spp Grasslands	0.186	0.202	0.105 ≤ *P* ≤ 0.267	"
Short open Shrublands	0.490	0.340	0.386 ≤ *P* ≤ 0.594	+
Randjie veld + Shrubby grassland	0.317	0.405	0.220 ≤ *P* ≤ 0.414	"
Gemsbok	Dry and Wet season combined (n = 130)			
Drainage lines + River thicket	0.008	0.053	0.000 ≤ *P* ≤ 0.028	-
Eragrostis spp Grasslands	0.246	0.202	0.152 ≤ *P* ≤ 0.340	"
Short open Shrublands	0.154	0.340	0.075 ≤ *P* ≤ 0.233	-
Randjie veld + Shrubby grassland	0.592	0.405	0.484 ≤ *P* ≤ 0.700	+
Mountain reedbuck	Dry and Wet season combined (n = 97)			
Drainage lines + River thicket	0.010	0.053	0.000 ≤ *P* ≤ 0.026	-
Eragrostis spp Grasslands	0	0.202	-	
Short open Shrublands	0.330	0.340	0.211 ≤ *P* ≤ 0.449	"
Randjie veld + Shrubby grassland	0.660	0.405	0.540 ≤ *P* ≤ 0.780	+

(a) Observed proportion occurring in the habitat type.

(b) Expected observations in habitat type

(c) 95% confidence interval of area under a neutral-selection hypothesis. Adjusted α level for this analysis was 0.99, with a corresponding Z-value of 2.73 for the Bonferroni corrections.

(d) The significant preferences and avoidances are denoted + and – respectively, while non-significant preferences is denoted “

Table 6.4 Bonferonni confidence intervals of eland, kudu and warthog.

Veld type	P_{io} (a)	P_{ie} (b)	Confidence intervals (95% CL) (c)	Pref (d)	P_{io} (b)	Confidence intervals (95% CL) (c)	Pref (d)
Eland		Dry season (n = 280)			Wet season (n = 181)		
Drainage lines + River thicket	0.135	0.053	0.084 ≤ *P* ≤ 0.186	+	0.099	0.044 ≤ *P* ≤ 0.154	"
Eragrostis spp Grasslands	0.211	0.202	0.150 ≤ *P* ≤ 0.272	"	0.255	0.017 ≤ *P* ≤ 0.336	"
Short open Shrublands	0.375	0.340	0.303 ≤ *P* ≤ 0.447	"	0.381	0.291 ≤ *P* ≤ 0.471	"
Randjie veld + Shrubby grassland	0.279	0.405	0.212 ≤ *P* ≤ 0.346	-	0.265	0.183 ≤ *P* ≤ 0.347	-
Greater kudu			Dry season (n = 212)			Wet season (n = 177)	
Drainage lines + River thicket	0.453	0.053	0.368 ≤ *P* ≤ 0.538	+	0.554	0.461 ≤ *P* ≤ 0.647	+
Eragrostis spp Grasslands	0.052	0.202	0.043 ≤ *P* ≤ 0.061	-	0.034	0.00 ≤ *P* ≤ 0.068	-
Short open Shrublands	0.382	0.340	0.298 ≤ *P* ≤ 0.466	"	0.288	0.203 ≤ *P* ≤ 0.373	"
Randjie veld + Shrubby grassland	0.113	0.405	0.059 ≤ *P* ≤ 0.172	-	0.124	0.062 ≤ *P* ≤ 0.186	-
Warthog			Dry Season (n = 146)			Wet season (n = 108)	
Drainage lines + River thicket	0.165	0.053	0.088 ≤ *P* ≤ 0.242	+	0.204	0.107 ≤ *P* ≤ 0.301	+
Eragrostis spp Grasslands	0.349	0.202	0.250 ≤ *P* ≤ 0.448	+	0.352	0.237 ≤ *P* ≤ 0.467	+
Short open Shrublands	0.370	0.340	0.270 ≤ *P* ≤ 0.470	"	0.370	0.254 ≤ *P* ≤ 0.486	"
Randjie veld + Shrubby grassland	0.116	0.405	0.050 ≤ *P* ≤ 0.182	-	0.074	0.011 ≤ *P* ≤ 0.137	-

(a) Observed proportion occurring in the habitat type.

(b) Expected observations in habitat type

(c) 95% confidence interval of area under a neutral-selection hypothesis. Adjusted α level for this analysis was 0.99, with a corresponding Z-value of 2.73 for the Bonferroni corrections.

(d) The significant preferences and avoidances are denoted + and – respectively, while non-significant preferences is denoted “.

6.3.2 Buffalo (*Syncerus caffer*)

Buffalo selection differed greatly from the expected (X^2= 827.86, df = 3, P < 0.001, Table 6.1). Buffalo had a clear preference for the riverine thicket and drainage line units in both seasons, while avoiding the other plant communities (Table 6.3). During the dry season large buffalo herds predominantly concentrated along the riverine thickets surrounding the Zeekoei river in the southern section of the reserve. However, during the wet season the majority of buffalo moved further north utilizing drainage lines and riverine thicket communities in the central and northern section of the reserve more regularly. During the wet season observations along the Zeekoei River became far more infrequent. Many of the older, solitary bulls and bachelor bull groups remained resident to specific drainage lines throughout both seasons (Figure 6.1)

The social organisation of DNR buffalo was made up of mixed groups that predominantly consisted of adult cows, sub-adults, juveniles and one or two bulls or solitary older bulls or bachelor male groups. Solitary bulls often joined mixed groups, many times remaining with the group for long periods at a time before wandering off again. Herd sizes varied generally from 6 - 13 animals per mixed group. Buffalo formed larger mixed groups during the dry season, occasionally forming herds of more than 40 individuals. During the wet season these large herds breaks up into smaller groups with herd sizes seldom larger than twenty animals per group. The mean mixed group size in the dry season was 16.348 (SE ± 2.206), while the mean group size in the wet season was 10.278 (SE ± 0.969). Bachelor bull groups varied between 2 – 4 animals (Dry: 2.722 [SE ± 0.158], Wet: 2.444 [SE ± 0.242]). During the wet season sighting of solitary bulls made up 37.21% of total observations and bachelor groups 20.93% of total sightings. However, during the dry season sightings of solitary bulls decreased dramatically to only 13.33% of total sightings, while sightings of bachelor groups increased to 40%. Therefore, indications are that solitary bulls also formed or joined bachelor groups during the dry season while wandering off again during the wet season.

6.3.3 Eland (*Tragelaphus oryx*)

Eland occurred over the largest area of all the game species, utilizing most of the habitat units available (Figure 6.2). The Bonferonni test, however, indicates a slight avoidance for the randjie veld and shrubby grassland habitat units during both the wet and dry seasons (Table 6.4). However, large groups of eland were relatively commonly sighted throughout the lower flatter western reaches of the randjie veld unit. Sighting of eland in the higher, steeper mountains of the eastern reaches covered by the randjie veld unit were far more infrequent and usually consisted of small groups, subsequently indicating a general overall avoidance of this habitat unit. During the dry season eland had a marginal preference for the riverine communities, particularly the drainage lines. However during the dry season all habitats except the randjie veld and shrubby grassland units were utilized in proportion to each unit's availability.

The social organisation was made up of mixed groups that consisted of males and females of all ages, bachelor groups and nursery groups. Herd sizes varied from 4 - 20 animals. Eland formed larger groups during the wet season (14.231 [SE ± 1.253]) than the dry season (10.228 [SE ± 0.534]). During the wet season, eland has occasionally been seen in groups of more than 150 animals. Sightings of nursery herds were very rare and only reached

3.87% (N=7) and 1.79% (N=5) off all sightings in the wet and dry season respectively. Juveniles and sub-adults occasionally formed more than two thirds of mixed groups. Bachelor groups never consisted of more than four individuals. Distinction between sexes proved extremely difficult due to their skittish behaviour; observations often being made a long distance from eland, and limiting sexual dimorphism of eland.

6.3.4 Greater Kudu (*Tragelaphus strepsiceros*)

The Chi-square goodness-of-fit test implies that habitat selection by Kudu differed vastly from the expected habitat selection for both seasons (Dry: $X^2 = 708.51$, df = 3, $P < 0.00001$, Wet: 897.44, df = 3, $P < 0.001$ (Table 6.2)). Kudu showed a very high preference for the river thicket as well as drainage lines community during both the wet and dry season (Table 6.4, Figure 6.3). Almost 50% of all the kudu observations were within these two communities although they only cover 4.7% of the total reserve area. The results of the Bonferonni test also indicate that there was no seasonal differences in the preference and utilization of habitat by kudu (Table 6.4). During both seasons the *Eragrostis lehmanniana* grassland, *Eragrostis chloromelas* grassland, randjie veld and shrubby grassland habitat units were avoided, while the short open shrubland was utilized in proportion to its availability.

The social organisation of kudu in DNR was loosely structured consisting of mixed groups that were made up of males and females of varying ages, female groups and their young, bachelor groups, solitary males and solitary females. Mixed herd sizes generally varied from 4 -13 animals per group although no groups larger than 10 animals were recorded during the wet season. Consequently, groups were significantly smaller during the wet season (4.514 [SE ± 0.152]) than during the dry season (7.154 [SE ± 0.29]). Bachelor groups were small during both seasons (2 - 5 animals) (Dry: 2.381 [SE ± 0.122}; Wet: 2.467 [SE ± 0.226]), while female groups were usually larger (3 – 8 animals) (Dry: 4.064 [SE ± 0.209}; Wet: 3.4 [SE ± 0.254]). Sightings of solitary females were the rarest of all social structures during both seasons, but were more frequent during the wet season (15.44% and 5.03% of all observations during the wet and dry seasons respectively). Mixed groups were loosely structured as small groups would often join other groups or just as regularly break away from larger groups. The number of adult bulls observed in mixed groups was significantly higher during the dry season (N =71, 65 groups) than the wet season (N= 18, 37 groups).

6.3.5 Red hartebeest (*Alcelaphus buselaphus*)

The results showed that only the river thicket and drainage line habitat units were avoided by red hartebeest. Red hartebeest was the only species that showed a strong preference for the short open shrubland unit (Table 6.3). Within the randjie veld community, only flat mountain plateau areas were selected, while the steep slopes were avoided. Although not indicated in Table 6.3, red hartebeest showed marginal seasonal variation in habitat selection. The *Eragrostis chloromelas* and *Eragrostis lehmanniana* grassland units were marginally more preferred during the wet season than during the dry season. Red hartebeest favoured the randjie veld community more during the dry season than wet season. Red hartebeest population densities were particularly high in the northern and south eastern section of the reserve (Figure 6.4) with isolated groups and the solitary males that occurred in the remaining far northern, central and western areas.

Group sizes varied from 5 - 13 individuals. Group sizes remained consistent throughout the wet (10.419 [SE ± 1.391]) and dry season (9.571 [SE ± 1.089]), although very large groups of over 40 individuals were observed on rare occasions during the wet season. The social organisation consisted of mixed groups, bachelor groups and solitary males. Solitary males were often spotted and made up a large proportion of the total observations (35.86% and 33.22% in wet and dry season respectively). Batchelor groups varied from 2 – 4 individuals during both seasons (Wet: 2.614 [SE ± 0.221], Dry: 2.831 [SE ± 0.204]). Sighting of bachelor groups was the lowest of all social structures (20% of total observations during both seasons combined)

6.3.6 Gemsbok (*Oryx gazella*)

The largest proportion of the gemsbok population was located west of the Zeekoei River with a very small population that occurred east of the Zeekoei River (Figure 6.5). The eastern population was almost entirely restricted to the higher mountain plateaus. Gemsbok showed a preference for the randjie veld and shrubby grassland units, while avoiding the riverine thicket, drainage lines and short open scrubland habitat units. Although results indicate that the alluvial flats and grassland units combined were utilized proportionately to its availability it was predominantly the far smaller grassland habitat unit that was selected rather than the larger alluvial flats unit. No seasonal habitat selection differences were found.

Herd sizes varied from 7 - 16 individuals during the dry season (8.941 [SE ± 0.998]) and from 5 – 8 individuals during the wet season (5.444 [SE ± 0.480]). The social organization consisted of mixed groups that predominantly consisted of adult females and sub-adults, solitary males and small bachelor groups of older bulls. Sightings of solitary males made up a very large proportion of all observations during both dry (48.61%) and wet (44.07%) season. Bachelor groups were very consistent in size and mostly consisted of pairs (Wet: 2.2 [SE ± 0.107], Dry: 2.35 [SE ± 0.133])

6.3.7 Warthog (*Phacochoerus africanus*)

Warthog showed a slight preference for the drainage line, river thicket, grassland and alluvial flat communities, while avoiding the randjie veld communities. The open shrubland community was proportionality utilized as expected. No difference in habitat selection between the wet and dry season was found. Although warthog showed slight preference for the drainage lines and river thicket communities, denser areas of these communities were entirely avoided. Warthog particularly selected more open areas within the riverine thicket communities in the central region of the reserve where standing water often created marshy conditions (Figure 6.6). Within the alluvial flat community, warthogs were particularly commonly observed in areas where deep red sandy soils occur, such as are predominantly found in the *Pentzia globosa*- *Eragrostis lehmanniana* plant community described in Chapter 3. Within these areas, as mentioned in Chapter 3, warthog have caused heavy overgrazing through their destructive feeding behaviour which involves uprooting plants.

The social organisation of warthog consisted of mixed pairs and their offspring, small male and female groups, as well as solitary individuals of both sexes. Bachelor groups were between 2-3 individuals during both seasons (Wet: 2.375 [SE ± 0.125], Dry: 2.3 [SE ± 0.105]). Most of the observations made of more than three warthogs were of females and their young. In highly desired areas, such as the marshy areas, high concentrations of warthog were found together that were made up of numerous smaller groups. Sightings of solitary females were very rare and contributed a small percentage to total sightings (4.59% Wet, 4.12% Dry).

6.3.8 Mountain reedbuck (*Redunca fulvorufula*)

Mountain reedbuck showed a preference for the higher mountainous terrain of the randjie veld unit (MU 7) during the wet and dry season. Generally only solitary males were encountered in other lower lying veld types, while larger groups were almost entirely restricted to the highest reaches of MU 7. Within the randjie veld community, indications were that mountain reedbuck prefer the steeper mid slopes and crest of higher hills to the open extended plateaus and foot slopes. No preference for slope aspect was found. Mountain reedbuck was the only ungulate species in DNR that regularly utilized the steeper mountain slopes.

Group sizes of mountain reedbuck varied from three to six individuals with solitary males and pairs also often sighted (35.88% and 26.23% of total observations respectively). Mixed groups either predominately or entirely consisted of adult females. Mixed group sizes remained consistent throughout both seasons (Wet season: 3.280 [SE ± 0.262], Dry season: 3.433 [SE ± 0.207]). No bachelor groups were observed during the study period. Alarmingly few sub-adults and juveniles were sighted throughout the study period.

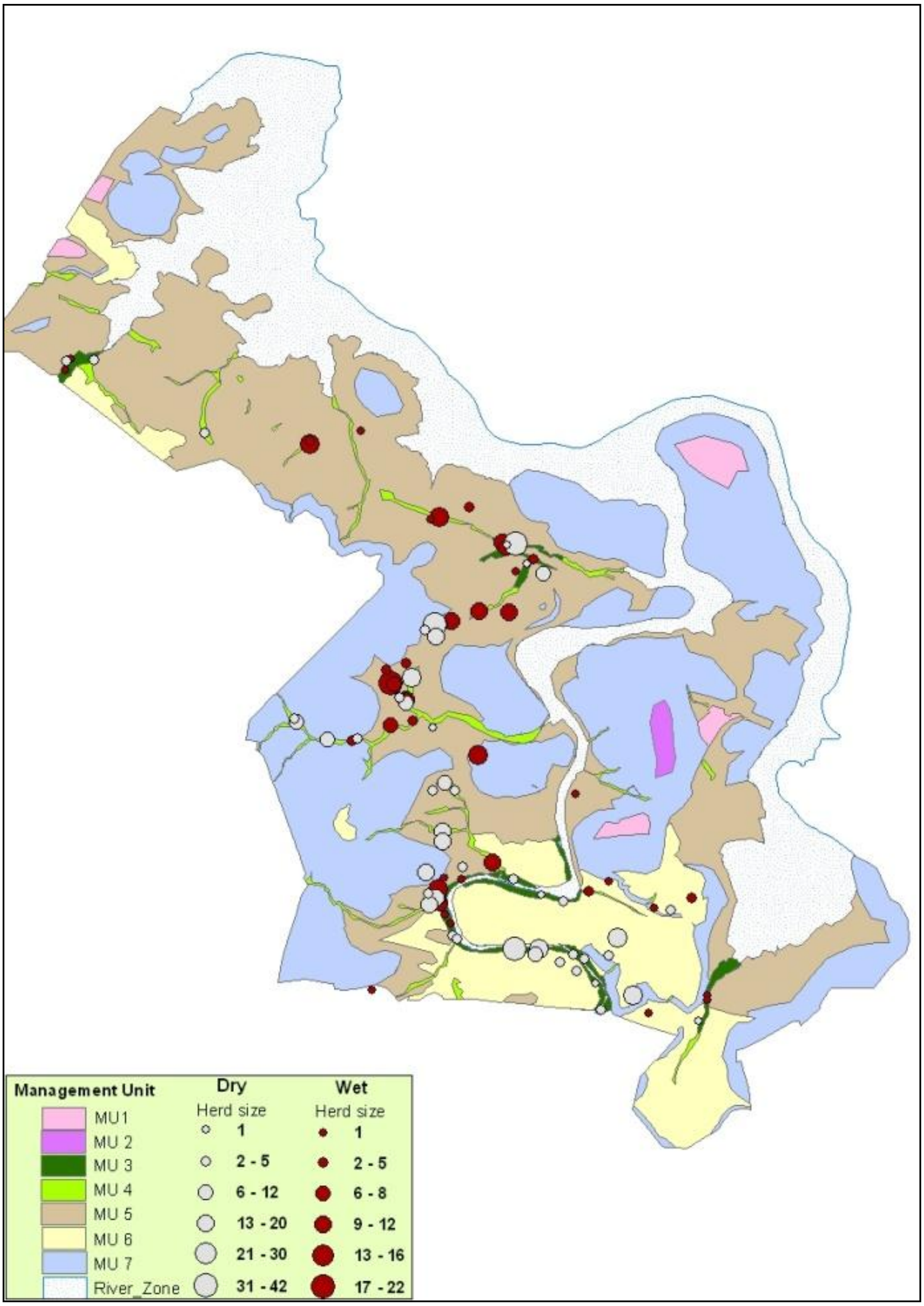


Figure 6.1 Dry and wet season habitat selection and group sizes of buffalo.

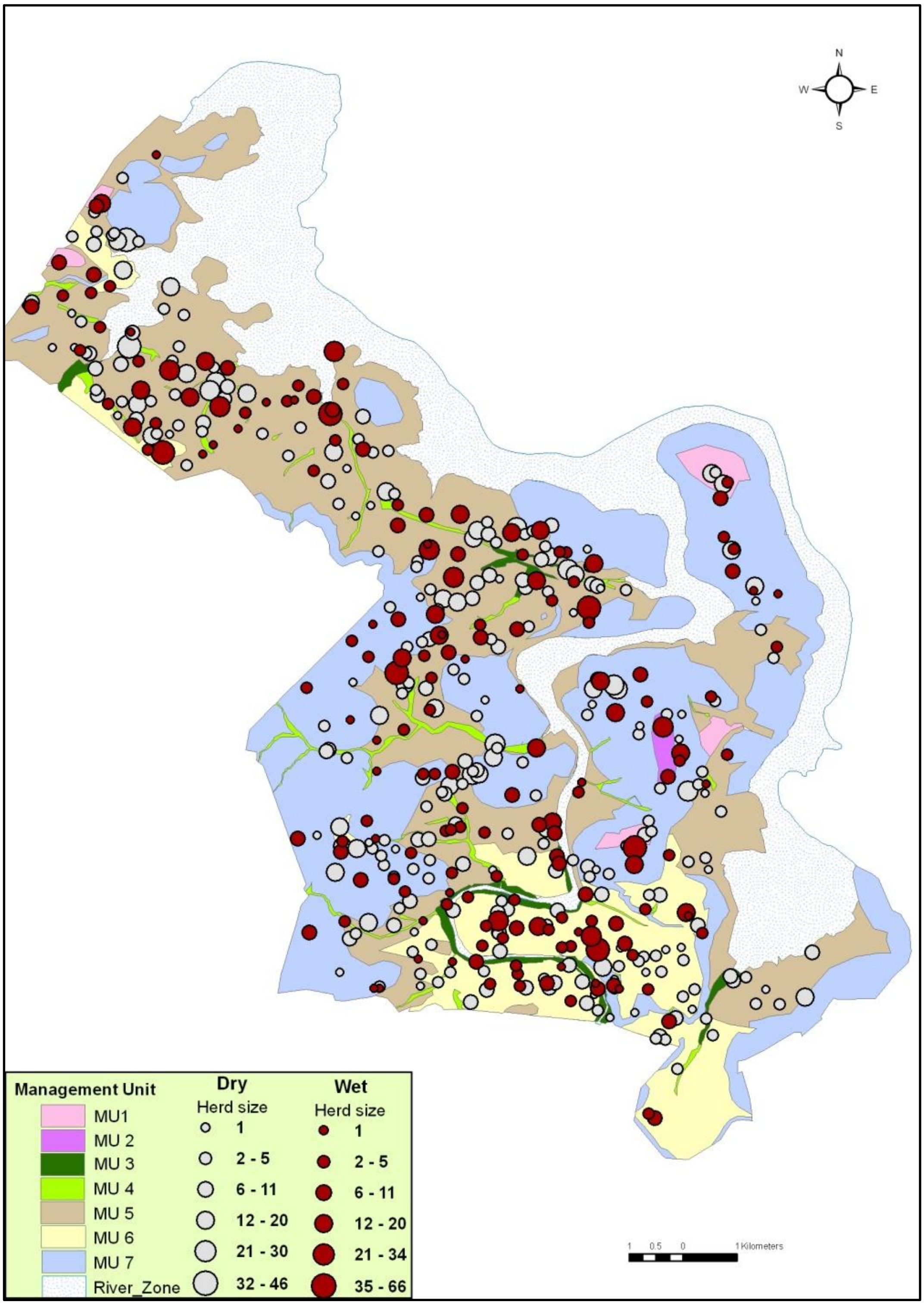


Figure 6.2 Dry and wet season habitat selection and group sizes of eland.

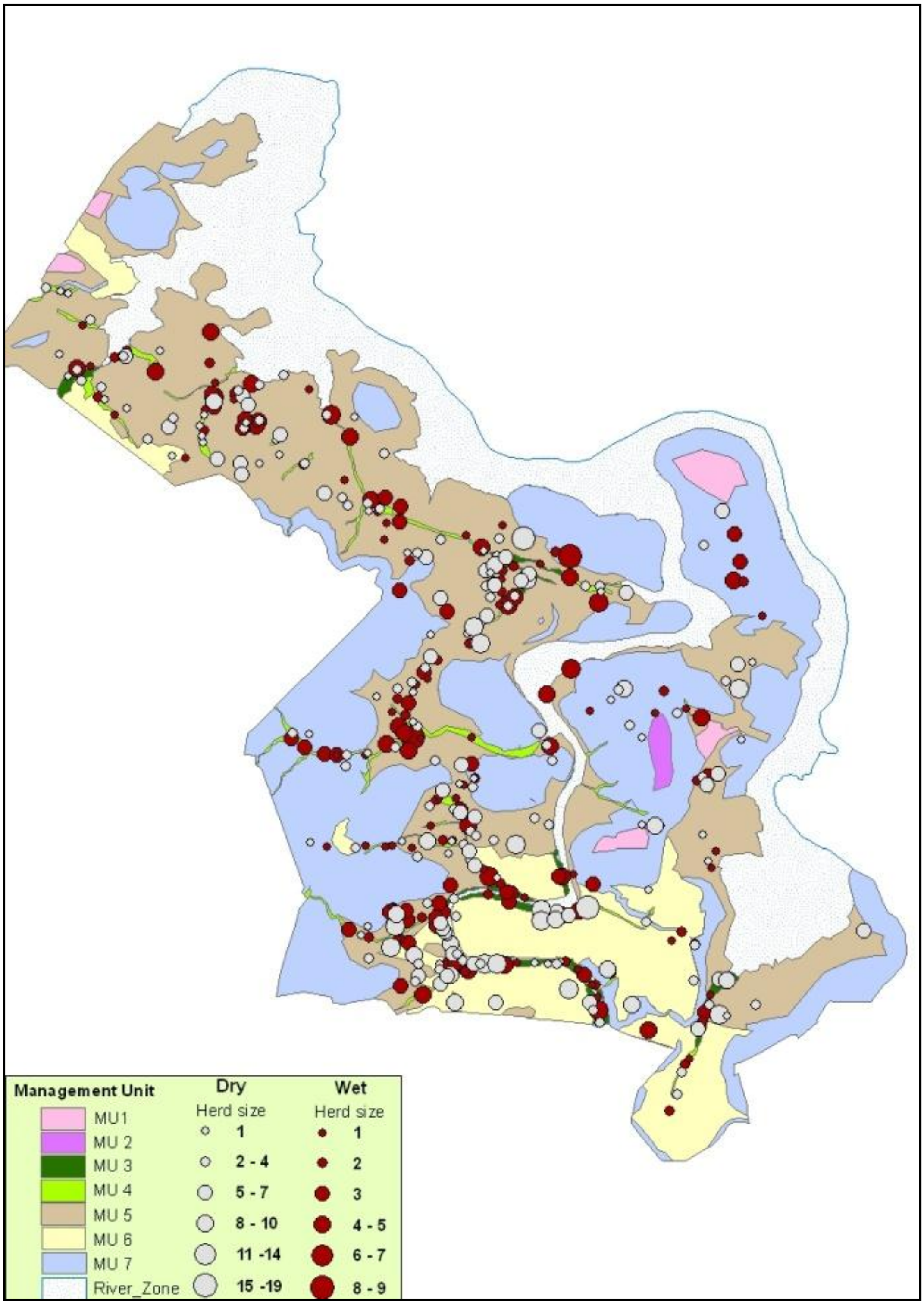


Figure 6.3 Dry and wet season habitat selection and group sizes of kudu.

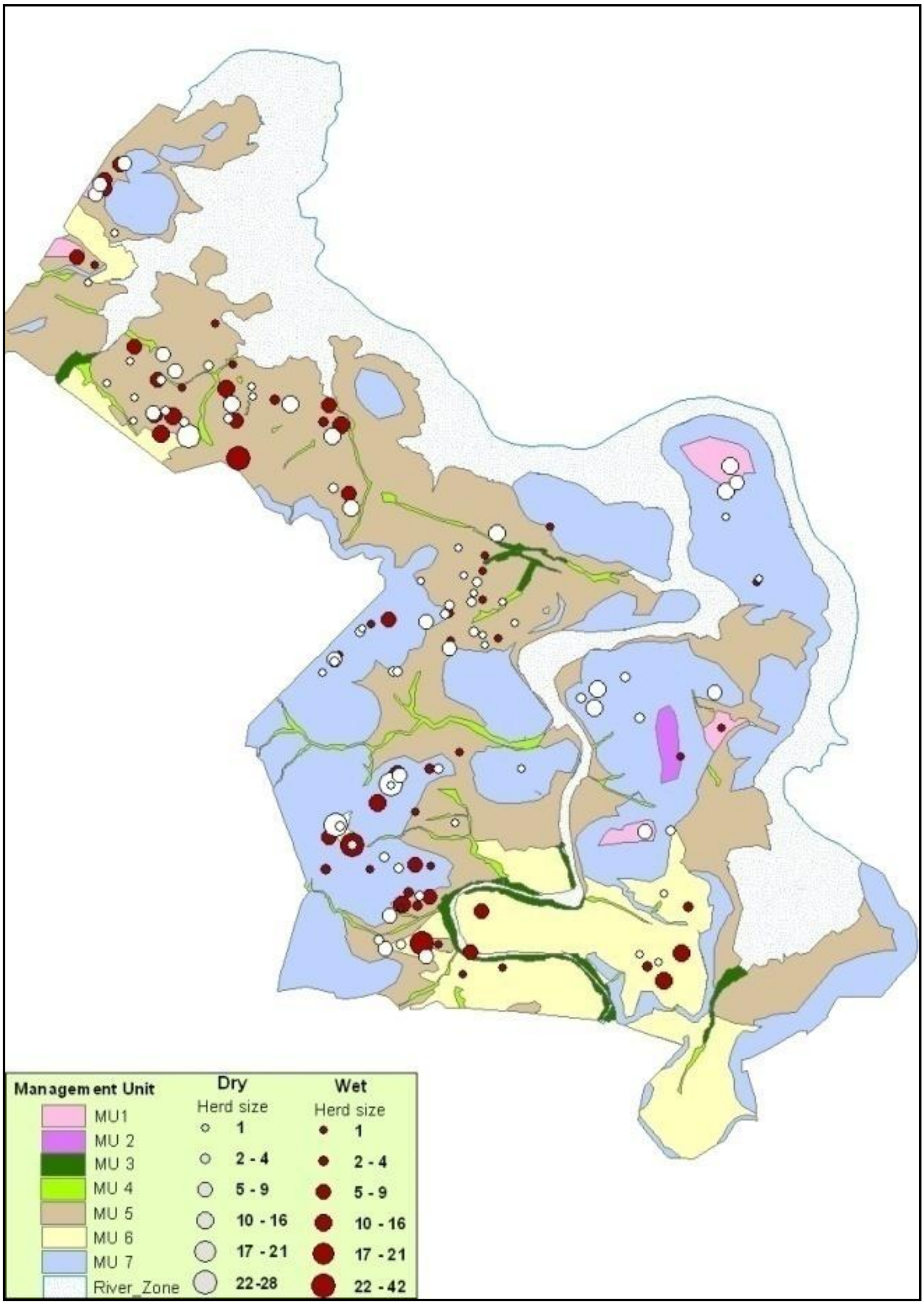


Figure 6.4 Dry and wet season habitat selection and group sizes of red hartebeest.

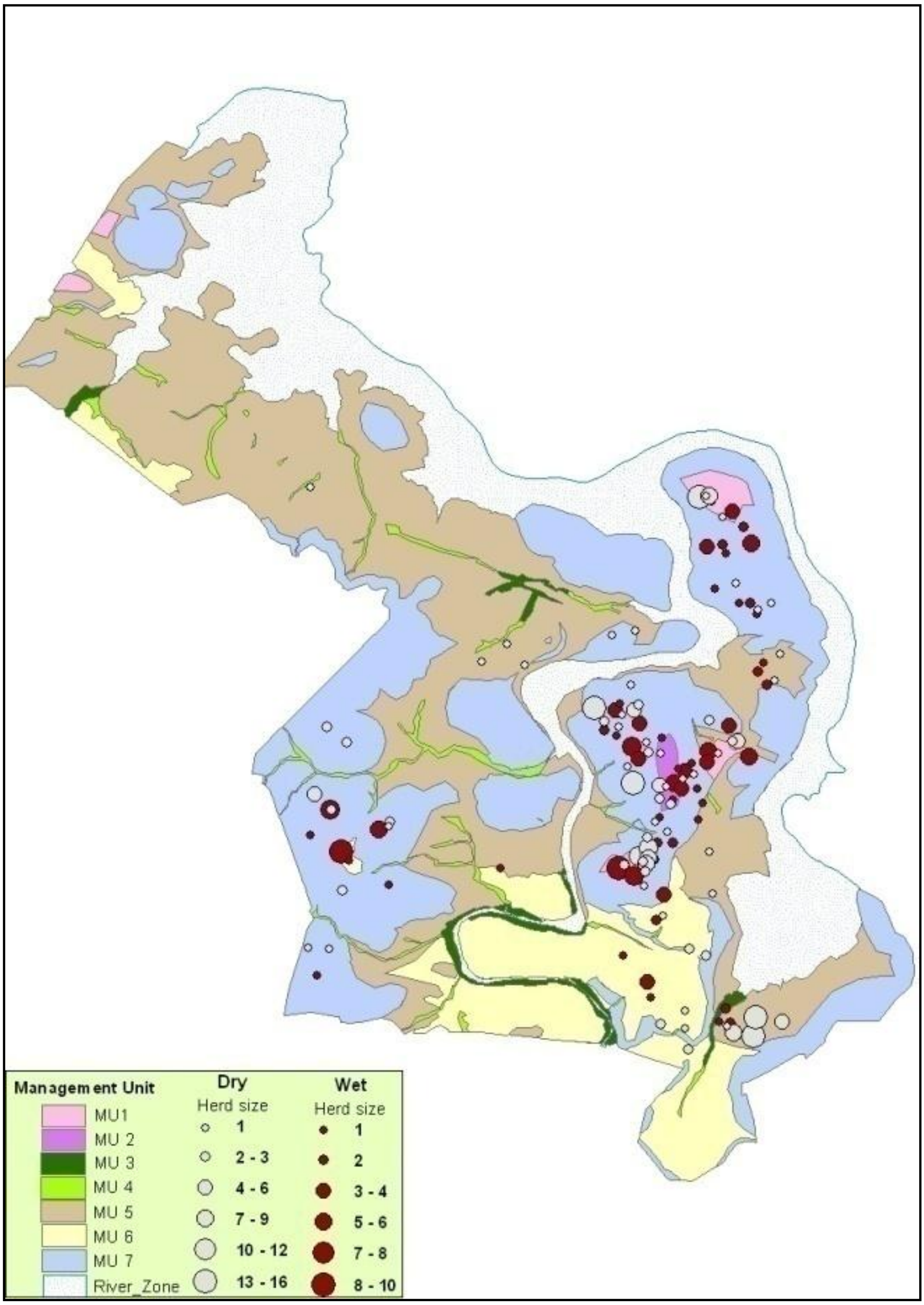


Figure 6.5 Dry and wet season habitat selection and group sizes of gemsbok.

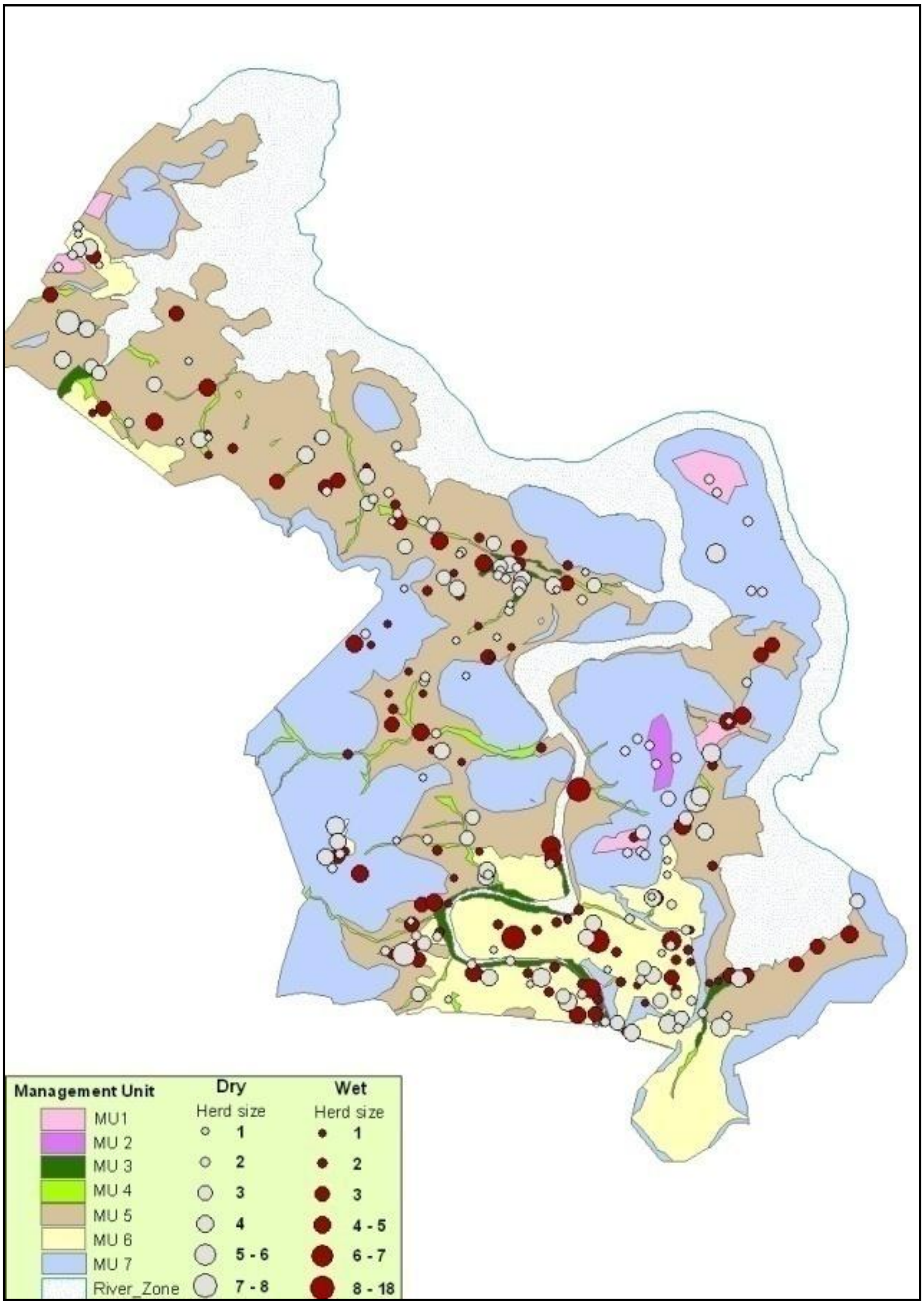


Figure 6.6 Dry and wet season habitat selection and group sizes of warthog.

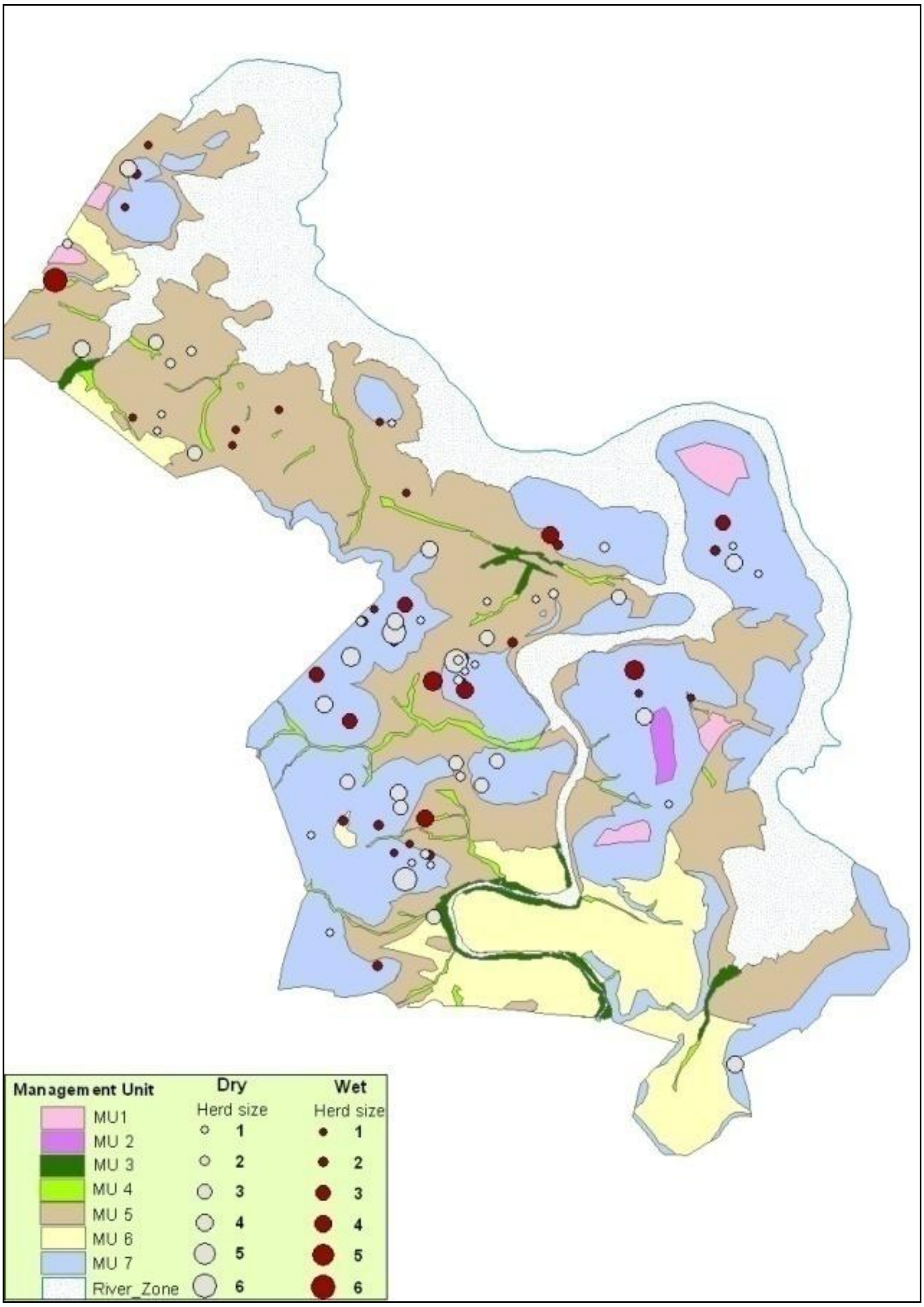


Figure 6.7 Dry and wet season habitat selection and group sizes of mountain reedbuck.

6.4 Discussion

6.4.1 Buffalo (*Syncerus caffer*)

The essential habitat requirements of the African buffalo include abundant intermediate to tall grasses, trees and shrubs for shade and abundant surface water such as found in the northern, north-eastern and eastern parts of the sub region (Skinner & Chimimba, 2005, Furstenburg, 2011). They do not select extended open grasslands or grasslands since buffalo require the shade of trees to rest under during the hotter periods of the day. However, buffalo may utilize these areas during the cooler periods after sunset. Similarly, buffalo of DNR remained almost entirely in the denser riverine thickets and drainage lines, which provided an abundance of shade. Results from this study concur with results found by Venter (2006) that Buffalo of DNR almost exclusively rest and hide during the daytime in the dense river thicket and drainage line communities. Buffalo in Addo Elephant National Park, from where the DNR population originates, are well known for resting during the day time in the thickets, while feeding occurs mainly during night time (Winterbach & Bothma, 1998). Night feeding is also common in other buffalo populations from other regions, such as lower sabie in the Kruger National Park (Ryan & Jordaan, 2005; Ryan *et al*., 2006), the Serengeti (Sinclair, 1977) and Matusadona National Park in Zimbabwe (Taylor, 1985). Buffalo in Willem Pretorious Nature Reserve show similar habitat preferences to those from DNR. In the Willem Pretorius nature reserve the only habitat preferred was the riverine communities. As with buffalo in DNR, the buffalo in Willem Pretorius Nature Reserve also originated from the Addo Elephant National Park (Winterbach & Bothma, 1998).

Buffalo are bulk grazers and roughage feeders (Skinner & Chimimba 2005, Furstenburg, 2011). They have the ability to feed more regularly on old grass than other game species and are also less partial to new growth and sprouting grasses (Furstenburg, 2011). Grasses that are preferred throughout their distribution are *Themeda triandra, Panicum* spp, *Heteropogon contortus* and *Digitaria* spp. Venter (2006) found in his study that the grass *Eragrostis lehmanniana* formed the bulk of buffalo's diet during the wet season (31 – 42% of diet), while the grasses *Themeda triandra* and *Heteropogon contortus* formed the bulk of their diet during the dry season (53.5% and 22.2% respectively of total diet). Therefore, it might be concluded that during the night time, when most of the feeding activity occurs, buffalo of DNR may have selected and utilized areas where these species are abundant. The *Eragrostis lehmanniana* grassland unit had a very high abundance of this species of grass and lies adjacent to large areas of riverine thicket. This unit was most likely the preferred feeding area during the wet season. Similarly, the lower reaches of the randjie veld and shrubland units were more important feeding areas during the dry season, where the respective preferred grass species during the dry season were most abundant. In the Hluhluwe-Umfolozi Game Reserve buffalo often grazed the high hilltops where the grass *Themeda triandra,* which formed a large part of the buffalo's diet in that region, was most abundant (Perrin & Brereton-Stiles, 1999). The importance of *Themeda traindra* as food species for buffalo during both the wet and dry season was also evident from the Fish River Nature Reserve, Eastern Cape (Chabalala, 2008). However, in contrast, some studies have found that buffalo from specific regions do not prefer areas dominated by *Themeda triandra* during the dry season (Field *et al.* 1973; Funston *et al*. 1994; Macanda *et al.* 2004). These studies were done in wetter, eastern lying regions and it is well known that the feeding suitability of *Themeda triandra* differs from region to region. *Themeda triandra*, is probably an important grass species for buffalo in DNR, particularly during the dry season, as found by Venter (2006). Buffalo in DNR are not known to climb larger hills and thus the topography of the randjie veld could be considered a major limiting factor influencing habitat selection of this unit where *Themeda traindra* was most abundant.

According to Funston *et al.* (1994), Buffalo have the ability to cause irreparable damage to habitats where their movement is restricted and numbers are not controlled, which often happens in smaller game reserves. This destructive ability was also evident in DNR where buffalo have caused severe overgrazing in many of the drainage lines and the largest parts of the riverine thicket community. Also feeding areas adjacent to drainage lines and riverine thickets showed signs of severe overgrazing. This problem was mainly caused due to buffalo concentrating in a very small area during the day time. Results from the Braun-Blanquet survey (Chapter 3) and point surveys (Chapter 4) indicated that most palatable grass species were absent from these communities.

Buffalo are gregarious and can form mixed groups of up to several thousand. Bulls also form bachelor herds of varying size. Small herds are stable units that form part of larger groups and join and disperse from time to time. Large herds often break up during the resting period only to re-join after the resting period (Skinner & Chimimba, 2005). Sinclair (1977) found that tight family cohesion persisted among cows that often lasted until adult life, which was not evident in bulls. Adult bulls in herds maintain linear hierarchy among themselves through predominantly threatening behaviour where serious fighting seldom occurrs (Skinner & Chimimba, 2005). Skinner & Chimimba (2005) state that the behaviour of bulls vary from region to region. In some regions old and young bulls form independent bachelor groups that play no role in reproduction. In other regions, such as Lake Manyara, bulls switched between mixed groups and bachelor groups every few weeks, while in Hluhluwe- Imfolozi National park the bulls switched every few days between groups (Turner, 2003). In the Serengeti

Sinclair (1977) found that bulls only joined mixed groups during the reproductive season. In DNR bulls were observed to join and disperse from mixed groups on a regular basis although it was unclear how regularly this happened and if this behaviour was only restricted to the mating season.

Buffalo herd sizes are known to differ from one season to another as was found in DNR. As results indicated, buffalo herds were larger during the dry season than the wet season. However, these results are contradicting to the results of other studies where buffalo formed larger groups during the wet season and dispersed into smaller groups during the dry season. Ryan *et al.* (2006) found that herd sizes in the Klaserie National Park were significantly larger during the wet season than the dry season. It may be that some or other limiting factor, such as food availability, or nutritional value of grasses restricts the areas suitable for buffalo and it requires further study.

Since the last introduction of buffalo to DNR in 2002, the population has increased annually by 20%. This rate of growth was slightly higher than the general natural population growth figures that usually vary between 6 – 18 % (mean 16%) (Fusternburg, 2011)

6.4.2 Eland (*Tragelaphus oryx*)

Eland are known to utilize a wide variety of habitats including regions such as the Kalahari-sandveld, most of the semi-arid regions of Namibia, Namaqualand, Karoo succulent scrub-veld, southern subtropical savanna bushveld, Eastern Cape valley bushveld thicket, highveld sour grassland and Cape fynbos. They are equally adapted to living in semi-desert scrubveld and in woodland, bushveld and montane grasslands and they do well on plains grassland and the outskirts of marshlands in coastal areas (Smithers, 1983). The only habitats totally avoided by eland are dense forests and true deserts (Estes, 1997; Bothma *et al*., 2002). Eland are found at annual rainfalls of 250-1 200 mm and at altitudes from sea level in the Eastern Cape, to 1 800 m above sea level in the montane grasslands of Zimbabwe and 4 000 m above sea level in eastern Africa. Eland are not dependent on water, but will drink regularly if it is available (Skinner & Chimimba, 2005). Rowe-Rowe (1983) found that of all the ungulate species occurring in the Giant's Castle Nature Reserve, eland utilized the widest variety of habitats, which included grassland, forest, woodland and scrub. Similarly, Watson & Owen-Smith (2002) found that almost all habitats in the Mountain Zebra National Park (MZNP) were utilized by eland at one stage or another through the year. The results of this study concur with the results of Rowe-Rowe (1982) and Watson & Owen-Smith (2002) where most habitats and the largest land area were utilized (Figure 6.2).

Eland from other areas are known to utilize different habitat units during different seasons. Watson & Owen-Smith (2000) found that eland in the MZNP typically favoured habitats with abundance of grass species during the early wet season, when grasses formed the bulk of their diet. Dekker *et al.* (1996) found that eland on the Messina Experimental farm, Limpopo Province showed seasonal habitat variations. During the warm, dry season, eland were associated with the *Kirkia acuminata- Enneapogon cenchroides* short closed woodlands. During the wet season, eland were associated with the *Abutilon austro-africanum* variant and the *Mariscus rehmanianus-Colophospermum mopane* low closed woodland. In this study only slight variation was found in the seasonal habitat selection of eland, showing a preference for drainage lines during winter months, while utilizing it as expected during the wet season being the only seasonal difference. Kloofs and bush thickets are regarded as important forms of shelter against rain and cold of winter, especially in mountainous areas (Bothma *et al.*, 2002) and could be one of the reasons why eland preferred the drainage lines during the winter months.

Eland require food with high protein content as they have high metabolic rates, a narrow thermal neutral zone and lose large quantities of urea in their urine. As a result, they need alternative resources in different seasons (Smithers, 1983). They are mixed feeders that can switch from browsing to grazing when the grass becomes green and rich in protein and *vice versa* and it enables them to flourish in grassland habitats, such as the montane grasslands of the eastern Free State, Eastern Cape, the eastern highveld of Mpumalanga, the Drakensberg and the coastal belt of the former Transkei (Smithers, 1983). Grass usually forms more than 33% of the dietary intake of eland at any time of the year. Grass can form up to 92% of their diet. Eland will graze on short and medium height grass (6-35 cm) of both sweet and sour species. It is only partly selective of specific plant parts (Smithers, 1983). In the semi-arid MZNP, however, Watson & Owen-smith (2000) found that grasses only formed 6% of the annual diet of eland. This is far less than the normal proportion of grasses utilized by eland in other parts of their distribution. They also found that grass consumption peaked at the beginning of the wet season when grasses were young with green foliage. Grass consumption rapidly declined as these grasses matured. Of the grasses utilized, *Cymbopogon pospischilli* (55.5%) formed the bulk of the grass eaten, followed by *Digitaria eriantha* (24.4%) and *Themeda triandra* (13.8%). They furthermore found that forbs only formed 3% of the diet, which is also far less than the normal proportion of forbs to their diet. Woody browse formed 91% of the diet for the largest part of the year. In contrast to the findings of Watson & Owen-smith (2000), Buys (1990) found that browse only formed 25% of the diet of the eland in the S.A. Lombard Nature Reserve during the summer and 65% of their diet during the winter. Interestingly, Buys (1990) also found that *Cymbopogon* *pospischilli, Digitaria eriantha* and *Themeda triandra* were the preferred grass species utilized by eland in the S.A. Lombard Nature Reserve. Indications were that eland in DNR predominately browsed throughout the year, feeding on shrubs and dwarf shrubs. Watson & Owen-Smith (2000) identified 70 different browse species utilized by eland in the MZNP. Eland can access fodder at a greater height by using their horns to break branches from trees and shrubs. This activity results in the destruction of vegetation and can be detrimental, especially during dry seasons and with high population densities of eland (Smithers, 1983, Nyengera & Sibata, 2009). Despite the high eland densities in DNR, damage to larger shrubs and trees was minimal.

Watson & Owen-Smith (2000) found that the habitat selection by eland on the MZNP was unrelated to the availability of palatable grass species in the habitat, but was rather determined by the quality of the woody browse on offer. The habitats of MZNP are closely related to those found in DNR and therefore it can be expected that eland in DNR would have similar food preferences. In MZNP dwarf shrubs formed a large part of the browse component. Many of the dwarf shrub species, such as *Felicia muricata*, *Selago geniculata* and *Helichrysum dregeanum*, that were preferred in MZNP (Watson & Owen-smith, 2000) are abundant in the grasslands and open shrubland units and most probably explains the selection of these units by eland. The reason for the randjie veld being utilized less, might be attributed to this unit having a low diversity of shrubs and dwarf shrubs which are also far less abundant than those other units. The relative abundance of evergreen tree and shrub species within the drainage line communities were most likely the main reason for its preference by eland during the dry season.

Eland tend to congregate in large herds of 40 - 300 animals on grass plains, but scatter in smaller groups of 3 - 20 animals in bushveld areas where browse form a large proportion of their diet (Smithers, 1983). Results of this study indicated that the group sizes were similar to those in bushveld areas. Rowe-Rowe (1994) described the unique social organization of eland as follows: during the summer months they form large mixed herds of up to 200, comprising of non-breeding and breeding males and females. Breeding females are served only by dominant males. In autumn the large herds disperse in numerous small groups of 4 – 10 animals of any age or sex. They are widely dispersed in winter. Just after the calves are born in spring, small groups begin joining together again to form large herds that gradually increase in size (Rowe-Rowe 1994). Underwood (1981) recorded a similar social organization in the Loskop Dam Nature Reserve and suggested that the total population of approximately 80 animals formed one diffuse social unit. It is not unusual for young to outnumber adults and there may even be herds composed entirely of calves and juveniles. Conversely, unisexual or bisexual small groups, consisting of adults only, are also common.

This variability reveals the open, fluid nature of eland society (Underwood, 1981; Hillman, 1988; Estes 1997). Results of the social organization of eland in DNR concur with the results of these studies. Eland typically dispersed during the dry season, forming smaller groups, while rejoining into larger groups during the wet season. As was found by Underwood (1981), juveniles and sub-adults often outnumbered adults in groups and on occasions formed groups of their own.

The results show that eland are thriving in DNR and are probably the best adapted species to the environment since they utilize the largest proportion of land available to them. Furthermore, the population has increased tremendously over the years, often reaching a 50% annual growth. Increase during 2009 more than a third of all eland were removed (118 removed, 207 remained), but only three years later the population had already grown to more than 30% its original size before removals (450+). The large number of juveniles and sub-adults recorded was also indicative of a high reproduction rate. The general annual growth rate is significantly higher than the natural growth potential which is normally between 11- 38 % (mean 20%) (Furstenburg, 2007).

6.4.3 Greater Kudu (*Tragelaphus strepsiceros*)

Greater kudu are regarded as a savanna woodland species and are widespread in the savannas of east and southern Africa, ranging from Sudan and Ethiopia in the north to the western and Eastern Cape in the south. Their wide distribution indicates high adaptability, but their use of specific habitats is reliant on the density of woody plants (Smithers, 1983). Kudu do not occur in desert, forest or open grasslands. In drier parts of their distribution such as the Nama Karoo, they are usually restricted to areas with dense woodland cover that provides sufficient protection and food (Grunow, 1980; Skinner & Chimimda, 2005). The preference for denser thicket by kudu in drier regions was also clearly evident from the results. Kudu densities and observations of kudu were highly concentrated within both the riverine thicket and drainage line communities which further emphasises the importance of dense scrub for the species within the reserve. Skinner & Chimimda (2005) mention that greater kudu show preference for broken, rocky terrain where woodland cover and water is nearby. The open shrubland habitat unit is similar in this regard and probably explains the utilization of this terrain in proportion to its availability. Kudu are highly sensitive to colds and sudden temperature changes. They are known to move away from low lying areas up the catena to warmer hill slopes on cold winter nights. They tend to move between aspects of slopes to the opposite sides of prevailing winds (Smithers, 1983). During hot sunny days kudu will keep close to the shade of trees and on cold winter days they will stick to the thicket. High mortalities are common when sudden wet, cold spells occur, especially during periods of drought. It is essential that the habitat encompasses a high diversity of fodder plants, especially trees and shrubs. Kudu do not thrive on homogenous vegetation of low diversity. Severe mortalities occurred in the north-western bushveld areas of the former Transvaal during the late 1970's and early 1980's due to high densities of kudu kept on recently enclosed farms with low density of woody plants. A gradual build-up of tannin in the fodder plants as well as limited access to alternative fodder species led to the mortalities (Bothma *et al.*, 2002).

The importance of woody cover is well known and has been mentioned by numerous authors from other studies. Smithers (1983) regarded tree density as the most critical parameter governing kudu's choice in habitat selection and as the main reason for them not selecting open areas. This is because trees provide the main fodder resource, refuge against predators and means of protection against colds. Skinner & Chimimba (2005) also state that kudu avoid open areas. In this study, all the habitat types that were avoided by kudu were more open habitat types of the grasslands and randjie veld community where tree densities were far lower than those of the preferred habitats (see Chapter 5). In other studies from wetter regions the importance of dense thicket is still strongly reflected. Van Eeden (2006) found that kudu from the Tempe National Park had a preference for closed woodlands found on clay and also for open woodlands. Van Eeden (2006) concluded that closed woodland provided sufficient cover for the kudu, while the open woodland had an abundance of preferred food species. Dörgeloh (2001) found that in the Nylsvlei Nature Reserve, both bachelor males and breeding herds of kudu utilized throughout the year *Aristida bipartita-Setaria sphacelata* savanna variation, which consisted mostly of large *Acacia karroo* trees. In the central Kruger National Park the preferred habitat of kudu was found to be drainage line and riverine communities (Du Toit, 1995). Similarly greater kudu from the semi-arid south-western Zimbabwe preferred *Acacia* spp. riverine thicket throughout the year Simpson (1968) and in the central Free State province kudu preferred river thickets and drainage lines throughout the different seasons (Janecke, 2010).

As the results indicate, no seasonal variation was found in the habitat selection of kudu in DNR. However, other studies from other regions have found seasonal changes in habitat utilization and particularly differences between sexes. According to Simpson (1968) adult males showed very little seasonal changes, while female herds increasingly selected the riverine thickets during the winter months as these areas provided better browse and cover. Identical results were found by Du Toit (1995) in the central Kruger National Park where bulls maintain a strong preference for riverine communities throughout the year, while cows increasingly used the riverine communities during the dry season. Similarly, Dörgeloh (2001) found that in the Nylsvlei Nature Reserve male kudu selected throughout the year the *Cymbopogon plurinodis - Combretum apiculatum* variation, which had a high tree density. On the other hand, breeding herds also utilized the *Eragrostis pallens - Burkea africana* savannas to a large extent. Dörgeloh (2001) concluded that habitat utilization by breeding herds is influenced by forage availability within a feeding height of less than 2m and with a high structural diversity.

Kudu are predominantly non-selective browsers, feeding on leaves, shoots, pods or fruits of a wide range of shrubs, trees, dicot forbs and succulents. Within their wide distribution range kudu are exposed to a variety of habitats. It follows that the diet of kudu from different regions differs vastly in terms of plant species composition. Within most habitats there are virtually no plant species that are completely avoided, and in the subregion they are the ungulate species that utilize the widest range of browse species (Smithers, 1983). According to Smithers (1983) kudu need a selection of vegetation components which encompasses (Smithers, 1983):

I. Palatable deciduous woody plants as dietary staple during the wet season,
II. Soft-stemmed dicot forbs and new woody foliage year round and during the lactating phase of cows,
III. Relatively palatable evergreen or late deciduous woody plants during the dry season,
IV. Fruits and pods during the dry season,
V. Woody plants which produce new leaves in advance of the first rains to bridge the critical transitional phase at the end of the dry season,
VI. Relatively unpalatable evergreen woods which are used as a last resort when all other food reserves have been depleted.

In the Eastern Cape Valley bushveld the diet of kudu consists of 5 to 12% grass, 15 to 18% herbaceous dicot forbs, and 70 to 80% browse. The forb and browse ratio differs vastly with rainfall and seasonal variations. Studies from the northern savanna mixed bushveld indicated a diet composition of 18% grass, 21% forbs and 61% browse (Smithers, 1983). In comparison, Novellie (1983) found that kudu in the Kruger National Park regularly preferred forbs to woody plant species, and that forbs composed more than 65% of their diet for the biggest part of the year. However, the utilization of forbs, dropped to less than 20% of their diet during the early growth season. During this time kudu preferred woody species which bloom early, like *Acacia nigrescens* and *Combretum hereroense*. Owen-Smith (1979) found the following seasonal fluctuations in the woody browse diet of kudu in the Kruger National Park: *Acacia nigrescens, Combretum hereoense, Lonchcarpus capassa* and *Acacia gerrardii* formed a large part of the recorded diet during the early leaf flush period commencing in

September, while the shrubs *Securime gavirosa* and *Dichrostachys cinerea*, and marula *(Sclerocarya birrea subsp. caffra)* fruit were most important during the mid-wet season, *Combretum apiculatum* appeared only in the diet during the early dry months. These results indicate the importance of a selection of vegetation types, as mentioned by Smithers (1983).

The results of this study therefore indicate that habitat selection was mainly influenced by vegetation structure and availability of woody plant species. The drainage line units had a variety of evergreen woody species that were important for feeding during the winter months, while the open shrubland unit also provided sufficient food for both seasons. Although the riverine thicket unit had a far less abundance of evergreens, the unit was still selected for during the dry season.

Greater kudu are gregarious, but generally only form small social groups that consist predominantly of females between six to eight individuals and seldom form groups larger than 14 individuals. Group sizes of kudu in Namibia tend to be slightly smaller than those from other regions (Annighöfer & Schütz, 2011). The group sizes of this study were found to be very similar to those found in other studies. Bulls are not territorial and are largely solitary or form small bachelor groups outside the rut. During the rut period an adult male often accompanies a female group and their offspring (Skinner & Chimanda, 2005; Annighöfer & Schütz, 2011). Owen-Smith (1984) concluded that the relationships among bulls are governed by an age-based dominance hierarchy. Bulls do fight occasionally to determine relative dominance, or reassign dominance among prime males (Owen-Smith, 1993)

Seasonal differences in group sizes, as was found with kudu in DNR, have also been recorded in other studies. In the valley bushveld in the Eastern Cape Province seasonal changes in mean group sizes of kudu were related to social behaviour rather than external factors such as rainfall (Perrin, 1999). Similarly to this study, Perrin (1999) found that groups were significantly smaller during the summer months, one major behavioural reason for the smaller groups being cows isolating themselves from groups during the calving period and remaining solitary for a period after the calves were born (December – February). Annighöfer & Schütz (2011) observed the same patterns in kudu in Namibia, also found that bulls joining and leaving groups within and outside the rut respectively, also greatly influenced mean seasonal group sizes. The results of Annighöfer & Schütz (2011) concur with the findings of Simpson (1968) who observed the largest kudu group sizes in Zimbabwe during the peak of the rut. The larger number of solitary females observed during the wet season in contrast to the dry season and the larger of adult bulls seen in mixed groups during the dry season in this study, is an indication of similar reasons influencing group size as determined by Perrin (1999) and Annighöfer & Schütz (2011).

Based on figures of both surveys and latest estimates, the kudu population steadily increased at an annual growth rate of 15%. This figure is lower than the natural population growth potential of the species which is usually between 20% - 30% and is similar to the growth rate in The Kruger National Park (14.8%) (Bothma *et al*., 2002). In the wild, the mortality among adults is between 10 – 15% annually. Mortalities are mainly caused by food shortages during the dry season and sudden cold spells (Furstenburg, 2010b).

6.4.4 Gemsbok (*Oryx gazella*)

Gemsbok is associated with open arid country. In Botswana and Namibia they are found in open grasslands, open bush savanna and in open woodland. In the Etosha National Park, gemsbok select both open and denser vegetation types, with particularly females often associated with the denser habitat types (Möller *et al.* 1996). Janecke (2010) found that denser habitats such as drainage lines and thickets were used for cover when the animals were frightened and that gemsbok are known to become bush dwellers where they are often disturbed (Furstenburg, 2010a). Water is not an essential habitat requirement, but desirable when grazing has low moisture content (Bothma *et al.*, 2002). Why gemsbok mainly occurred in the western sector of the reserve was somewhat unclear (Figure 6.4). It might be that the Zeekoei River itself and its associated riverine thicket community formed a barrier that gemsbok were reluctant to cross. Preferred habitat types are typically arid shrub communities that include karoo dwarf shrubland (Furstenburg, 2010). This might explain the utilization of both the grasslands communities and randjie veld communities. Both the grassland units had abundant dwarf shrubs, while the randjie veld is essentially a shrubland unit with a well represented grassy layer.

Gemsbok is classified as a roughage feeder which enables it to digest a high fibre diet. They are essentially grazers. Dieckmann (1980) noted that gemsbok flourished on browse and ephemeral plants where introduced to areas with limiting grass cover. Gemsbok was never recorded browsing during the study period, which indicated sufficient grass availability throughout the year. In arid regions gemsbok dig for succulent subterranean roots, rhizomes and bulbs if water is unavailable (Skinner & Chimimda, 2005). In the karoo region gemsbok are known to cause severe damage to slow growing karoo shrubs by digging out and eating the roots of these plants (Furstenburg, 2010). These grazing effects were not observed in DNR, but may influence browsing pressures on certain dwarf shrubs.

Gemsbok are gregarious and form small groups, but solitary females and adult bulls are not uncommon. In Southern Namibia herds can be as large as 300 individuals, but usually consist of smaller herds of up to 30 individuals and solitary males are also found (Skinner &

Chiminda, 2005). The social organization comprises of mixed herds, nursery herds and solitary males. Males are territorial although relatively tolerant towards other males. The results of this survey, that gemsbok formed smaller groups in the dry season than the wet season, concur with results of other surveys by other authors (Dieckmann, 1980, Skinner & Chimimda 2005, Janecke, 2010). In these studies the main reason for gemsbok dissolving into smaller groups during the dry seasons was related to greater food scarcity experienced during this period.

Based on survey numbers and current estimates the population growth of gemsbok has remained slow ever since their introduction. The annual growth rate being consistently around 10%. This figure is similar to population growth figures of the Eastern Cape (8 – 12%), which is considered a marginal habitat (Furstenburg, 2010a). In areas of Botswana where veld conditions are good, the annual growth rate can be as high as 33%. In general, the annual growth rate varies between 15 to 25% (Furstenburg, 2010a). The growth figures of DNR being comparable to those of the Eastern Cape, combined with no nursery herds and relatively few juveniles sightings, were all further indications that the habitats of DNR are marginal for gemsbok. It was unlikely that predation by caracal and black-backed jackal played a major role in limiting population growth, since the protective nature of gemsbok makes it difficult to be preyed upon.

6.4.5 Red hartebeest (*Alcelaphus buselaphus*)

Red hartebeest select a variety of open habitat types such as various types of grasslands which include floodplain grassland and vleis. Areas such as semi-desert bush savanna and to a lesser extent open woodland are also selected, while denser and closed types of woodland are avoided (Smithers, 1983, Skinner & Chiminda, 2005, Furtenburg, 2008a). In Botswana, denser woodlands form barriers through which red hartebeest are reluctant to move through. In this study red hartebeest also avoided the dense vegetation of the riverine thicket and drainage line management units. Red hartebeest are dependent on surface water throughout their distribution. Bothma *et al*. (2002) states that red hartebeest are the first species to lose physical condition when veld deteriorates and they are susceptible to prolonged cold conditions.

The habitat preference of red hartebeest in this study are very similar to those of a small private game reserve situated in the central Free State Province (Janecke, 2010). In both studies the animals selected grasslands and open thickets. Although the latter study also determined that red hartebeest did not have seasonal differences in habitat unitization, slight seasonal variations in habitat utilization were observed in red hartebeest of DNR. Like buffalo, red hartebeest most probably utilized both the *Eragrsotis lehmannian*a and *Eragrostis chloromelas* grasslands units less during the dry season due to the lower nutritional value of many of the dominant grass species in these units. Furthermore, grasses became within these management units far less abundant during the dry season as many of the species are short lived annual species. In another study, Noveliie (1990) observed that red hartebeest in the Mountain Zebra National Park selected the tall grasslands on plateaus consisting of sandstone. These regions were most notably dominated by the tall growing grass *Themeda triandra*. The plateaus of the randjie veld management unit were very similar to the sandstone plateaus of the Mountain Zebra National Park in vegetation structure and composition, and thus not surprisingly red hartebeest of DNR also utilized these plateaus regularly, avoiding however, steep slopes.

Red hartebeest are classified as tall grass grazers (Skinner & Chimimda, 2005; Novelie, 1990; Novelie & Kraaij, 2010). Some studies have found that browse formed a large part of the diet of red hartebeest. Van Zyl (1965) and Kok & Opperman (1975), recorded respectively 44% and 40% browse in their diet, while Killian (1993) reported that browse was of significance during the dry critical periods from September to October. It is unclear whether red hartebeest in DNR do browse, but the availability of a variety of shrubs and dwarf shrubs combined with the preferred vegetation structure of an open shrubland community, may explain the preference for this unit during both seasons. Kok & Opperman (1975) listed *Themeda triandra* as an important grass species that is eaten throughout the year in the Free State province and it can also be regarded as an important food species of red hartebeest in DNR during both seasons. According to Novelie & Kraaij (2010) red hartebeest were one of the ungulate species in the Mountain Zebra National Park that utilized young veld up to four years after veld fires.

Red hartebeest is classified as a gregarious species that form small herds of up to 20 individuals per group (Skinner & Chimimba, 2005). The average herd size and structure of red hartebeest in DNR were found to be consistent with the typical herd size normally associated with red hartebeest. The social organization of natural occurring populations has not yet been studied in detail (Skinner & Chimimba, 2005). According to Kok (1975) males were territorial and remained with a harem of females, actively protecting their harem from other bulls. Kok (1975) stated that harems consisted of females and their young, a dominant bull and young bulls, of all ages that were not part of a harem formed bachelor groups. Solitary males were seldom observed by Kok (1975). Bulls proved to be very territorial in DNR and actively marked their territories although no fighting was observed. A few solitary bulls were frequently observed during the study. Interestingly, these bulls displayed territorial behaviour by marking territories through hoof scratching and visible dung heaps. They remained in their territories throughout the study period and no harem groups were recorded within these areas. Bachelor groups were not as regularly observed as harems or solitary males. Both solitary males and bachelor groups were mostly observed in areas between the areas where high densities of harem groups occurred, such as the central and western section of the reserve (Figure 6.5). Many of these areas selected by the bachelor groups and solitary males were regarded as less desired regions than those regions where high densities of red hartebeest occurred, since grasses were not as abundant in these regions as in other regions. These findings further support the results of Kok (1975) that harem herds occupied the best grazing region, while bachelor groups had to make do with less favourable areas.

Red hartebeest seem well adapted to DNR, since the largest habitat units utilized were utilized by them. Survey counts indicate that population growth from 2004 to 2009 was initially slow increasing only at an approximate rate of 13% annually. In the short period following 2009, the annual growth rate sharply increased to an approximate 27% annual growth. It may well be that growth was initially slow, as the population was still stabilizing. DNR also received below average rainfall from 2007 to 2009 (see Chapter 2) that may have put further strain on population growth.

6.4.6 Warthog (*Phacochoerus africanus*)

Warthogs are found in a wide range of open habitat types that include open plains and bushland, shorter grassland, floodplains, vleis and open areas around waterholes and pans. Dense habitat types such as thick bush, dense riverine and montane forest, as well as forests are avoided (Skinner & Chimanda, 2005). Skinner & Chimimba (2005) state that water is not an essential habitat requirement, even though warthogs are often found where water is available. The availability of surface water seemed the likeliest reason why warthogs preferred the drainage line unit, especially since the areas that were preferred within these units had abundant surface water available and formed marshy conditions (Figure 6.7). The denser areas of the drainage line and riverine thickets were avoided.

Another reason for warthogs selecting areas where water occurs, is the availability of short preferred grasses. Warthog prefer grasses growing in damp places as these grasses remain greener and fresher while the rhizomes also retain more moisture (Skinner & Chimimba, 2005). In DNR the mat forming grasses *Cynodon dactylon* and *Cynodon hirsitutus* are the main species that grow in areas where standing water cause marshy conditions. These grasses form lawn like conditions which are the ideal grazing height for warthogs (Skinner &

Chimimba, 2005). Mason (1982) also listed *Cynodon dactylon* as one of the important grass species that comprises the diet of warthogs in Kwazulu-Natal. Treydte *et al.* (2006) also noted that the grass *Cynodon dactylon* was a very important food species for warthogs on former cattle grounds in Tanzania.

Figure 6.8 Illustration of typical open areas within drainage line communities selected by warthog.

In areas where warthogs dig for rhizomes the soil is churned up to a depth of 5 - 10cm (Skinner & Chimimba, 2005). This is done by kneeling on the front legs while digging with the hard snout. In DRN this rooting feeding behaviour only occurred in areas with deep reddish soil, as also discussed in Chapter 3. These areas of red soil are therefore most probably associated with the availability of rhizomes and roots of preferred food species, although it is unclear which species these may be. Warthogs are classified as high-impact veld degraders due to this destructive feeding behaviour (Furstenburg, 2008a).

The warthog population in DNR exploded ever since the first warthogs established themselves around 2003. While the number of warthog individuals was only 9 in 2004, a total of 130 individuals were recorded during the 2009 survey, implying a staggering annual population growth of 170%. It was estimated that the population increased from there on at a slightly less rapid rate, being over 200 during the study period, despite the removal of 40% of the population during 2009. Due to warthogs having multiple litters they have the highest natural population growth potential of all African game species. Population growth can fluctuate from 6 to 120% per year, with an average of 75% (Furstenburg, 2008b). However, warthog populations are extremely sensitive to feeding stress, especially during droughts, when large numbers can perish. Sporadic population explosions and sudden collapses are known to have occurred (Furstenburg, 2008b).

6.4.6 Mountain reedbuck (*Redunca fulvorufula*)

Throughout their distribution, mountain reedbuck inhabit the dry, medium to tall grass-covered, undulating stony terrain associated with hills and mountains, which also provide cover in the form of bushes or scattered trees. They move to flats adjacent to their stony habitat to feed or to drink, as the availability of water is an essential habitat requirement (Skinner & Chimimba, 2005). These rocky hillsides and steep mountain grasslands are often considered a marginal habitat for other ungulate species (Rowe-Rowe, 1983, 1994). The flat ecotones surrounding mountain slopes are often grazed, but mountain reedbuck never wanders further than 1 km from the safety of slopes (Furstenburg, 2006). A study done by Skinner (1980) in the Mountain Zebra National Park (MZNP) concluded that mountain reedbuck are particularly well adapted to the terrain they inhabit. A study of Rolfontein nature reserve indicated that mountain reedbuck are susceptible to nutritional stresses following veld fires (Anderson & Koen, 1993). In the Giants Castle Nature Reserve mountain reedbuck preferred valley slopes above any other land types and they utilized the cooler, wetter, southern and eastern facing slopes far more than any other antelope species in the reserve. Similar results were delivered in this study regarding the habitat preference of mountain reedbuck. Mountain reedbucks were regularly observed on the steeper slopes of the randjie veld and they were also the only species that actively utilized the steep slopes of the randjie veld community. Mountain reedbuck do not migrate easily in search of better grazing (Furstenburg, 2006), which was also evident in this study.

Figure 6.9 The hills and mountain slopes selected by mountain reedbuck.

Mountain reedbuck are selective grazers with the ability to digest coarse grass of low quality in the dry season (Skinner & Chimimba, 2005). A study done by Rowe-Rowe (1994) concluded that the distribution of mountain reedbuck was closely related to the abundance of the grasses *Themeda triandra* and *Sporobolus fimbriatus*, which are regarded as important dietary species. Irby (1976) also observed that *Themeda triandra* and *Hyparrhennia hirta* ranked highly among the 11 grass species selected by mountain reedbuck in the Loskop Dam Nature Reserve. The grass *Themeda triandra* was particularly dominant in the randjie veld community, as discussed in Chapters 3 and 4, and is possibly an important factor influencing the preference for this community.

The group sizes of mountain reedbuck in DNR are similar to the standard group sizes associated with mountain reedbuck, which is between 3 - 8 individuals per group. The social organisation of reedbuck consists of territorial males, non-territorial males, herds of females with young and bachelor groups. The social organisation of mountain reedbuck of DNR is consistent with the normal expected social organisation, although throughout the study period no bachelor groups were observed. Territorial males occupy their territories all year, while females move from the territory of one male to that of another (Irby, 1976; Dunbar & Roberts, 1992). In the Sterkfontein Dam Nature Reserve the home ranges of territorial mountain reedbuck males varied between 7.6 to 20.6 ha while the home range of territorial males in Loskop Dam Nature Reserve averaged 28 ha. The territories used by males in Sterkfontein Dam Nature Reserve all included areas with steep slopes.

Studies done by Dunbar & Roberts (1992) observed strong correlations with steeper slopes in the areas selected by mountain reedbuck females. Dunbar & Roberts (1992) concluded that female mountain reedbuck selected these areas mainly for safety against predators, although compromising access to food recourses in the process. The results of this study indicate that most mountain reedbuck females of DNR, particularly larger female groups, also prefer steeper terrain, the bulk of observations being made on or near the shoulder of hills where steeper cliffs occur.

DNR still boasts a healthy population of mountain reedbuck that is estimated to be around 300. However, the general consensus of park management and also neighbouring farming communities were that the population is rapidly declining. Sightings of large herds of up to 30 individuals was once regarded as a common phenomenon in the region, but they are now non-existent. Bothma *et al*., (2002) states that high mortalities among mountain reedbuck lambs are often caused by predators such as caracal and black-backed jackal. DNR and surrounding areas are still home to a large population of both these predators and they may have a large impact on the mountain reedbuck population. Further evidence of the possible effects of predators, is the very low number of sightings of both lambs and sub-adults. Only two lambs where recorded during the entire study period. Furthermore, numerous carcasses of adults that were predated on by caracal were also encountered during the same period. However, mountain reedbuck lambs remain hidden for the first few months of their lives (Bothma *et al*., 2002) which probably contributed to the rarity of these sightings. In the MZNR, the growth rate of mountain reedbuck was calculated around 29% over a six year period and this reserve also has a high density of caracal and black-backed jackal.

6.5 Conclusion

The habitat selections of all species studied were predominantly as expected and concured with findings of numerous studies from other regions. For most species, the essential habitat requirements such as food, water and shelter were adequately met. Based on the results of their social organization, most species displayed normal social habits typically associated with each species. This indicated that species behaviour was not influenced by external factors. The cases where species habitat selection and group organizations differed from the wet to the dry season, could almost entirely be attributed to scarcer food resources and higher nutritional stresses experienced during the dry season. Indications were that the habitat types of species that did not show seasonal variations in habitat selection provided sufficient food and shelter. In many of these instances feeding behaviour and food selection rather than habitat selection changed from the dry to the wet season. During the dry season more time was spent on grazing and browsing and larger areas were utilized.

Species such as buffalo, eland, red hartebeest and warthog seemed to be doing exceptionally well in DNR. However, these species were also the ones that caused most altercation to the environment. As discussed in Chapter 3 and 4, buffalo have caused overgrazing in many of the drainage lines and riverine thickets, as well as adjacent management units. Eland caused more damage to the vegetation through trampling than direct feeding since eland in DNR were predominantly browsers. However, many desired dwarf shrubs were over utilized by eland over large areas, especially in habitats such as the *Eragrostis lehmanniana* grasslands where less desired species replaced desired species and became dominant. Warthog caused damage to the environment through their feeding behaviour that involved digging up roots of desired food species.

Gemsbok and mountain reedbuck appeared to be the two species least suited to the environment. The main reason for the slow population growth of gemsbok and the population decline of mountain reedbuck remains unclear. All habitat requirements for both species, particularly mountain reedbuck, were met, while all indications were that the social organization functioned normally. With regards to mountain reedbuck, the effect of predators may have been the major but not sole reason for the decline in population. This is backed up by data from other regions where mountain reedbuck observed in similar habitats, that support the same predators at similar densities, still managed to maintain a high growth rate. Competition from other species or habitat changes by species, was also excluded as possible factors since mountain reedbuck utilized habitats avoided by other species. Gemsbok also typically utilised specific habitats that were less favoured by other species, which partly eliminated competition, while predators were not regarded as a limiting factor that influenced growth rates. It may well be that diseases and parasites were affecting both species, but it requires more study. Gemsbok evolved in an arid environment in the absence of tropical diseases and parasites. Consequently, gemsbok never developed inter-animal contact and grooming behaviour that helps eliminate external parasites (Furstenburg, 2008a). Therefore, they cannot tolerate high levels of parasite and tick infections. They are susceptible to both hartwater and lame-sickness and especially to pneumonia during wet cold spells.

Chapter 7: Development of a Habitat suitability index for the introduction of game species

7.1 Introduction

Habitat suitability models (HSM), often also known as Resource Selection Functions (RSF), capable of predicting the spatial distribution of species, are becoming increasingly important tools used by conservationist for management of game species (Guisan & Zimmermann, 2000; Manly *et al*. 2002; Guisan & Thuiller 2005). Habitat suitability models are especially useful in understanding species niche requirements and predicting species potential distributions, and are gaining interest as tools to address conservation issues, such as managing species distribution, assessing ecological impacts of various factors, managing endangered species (Scott *et al.*, 2002; Guisan & Thuiller, 2005)

They are typically computerized models that combine Geographic Information Systems (GIS) with multivariate models to predict the possible presence of game species (Marzluff *et al*., 2004; Buk & Knight, 2102). In essence, the models statistically relate field observations of species to a set of environmental variables regarded as important factors that influence habitat selection. These include factors such as vegetation cover, topography and land-type. They produce spatial predictions in the form of suitability maps, indicating the suitability of specific locations for a target species, community or biodiversity. Different types of modeling techniques are used to fit different types of biological information recorded at each sample site. These models, however, depend on presence/absence or presence only data where variables are measured (Hirzel *et al*., 2006; Buk & Knight, 2012). Therefore, the development of these models depend on studying species in their natural environment to relate the habitat or patch selection of game species to measurable habitat variables.

However, the development of a broad habitat suitability model for a large number of different species is nearly impossible as it requires in depth study of each individual species to formulate the required models. Furthermore, these models may also only be applicable to the region of study as habitat selection of game species may vary from region to region. Considering, therefore, the restrictions of these models, the objective of this study was to develop an alternative user friendly, flexible, structured decision support system to assist in the decision making process by determining the suitability of a specific region for game species. Current HSM requires extensive knowledge of GIS programming and also vast datasets to compute accurate models. Most of these models also include a few variables for measurement that almost always relate to environmental factors only. Different to most HSM that only include specific habitat variables for measurement, the suitability index proposed here is an attempt to develop a model that differs in approach by incorporates a range of considerations that not only include habitat variables, but also includes other variables such as economical and conservation related considerations. This index can therefore form the basis for future development of more advanced models incorporating the same concepts included in this index.

The variables included in this model are scored by evaluating sets of criteria. These criteria incorporate both scientific surveys and information from the literature for evaluation. Another major difference and purpose of the proposed model, is to develop a tool of measuring habitat suitability for species that are not already present. Criteria that are included in the scoring, which are regarded as important are presented in Table 7.1

Table 7.1 Overview of the criteria, data source and scoring value of the suitability index model.

Criterion	Criteria score (potential maximum)	Data source	Description
Conservation considerations	**45**		
Conservation status	15	Literature	Conservation status of species as classified by IUCN
Historical distribution	15	Literature	Refers to historical distribution of game species, taking into consideration also present distribution
Impact on environment	15	Literature	Considers the potential impact game species may have on their environment
Habitat considerations	**140**		
Water availability	20	GIS or related geographical spatial program	Considers the availability of surface water within travel distance of a species
Food	40	Plant species composition (e.g Point Surveys and BECVOL surveys)	Considers the quality and quantity of food available
Vegetation structure	40	Literature, field surveys	Considers the vegetation structure of the herbaceous and woody layer

Habitat considerations continued			
Topography and terrain	20	Literature, field surveys	Considers the vegetation types suitability as well as geomorphological aspects such as slope, land-type, soil type, rockiness and so forth
Climate	20	Literature and field surveys	Considers the rainfall
Economical consideration	**55**		
Species live sales value	25	literature	Considers value of species on live auction
Demand trend	15	literature	Considers relative trend by evaluating price increase, decrease
Production potential	15	literature	Refers to the natural reproduction potential of a species

7.2 Description and scoring of suitability criteria

7.2.1 Conservation considerations

Although various forms of protected areas exist that each has its own objectives and management policies, the main purpose of all conservancies still centres around the conservation of the biodiversity of the region and the environment in its pristine state (Rodrigues *et al.* 2004; Ehrlich & Pringle 2008). It is therefore important, from a conservation management point of view to evaluate the importance of some conservation aspects related to game species to ensure the successful management of these regions.

Three important conservation aspects are included in the suitability index, which are: the conservation status of game species; the historical distribution of game species and the potential impact of these species on the environment.

7.2.1.1 Conservation status of game species

The scoring of the conservation status of South African ungulates is based on the conservation status of species as listed in the Red data book of the mammals of South Africa (RDB). The RDB incorporates the conservation priority of mammals at a regional level by using the categories and guidelines for risk assessment as stipulated by the IUCN List (IUCN, 2001). Based on the risk of species becoming extinct, species are listed under one of the following eight threat categories: Extinct (X), Extinct in wild (EW), Critically Endangered

(CN), Endangered (EN), Vulnerable (VN), Near Threatened (NT), Least Concern (LC) and Data Deficient (DD).

For the scoring, only five of the RDB categories are currently of relevance to game species, which are: the Critically Endangered (CE), Endangered (EN), Vulnerable (VU), Near Threatened (NT) and Least Concern (LC) categories. All South African ungulates are listed under one of these categories according the Red data book of the mammals of South Africa (2004). Scoring is based on a scaling model with the highest points allocated to the categories for highest extinction risk, with a subsequent decrease in points as the risk of extinction of the categories decreases. Scoring is particularly high for species listed under one of the endangered categories (CE, EN, VU), while scoring is significantly lower for categories that are not considered as endangered (NT, LC) (RDB, 2004). The population trends of the species, as stated by the RDB (2004) (populations can decrease, increase or be stable) are also incorporated into the scoring system they indicate the potential increase or decrease in the risk of extinction in the future. The conservation status and population trend of species are presented in Appendix Di. The scores of the RDB conservation status categories are presented in Table 7.2.

Table 7.2 The suitability scores for each of the conservation categories for use in the suitability index.

Conservation Category	Suitability score
Critically Endangered (CR), population decreasing	**15**
Critically Endangered (CR), population increasing, stable	**14**
Endangered (EN), population decreasing	**12**
Endangered (EN). population increasing, stable	**10**
Vulnerable (VN), population decreasing	**9**
Vulnerable (VN), population increasing, stable	**8**
Near threatened (NT), population decreasing	**4**
Near threatened (NT), population increasing, stable	**3**
Least Concern (LC), population decreasing	**2**
Least Concern (LC), population increasing, stable	**1**

7.2.1.2 Historical distribution of game species

The PROTECTED AREAS ACT (2003) stipulates that the main objectives of conservation areas are to preserve the ecological integrity of the area and to protect areas representative of all ecosystems, habitats and species. To ensure that the integrity of the ecosystems is not compromised, conservancies ideally attempt to maintain and preserve the ecosystem in its most natural state. Both plant and animal species have evolved and adapted to survive in unique ecosystems. The introduction of exotic or extralimital species to a new environment, or the removal of species from the existing environment, often leads to disruptions in the natural processes of the ecosystems (Bothma *et al*., 2002). Therefore, the status of species as native or extralimital is regarded as important for conservation.

The scoring is based on both the historical and current distribution range of game species. A further distinction is also made between permanent and temporary resident species. Temporary residents are species that only occurred/occur in specific regions for the duration of favourable environmental conditions (migratory species), while permanent residents remain permanently in the region as the environmental conditions remain favourable. Differentiation between temporary and permanent resident species is important in scoring, since permanently resident species are usually better adapted to the environment than species that are only resident during favourable periods.

It should also be noted that the true historical extent and boundaries of the distribution range of a species is often unclear. In many instances the historical boundary of animal species distribution is regarded as the transition zone from suitable or marginal habitat to unsuitable habitat. Areas regarded as the boundary of the species are given intermediate scores, because these regions have often less suitable vegetation. The distribution categories and their scoring values are presented in Table 7.3. The highest scores are allocated to the species that occurred historically in the region, while, the lowest scores are subsequently allocated to extralimital species.

Table 7.3 The scoring of the historical distribution of game species.

Distribution category	Suitability score
Historically permanent resident, currently not present	**15**
Historically temporarily resident, currently not present	**13**
Historically permanent resident, already present	**12**
Historically temporarily resident, already present	**10**
Historically distribution boundary, currently not present	**9**
Historically distribution boundary, already present	**8**
Distribution unknown, possibly historically present	**7**
Distribution unknown, unlikely historically present	**5**
Extra-limital species, already present	**2**
Extralimital species, not currently present	**1**

7.2.1.3 Animal species impact on the environment

Some herbivore species have the ability to cause changes to their environment through activities such as grazing, browsing, trampling, defecation and urination (Wisdom *et al.* 2006; Allred *et al*., 2012). Allred *et al*. (2012) stated that herbivores have an influence on both the species composition as well as the stability of plant communities of ecosystems. The changes caused by herbivores usually include the reduction of forage availability, altercation of species composition and changes in vegetation structure (Canter, 2008; Allred *et al*., 2012). The preservation and conservation of natural ecosystems by reducing the loss of biodiversity are core principles of most protected area management programmes (Rodrigues *et al.* 2004; Ehrlich & Pringle 2008). The potential impact of a species on its environment is therefore an important aspect of conservation management.

Collinson & Goodman (1982) classified four categories of game species based on the impact they have on the vegetation and habitat and how these species react to vegetation changes. These categories are:

<u>Category I species</u>

These are large bodied bulk feeding herbivore species, such as elephant, white rhinoceros, buffalo and plains zebra that have the ability to cause drastic changes to the vegetation.

Category II species

Species that have a low impact on the vegetation and are negatively affected by the actions caused by category I species and decrease in numbers as a result of these changes are classified as category II species. They include species such roan antelope, sable antelope, tsessebe and waterbuck.

Category III species

Category III species are those species that perpetuate the vegetation state that was first introduced by category I species and cause further changes to the vegetation. Category III species also increase in respond to changes caused by category I species. They include blue wildebeest, warthog, impala and red hartebeest.

Category IV species

Category IV Includes species that may increase because of the changes brought about by category I and III species. They have little impact on the vegetation. They are mainly browsers or selective feeders.

The categories described by Collinson & Goodman (1982) provide an ideal basis to grade the potential environmental impact of species on a scoring scale. The scoring of these categories is presented in Table 7.4. The highest scores are allocated to the species categories that have the lowest potential impact, and scores decrease as the potential impact increases. Category I species were further divided into a low density and high density category because the natural density at which species occur will also influence the scale of potential environmental change. Category III species are all intermediate to high density species and therefore they were not sub-divided. The categories to which each species belong are presented in appendix Dii. It should be noted that the category type a species belong to may differ from one region to another based on the habitat and can be grouped into one of the other categories where necessary.

Table 7.4 The scoring categories of the impact of different game species on the environment.

Species impact categories	Suitability score
Category II species	15
Category IV species	12
Category I species, low density	7
Category III species	3
Category I species, intermediate/high density	1

7.2.2 Habitat suitability considerations

The effective management of wildlife populations depends largely on an understanding and prediction of their habitat needs (Dörgeloh, 2001). It is also a prerequisite for understanding the abundance and distribution of game species and to evaluate the suitability of the introduction of a species to any specific region (Grunow, 1980, Dekker *et al.* 1996). According to Melton (1987) the quality of habitats for game species varies and is based on opportunities such as food and risks such as predators. The quality of the habitat directly influences the ability of an individual to survive and reproduce (Melton, 1987). As a result, the evaluation of habitat quality has emerged as a vital component of effective wildlife conservation and management (Fabricius & Mentis 1991).

The following variables are regarded as the most important determinants of habitat quality, and are subsequently included into the index for evaluation: surface water, food source, herbaceous layer structure, woody layer structure, topography and terrain, and climate of the region.

7.2.2.1 Surface water

Water is regarded as the one of the fundamental requirements of life and affects all aspects of animals ecology (Hayward & Hayward, 2012). The availability of surface water is often the main parameter that restricts the distribution of game species, particularly during dry periods (Redfern *et al*. 2003; Smit *et al*. 2007; Smit, 2011). The water requirements of game species therefore dictate the range and regions within habitats that the animal species can utilize. According to Grossman *et al*. (1999), game species can be classified as either water dependant or water independent, while water dependent species can be further classified as either being mobile or non-mobile species. Water independent species typically include arid and semi-arid adapted species that can survive for long periods without surface water and include species such as gemsbok and eland. Water dependant species require access to drinking water on a daily basis, while being mobile or non-mobile refers to the general distance water dependant species can move away from water. Non-mobile species are largely restricted to a zone of up to 5-6 km away from drinking water and include species such as impala (*Aepyceros melampus*) and bushbuck (*Tragelaphus scriptus*). The densities of these species decline drastically further than 5-6 km from surface water. Mobile species have the ability to utilize areas of up to 10 km away from surface water and include species such as, roan (*Hippotragus equinus*) and sable (*Hippotragus niger*). At distances further than 10 km from surface water, water independent species occur on a more permanent basis.

Because water availability restricts the range species can move away from surface water, areas within habitats beyond the distance species can move from surface water cannot be utilized. Range limitations that water availability has on species and the relative area that can be utilized by species can be calculated. Species distribution is also not uniform within the maximum range that they can utilize. Grossman *et al.* (1999) states that animal densities decrease as the distance from water increases up to the maximum range species can utilize.

To assess the suitability of each habitat in terms of surface water availability, the surface area that falls within the distance that species can utilize away from water, is used as measure of the habitat suitability. The decrease in animal densities as distance from water increases, must also be taken into account. The potential range of each water dependence class, as defined by Grossman *et al.* (1999), was further divided into zones A, B and C. Zone A represents the area surrounding the surface water which normally experiences the highest animal densities, while zone B borders on zone A and represents the area of intermediate animal densities, and subsequently zone C borders on zone B and is the area of lowest animal densities. The range of zones A to C depends on the water dependence classes of the species in question. The water dependence classes of each species are presented in Appendix Diii. Zones A to C are also the criteria for scoring. The scoring value of each zone is presented in Table 7.5.

The calculation of the scores is done by calculating the percentage area each of the defined zones covers of the habitat that. This is done by the following equation:

$$\text{HSS} = \sum \left(\mathrm{A}i \; x \; \frac{\mathrm{b}i}{\mathrm{B}} \right)$$

Where HSS = Habitat suitability score

A = Category score of water zone (Zone A to C)

b = Area zone covers of habitat

B = Total area of habit

Calculations are done for both the dry and wet season separately since water availability will differ between the two season. The scores of the both the dry and wet season calculations are added together to get the final suitability score.

Table 7.5 The water zones, distance of each zone and scoring value of zones.

Zone	Distance from water source			
	Water dependent non-mobile	Water dependent mobile	Water independent	Suitability score
Zone A	1 km	3 km	15 km	10
Zone B	1-3 km	3 – 7 km	> 15 km	7
Zone C	3 -5 km	7 -10 km	n.a	4

7.2.2.2 Food resources

Numerous authors have reported the importance of both food quantity and quality for the survival of herbivore species and its influence in regulating herbivore abundance and performance over a range of different habitats and regions (Fritz & Duncan, 1994; Grant *et al.,* 2009; Fynn, 2012; Seydack, 2012). The evaluation of food quantity and quality is thus an essential requirement for any habitat assessment.

According to Venter (1994), it is possible to determine the amount of suitable forage currently available for the specific species based on the herbaceous species composition and biomass, and by using data from feeding studies of the relevant animal species. Therefore, the plant species composition data obtained from point surveys is ideal for the use of assessing the quality of grazing material, while the data from BECVOL-surveys can be used for the same purpose of assessing the quality of the browsing material. Two separate food variables are scored and the food quality and quantity as well as food species diversity.

<u>7.2.2.2.1 Food quality and quantity</u>

The first stage of scoring requires assessing the individual suitability score of each plant species recorded in both the point- and BECVOL surveys. The higher the scores the higher the relative importance of the food items for game species. To ensure the credibility of these scores, four important factors that ultimately determine the importance of the plant as a food are evaluated separately. The scores of the individual factors are then summed together to give the suitability score. The criteria of scoring for each of the four factors is presented in Table 7.7, and the factors are as following:

Production potential – The production potential of plants refers to the amount of edible plant material that the plant species can produce. Larger plants will produce larger volumes of material than smaller plants.

Palatability – The palatability of plants refers to its acceptability as food item for herbivores. The palatability of a plant is determined by factors such as its nutritional value, chemical composition and the digestibility of plant material (Van Oudshoorn, 2003). It should be noted that the palatability of plant species will differ from one herbivore species to another based on their unique food preferences and also their feeding guild. Less palatable plant species will be more acceptable to large bodied roughage bulk feeders than to smaller sized selective feeders (Redfern *et al*. 2003). Large-bodied mammalian herbivores, because of greater digestive efficiency and lower metabolic demands per unit of body mass, can survive on foods of lower nutritional value than small-bodied species (Belovsky, 1997; Redfern *et al*. 2003).

Ecological status (herbaceous species)/ seasonality – The ecological status of herbaceous plants refers to the ecological classes the species belong to. The ecological classes are indications of how species respond to grazing pressures, as well as their relative ecological importance. When shrubs and trees are scored for browsers, the phenology of the plants is taken into considered, as well as the invasive nature of the plant. The phenology of the plant will determine if the plant is either evergreen or deciduous. Deciduous species lose their leaves during the dry winter months and do not provide adequate food for browsers during this period, while evergreen species retain their leaves and provide sufficient edible material throughout the year. Therefore, evergreen species should generally be scored high in this category, while deciduous species should be given an intermediate score. If invasive woody species have encroached the habitat, the species is allocated a low score.

Moribund (grasses)/ accessibility – Moribund refers to the amount of dead organic material in the grass tuft that accumulates when grasses are not regularly grazed or burned (Tainton, 1999; Van Oudtshoorn, 2004). An accumulation of dead material results in a decrease in palatability of the grass for grazers. When evaluating the accessibility of herbaceous species, the general height of the plant must be considered. In addition to preferences for plant species, grazers also have preferences for the plant height they feed on. On the basis of plant height preference, grazers are classified as short-, intermediate- or tall grass grazers (Bothma, 2002). The general height of each grass species within the vegetation type can be roughly estimated from field observations, or measured. In the case of woody plant species, the accessibility of the plant refers to the height at which edible material occurs and is based on the amount of browse that is within specific browsing reach of the browsing species. This can be evaluated by comparing the tree density and/or ETTE/ha value to the relative Leaf Dry Mass (kg)/ ha value of the species, which can be calculated with the BECVOL model.

Table 7.6 The scoring criteria of the factors included in assessing plant suitability scores.

Factor	Importance score		
	low	intermediate	High
Production potential	1	3	5
Palatability	1	3	5
Ecological status/ seasonality	1	3	5
Moribund/ accessibility	1	3	5

After the suitability values of species have been established the calculation of the final suitability score of the habitat can be achieved. The calculation is done from the point survey data by using the following equation:

$$HSS = \sum (\mathrm{A}i \; x \; \frac{\mathrm{b}i}{100})$$

Where HSS = Habitat suitability score

A = Importance index score of species

b = Percentage occurrence of species

The calculation of the browse is done by using the following

$$HSS = \sum (\mathrm{A}i \; x \; \frac{\mathrm{b}i}{\mathrm{B}})$$

Where HSS = Habitat suitability score

A = Importance index score of species

b = Leaf dry mass (kg)/ha of species

B = Total leaf dry mass/ha of habitat, minimum value 150 kg/ha

Based on the results of Chapter 5, a LDM value of 150kg/ha is the threshold value where the browsing capacity starts decreasing below the desired browsing capacity. The desired browsing capacity in this instance was regarded as 15 ha/BU, because it is the maximum stocking density at which kudus can be kept in regions receiving between 350-450 mm annual rainfall (Furstenburg, 2010).

When calculating the final scores of mixed feeders, the score of both the herbaceous and woody surveys are added together after adjusted the weighting of the score according to the contribution the browse or graze constituted of the diet.

7.2.2.2.2 Food species diversity

Many species require a diversity of plant species within their habitats to satisfy their nutritional requirements. Species seldom flourish in homogenous vegetation of low diversity and therefore evaluating the diversity of species is regarded as equally important. The diversity is evaluated subjectively based on the point- and BECVOL survey and the individual need of the species. Only edible plants should be considered. The type of feeder should also be taken into consideration, since selective feeders may require a wider diversity of plant species than bulk feeders. The scoring criteria are presented in Table 7.7.

Table 7.7 The criteria for scoring the plant diversity.

Aspect	Category	Score
	None to very low	1
Plant species diversity	Low	5
	Medium	10
	High	15
	Very high	20

7.2.2.3 Vegetation structure

The structure of vegetation is often the main determinant of habitat suitability for game species. According to Dörgeloth (2001) the availability of forage to herbivores is determined by the vegetation structure. Apart from the forage quantity, the vegetation structure may also determine the quality of the plant material available (Frits & Duncan, 1994; Treydte *et al*., 2007; Grant *et al*., 2009). The structure of the vegetation plays an equally important role in providing shelter and avoidance and detection of predators (Vermaak, 1996). Therefore, evaluating the habitat of both the woody and herbaceous structure is an essential requirement for determining the habitat suitability. The scoring of the herbaceous and woody layer is done separately because each can play an equally important role in determining habitat suitability.

Herbaceous plant structure and veld condition

The two factors that are taken into consideration for the herbaceous layer are the grass height and veld condition of the vegetation. The suitability of the herbaceous layer is based on one of the following two factors: (i) its ability to provide adequate shelter/cover and (ii) the quality and abundance of food it provides. The grass height refers to the average height of grass of the habitat in question. Game species prefer habitats with specific grass heights. Short grass grazers will prefer areas with short grass, while tall grass grazers will prefer areas with tall grass. Grass height can be important to browsers for the provision of shelter or may influence vision and movability. Based on literature, general grass height categories regarded as suitable, marginal and unsuitable, were derived.

The veld condition refers to the general health of the herbaceous layer and it is well known that some species are sensitive to changes in the vegetation and require habitats in pristine conditions. From literature, the preferred veld condition of the vegetation was categorised as suitable, marginal or unsuitable to the species. The results of veld condition assessments are preferably used.

Both the values of grass height and those of the general veld condition regarded as suitable, marginal or unsuitable for the species evaluated in this study is presented in Appendix Diii. The scoring of the categories is presented in Table 7.8

Table 7.8 The scoring of the vegetation structure of both the woody and herbaceous layer.

		Category Score		
Plant layer	**Consideration**	**Unsuitable**	**marginal**	**Suitable**
Herbaceous layer	Grass height	1	5	10
	Veld condition	1	5	10

7.2.2.4 Woody plant structure

The woody layer variables that are assessed are the percentage canopy cover and structure of the woody plants. Based on literature on the types vegetation selected by species regarding their openness in terms woody density (Kok & Opperman, 1975; Grunow, 1980; Smithers, 1983; Rowe-Rowe, 1994; Dekker *et al.,* 1996; Winterbach & Bothma, 1998; Watson & Owen-Smith, 2000; Dörgeloh, 2001; Bothma *et al.*, 2002; Skinner & Chimimba, 2005; Furstenburg, 2006; Furtenburg, 2008a; Furstenburg, 2010a; Janecke, 2010; Novelie & Kraaij, 2010; Furstenburg, 2011; Buk & Knight; 2012), canopy cover values were derived for suitable, marginal and unsuitable for each species. The canopy cover range of woody plants regarded suitable, marginal or unsuitable for each species evaluated in this study is presented in Appendix Ciii.

However, the canopy cover of woody plants alone is not adequate to evaluate the suitability of the habitat and therefore, the structure of the woody plants is also subjectively evaluated. The structure of the woody plants refers to the presence and abundance of woody plants of different heights. Habitats of large bodied species, such as buffalo that require woody plants for cover or shade, consisting of short shrubs will be inadequate. Similarly, some small bodied herbivores, such as blue duiker, require both dense underbrush and a closed canopy of larger trees (Skinner & Chimimba, 2005). The suitability of the structure is evaluated and scored subjectively since measuring the degree of suitability is nearly impossible. The scoring of the two woody variables is presented in Table 7.9

Table 7.9 The Scoring criteria of the woody layer.

		Category Score		
Plant layer	**Consideration**	**Unsuitable**	**marginal**	**Suitable**
Woody layer	Canopy cover	1	5	10
	Structure	1	5	10

7.2.2.5 Topography and Terrain

Animals not only show preferences for different habitats for shelter and diet, but also for topographical features such as slopes or areas of differing soil types or degree of rockiness. (Bell 1971; Bothma & Van Rooyen 1989; Novellie 1990). Therefore, the topography and terrain characteristics of the habitat is also included in the index for assessment.

Based on the available information in literature (Kok & Opperman, 1975; Grunow, 1980; Smithers, 1983; Rowe-Rowe, 1994; Dekker *et al.,* 1996; Winterbach & Bothma, 1998; Watson & Owen-Smith, 2000; Dörgeloh, 2001; Bothma *et al.*, 2002; Skinner & Chimimba, 2005; Furstenburg, 2006; Furtenburg, 2008a; Furstenburg, 2010a; Janecke, 2010; Novelie & Kraaij, 2010; Furstenburg, 2011; Buk & Knight; 2012), the topographical and terrain characteristics were categorised as either being suitable, marginal or unsuitable and are also the categories for scoring. Only relevant topographical and terrain characteristics that influence the habitat quality for the specific species, were included. The categorization of topographical and terrain characteristics is presented in Appendix Diii. The scoring of the categories for topography is presented in Table 7.10.

Table 7.10 The scoring of the topography and terrain aspects.

Aspect	Category	Score
	Unsuitable	1
Topography / terrain	Marginal	10
	Suitable	20

Because the topography within each habitat may differ vastly from one area to another, some areas can be more suitable than others within the same habitat. To overcome this problem the final suitability score is calculated as follows:

HSS = $\sum \left(\mathrm{A}i \; x \; \frac{\mathrm{b}i}{\mathrm{B}} \right)$

Where HSS = Habitat suitability score

A = Topography and terrain category score

b = Area covered by topography of the category

B = Total area of habitat

7.2.2.6 Climate conditions

The climate of a region is often the primary determinant of the vegetation structure, composition and distribution of the vegetation (Sankaran & Anderson, 2009; Higgings *et al*., 2010). Climate variations, particularly rainfall, are also largely responsible for changes in the species composition of vegetation (Buitenwerf *et al.*, 2011). It is important to take into consideration the climate of a region since the climate primarily influences the habitat characteristics and species are adapted to specific environments that are a function of the climate. The importance of the climate cannot be overlooked when assessing environments for species.

Only one climate variables were regarded as the most important determent of habitat suitability and is the annual rainfall of region.

For this category relative annual rainfall figures were categorizes as being optimal, marginal or unsuitable to the species. The rainfall figures were derived from both literature and by assessing the relevant climate conditions of each game species distribution range.

The rainfall scores will not differ between the habitats assessed, but rather between the different species assessed. The rainfall scores will therefore not contribute in assessing the habitat quality of each habitat separately, but rather the suitability of the region as a whole. The scoring of the climate is presented in Table 7.11

Table 7.11 The scoring of the climate conditions.

Aspect	Category	Score
	Unsuitable	0
Rainfall	Marginal	5
	Optimal	10

7.2.2.6 Final calculations of habitat consideration scores

The relative carrying capacity of each habitat is an important aspect in determining its suitability and the numbers of the species it can support. A habitat may be scored as suitable, but be too small to support a viable population.

The number of habitats that are included for calculation is solely based on the total carrying capacity required to support the desired number of animals. By starting with the habitat with the highest suitability score, followed by the habitat with the next highest score, habitats are continuously included in the suitability calculations until the required carrying capacity is reached. Only the included habitats are then used for the calculations. All habitats can be included if the aim is to assess the suitability of the area as a whole.

To determine the final habitat score, the weighting of the score of each habitat included is adjusted based on the contribution it makes to the required carrying capacity. This can easily be done by the following equation.

$$\text{HSS} = \sum \left(\text{A}i \; x \; \frac{\text{b}i}{\text{B}} \right)$$

Where HSS = Habitat suitability score

A = Suitability score of habitat

b = Carrying capacity of habitat (Grazer unit or Browser units)

B = Total carrying capacity required or available (Grazer unit or Browser units)

The combined size of the habitats included for calculations should always be large enough to support at least a minimum viable population.

7.2.3 Economic considerations

In the past, game species were viewed as of little value by land owners and because wildlife competed with livestock for valuable grazing land, it led to large scale elimination of wildlife outside protected areas (NAMC, 2006; Lindsey & Davies-Mostert, 2010). However, the value of wildlife started increasing when its potential as an agricultural commodity developed over time. Policy changes during the 1960's and 1970's have resulted in the devolution of user-rights over wildlife to private land owners in South Africa. During this period land owners also started realising the economic potential of the great variety of indigenous wildlife species in South Africa (NAMC, 2006). This resulted in a gradual change in the perception of the value of wildlife to private land owners and a shift from livestock farming to wildlife ranching across large areas (NAMC, 2006, Lindsey & Davies-Mostert, 2010). The utilization of wildlife on private land throughout South Africa escalated to various wildlife production enterprises, and is widely recognised today as the fastest growing agricultural activity in South Africa in the past three decades (Berry, 1986; NAMC, 2006). The growth of the game ranching industry is best illustrated in the increase in turnover generated at game auctions over the years. In 1991 the auction turnover was R9 million, in 2002 it increased to R105 million turnover, while in 2012 the live sales of game species alone generated a R 960 million turnover (Ellof, 2004; Cloete, 2013).

According to Van Zyl & Sartorius von Bach (2002), in addition to the essential ecological planning and sustainable wildlife management programme, there should be a thorough economic and financial management plan. The consideration of some economical aspects of game is important for particularly game ranching enterprises. The aspects regarded as important economical considerations that are included in the index, are: the live sales value of species, the trend in species demand, the population growth potential of the species, and the limitations of legislation.

7.2.3.1 Species live sale value

The value of species is one of the most important economic considerations that game ranchers take into account when considering the optimum species combination. The value of species may differ from one year to another and is largely influenced by supply and demand for the species (Van der Merwe, 2004). Currently the most valued species are rare game species, such as disease free buffalo, sable antelope and colour variants (Cloete, 2013).

For the scoring of the species value, species were divided into different scoring criteria based on their latest average auction values. The average prices where calculated from 58 official game auctions held across the country in 2012 and represent reference prices for each species that is comparable with previous and following years (Cloete, 2013). The criteria are presented in Table 7.12. The latest auction values of all game species (Cloete, 2013) are presented in Appendix Div. For the use of this economic consideration the latest average auction prices should be used when it it becomes available. A separate scoring criterion for scoring the price values of only species regarded as recreational hunting species, is also included in Table 7.12. This was done to enable evaluating species if the purpose of the game ranch enterprise is solely recreational hunting.

Price classes were classified to include species of similar value, such as very common species (usually valued under R2 500) and rare game species (usually above R100 000). Although some species, such as buffalo, may value far more than R100 000, it was decided that R100 000 is the benchmark value for the most sought after and highest valued species.

Table 7.12 The live sale value categories and scoring value.

Live sales value Criteria	Suitability score
>R100 000	25
R50 - 100 000	20
R30 – 50 000	15
R15 - 30 000	10
R7 500 – 15 000	5
R2 500 – 7 500	3
< R2 500	1
Recreational hunting	
>R10 000	25
R 7 500 - 10 000	20
R 5 000 – 7 500	15
R 3 500 – 5 000	10
R 2 000 – 3 500	5
R1 000 – 2 000	3
< R1 000	1

7.2.3.2 Species demand

The trend in the commercial value of a species is an important consideration when deciding on possible species introduction. Species, particularly rare species such as disease free buffalo and sable antelope, have increased considerably in value over the past few years (Van Zyl & Sartorius von Bach, 2002). These increases have been driven by an increase in demand for these species in relation to the supply thereof (Van der Merwe, 2004). Other species have declined in value due to a variety of reasons. The trend in demand for specific species is regarded as an important conservation consideration because it indicates potential changes in the value of the species.

To assess the trend in demand for the various species, the average change in the live sales values over the past five years was calculated. The use of the price changes was considered the most accurate indication of the trend in the demand. This is because a general increase in demand for specific species will lead to an increase in value, while similarly a decrease in demand will lead to a decrease in value. The average price change was calculated by determining the mean annual price changes of live sales values from the period 2008 to 2012. Price changes where adjusted by 6% to offset the influence of inflation on the prices. From these result the suitability categories for scoring were determined and are presented in Table 7.13 The value trend of each species is presented in Appendix Div.

Table 7.13 Scoring criteria for value trends of games species.

Trend criteria	Suitability score
>10% annual increase	15
5-10% annual increase	12
0-5% annual increase or decrease	9
5-10% annual decrease	5
>10% annual decrease	1

7.2.3.3 Population growth rate

The population growth of a species measures the temporal increase of a population per unit time. A sound understanding of the growth rate is essential to the management of any game ranch, because it measures the reaction of animals to their environment, and indicates the success or failure of veld management and habitat improvement in particular. It also serves as a basis for determining realistic long-term harvesting quotas (Bothma, 2002). The potential population growth of any species is important from a commercial point of view as it directly influences the number and regularity of the harvesting/hunting of animals(Bothma, 2002).

For scoring, the different criteria were established based on population growth numbers. These criteria are presented in Table 7.14. The potential growth potential of species is presented in appendix Div. Determinants such as habitat quality and predation all play a role in the population growth of a species. Therefore, if the habitat is marginal (based on suitability score) and/or predation risk is very high; the lower end values presented in

Appendix Div for each species, should apply. If the habitat is suitable and predation risk low to moderate, the high end values should apply.

Table 7.14 The scoring criteria of the annual growth rate of species.

Annual growth rate criteria	Suitability score
>30% increase	15
21-30% increase	12
16-20% increase	9
11-15% increase	5
<10% increase	1

7.3 Overview and use of the suitability index

One of the main objectives of the suitability index is for it to be flexible in use based on the purpose or goals of the region. Therefore, sections can be left out when scoring or the importance of some sections increased. For example, the conservation consideration of game species is generally not of concern for game ranchers. Similarly, the economical considerations of game is not of often regarded by conservancies.

The scores of the conservation and economical considerations can also be used to compare or decide between species with very similar habitat consideration scores. The scores of any of the aspects within the three considerations regarded as the most important determinants can also be increased. Such an example might be the doubling of the scoring value of animal’s impact on the environment.

Many of the individual aspects should also serve as guides when considering animals, regardless of total scores. This is because many of the single factors alone can have major implications on the health and survivability of a population, such as predation or lack of water. It must be noted that the suitability index evaluates numerous aspects and therefore scores could still be high but the habitat not suitable.

It should also be noted that numerous aspects not included into the suitability index can also influence the survivability and performance of animal populations within a given area. This includes aspects such as the influence of predators, the outbreak of diseases, environmental changes, intraspecific competition and inbreeding. The potential influence of the above mentioned aspects on animal populations is often difficult to accurately predict and where excluded for this reason.

7.4 Application of Habitat Suitability Index of DNR species and potential species for introduction

The suitability index was used to calculate the suitability scores of the game species of DNR whose habitat selection was studied (Chapter 6), to measure the relative accuracy in predicting the habitat selection of game species. The suitability scores were also calculated to compare species to one another and determine which species are best adapted to the semi arid environment of DNR. Two game species, namely black rhinoceros and Cape mountain zebra, which were considered for introduction by the reserve management, was also evaluated. The results of each species is presented in Tables 7.15 – 7.23.

Table 7.15 The suitability scores for buffalo.

Ecological consideration		
Conservation category	**Criteria**	**Suitability score**
Conservations status	LC, decreasing	**2**
Historical distribution	Historical range unknown, possibly present	**7**
Species impact on environment	Category I high density species	**1**
	Final score	**10**

Habitat consideration						
Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	26	22	11	12	**91**
MU 2	20	26	30	1	12	**89**
MU 3	20	13	26	20	12	**91**
MU 4	18	12	30	20	12	**92**
MU 5	19	28	35	20	12	**114**
MU 6	20	25	22	20	12	**99**
MU 7	18	27	30	5	12	**92**
					Final Score population:	**114**
					DNR whole:	**95**

Economical considerations		
Economical category	**Criteria**	**Suitability score**
Live sales value	R > R100 000	**25**
Demand trend	>10 % annual decrease	**15**
Population growth	16-20% increase	**9**
	Final score	**49**

Table 7.16 The suitability scores for eland.

Ecological consideration

Conservation category	Criteria	Suitability score
Conservations status	LC, decreasing	**1**
Historical distribution	Historical found, present	**12**
Species impact on environment	Category 3 species	**3**
	Final score	**16**

Habitat consideration

Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	22	22	20	20	**104**
MU 2	20	20	40	20	20	**120**
MU 3	20	27	40	20	20	**127**
MU 4	20	27	40	20	20	**127**
MU 5	20	31	40	20	20	**131**
MU 6	20	23	30	20	20	**113**
MU 7	20	17	35	15	20	**107**
					Final Score population:	**130**
					DNR whole:	**130**

Economical considerations

Economical category	Criteria	Suitability score
Live sales value	R 2 500 –R 7500	**3**
(recreational hunting)	R 5 000 – R 7500	**15**
Demand trend	>10 % annual decrease	**1**
Population growth	>30% increase	**15**
	Final score (**R. Hunting)**	**19** (**31)**

Table 7.17 The suitability scores for kudu.

Ecological consideration		
Conservation category	**Criteria**	**Suitability score**
Conservations status	LC, decreasing	**1**
Historical distribution	Historical found, present	**12**
Species impact on environment	Category IV species	**12**
	Final score	**25**

Habitat consideration						
Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	4	22	20	20	**86**
MU 2	20	20	35	20	20	**115**
MU 3	20	25	40	20	20	**125**
MU 4	20	32	40	20	20	**132**
MU 5	20	28	35	20	20	**123**
MU 6	20	11	22	20	20	**83**
MU 7	20	11	32	20	20	**103**
					Final Score population:	**124**
					DNR whole:	**124**

Economical considerations		
Economical category	**Criteria**	**Suitability score**
Live sales value	R 2 500 – R 7 500	**3**
(recreational hunting)	R 5 000 – R 5 000	**10**
Demand trend	>10 % annual decrease	**1**
Population growth	21-30% increase	**12**
	Final score (R. Hunting)	**16 (23)**

Table 7.18 The suitability scores for red hartebeest.

Ecological consideration		
Conservation category	**Criteria**	**Suitability score**
Conservations status	LC, decreasing	**1**
Historical distribution	Historical found, present	**12**
Species impact on environment	Category III species	**3**
	Final score	**16**

Habitat consideration						
Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	20	25	20	20	**105**
MU 2	20	21	36	20	20	**117**
MU 3	20	15	10	20	20	**85**
MU 4	20	15	10	20	20	**85**
MU 5	20	25	40	20	20	**125**
MU 6	20	24	32	20	20	**116**
MU 7	20	32	36	11	20	**109**
					Final Score population:	**125**
					DNR whole:	**123**

Economical considerations		
Economical category	**Criteria**	**Suitability score**
Live sales value	R 2 500 – R 7 500	**3**
(recreational hunting)	R 5 000 – R 5 000	**10**
Demand trend	0-5% annual decrease	**9**
Population growth	>30% increase	**15**
	Final score (R. Hunting)	**27 (34)**

Table 7.19 The suitability scores for gemsbok.

Ecological consideration

Conservation category	Criteria	Suitability score
Conservations status	LC, decreasing	**1**
Historical distribution	Historical boundary, currently present	**8**
Species impact on environment	Category III species	**3**
	Final score	**12**

Habitat consideration

Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	25	22	15	12	**94**
MU 2	20	25	40	15	12	**122**
MU 3	20	13	6	20	12	**71**
MU 4	20	12	14	20	12	**78**
MU 5	20	24	35	20	12	**115**
MU 6	20	25	35	20	12	**112**
MU 7	20	27	35	15	12	**109**

Final Score
population: **116**
DNR whole: **112**

Economical considerations

Economical category	Criteria	Suitability score
Live sales value	R 2 500 – R 7 500	**3**
(recreational hunting)	R 5 000 – R 5 000	**10**
Demand trend	0-5% annual decrease	**9**
Population growth	>30% increase	**9**

Final score **21**
(R. Hunting) **(28)**

Table 7.20 The suitability scores for mountain reedbuck.

Ecological consideration		
Conservation category	**Criteria**	**Suitability score**
Conservations status	LC, decreasing	**1**
Historical distribution	Historical boundary, currently present	**12**
Species impact on environment	Category III species	**15**
	Final score	**12**

Habitat consideration

Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	21	40	12	12	**105**
MU 2	20	21	40	13	12	**106**
MU 3	20	13	8	1	12	**54**
MU 4	18	12	13	1	12	**56**
MU 5	19	24	36	16	12	**107**
MU 6	20	25	35	11	12	**103**
MU 7	18	29	35	20	12	**114**
					Final Score population:	**114**
					DNR whole:	**111**

Economical considerations		
Economical category	**Criteria**	**Suitability score**
Live sales value	R 2 500 – R 7 500	**3**
(recreational hunting)	R 2 000 – R 3 500	**5**
Demand trend	0-5% annual decrease	**12**
Population growth	>30% increase	**15**
	Final score	**27**
	(R. Hunting)	**(34)**

Table 7.21 The suitability scores for warthog.

Ecological consideration		
Conservation category	**Criteria**	**Suitability score**
Conservations status	LC, decreasing	**1**
Historical distribution	Historical boundary, currently present	**12**
Species impact on environment	Category III species	**15**
	Final score	**12**

Habitat consideration						
Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	25	30	20	12	**107**
MU 2	20	25	35	20	12	**112**
MU 3	20	14	30	20	12	**96**
MU 4	18	18	30	20	12	**98**
MU 5	19	24	35	20	12	**110**
MU 6	20	26	30	20	12	**108**
MU 7	18	25	26	11	12	**92**
					Final Score population:	**110**
					DNR whole:	**101**

Economical considerations		
Economical category	**Criteria**	**Suitability score**
Live sales value	R 2 500 – R 7 500	**1**
(recreational hunting)	R 2 000 – R 3 500	**1**
Demand trend	>10% annual increase	**15**
Population growth	>30% increase	**15**
	Final score (R. hunting)	**27 (34)**

Table 7.22 The suitability scores for black rhinoceros.

Ecological consideration		
Conservation category	**Criteria**	**Suitability score**
Conservations status	Vulnerable, stable	**8**
Historical distribution	Historical present, not currently present	**15**
Species impact on environment	Category IV species	**12**
	Final score	**35**

Habitat consideration						
Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	4	20	11	20	**75**
MU 2	20	20	20	1	20	**81**
MU 3	20	25	40	20	20	**125**
MU 4	20	32	40	20	20	**132**
MU 5	20	28	35	20	20	**123**
MU 6	20	11	20	20	20	**108**
MU 7	20	11	20	1	20	**72**
					Final Score population:	**124-126**
					DNR whole:	**122**

Economical considerations		
Economical category	**Criteria**	**Suitability score**
Live sales value	R 2 500 – R 7 500	**25**
Demand trend	>10% annual dencrease	**1**
Population growth	11- 15 % increase	**5**
	Final score	**31**

Table 7.23 The suitability scores for Cape mountain zebra.

Ecological consideration

Conservation category	Criteria	Suitability score
Conservations status	Vulnerable, increasing	**8**
Historical distribution	Distribution unknown, unlikely present	**5**
Species impact on environment	Category III species	**3**
	Final score	**16**

Habitat consideration

Management Unit	Water	Food	Vegetation structure	Topography and terrain	Climate	suitability score (Before adjustmen)
MU 1	20	28	26	15	20	**109**
MU 2	20	25	40	20	20	**125**
MU 3	20	12	12	5	20	**59**
MU 4	20	14	17	5	20	**66**
MU 5	20	29	35	15	20	**119**
MU 6	20	27	26	10	20	**103**
MU 7	20	27	40	20	20	**127**
					Final Score population:	**127**
					DNR whole:	**124**

Economical considerations

Economical category	Criteria	Suitability score
Live sales value	R 7 500 – R 15 000	**5**
(recreational hunting)	>R 10 000	**25**
Demand trend	>10% annual decrease	**1**
Population growth	21-30% increase	**12**
	Final score **(R. Hunting)**	**18** **(38)**

7.5 Results and general discussion

The results of the suitability index evaluations indicated that this approach to suitability evaluations of this kind might hold potential for future use in determining habitat suitability. For most of the species evaluated, the habitats that had the highest suitability scores (before adjusting scores to its relative carrying capacity), were also the habitats that the species preferred and selection for (see Chapter 6). Similarly, the habitats that received the lowest scored were also the habitats that the species were found to avoid. Gemsbok was the only species whose habitat scores did not accurately predict the actual habitat utilization of the species. This may be because gemsbok populations were mainly restricted to the western Section of DNR and therefore did not utilize the region to its full potential.

The general indication from the habitat scores was that scores above 120 was and indication of optimal habitat to the species, a score of 95-119 of suitable habitat, a score of 80-95 of marginal habitat and scores less than 80 unsuitable of unsuitable habitat. Based on this, the habitat of DNR as a whole was found to be optimal habitats for species such as eland, kudu, and red hartebeest, while suitable for gemsbok, mountain reedbuck and warthog and marginal for buffalo. There suitability scores did however also indicate that enough suitable habitat was available for buffalo to support the population at the time. Interestingly, both buffalo and warthog were the only two species that did not occur in the region historically and this may be the reason why DNR is less suitable to these species. The results also indicated that black rhinoceros and Cape mountain zebra would do well in DNR with abundant habitat of optimal quality available.

The calculation of ecological and economical considerations was also valuable guides in indicating and distinguish between species based on their conservation priority and economical value. Similarly to the habitat consideration scores, ecological consideration scores of buffalo and warthog were also the lowest. Not surprisingly these two species were also the two species that was causing the most environmental damage to the reserve. It seems therefore that the ecological scores may be value for particularly conservation assessment not related to the habitat itself. The high economical score of buffalo also indicate why commercial considerations often overrule ecological considerations for game ranching enterprises.

Both the ecological and economical considerations do however require the addition of more aspects to measure, to increase the legitimacy of these score. The current included aspects still provides a relative clear indication of the importance of the consideration.

7.6 Conclusion

It is clear that the use of habitat suitability models as tools for effectively management of game species and environments holds great potential. The suitability model developed for this study, even if relatively simple in use, was able to accurately predict the preferred and avoided habitats of the game species studied. It also proved to be a valuable tool to use for comparing the relative suitability of each species with one another.

In conclusion the model proposed does seem to hold great potential. It is the fore recommended to increase the predictive power and accuracy of this proposed model that further refinement is done to the method of scoring and evaluations and that additional considerations not already included be added to the index. In time the thorough testing and implementing of the model for different scenarios and environments will ultimate prove its value as an assessment tool.

Chapter 8: General conclusion and recommendations

8.1 General conclusions

The following broad general conclusions could be made from this study:

- The vegetation of Doornkloof nature reserve is diverse and this diversity is mainly the result of the highly variable topography of the game reserve.

- The species composition and vegetation characteristics of the reserve were influenced by both the impact of animals and rainfall, thus indicating that both equilibrial and non-equilibrial variables play a role in this semi-arid environment in determining species composition.

- A high seasonal variability in both the quantity and distribution of the rainfall influenced the grass species composition and biomass production in the short term, while grazers have altered the vegetation in the long term.

- Despite the effects of herbivores on the vegetation, rainfall remained the main determinant of the general trend of the veld condition of the vegetation.

- The veld condition differed distinctly between different vegetation units, with the less utilized mountainous regions in the best condition, while lower laying areas of flattish terrain were generally in poorer condition and the azonal vegetation in the worst condition.

- The total grazing capacity of DNR was adequate to support the current population of grazers. However, the randjie veld management unit that contributed almost 75% to the total grazing capacity of DNR, was also the least favoured by game species. This resulted in high densities of grazers in the remainder of the management units which were more preferred and consequently led to overgrazing in these areas.

- Based on the browsing capacity calculations, the DNR was substantially overstocked by browsers. Despite this apparent overstocking, no mortality of browsers was observed and the woody vegetation was not obviously damaged. This indicates that the utilization factors on which the browsing capacity calculations were based, may have been too conservative. In view of the highly variable rainfall and winter deciduous nature of the woody plants, a more conservative stocking rate of browsers is advisable for the long-term sustainability of the reserve.

- The habitat preference of the game species on DNR concur with results of other studies and was an indication of functional populations. Several of the species, such as eland and kudu, were thriving in the reserve, while species such as gemsbok and mountain reedbuck were not performing well.

- The developed suitability model showed potential in predicting the habitat suitability of species and concurred largely with the results of the habitat selection study. The model also proved to be a helpful guide in evaluating the relative ecological importance of species and their need to be conserved.

8.2 General recommendations

Based on the results of this study, the following recommendations are made:

With the vegetation of DNR described and the various management units being demarcated, different monitoring sites must be identified and allocated within each of these management units. These sites will serve as benchmarks for long-term vegetation monitoring that includes veld condition assessment and calculations of carrying capacity, as was done in this study. It is important that these sites are carefully selected to ensure that they are representative of the management units. The current monitoring sites in DNR were selected to represent the different topographical areas of the region and subsequently many important habitats, such as the azonal vegetation, were excluded for monitoring purposes.

The newly selected monitoring plots should be sampled on a yearly basis to assess if veld degradation is taking place, which will enable suitable management interventions to avoid further damage. Grazing and browsing capacities should be determined on a yearly basis and animal numbers, within practical limits, adjusted accordingly. This study clearly demonstrated how the grazing capacity can vary from one season to another based on the rainfall and this emphasizes the need of regular calculations of the grazing capacity.

Regarding the game species of DNR, a serious effort should be made to completely remove warthogs from DNR. The impact of warthogs on the environment was severe and caused extensive damage to the vegetation. Since this species is also an extralimital species and not endangered, it does not offer any ecological justification to retain them. Total removal might prove to be difficult and thus numbers should be kept as low as possible through intensive culling operations on a regular basis.

Similarly, buffalo also caused severe damage to some of the vegetation types, most notably those of the river communities and surrounding vegetation. However, buffalo do hold significant economical value and as one of the big five species they contribute to the tourism potential of the reserve. It is therefore recommended that the numbers only be reduced to approximately half the current population and maintained at that level. The auctioning of these highly valuable species on a regular basis can also serve as a method to fund conservation operations that are often in need of more funding.

It was also evident that DNR was potentially overstocked by browsers, particularly kudu and eland. The populations of these two species should be reduced and maintained at a lower level. It is recommended that the eland population be reduced to a third of, and kudu to half of their current population. The population growth rate of these species requires regular harvesting of the species.

The possible introduction of the endangered black rhinoceros and Cape mountain zebra should also be strongly considered. Indications are that both black rhinoceros and mountain zebra are adapted to the environment and will do well in DNR. Cape mountain zebra have the further advantage of probably utilizing the large mountainous randjie veld community areas, which are currently under utilized by game species. Furthermore, the addition of these species will not only contribute to their conservation, but will also considerably boost the importance of DNR as a conservation area and increase its lure as a tourist attraction.

ABSTRACT

THE ECOLOGICAL PLANNING OF THE DOONRKLOOF NATURE RESERVE, NORTHERN CAPE

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The successful and effective management of conservation areas can only be achieved with access to sound environmental data. The Doornkloof Nature Reserve (DNR) in the Northern Cape Province, was in need of such data which was essential for the development of proper management policies. The objectives of this study were to identify, describe and measure the most important environmental characteristics of the reserve, which will be used as the baseline data for the refinement of management policies. This included the identification and description of the plant communities; the demarcation of management units; determining the botanical composition and the veld condition of each management unit; quantifying the density; species composition and above-ground biomass of woody plants; calculating the carrying capacity (graze and browse); determining the seasonal habitat selection, group sizes and social structures of the ungulate species of DNR and developing a suitability index to assists management decisions.

The Braun-Blanquet method was used to identify the plant communities of DNR. A total of 204 reléves were sampled and upon analysis six major plant communities and 14 sub-communities were identified. The plant communities and sub-communities were grouped into seven management units. Due to the heterogeneous landscape of the reserve, the vegetation of DNR was relatively diverse, consisting of grasslands, shrublands and riverine communities. A step point-method and the Ecological Index Method were used to determine the species composition and veld condition of the herbaceous layer of each management unit respectively. The grazing capacity of each management unit was determined by two separate methods.

The floristic diversity differed substantially between topographical features, rather than between management units. The mountainous areas were in excellent veld condition and had a high grazing capacity, while the more degraded lower regions were in poor to good condition and had substantially lower grazing capacities. Rainfall and grazing played an important role in the study area and indicated that the vegetation of Doornkloof Nature Reserve displays both equilibrial and non-equilibrial trends.

A quantitative description technique, (BECVOL3-model), was used to quantify the plant densities, species composition and above ground biomass of the woody plants of each management unit. Browsing capacities were calculated for different browsing heights (1.5m, 2m and 5m). Both plant densities and browsing capacities differed substantially between the various units. Plant densities varied from 40 plants/ha to 1 120 plants/ha, while browsing capacity varied from 4 ha/Bu to 157 ha/BU at a browsing height of 2 m. The browsing capacity did not decline substantially from the wet to the dry season, predominantly due to the abundance of evergreen species.

The habitat selection of seven ungulate species was investigated by recording sightings of game species within each habitat unit. A goodness-of-fit test was applied to the data to determine if habitat selection of game species differed from being random. Habitat selection was found not to be random. Confidence intervals were calculated by means of the Bonferroni method to determine the habitat preference of each game species. The results indicated that species had clear habitat preferences and that some species showed seasonal changes in habitat selection. Species such as buffalo and mountain reedbuck were found to be habitat specialists, while species such as eland were more habitat generalist. The results indicated that eland, kudu and warthog were thriving in the environment, while the gemsbok and mountain reedbuck population were not adapting as well as expected.

An alternative approach to conventional habitat suitability models was attempted in this study. The proposed suitability model proved to be relatively accurate in predicting both the habitat selection of game species and the quality of the habitats of DNR. The potential use of similar suitability models holds potential as a tool in assisting with objective management decisions.

Keywords: Braun-Blanquet, management units, herbaceous layer, woody layer, veld condition, grazing capacity, browsing capacity, habitat selection, suitability index.

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Appendix

Appendix Aii The Synoptic table, indicating the fidelity value of each species

Plant community	1		2		3	4				5			6		
Sub- community	**1.1**	**1.2**	**2.1**	**2.2**	**3**	**4.1**	**4.2**	**4.3**	**4.4**	**5.1**	**5.2**	**5.3**	**6.1**	**6.2**	**6.3**
Species Group A															
Aristida adscensionis	27.5	13.7							0.4	6.3					
Eragrostis chloromelas	35.3	38.3													
Chloris virgata	37.7	12													
Species Group B															
Felicia muricata	21.7														
Eragrostis obtusa	5.2														
Salsola glabrescens	4.7														
Species Group C															
Cynodon hirsitus			38.2	27.2											
Melianthus comosus			7.1	12											
Lycium cinereum			31.7			0.5									
*Urtica dioica**			7.6	8.3											
Salvia verbenaca			4.2	4.2					2.6						
Hibiscus pusillus			7	3											
Salvia disermas			4.1	2.9											
Species Group D															
Setaria verticillata			26.3												
Lycium hirsutum			26.2												
Melica decumbens			22.1												

Sub- community	1.1	1.2	2.1	2.2	3	4.1	4.2	4.3	4.4	5.1	5.2	5.3	6.1	6.2	6.3
Species Group E															
Acacia karroo			52.1	34.2	2.1										
Searsia lancea			1	38.3	35										
Diospyros lycioides			4.7	10.1	9.3										
Species Group F															
Salvia namaensis				4	22.5									2.2	
Species Group G															
Hyparrhenia hirta					17.7										
Panicum coloratum					9.4										
Species Group H															
Olea europaea subsp. *africana*					49.5	1.4	3		2.6						
Ziziphus mucronata					0.7		1.9		18						
Species Group I															
Tarchonanthus camphoratus						16.1									
Solanum lichtensteinii						6.9									
Species Group J															
Melinis repens							7.1								
Limeum aethiopicum							6.1								
Barleria rigida							4.6								
Enneapogon scaber							5.8								
Rhigozum obovatum							5.6								
Jamesbrittenia albiflora							2.9								
Species Group k															
Stipagrostis ciliata									15.8						
Dicoma capensis									8.2						
Species Group L															
Indigofera nigromontana							1.6	1.5							
Indigastrum argyroides								2		2.3					
Kohautia cynanchica							3.2			2.5					

Sub Communities	1.1	1.2	2.1	2.2	3	4.1	4.2	4.3	4.4	5.1	5.2	5.3	6.1	6.2	6.3
Species Group M															
Selago saxatilis								1.3	4		5.8				
Geigeria filifolia															
Species Group N															
Pentzia globosa												4.9			
Aptosimum marlothii									1.4	6	2.3	4			
Gnidia polycephala											3	3.8			
Phymaspermum parvifolium											2.3	1.8			
Helichrysum zeyheri											4.6	1.7			
Pteronia glauca										3	3.6				
Species Group O															
Eriocephalus spinescens							1.3					12			
Aristida congesta subsp. *congesta*												5			
Stipagrostis obtusa									1.7			7.7			
Stipagrostis uniplumis var. *neesii*												4.6			
Species Group P															
Indigofera alternans									4.9	1.2					
Nenax microphylla											5.4	5.1			
Selago geniculata							0.3		5.9						
Aptosimum procumbens								2.1							
Plinthus karooicus									3.5	2.4					
Jamesbrittenia atropupurea									2.9						
Enneapogon desvauxii												2.1			
Osteospermum leptolobum							1.8								
Rosenia humilis												2			
Hermannia linearifolia								2.4							

Sub- community	**1.1**	**1.2**	**2.1**	**2.2**	**3**	**4.1**	**4.2**	**4.3**	**4.4**	**5.1**	**5.2**	**5.3**	**6.1**	**6.2**	**6.3**
Species Group Q															
Aristida congesta						13.4	2.3			10		3.8			
Eriocephalus ericoides						2.5	1.6			1.9		12.7			
Monechma incanum						5.2									
Species Group R															
Eragrostis lehmanniana									16.5	10	19.1	1.6			
Fingerhuthia africana							4.2	4.3		2.5					
Species Group S															
Themeda triandra													16.1	30.3	49.5
Digitaria eriantha													7.7	6.8	1.9
Euclea crispa subsp. *ovata*														21.9	1.8
Stachys linearis													2.8		6.6
Cheilanthes hirta														2	
Pellaea calomelanos														3.1	
Species Group T															
Boophane disticha													4.8		
Species Group U															
Sporobolus fimbriatus														10	
Cymbopogon pospischilii														9.3	
Species Group V															
Melolobium microphyllum															3.8
Species Group W															
Cenchrus ciliaris													3.8		
Asparagus striatus														2.5	
Eustachys paspaloides													3.8		

Sub- community	1.1	1.2	2.1	2.2	3	4.1	4.2	4.3	4.4	5.1	5.2	5.3	6.1	6.2	6.3
Species Group X:															
Searsia burchellii		10.6					4	4.5							5.3
Aristida diffusa												8.3			
Searsia ciliata								3.7					4.1	4.1	
Enneapogon scoparius								3.6					3.7		
Diospyros austro-africanum					6.8									5.6	
Asparagus cooperi						4.3									
Helichrysum dregeanum															
Freesia andersoniae						2.7									
Sutera halimifolia															
Hermannia comosa															
Haemanthus humilis															
Nemesia fruticans					4.4										
Walhenbergia nodosa															
Species Group Y															
Pentzia incana		12.6				1.9						5.2			
Hermannia coccocarpa										2.8					
Species Group Z															
Chrysocoma ciliata						1.6	0.7		0.7	3	8.9	1.5			
Asparagus suaveolens			6.5				0.3			0.9					
Heteropogon contortus							11.6	6.2					11.4		
Oxalis depressa	3.2	0.8								1.2					
Homeria pallida		4.7													
Oropetium capense															
Tragus berteronianus															

Appendix Bi The succession status and ecological groups of the herbaceous plant species recorded during point survey.

Scientific name	Common name (English)	Succession status	Ecological Group
Perennial grasses			
Aristida diffusa	Iron grass	Climax	Increaser IIa
Cenchrus ciliaris	Foxtail buffalo grass	Climax	Decreaser
Cymbopogon pospischilii	Narrow-leaved turpentine grass	Climax	Increaser IIa
Digitaria eriantha	Common finger grass	Climax	Decreaser
Enneapogon scaber	Rock nine-awned grass	Climax	Increaser IIb
Enneapogon scoparius	Bottlebrush grass	Climax	Increaser IIb
Eragrostis chloromelas	Weeping love grass	Sub-climax	Increaser Ia
Eragrostis Lehmanniana	Lehmann's love grass	Sub-climax	Increaser Ia
Eragrostis obtusa	Dew grass	Sub-climax	Increaser IIb
Eustachys paspaloides	Brown Rhodes Grass	Climax	Decreaser
Fingerhuthia africana	Thimble grass	Sub-climax	Decreaser
Heteropogon contortus	Spear grass	Sub- climax	Increaser Ia
Hyperhinnia hirta	Common Thatching Gras	Climax	Increaser IIb
Melica decumbens	Staggers grass	Climax	Increaser IIb
Melinis repens	Natal red top	Sub- climax	Increaser IIb
Panicum coloratum	Small buffalo grass	Climax	Decreaser
Sporobolus fimbriatus	Dropseed grass	Climax	Decreaser
Stipagrostis ciliata	Tall bushman grass	Climax	Increaser Ia
Stipagrostis optusa	Small Bushman grass	Climax	Increaser Ia
Stipagrostis uniplumis	Silky Bushman grass	Sub- climax	Increaser Ia
Themeda triandra	Red grass	Climax	Decreaser

Annual grasses			
Aristida adscensionis	Annual Three-awn	Pioneer	Increaser IIc
Chloris virgata	Feather-top Chloris	Pioneer	Increaser IIc
Cynodon hirsutus	Kweekgras	Pioneer	Increaser IIb
Aristida congesta	Spreading Three-awn	Pioneer	Increaser IIc
Enneapogon desvauxii	Eigt day grass	Pioneer	Increaser IIc
Oropetium capense	Dwarf grass	Pioneer	Increaser IIc
Setaria verticilata	Bur bristle grass	Pioneer	Increaser IIc
Tragus betrianus	Carrot-seed grass	Pioneer	Increaser IIc
Urucloa panicoides	Garden uruchloa	Pioneer	Increaser IIc
Shrubs and forbs			
Aptostimum marlothii		Dwarf shrub	Increaser IIc
Aptostimum procumbuns		Karoo shrub	Increaser IIc
Chrysocoma ciliata		Karoo shrub	Increaser IIc
Felicia muricata		Karoo shrub	Increaser Ia
Forbs		Forb	Increaser IIc
Gnidia polychephala		Karoo shrub	Increaser IIc
Helicrysum dregeanum		Karoo shrub	Increaser Ia
Isolepis setacea		Forb	Increaser IIc
Jamesbrittenia albiflora		Forb	Increaser IIb
Eriocephalus ericoides		Karoo shrub	Increaser IIb
Eriocephalus spinences		Karoo shrub	Increaser IIb
Limeum aethiopicum		Forb	Decreaser
Melolobium microphyllum		Karoo shrub	Increaser IIc
Monechma incanum		Karoo shrub	Increaser Ia
Nenax mycrophyla		Karoo shrub	Increaser Ia
Plinthus karrooicus		Karoo shrub	Increaser Ia
Pentzia globosa		Karoo shrub	Increaser IIb

Pentzia incana		Karoo shrub	Increaser IIb
Pentzia quinquefida		Karoo shrub	Increaser IIb
Plinthus karrooicus		Karoo shrub	Increaser Ia
Salvia namahensis		Karoo shrub	Increaser IIb
Selago geniculata	Waterfinder	Karoo shrub	Increaser IIb
Selago saxatilis		Karoo shrub	Increaser IIc
Stachys linearis		Forb	Increaser IIc

Appendix Bii 1 The veld condition scores and species composition of each point survey site

Management unit	**6**
Plot no	**1**
VCS	**273**
Species	**% cover**
Aristida adscensionis	3.5
Aristida congesta subsp.bar.	3.5
Bare	5
Chrysocoma ciliata	4
Eragrostis lehmanianna	31.5
Eriocephalus ericoides	11
Gnidia polycephala	1
Jamesbrittenia albiflora	2
Pentzia globosa	8
Pentzia incana	7.5
Plinthus karooicus	6.5
Rock	0
Selaga saxatilis	13
Stipagrostis ciliata	1
total	100

Management unit	**6**
Plot no:	**2**
VCS	**497.5**
Species	**% cover**
Aristida adscensionis	2.5
Aristida congesta subsp. bar.	14
Aristida diffusa	17.5
Bare	9
Cymbopogon pospischilii	1.5
Eragrostis lehmanianna	41
Eriocephalus ericoides	1.5
Eriocephalus spinescens	0.5
Fingerhuthia Africana	4
Gnidia polycephala	0.5
Jamesbrittenia albiflora	0.5
Plinthus karooicus	0.5
Rock	0
Selaga saxatilis	5
Stipagrostis optusa	0.5
Stipagrostis ciliate	0.5
Stipagrostis uniplumis	1
total	100

Management unit	1
Plot no	**3**
VCS	**220**
Species	**% cover**
Aptosimum procumbens	0.5
Aristida congesta subsp. bar.	34.5
Aristida diffusa	3
Bare	7.5
Chrysocoma ciliate	18
Eragrostis lehmanianna	5
Eragrostis obtuse	2.5
Eriocephalus ericoides	1.5
Eriocephalus spinescens	3.5
Fingerhuthia Africana	1.5
Forbs	1.5
Heteropogon contortus	1
Pentzia globosa	9
Pentzia incana	11
Rock	0
total	100

Management unit	1
Plot no	**4**
VCS	**409.5**
Species	**% cover**
Aristida adscensionis	20.5
Aristida congesta subsp. bar.	17.5
Bare	1.5
Chrysocoma ciliate	0.5
Eragrosits chloromelas	58.5
Rock	0
Tragus berteronianus	1.5
total	100

Management unit	4
Plot no	**5**
VCS	**217.5**
Species	**% cover**
Aristida congetsa subsp. bar.	1.5
Aristida diffusa	3
Bare	67
Chrysocoma ciliate	1
Eragrostis lehmanianna	2
Fingerhuthia africana	1.5
Hyparrhenia hirta	20.5
Panicum coloratum	0.5
Pentzia incana	1.5
Rock	0
Sporobolus fimbriatus	1.5
total	100

Management unit	5
Plot no	**6**
VCS	**497.5**
Species	**% cover**
Aristida congesta subsp. bar.	2.5
Aristida diffusa	41
Bare	16.5
Chrysocoma ciliata	3
Enneapogon scoparius	9.5
Eragrostis lehmanianna	8
Eriocephalus ericoides	2.5
Fingerhuthia africana	4.5
Forbs	0.5
Heteropogon contortus	7
Melinis repens	1.5
Nenax microphylla	1
Pentzia incana	0.5
Rock	0
Selago geniculata	1
Selago saxatilis	1
Total	100

Management unit	**5**
Plot no	**7**
VCS	**298.5**
Species	**% cover**
Aristida congesta subsp. bar	29
Bare	13
Chrysocoma ciliata	21.5
Enneapogon scaber	1
Eragrostis lehmanianna	17.5
Eragrostis obtusa	0.5
Fingerhuthia africana	1
Forbs	1
Heteropogon contortus	13
Monechma incanum	2.5
Rock	0
Total	100

Management unit	**7**
Plot no	**8**
VCS	**886**
Species	% cover
Bare	0
Cenchrus ciliaris	2
Enneapogon scoparius	8
Eragrostis lehmanianna	0.5
Fingerfuthia Africana	0.5
Forbs	1
Heteropogon contortus	10
Melinis repens	0.5
Rock	2
Themeda triandra	75.5
Total	100

Management unit	**7**
Plot no	**9**
VCS	**803**
Species	**% cover**
Aristida congesta subsp. bar	5
Aristida diffusa	5.5
Bare	1
Chrysocoma ciliata	2.5
Eragrostis chloromelas	2.5
Eragrostis lehmanianna	0.5
Eragrostis obtusa	3.5
Heteropogon contortus	11
Pentzia globosa	3.5
Rock	0.5
Sporobolus fimbriatus	0.5
Stachys linearis	1
Themeda triandra	63
Total	100

Management unit	**3**
Plot no	**10**
VCS	**224.5**
Species	**% cover**
Bare	34.5
Cynodon hirsutus	49
Forbs	11.5
Melica decumbens	1
Panicum coloratum	0.5
Rock	0
Setaria verticillata	3
Sporobolus fimbriatus	0.5
Total	**100**

Management unit	**7**
Plot no	**11**
VCS	**965**
Species	**% cover**
Bare	0
Eragrostis lehmanniana	0.5
Fingerhuthia africana	1
Heteropogon contortus	3.5
Rock	2
Themeda triandra	93
Total	**100**

Management unit	**7**
Plot no	**12**
VCS	**838.5**
Species	**% cover**
Bare	2
Chrysocoma ciliate	1
Fingerhuthia africana	0.5
Heteropogon contortus	2
Rock	12.5
Sporobolus fimbriatus	1
Themeda triandra	81
Total	100

Management unit	**1**
Plot no	**13**
VCS	**509.5**
Species	**% cover**
Aristida congetsa subsp. bar	14
Bare	3
Chloris virgata	9.5
Chrysocoma ciliata	1
Eragrostis chloromelas	48
Eragrostis obtusa	1.5
Felicia muricata	14.5
Fingerhuthia africana	2
Heteropogon contortus	0.5
Pentzia incana	3.5
Pentzia quinquefida	2.5
Rock	0
Total	100

Management unit	7
Plot n0	14
VCS	683
Species	**% cover**
Aristida diffusa	1
Bare	3
Chrycocoma ciliata	4
Digitaria eriantha	2
Enneapogon scoparius	4.5
Eragrostis lehmanniana	1.5
Eustachys paspaloides	1
Heteropogon contortus	15.5
Melinis repens	1.5
Melolobium microphyllum	1.5
Rock	12.5
Sporobolus fimbriatus	4.5
Stachys linearis	2.5
Themeda triandra	45
Total	100

Management unit	1
Plot no	15
VCS	302
Species	**% cover**
Aristida adscensionis	2.5
Aristida congesta subsp. bar	38
Bare	9.5
Chloris virgata	5
Chrysocoma ciliata	5
Eragrostis chloromelas	5.5
Eragrostis obtusa	1.5
Felicia muricata	28
Heteropogon contortus	1
Rock	0
Salsola glabrescens	4
Total	100

Management unit	3
Plot no	16
VCS	286
Species	**% cover**
Bare	0
Cynodon hirsutus	46.5
Forbs	11
Melica decumbens	15.5
Rock	0
Setaria verticillata	27
Total	100

Management unit	6
Plot no	17
VCS	265.5
Species	**% cover**
Aptosimum marlothii	1.5
Aristida congesta subsp. bar.	14
Bare	19
Chrysocoma ciliata	15
Eragrostis lehmanniana	14
Eriocephalus ericoides	25
Eriocophalus spinescens	3.5
Fingerhuthia africana	0
Pentzia globosa	3.5
Pentzia incana	1.5
Rock	0
Salsola glabrescens	0.5
Tragus berteronianus	2.5
total	100

Management unit	**5**
Plot no	**18**
VCS	**437**
Species	**% cover**
Aristida congesta subsp. bar	22.5
Aristida diffusa	2.5
Bare	2
Chrysocoma ciliata	7.5
Eragrostis lehmanniana	21
Eragrostis obtusa	14
Eriocephalus spinesces	0.5
Fingerhuthia africana	2
Helichrysum dregeanum	0.5
Heteropogon contortus	19
Jamesbrittenia albiflora	0.5
Pentzia incana	6
Pentzia quinquefida	2
Rock	0
Total	100

Management unit	**5**
Plot no	**19**
VCS	**405.5**
Species	**% cover**
Aptosimum procumbens	1
Aristida adscensionis	6
Aristida congesta subsp. bar.	6.5
Aristida diffusa	18
Bare	6.5
Chrysocoma ciliata	14
Eragrostis lehmanniana	21
Eragrostis obtusa	1.5
Eriocephalus ericoides	6.5
Fingerhuthia africana	0.5
Heteropogon contortus	12.5
Pentzia globosa	1
Pentzia incana	1.5
Rock	0
Stipagrostis ciliata	3.5
total	100

Management unit	7
Plot no	**20**
VCS	**730**
Species	**% cover**
Aristida congesta subsp. bar	4
Aristida diffusa subs. burkei	1
Bare ground	1
Cenchrus ciliaris	5
Digitaria eriantha	2.5
Enneapogon scoparius	9
Fingerhuthia africana	1
Heteropogon contortus	25.5
Frobs	0.5
Melinis repens	5
Rock	1.5
Themeda trinandra	44
Total	100

Management unit	5
Plot no	**21**
VCS	**295**
Species	**% cover**
Aptosimum procumbens	1
Aristida congesta subsp. barb	34.5
Aristida diffusa subs. burkei	12
Bare ground	8.5
Chrysocoma ciliata	0.5
Digitaria eriantha	1.5
Forb	1.5
Enneapogon scoparius	2.5
Eragrostis obtusa	0.5
Eriocephalus ericoides	1.5
Fingerhuthia africana	2.5
Heteropogon contortus	6.5
Isolepis setacea	5.5
Melinis repens	2
Monechma incanum	4
Oropetium capense	7
Rock	2
Selago geniculata	6
Sporobolus fimbriatus	0.5
Total	100

Management unit	**6**
Plot no	**22**
VCS	**541**
Species	**% cover**
Aptosimum marlothii	1.5
Aristida congesta subsp. barb	9
Pantzia globosa	0.5
Chrysocoma ciliata	8
Forbs	3
Eragrostis lehmanniana	67.5
Eriocephalus ericoides	4
Eriocephalus spinescens	0.5
Pentzia incana	4
Plinthus karrooicus	1.5
Setaria verticillata	0.5
total	100

Management unit	**3**
Plot no	**23**
VCS	**313**
Species	**% cover**
Bare ground	3
Chloris virgata	0.5
Cynodon hirsitus	32
Eragrostis lehmanniana	8.5
Forb	11
Felicia muricata subs. Cinerascens	11.5
Salsola glabrescens	2.5
Setaria verticillata	31
Total	**100**

Management unit	**4**
Plot no	**24**
VCS	**464**
Species	**% cover**
Aristida congesta	7
Aristida diffusa	0.5
Forbs	5.5
Bare ground	17.5
Chrysocoma ciliata	1.5
Enneapogon scoparius	3
Eragrostis obtusa	0.5
Eriocephalus ericoides	1.5
Fingerhuthia africana	10
Heteropogon contortus	6.5
Hyparrhenia hirta	14
Melinis repens	5
Monechma incanum	4
Panicum coloratum	11
Rock	7
Sporobolus fimbriatus	0.5
Themeda triandra	5
Total	**100**

Management unit	**2**
Plot no	**25**
VCS	**598.5**
Species	**% cover**
Aristida congesta	2
Bare	3.5
Digitaria eriantha	3
Eragrostis chloromelas	58
Eragrostis obtusa	2
Eriocephalus ericoides	0.5
Forbs	0.5
Heteropogon contortus	7
Pentzia globosa	2
Pentzia incana	14.5
Rock	2.5
Themeda triandra	4.5
total	**100**

Management unit	**2**
Plot no	**26**
VCS	**523.5**
Species	**% cover**
Aristida congesta subsp. Con.	1.5
Bare	4
Cynodon hirsutus	13
Eragrostis chloromelas	50.5
Eragrostis lehmanianna	2
Eragrostis obtusa	2.5
Forbs	0.5
Heteropogon contortus	3.5
Pentzia globsa	1.5
Penzia incana	13
Rock	3
Stachys linearis	2.5
Themeda triandra	0.5
Urucloa panicoides	2
Total	**100**

Appendix Ci The phynolology values used for each woody species recorded during the BECVOL3 survey

SP_NR	SPECIES	MOD	F_L	F_S	P_01	P_02	P_03	P_04	P_05	P_06	P_07	P_08	P_09	P_10	P_11	P_12
1	*Acacia karroo*	1	0.40	0.15	1.00	1.00	1.00	1.00	0.80	0.50	0.40	0.10	0.10	0.70	0.90	1.00
2	*Diospyros austro-*	8	0.20	0.15	1.00	1.00	1.00	1.00	0.80	0.60	0.20	0.10	0.10	0.80	1.00	1.00
3	*Diospyros lycioides*	8	0.20	0.05	1.00	1.00	1.00	1.00	0.80	0.50	0.40	0.10	0.10	0.70	0.90	1.00
4	*Ehretia rigida*	8	0.30	0.05	1.00	1.00	1.00	0.90	0.80	0.50	0.40	0.10	0.10	0.70	0.90	1.00
5	*Euclea crispa*	8	0.10	0.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	*Lycium cinereum*	7	0.30	0.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	*Lycium hirsitum*	8	0.20	0.05	1.00	1.00	1.00	1.00	0.80	0.70	0.50	0.30	0.60	0.80	1.00	1.00
8	*Searsia burchelli*	8	0.20	0.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
9	*Searsia ciliata*	8	0.20	0.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
10	*Olea europeae*	8	0.50	0.20	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
11	*Searsia lancea*	8	0.30	0.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
12	*Tarchonanthus camphoratus*	8	0.10	0.05	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
13	*Ziziphus mucronata*	8	0.40	0.15	1.00	1.00	1.00	0.90	0.80	0.50	0.40	0.10	0.10	0.70	0.90	1.00

Appendix Di The Conservation status of each species according to the Red Data Book of South Africa (2004), also indicating the population trend of species in terms of increasing, decreasing or remaining stable

Species		Year assessed	Conservation status	Population trend
Scientific name	**Common name**			
Aepyceros melampus melampus	Common Impala	2008	Least Concern	Stable
Aepyceros melampus petersi	Black-faced Impala	2008	Vulnerable	Stable
Antidorcas marsupialus	Springbok	2008	Least Concern	Increasing
Tragelaphus scriptus	Bushbuck	2008	Least Concern	Stable
Tragelaphus angasii	Nyala	2008	Least Concern	Stable
Tragelaphus spekei	sitatunga	2008	Least Concern	Decreasing
Tragelaphus strepsiceros	Greater Kudu	2008	Least Concern	Stable
Tragelaphus oryx	Eland	2008	Least Concern	Stable
Oryx gazella	Gemsbok	2008	Least Concern	Stable
Hippotragus equinis	Roan Antelope	2008	Least Concern	Decreasing
Hippotragus niger	Sable antelope	2008	Least Concern	Stable
Kobus ellipsiprymnus	Waterbuck	2008	Least Concern	Decreasing
Kobus leche	Lechwe	2008	Least Concern	Stable
Kobus vardonii	Puku	2008	Near Threatened	Decreasing
Redunca arundinum	Southern Reedbuck	2008	Least Concern	Stable
Redunca fulvorufula	Mountain reedbuck	2008	Least Concern	Stable
Pelea capreolus	Grey Rhebok	2008	Least Concern	Stable
Oreotragus oreotragus	Klipspringer	2008	Least Concern	Stable
Ourebia ourebi	Oribi	2008	Least Concern	Decreasing
Raphicerus campestris	Steenbok	2008	Least Concern	Stable
Raphicerus melanotis	Cape Grysbok	2008	Least Concern	Stable
Raphiicerus sharpei	Sharpe’s Grysbok	2008	Least Concern	Stable
Neotragus moschatus	Suni	2008	Least Concern	Stable
Madoqua kirkii	Damara Dik-dik	2008	Least Concern	Stable
Sylvicapra grimmia	Grey Duiker	2008	Least Concern	Stable
Cephalophus natalensis	Red duiker	2008	Least Concern	Decreasing
Philantomba	Blue duiker	2008	Least Concern	Stable

monticola				
Damaliscus pygargus philipsi	Blesbok	2008	Least Concern	Stable
Damaliscus pygargus pygargus	Bontebok	2008	Near Threatened	Stable
Damaliscus lunatus	Tsessebe	2008	Least concern	Increasing
Alcelaphus buselaphus	Red Hartebeest	2008	Least concern	Stable
Alcelaphus lichtensteinii	Lichtenstein's Hartebeest	2008	Least Concern	Stable
Connochaetes gnou	Black wildebeest	2008	Least Concern	Stable
Connochaetes taurinus	Blue wildebeest	2008	Least Concern	Stable
Cyncerus caffer	Buffalo	2008	Least Concern	Decreasing
Equus qagga	Plains zebra	2008	Least Concern	Stable
Equus zebra zebra	Cape Mountain Zebra	2008	Vulnerable	Increasing
Equus zebra hartmannae	Hartmann's Mountain Zebra	2008	Vulnerable	Unknown
Phacochoerus africanus	Common Warthog	2008	Least Concern	Stable
Potamochoerus larvatus	Bushpig	2008	Least Concern	Stable
Giraffa camelopardalis	Giraffe	2010	Least Concern	Decreasing
Loxodonta Africana	African Elephant	2008	Vulnerable	Increasing
Ceratotherium simum	White Rhinoceros	2011	Near Threatened	Increasing
Diceros bicornis	Black rhinoceros	2011	Vulnerable	Increasing
Hippopotamus amphibius	Hippopotamus	2008	Vulnerable	Decreasing

Appendix Dii The species categories of game animals based on their impact on the environment

Species	*Species category* *(impact on inveronment)*
Blesbok	High density Category III
Bontebok	High density Category III
Buffalo	Category I
bushbuck	Category II
Bushpig	Category I
Duiker – blue	Category II
Duiker - grey	Category IV
Eland	High dentsity Category III
Elephant	Category I
Gemsbok	Category III
Giraffe	Low density Category III (Category I)
Grey Rhebok	Category II
Hartebeest – lichtensteini	Category III
Hartebeest - Red	Category IV
Hippo	Category I
Impala	Category IV
Klipspringer	Category IV
Kudu	Category IV
Lechwe	Category IV
Nyala	Category IV
Rhino – black	Category IV
Rhino- white	Low density category I
Reedbuck- Mountain	Category II
Reedbuck - Southern	Category II
Roan	Category II
Sable	Category II
Springbok	Category III
Steenbok	Category IV
Tsessebe	Category III
Warthog	High density category I
Waterbuck	Category IV
Wildebeest- Black	Category III
Wildebeest- Blue	Category III (marginal habitats)
Zebra – Hartman mountain	High density Category III
Zebra – Cape mountain	High density Category III
Zebra - plains	High density Category III

Appendix Diii Habitat consideration of game species for suitability calculations

Species	Water & Food	Vegetation structure	topography and terrain	Climate
Buffalo	Water dependant-non-mobile Bulk intermediate to tall grass grazer	**Optimal:** Woody layer C: 21 -75% Herbaceous layer H: 25 -120 cm VC: good, excellent **Marginal** Woody layer C: 11 -20%, 75 - 85% Herbaceous layer H: 12 -25 cm VC: Moderate **Unsuitable** Woody layer W: 0-10%, 85-100% Herbaceous layer H: 0 – 12 cm VC: poor, very poor	**Suitable** -Moderate steep slopes -Hills and mountainous terrain **Marginal** -Moderate slopes **Unsuitable** -Mountain Plateaus -Steep slopes	**Suitable** 400- 600mm **Marginal** 300 - 400, >600mm **Unsuitable** 0-300mm
Eland	Water independent Mixed feeders (20 -90% grass)	**Suitable** Woody layer c: 15 – 75% Herbaceous H: 15-45 cm VC: good to excellent **Marginal** Woody layer c: 5- 15, 75-85% Herbaceous layer H: 45-60cm VC: fair **Unsuitable** Woody layer W: 0 -5%, 85-100% Heraceous layer H:>60 cm VC very poor to poor	**Suitable** All terrain types All topography types except steep slopes **Marginal** -Very steep slopes **Unsuitable** **-**	**Suitable** 250-1 000mm **Marginal** 150 -250, >1 000mm **Unsuitable** 0-150mm

Gemsbok	Water independent mMxed feeder 70 -85 % Grass 15 -30 % Browse	**Suitable:** <u>Woody layer</u> C: 15 – 50% <u>Herbaceous layer</u> H: 2 – 30cm VC: good to excellent **Marginal** <u>Woody layer</u> c: 50 -75% VC: fair <u>Herbaceous layer</u> H: 30 - 60 cm VC; fair **Unsuitable** <u>Woody layer</u> c: 75-100% <u>Herbaceous layer</u> H: >60cm VC: very poor to poor	**Suitable** **Vegetation** All terrain types, Except steep slopes Sandy soils **Marginal** -Most Soils other than sandy -Steep slopes **Unsuitable** -Clayey soils	**Suitable** 150 -300mm **Marginal** 50 -150, 300-600mm **Unsuitable** 0-50mm. >600mm
Red Hartebeest	Water independent Mixed veeders 60-75% grass 40 – 25% browse	**Suitable:** <u>Woody layer</u> C: 10 – 45% <u>Herbaceous layer</u> H: 12 – 35cm VC: good to excellent **Marginal** <u>Woody layer</u> c: 0-10%, 45-60% <u>Herbaceous layer</u> H: 35 - 60 cm VC; fair **Unsuitable** <u>Woody layer</u> c: 60-100 <u>Herbaceous layer</u> H: >60cm VC: very poor to poor	**Suitable** -Flat to undulating terrain -Foot slopes of hills and ridges -Mountain plateaus All soil types **Marginal** -Moderately steep slopes **Unsuitable** Steep slopes	**Suitable** 250 – 450mm **Marginal** 150 - 250 mm **Unsuitable** 0-150mm
Kudu	Water dependent mobile Browser	**Suitable:** <u>Woody layer</u> c: 15-85% **Marginal** <u>Woody layer</u> c: 5-15% **Unsuitable** <u>Woody layer</u> c: 0- 10%	**Suitable** All soil types All topography types **Marginal** - **Unsuitable** -	**Suitable** 300 – 650mm **Marginal** 200 – 300, >650 mm **Unsuitable** 0-200mm

Rhino – black	Water dependant - mobile partly selective, bulk roughage browser	**Suitable** Woody layer c: 50-85% **Marginal** Woody layer c: 15-50%, 85-100% **Unsuitable** Woody layer c: 0- 15%	**Suitable** -Flat to undulating terrain **Marginal** -Moderate steep slopes **Unsuitable** -Steep slopes Mountain plateaus	**Suitable** 250 -800mm **Marginal** 100-250, >800mm **Unsuitable** 0-100mm
Reedbuck-Mountain	Water dependent non-mobile Selective Grazer	**Suitable** Woody layer c: 0 -15% Herbaceous layer H: 15 - 60 cm VC: good to excellent **Marginal** Woody layer c: 0-5, 26 - 50% Herbaceous layer H: 0-5,25 – 60 VC; fair **Unsuitable** Woody layer c: 50 -100% Herbaceous layer H: >60 VC: very poor to poor	**Suitable** -Very steep slopes >20 -Mountain plateaus -Rocky terrain **Marginal** - **Unsuitable** -Flat terrain without nearby cliffs or slopes -Surface without rock cover	**Suitable** 250 -800mm **Marginal** 100-250, >800mm **Unsuitable** 0-100mm
Warthog	Water dependent non-mobile Short grass grazer	**Suitable** Woody layer c: 15 - 60% Herbaceous layer H: 0 - 15 cm VC: fair to good **Marginal** Woody layer c: 10 -30, 45 -65% Herbaceous layer H: 15 – 45cm VC: very poor to poor, excellent	**Suitable** Marginal Unsuitable types such as Steep slopes	**Suitable** 450 – 750mm **Marginal** 300 -450, >750mm **Unsuitable** 0 -300mm,

		Unsuitable Woody layer c: 0-10, 65-100% Herbaceous layer H: >45cm		
Zebra – Cape mountain	Water dependent – mobile Bulk short grass to medium grass grazer	**Suitable** Woody layer c: 10 - 30% Herbaceous layer H: 6 - 45 cm VC: Good to excellent **Marginal** Woody layer c: 0 -10, 30 - 50% Herbaceous H: 45 - 60 VC: fair **Unsuitable** Woody layer C: 0-10, 65-100% Herbaceous H: >60cm VC very poor to poor	**Suitable** -Plateaus and slopes rugged, broken mountainous and escarpment areas Marginal - Unsuitable -extensive flat terrain	**Suitable** 250 -800mm **Marginal** 150-250, >800mm **Unsuitable** 0-150mm

Appendix Div. The economical aspects of game species for scoring in suitability index

Species	Average auction value (2012)	Ave annual growth 2008 -2012	Population Growth
Blesbok	R 1 226	-4.75	18-55% (mean 30%)
Bontebok	R 9 806	20%	18-55% (mean 30%)
Buffalo	R 447 494	25.75	6-18% (mean 16%)
bushbuck	R 7 135	18.24	13-52%
Bushpig	R 600	44	60-80% (mean 65%)
Duiker – blue	R 10 000 (2011)	0	15%
Duiker - grey	R 1 941	36%	20-60% (Mean 45%)
Eland	R 5 473	-10%	11-38% (mean 20%)
Elephant	R	-	2-11% (mean 7%)
Gemsbok	R 4 860	-2%	11-38% (mean 20%)
Giraffe	R 15 678	-3.25%	5-16% (Mean 12%)
Grey Rhebok	-	-	25-30 %
Hartebeest – lichtensteini	R 140 000 (2011)	19.5%	20-32% (mean32%)
Hartebeest - Red	R 3 828	-3.75%	20-32% (mean32%)
Hippo	R 34 500	-9	5-37% (Mean 14%)
Impala	R 1 122	-7	12-48% (mean 35%)
Klipspringer	R 10 000	-6	
Kudu	R 4 124	-10.25	13-30% (mean 19%)
Lechwe	R 8 533	-9.5	
Nyala	R 7 686	9%	18-35% (mean 28%)
Rhino – black	R 200 000	-9.25%	3-15% (mean 8%)
Rhino- white	R 231 807	-9.25%	5-15% (mean 8%)
Reedbuck- Mountain	R 3 110	6.75	25-35% (mean 29%)
Reedbuck - Southern	R 7 299	4%	15-25% (mean 21%)
Roan	R 223 650	77.5%	7-25%(mean 22%)
Sable	R 178 121	22.25%	12-28% (mean 19%)

Springbok	R 1 451	3.25%	28-45% (mean 33%)
Steenbok	R 4 355	33%	21-32% (mean 27%)
Tsessebe	R 14 317	-1.25%	25.7%
Warthog	R 1 000	28%	65-120% (mean 75%)
Waterbuck	R 4 311	-8.75%	15 - 35% (mean 28%)
Wildebeest- Black	R 2 192	-9.5	28-37% (mean 32%)
Wildebeest- Blue	R 2 156	-9.5%	28-33% (mean 30%)
Zebra –Hartmanmountain	R 9 108	-6	17-35% (mean 25%)
Zeba – Cape mountain	R 11 704	-14.5%	15-29% (mean 20%)
Zebra - plains	R 4 262	-10.75	15-29%