# Impacts of degradation on critically endangered Oudtshoorn Gannaveld



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Supervisor: Dr. R. Knight.

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This thesis is dedicated to my late father, William Edgar Wheeler.

**DECLARATION**

I ALAN DAVID WHEELER declare that “Impacts of degradation on critically endangered Oudtshoorn Gannaveld” is my own work, that it has not been submitted before for any degree or assessment in any other university, and that all the sources I have used or quoted have been indicated and acknowledged by means of complete references.

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Date: 3 March 2010

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**Abstract**

In the Succulent Karoo biome of South Africa vegetation degradation by overgrazing is a recognized threat to biodiversity. In the eastern Little Karoo region of the Western Cape Province, ostrich farming has degraded large areas of natural vegetation, particularly in the Gannaveld habitat of the Oudtshoorn basin. Little quantified vegetation data exists on the impacts of degradation and the composition of the Gannaveld vegetation types. This study quantifies the composition of Oudtshoorn Gannaveld and the impacts of degradation on this critically endangered vegetation type. The diversity of this vegetation type is added to by the occurrence of mima-like circular soil mounds, termitaria, which support distinctive plant assemblages. Perennial plant data and soil data were collected from the largest remaining remnant of Oudtshoorn Gannaveld perceived to contain different levels of degradation from near pristine to severely degraded. The results show 72 species in 49 genera and 17 families were recorded with the Aizoaceae, Asteraceae and Amaranthaceae families being dominant. The off termitaria plant community is dominated by the Asteraceae, Aizoaceae and Crassulaceae families while the on termitaria community is dominated by the Asteraceae, Amaranthaceae and Zygophyllaceae families. Four levels of degradation were identified in each of the broader on and off termitaria communities. It was found that grazing and trampling induced degradation on termitaria results in the loss of perennial plant cover and plant litter and an increase in bare ground while degradation off termitaria results in a loss of species. There are changes in soil chemistry both on and off termitaria as a result of vegetation degradation. Degradation results in palatable species being replaced by unpalatable and disturbance indicating species. Perennial plant cover off termitaria is resilient to grazing and trampling, however species richness, plant functional type composition and the abundance of individual species are not. Species richness on termitaria is resilient to grazing and trampling but cover, plant functional type composition and the abundance of individual species are not. Degradation results in shifts from succulent and woody shrub dominated communities to dwarf succulent and dwarf succulent shrub dominated communities. These changes hold implications for agriculture, biodiversity conservation and the provision of ecosystem services.

## Acknowledgements

I wait eagerly for the Lords help, and in his word I trust. Psalms 130:5.

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I would especially like to thank my wife and children for the patience, understanding and support they have shown throughout the time I have been busy with this study.

**Impacts of degradation on critically endangered Oudtshoorn Gannaveld**

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## Thesis structure

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This thesis is divided into two sections, section A and section B.

Section A provides background to the study and descriptions of the Oudtshoorn Gannaveld vegetation type. Section B describes the patterns and processes of degradation in Oudtshoorn Gannaveld.

Section A consists of three chapters. In chapter one I outline the main objective of the study and the research questions I focus on in each chapter. I contextualise the study through a general introduction that places it within the larger framework of biodiversity conservation and vegetation degradation in the Succulent Karoo biome of South Africa. I discuss the importance of Little Karoo plant diversity and the impact of past land management practices in the region, particularly on the Gannaveld habitat type. I discuss the conservation status and the current threats to vegetation types in these highly threatened areas of the Little Karoo. In chapter two I quantify the perennial plant composition of the most critically endangered vegetation type in the Gannaveld habitat, Oudtshoorn Gannaveld. Chapter three focuses on the differences between the two major vegetation communities in the Gannaveld habitat type, the on termitaria community and off termitaria community.

Section B consists of four chapters. In chapter four I determine the different plant communities that occur within the broader on termitaria and off termitaria communities of Oudtshoorn Gannaveld and analyse the differences between them. In chapter five I assess the condition of each of these vegetation communities based on various indicators of degradation in semi-arid areas. In chapter six I discuss the characteristics of each of these communities. Chapter seven is a general discussion chapter for section B where I discuss processes of degradation and implications for biodiversity conservation and agriculture in the Little Karoo, South Africa.

**Study objectives**

The main objective of this study is to describe and characterise degradation in a critically endangered vegetation type of the Little Karoo in South Africa, Oudtshoorn Gannaveld. Arising from this objective a number of research questions can be formulated. These questions are addressed in the following chapters.

**Section A**

**Chapter 1. General introduction.**

The general introduction chapter contextualises the study, placing it within the larger framework of biodiversity conservation in the Succulent Karoo biome of southern Africa.

**Chapter 2. Quantitative vegetation description of Oudtshoorn Gannaveld**

In this chapter I determine the composition of the persistent perennial plant component of critically endangered Oudtshoorn Gannaveld. The research question for this chapter is:

- What is the perennial plant composition of Oudtshoorn Gannaveld?

**Chapter 3. On and off termitaria perennial plant communities of Oudtshoorn Gannaveld**

In this chapter I discuss the on termitaria and off termitaria vegetation of the Oudtshoorn Gannaveld vegetation type, comparing the vegetation on mima-like earth mounds or "heuweltjies" and the matrix vegetation and discussing the differences between these two distinct plant communities. The research question for this chapter is:

- What are the differences in composition between termitaria and off termitaria vegetation communities in Oudtshoorn Gannaveld?

**Section B**

**Chapter 4. Determining plant communities on and off termitaria**

In this chapter I determine the different plant communities that occur in the broader on and off termitaria vegetation communities of Oudtshoorn Gannaveld and analyse the differences between them. The research question for this chapter is:

- Are there distinct perennial plant communities within the broader on and off termitaria plant communities of Oudtshoorn Gannaveld?

**Chapter 5. Determining the vegetation condition of communities**

In this chapter I determine the condition of the different vegetation communities identified in the on and off termitaria plant communities of Oudtshoorn Gannaveld. The research question for this chapter is:

- Do different vegetation communities on and off termitaria in Oudtshoorn Gannaveld represent different states of vegetation condition?



**Chapter 6. Community characteristics**

In this chapter I describe the characteristics of the different vegetation communities identified on termitaria and off termitaria in Oudtshoorn Gannaveld and the processes of degradation in each.

The research questions for this chapter are:

- What are the characteristics of plant communities on and off termitaria that indicate Oudtshoorn Gannaveld in an intact condition?
- What are the characteristics of plant communities on and off termitaria that indicate Oudtshoorn Gannaveld in a degraded condition?

- What compositional shifts take place between intact and degraded conditions of on and off termitaria vegetation in Oudtshoorn Gannaveld?

**Chapter 7. General discussion**

Chapter seven is the general discussion chapter for section B where I discuss processes of degradation and implications for biodiversity conservation and agriculture in the Little Karoo.

**Section A**

**Chapter 1**

## General introduction

South Africa falls within two of the worlds six floral kingdoms, the Paleotropical Floral Kingdom and the Cape Floral Kingdom and is divided into nine biomes (Mucina and Rutherford 2006) representing nine major habitat types (Rouget *et al.* 2004) (Table 1). The Cape Floral Kingdom of South Africa contains Fynbos, Forest, Nama Karoo, Succulent Karoo and Thicket biomes.

Located in the Succulent Karoo biome, the Little Karoo (Figure 1) is an east - west oriented semi desert valley lying between two parallel mountain ranges of the Western Cape of South Africa (Le Maitre *et al.* 2007). The Langeberg, Outeniqua, Tsitsikamma mountain range separates the Little Karoo from the coast in the south and the Witteberg, Swartberg, Baviaanskloof mountain range separates it from the Great Karoo in the north. The area extends approximately from the town of Uniondale in the east to Montagu in the west (Cupido 2005, Vlok *et al.* 2005). The mountains receive relatively high rainfall (> 900 mm per year), but the lower lying areas lie in a rain shadow and receive only between 150 mm and 350 mm annually (Le Maitre *et al.* 2007).

Table 1

The biomes of South Africa showing area in km$^2$ covered by the biome, the percentage of South Africa covered by the biome and the percentage of the biome protected in formally protected areas (Rouget *et al.* 2004).

| Biome | area (km$^2$) | % total area | % protected |
|---|---|---|---|
| Fynbos | 84 580 | 6.7 | 11 |
| Grassland | 373 984 | 29.5 | 1.9 |
| Savanna | 412 753 | 32.6 | 8.9 |
| Albany Thicket | 30 256 | 2.4 | 6.3 |
| Wetlands | 16 790 | 1.3 | 4.6 |
| Desert | 8 548 | 0.7 | 12.5 |
| Forest | 4 730 | 0.4 | 39.6 |
| Succulent Karoo | 85 207 | 6.7 | 3.1 |
| Nama Karoo | 250 069 | 19.7 | 0.6 |

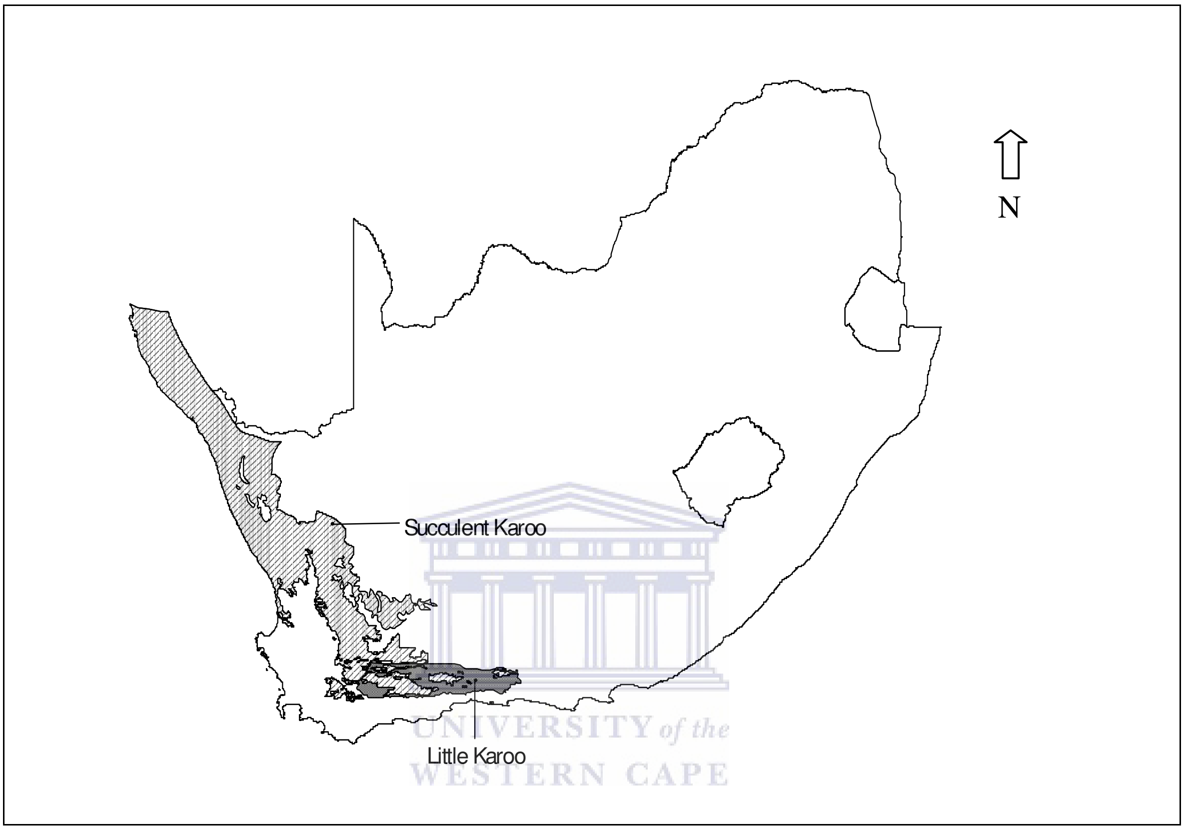




Figure 1

Map of South Africa showing the Succulent Karoo Biome and the Little Karoo area.

The Little Karoo has been identified through a number of processes as an area of critically important biodiversity. It contains three of 34 global biodiversity hotspots, the Succulent Karoo, Maputaland - Pondoland - Albany and the Cape Floristic Region Biodiversity hotspots (Figure 2). Biodiversity hotspots are identified as the most biologically rich and the endangered terrestrial eco-regions on earth. They contain at least 1 500 species of vascular plants as endemic species and have lost 70% or more original habitat (Mittermeier *et al.* 2005).

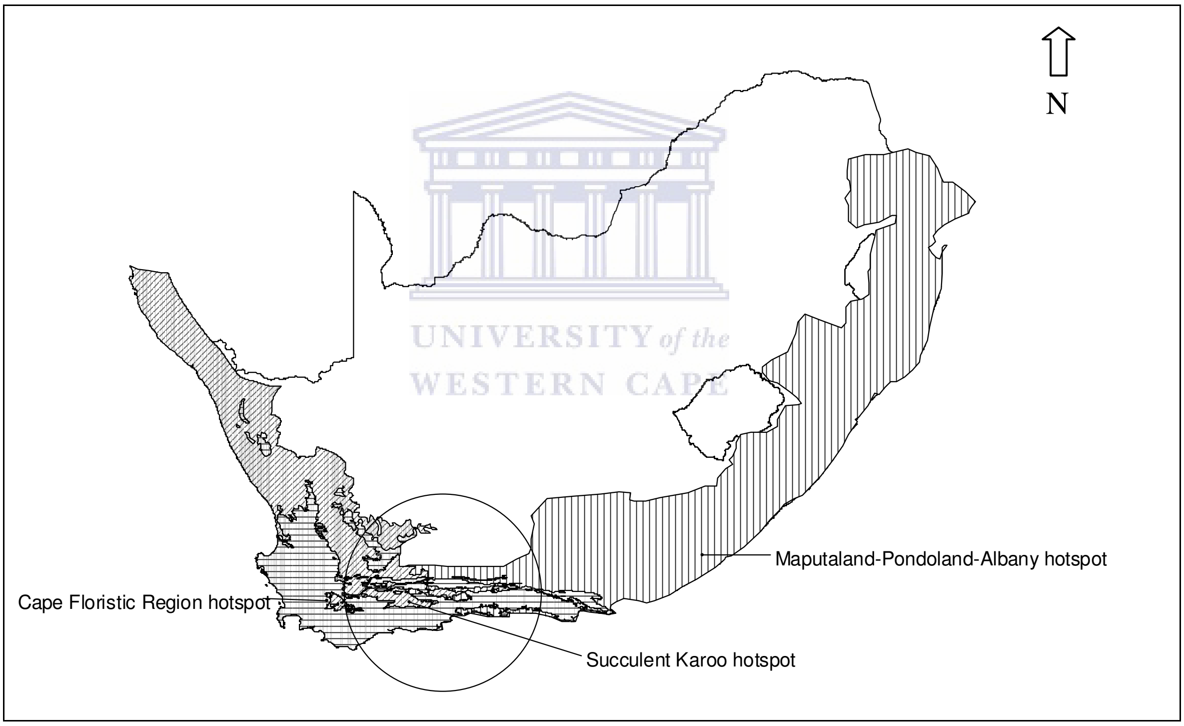


Figure 2

Map of South Africa showing the Maputaland-Pondoland-Albany, Cape Floristic Region and Succulent Karoo biodiversity hotspots (Mittermeier *et al.* 2005). The circle shows the intersection of the three hotspots in the Little Karoo.

The Succulent Karoo biodiversity hotspot that extends from the southwest of South Africa through the north-western areas of South Africa and into southern Namibia (Anonymous 2008) has extraordinarily high plant endemism. The Succulent Karoo has the richest succulent plant diversity in the world (Desmet and Cowling 2005). More than 6 350 vascular plant species have been recorded in this hotspot, with approximately 2 440 (38%) species endemic and 936 (15%) International Union for Conservation of Nature (IUCN) Red Data listed species (Driver *et al.* 2003). The Monte desert that extends from north to south in central and western Argentina is mostly uniform in terms of its physiognomy and floristic composition despite the vast area it covers (50 million hectares) and the associated variability in soils and climate (Guevara *et al.* 1997). At the 0.1 hectare scale, succulent karoo communities have the third highest richness of all the southern African biomes and are significantly higher than those from the Nama-Karoo. This richness in the Succulent Karoo is higher than that recorded for Sonoran Desert communities which are regarded as some of the most species-rich vegetation in North Africa, and is comparable to the richness from the winter rainfall, semi-arid steppes and deserts of the middle east (Cowling and Hilton Taylor 1999). Succulent Karoo diversity is higher than the Mojave and Colorado Deserts of southern California, an area of approximately 10 million hectares (Lovich and Bainbridge 1999).



Using priority scores obtained for species, habitats and ecological processes across the nine biomes to identify overall priority conservation areas in South Africa (Table 2), the South African National Spatial Biodiversity Assessment (NSBA) (Rouget *et al.* 2004) identified the Succulent Karoo Biome as a priority terrestrial conservation area. However, at the broader scale of the NSBA mapping, the Gannaveld habitat of the Little Karoo is included with numerous other vegetation types into the Gamka thicket vegetation type and is categorised as poorly protected and least threatened (Rouget *et al.* 2004). Despite this certain Succulent karoo vegetation types in the Little Karoo are critically endangered (Reyers 2008).

Table 2

South Africa’s nine priority terrestrial conservation areas (Rouget *et al.* 2004).

| South African priority terrestrial conservation areas |
| --- |
| North Eastern Escarpment |
| Bushveld-Bankenveld |
| Wet Grasslands |
| Dry Grasslands |
| South Eastern Escarpment |
| Maputaland Pondoland |
| Albany Thicket and Wild Coast |
| Cape Floristic Region |
| Succulent Karoo |

The Succulent Karoo Ecosystem Plan (SKEP), a plan to develop an overarching framework for biodiversity conservation and sustainable development in the Succulent Karoo biodiversity hotspot (Anonymous 2008) identified the Central Little Karoo as one of nine geographic priority areas of South Africa and Namibia for conservation in the Succulent Karoo biome (Driver *et al.* 2003) (Figure 3). This Succulent Karoo priority area is currently part of a Western Cape Nature Conservation Board application to the IUCN for world heritage site status.

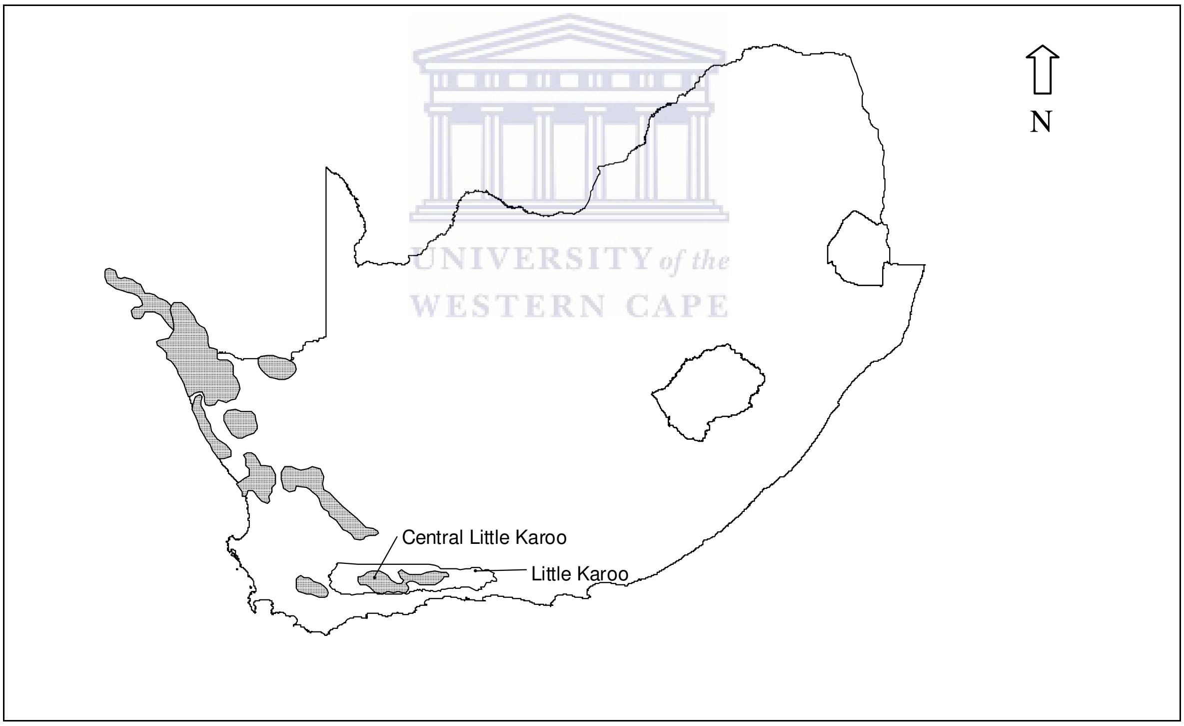




Figure 3

Map of South Africa showing the Little Karoo area and the Succulent Karoo Ecosystem Programmes nine priority conservation areas. The SKEP Central Little Karoo priority area falls within the Little Karoo.

Locally, the Little Karoo is recognised as a critical biodiversity area within the Gouritz Initiative planning domain. The Gouritz Initiative is a landscape scale biodiversity conservation initiative funded by the Critical Ecosystems Partnership Fund and implemented by the Western Cape Nature Conservation Board. The Gouritz Initiative aims to restore priority biodiversity in the planning domain by establishing partnerships and creating social and economic opportunities that benefit local communities. It incorporates a planning domain first identified by the CAPE Project (Cape Action for People and the Environment), as the core for the proposed Gouritz Mega Reserve (Cowling *et al.* 1999b).

In an overview of the eco-regional planning process it was recommended that the Little Karoo Mega Park be established (Younge and Fowkes 2003). The Gouritz Initiative domain was further delineated and important biodiversity patterns and processes identified through a number of expert workshops held during 2003 (Lombard and Wolf 2004) (Figure 4). One of the major focuses of the Gouritz Initiative is to promote sustainable land management in the Little Karoo (Lombard and Wolf 2004).

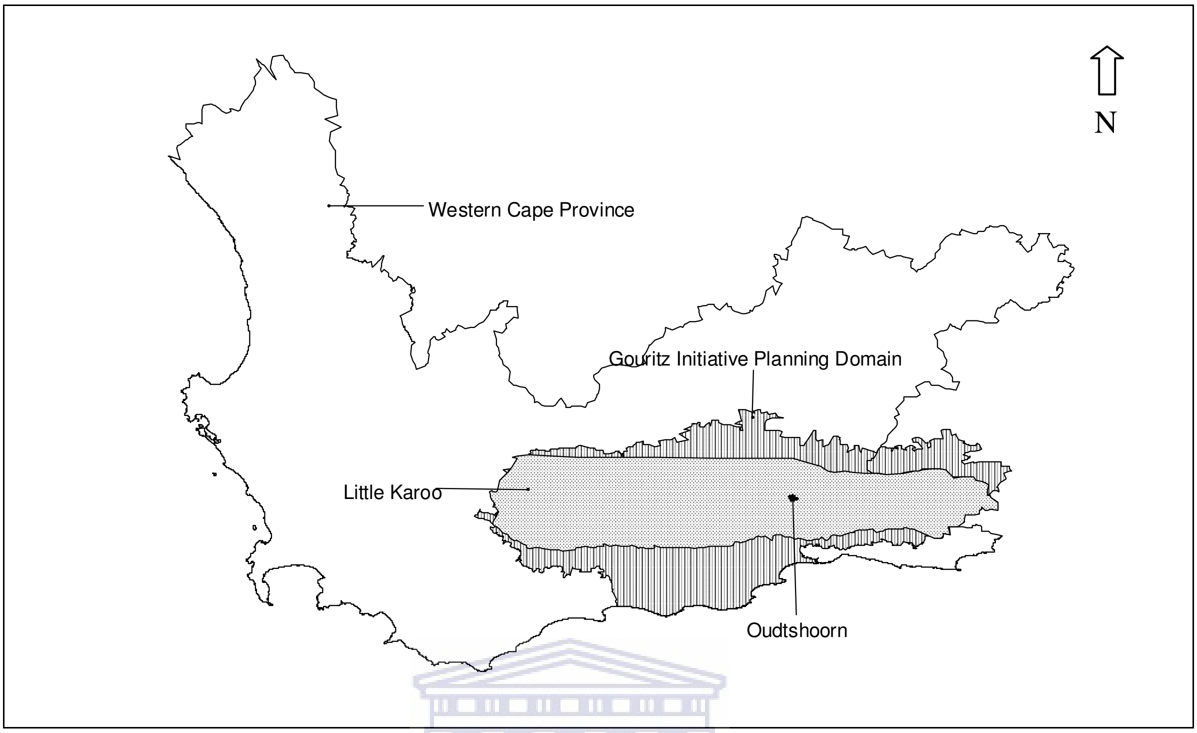




Figure 4

Map of South Africa showing the Western Cape Province boundary, the Gouritz Initiative planning domain, the Little Karoo area and the town of Oudtshoorn.

The diversity and complexity of Succulent Karoo habitats resulting from variable topography, geology and rainfall (Dean and Milton 1999) has been further revealed through fine scale vegetation mapping of the Little Karoo (Vlok *et al.* 2005). The vegetation mapping project identified 369 vegetation units in 56 habitat types in the Little Karoo. As vegetation maps also serve as convenient and effective ways of mapping habitats (Rouget *et al.* 2004) the vegetation map of the Little Karoo shows that the area encompasses a remarkable biological diversity.

This fine scale vegetation mapping reveals more closely the true diversity of the Little Karoo compared to the more broadly classified vegetation types of the South African National Spatial Biodiversity Assessment (NSBA) (Rouget *et al.* 2004).

Unfortunately much of the Little Karoo vegetation has been degraded. The Little Karoo has been the centre of ostrich farming in South Africa since the early 1860s (Cupido 2005, Thompson *et al.* 2009) and stocking densities have far exceeded a natural density of approximately 1 ostrich per 100 hectares (Esler *et al.* 2006). Ostrich farming is recognised as the major agent of habitat degradation in the region (Beinhart 2003, Cupido 2005, Thompson *et al.* 2005, Thompson *et al.* 2009).

The State of the Environment Overview Report (Anonymous 2004) highlighted poor vegetation condition and soil degradation in the Little Karoo specifically around the towns of Oudtshoorn and Calitzdorp, and a study of the transformation of Little Karoo vegetation (Thompson *et al.* 2005) revealed a large proportion of the vegetation of the lower lying areas of the Little Karoo having undergone severe degradation. Kirkwood *et al.* (2007) show a high percentage of the Little Karoo vegetation, in the ostrich farming areas in particular, to be critically endangered or endangered. These areas are classified in the Western Cape Nature Conservation Board Integrated Biodiversity geographic information Layers (IBL) as Critical Biodiversity Areas. A conservation assessment by Reyers (2008) highlights the severity of the degradation, showing that of the 369 vegetation units in the Little Karoo, 25 are critically endangered (there is less natural vegetation left than the minimum size needed to protect the unit), 29 vegetation units are endangered (there is less than the minimum area needed + 15%) and 30 vulnerable vegetation units (less than 60% of the vegetation type left).

Thompson *et al.* (2009) found that grazing and browsing induced habitat degradation is widespread in the Little Karoo with approximately 91% of the semi-arid natural habitat degraded to some extent. It was found that degradation was most severe in the lower lying “bottomland” and pediment habitats of Gannaveld and Apronveld. This is where free ranging ostrich production is concentrated because of the gentle slope and relatively low vegetation structure (Cupido 2005).

The deterioration of semi-arid rangelands in general as a result of overstocking with domestic animals has been well documented (Noy-Meir *et al.* 1989, Westoby *et al.* 1989, Olsvig-Whittaker *et al.* 1993, Milton *et al.* 1994, Milton and Hoffman 1994, Stokes 1994, Todd and Hoffman 1999, Cupido 2005). The responses of vegetation to overstocking in the Succulent Karoo include loss of species diversity and a reduction of plant canopy cover (Palmer *et al.* 1999); a loss of palatable species and an increase in spiny and less palatable species (Todd and Hoffman 1999); an increase in the cover of annuals and short lived creeping succulents (Cupido 2005; Esler *et al.* 2006); an increase in water run-off and soil erosion (Le Maitre *et al.* 2007); and a simplification of vegetation into a more homogenous shrub layer (Thompson *et al.* 2009). When herbivory becomes sufficient to prevent seeding of palatable plants, palatable shrubs will be replaced by seedlings of unpalatable plants. Continual grazing that prevents palatable species from reproducing will result in the eventual disappearance of palatable species. Long lived unpalatable species and thorny shrubs will become dominant. More intense herbivory will destroy most perennial seedlings before they set seed. Few of the longer lived shrubs have dormant seeds so there is no soil stored seed bank. This results in the loss of perennial species from the system and ephemeral species with dormant seed emerge (Esler *et al.* 1992, Esler 1993).

These effects of rangeland overstocking on the long-lived plant communities in arid areas may take decades to become obvious (O'Connor and Roux 1995, Wiegand and Milton 1996). By the time these changes do become evident it may not be possible for the vegetation to rehabilitate without active human intervention (Wiegand and Milton 1996). Large periodic mortality and recruitment events are known to be key processes driving the dynamics of semi-arid plant communities and establishment events can determine the composition of plant communities for long periods (Jeltsch *et al.* 1999).

The major cause of plant mortality in these communities is drought, especially after high rainfall periods (Wiegand *et al.* 1995). Mortality and recruitment in these communities also depends on the drought tolerance of species, their longevity and their competitive ability (Milton *et al.* 1999). However, domestic livestock grazing may be able to override weather patterns and influence the dynamics of the plant populations (Milton and Hoffman 1994, O’Connor and Roux 1995).



Also, to actively rehabilitate degraded karoo rangeland may not always be practical or economical and may require costly active intervention by the land manager (Milton and Hoffman 1994, Novellie 1999, Herling *et al.* 2007). Even though detecting change in karoo vegetation is difficult because of the slow rate of population turnover (Yeaton and Esler 1990), small positive or negative responses to grazing treatment may be consistent in direction and can accumulate considerable magnitude over time (Vorster 1999). It is therefore important to understand the changes that take place as vegetation degrades in the Little Karoo and be able to identify grazing induced vegetation degradation early.

However, in the Little Karoo, although fine scale information is available on the complex diversity of vegetation at a vegetation unit level (Vlok *et al.* 2005), quantitative studies of plant community composition and structure and the finer levels of domestic stock induced vegetation change are lacking. These individual vegetation units constitute critical components of the Little Karoo environment and must be understood in order to inform decisions and actions necessary to conserve the biodiversity of the region (Vlok *et al.* 2005). With the lack of information regarding the composition of the vegetation types of the Gannaveld habitat and the importance of understanding the impacts that ostrich farming has on this highly threatened ecosystem, the quantification of Oudtshoorn Gannaveld and the changes that take place in this vegetation type are critical for the long term management of Gannaveld in the Little Karoo.



The Oudtshoorn basin of the Little Karoo (Figure 5) is an area dominated by Succulent Karoo vegetation and lies between the towns of Oudtshoorn and Calitzdorp. It is the area in which ostrich farming in the Little Karoo has been most concentrated for more than 150 years (Thompson *et al.* 2009). The area lies within the Olifants River - Gamka Agricultural Region and is considered to be the most important ostrich producing region in South Africa with more than 70% of all ostrich products produced here (Cupido 2005, Murray 2008b).

These low lying areas of the Oudtshoorn basin consisting of dwarf, succulent shrublands associated with the Succulent Karoo biome (Thompson *et al.* 2009) are made up predominantly of the Gannaveld and Apronveld vegetation types (Vlok *et al.* 2005). The Gannaveld habitat type occurs on the large flatter plains, above the river and floodplain habitat types (Vlok *et al.* 2005) and is where ostrich farming has had the greatest impact on vegetation condition in the Little Karoo (Cupido 2005).

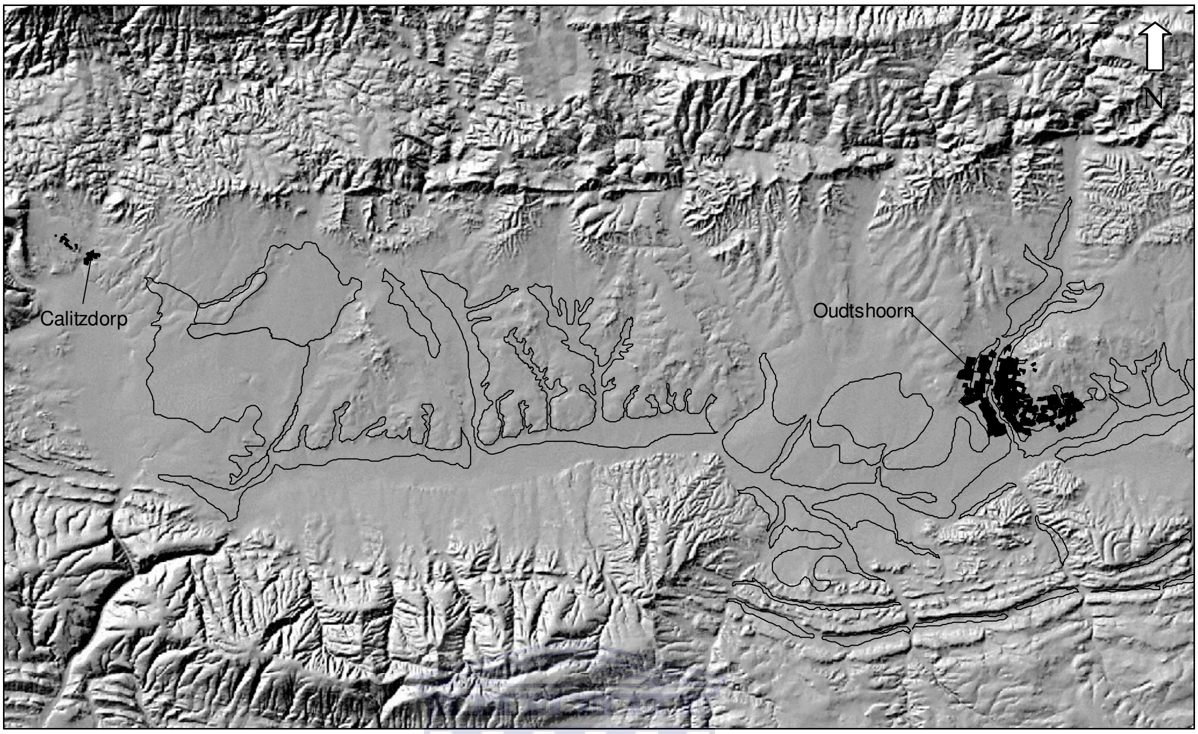


Figure 5

The Oudtshoorn basin between the towns of Oudtshoorn and Calitzdorp. The black boundary indicates the original extent of the Gannaveld habitat in the Oudtshoorn basin (Vlok *et al.* 2005).

The Gannaveld habitat varies greatly in species composition and structure resulting in 26 recognised Gannaveld vegetation units (Vlok *et al.* 2005). Reyers (2008) categorised the conservation status of Little Karoo vegetation types using conservation targets set for each unit and based on the Vlok *et al.* (2005) fine scale vegetation map and Little Karoo vegetation transformation mapping (Thompson *et al.* 2005). The 26 Gannaveld habitat vegetation types and conservation status are shown in Table 3.

Table 3. Gannaveld habitat vegetation types showing original extent in hectares (Total), area that has been severely transformed (Severe), area that has been totally transformed (Trans), the remaining natural area (Rem) which is a combination of pristine and moderately transformed vegetation, the conservation target in hectares (Target ha), the current percentage of the conservation target achieved in terms of natural vegetation (% of target) and the conservation status of the vegetation type (Reyers 2008). CR = critically endangered; EN = endangered; VU = vulnerable; LT = least threatened.

| Vegetation type | Total | Severe | Trans | Rem | Target ha | % of target | Status |
|---|---|---|---|---|---|---|---|
| Oudtshoorn Gannaveld | 9993 | 2077 | 7307 | 609 | 2298 | -17 | CR |
| Volmoed Gannaveld | 6692 | 1527 | 4186 | 979 | 1539 | -8 | CR |
| Montagu Gannaveld | 2833 | 516 | 1875 | 442 | 652 | -7 | CR |
| Kruisrivier Gannaveld | 2444 | 2062 | 0 | 382 | 562 | -7 | CR |
| Doornkloof Gannaveld | 2274 | 1876 | 1 | 397 | 523 | -6 | CR |
| Koktyls Gannaveld | 825 | 605 | 0 | 220 | 190 | 4 | EN |
| Calitzdorp Gannaveld | 4269 | 3071 | 42 | 1156 | 982 | 4 | EN |
| Van Zylsdamme Gannaveld | 729 | 74 | 448 | 207 | 168 | 5 | EN |
| Lemoenshoek Gannaveld | 2874 | 1400 | 472 | 1002 | 661 | 12 | EN |
| Grootrivier Gannaveld | 4771 | 3062 | 0 | 1709 | 1097 | 13 | EN |
| Vlakteplaas Gannaveld | 4086 | 744 | 1652 | 1690 | 940 | 18 | VU |
| Rheboksfontein Gannaveld | 2835 | 1196 | 435 | 1204 | 652 | 19 | VU |
| Ladismith Gannaveld | 7297 | 3569 | 199 | 3529 | 1678 | 25 | VU |
| Algerynskraal Gannaveld | 664 | 122 | 213 | 329 | 153 | 27 | VU |

Table 3 continued.

| Vegetation type | Total | Severe | Trans | Rem | Target ha | % of target | Status |
|---|---|---|---|---|---|---|---|
| Hartbeesvlakte Gannaveld | 2513 | 985 | 112 | 1416 | 578 | 33 | VU |
| Koeniekuils Gannaveld | 20387 | 6406 | 1191 | 12790 | 4689 | 40 | LT |
| Kandelaars Gannaveld | 1634 | 194 | 329 | 1111 | 376 | 45 | LT |
| Leopard Rock Gannaveld | 229 | 9 | 57 | 163 | 53 | 48 | LT |
| Nouga Gannaveld | 2648 | 364 | 328 | 1956 | 609 | 51 | LT |
| Touws Gannaveld | 1833 | 427 | 19 | 1387 | 422 | 53 | LT |
| Puts Gannaveld | 2400 | 391 | 149 | 1860 | 552 | 55 | LT |
| Brakrivier Gannaveld | 3295 | 536 | 178 | 2581 | 758 | 55 | LT |
| Spreeufontein Gannaveld | 509 | 37 | 36 | 436 | 117 | 63 | LT |
| Boerboonleegte Gannaveld | 4063 | 359 | 216 | 3488 | 934 | 63 | LT |
| Ratelfontein Gannaveld | 3933 | 447 | 0 | 3486 | 905 | 66 | LT |
| Sandfontein Gannaveld | 1315 | 76 | 27 | 1212 | 302 | 69 | LT |

The Oudtshoorn Gannaveld vegetation type is the most critically endangered vegetation type in the Gannaveld habitat in Little Karoo Succulent Karoo vegetation. The remaining natural Oudtshoorn Gannaveld area, consisting of moderately transformed and pristine areas, contributes only 6.1% to the conservation target of 23% (Reyers 2008). None of this vegetation type is formally protected and it remains under severe threat from ostrich farming activities.

Cupido (2005) found that ostrich farmers are most likely to overestimate their grazing capacity by more than 66% and more than 80% of the farmers believed their vegetation to be in good to excellent condition, while fewer than 3% believed their vegetation to be in a degraded condition. This is in contrast to the findings of Thompson *et al.* (2009) that 91% of remaining natural habitat in the Little Karoo is degraded to some extent. Murray (2008a) shows current ostrich stocking densities far in excess of the 22.8 hectares per ostrich recommended by the Western Cape Provincial Department of Agriculture. This figure is based on the voluntary information supplied by ostrich farmers taking part in the South African Ostrich Business Chamber Biodiversity Project. Accurate stocking density data for most of the farms in the low lying habitats of the Little Karoo are very difficult to obtain with a survey that managed to cover 20% of the Little Karoo breeding ostriches deemed to be the only available information regarding the stocking densities range based breeding (Murray 2008a). However, a recent survey (Shaw 2008) found that all ostrich farming areas sampled in the Little Karoo low lying vegetation types fell well below an average biodiversity integrity rating.

The ostrich industry is the dominant economic driver of the Little Karoo and has a substantial influence on socio-economic conditions of the region. An agricultural economics study of the economic importance of the ostrich farming industry to the Little Karoo (Murray 2008a) shows that at least 75% of ostrich output originates from the Western Cape, with the Little Karoo ostrich farming areas dominating production. South Africa accounts for 90% of ostrich products traded internationally, contributing R1.2 billion per annum to the South African economy. In the Little Karoo ostrich production represents 72% of total farm output in the region and 29.2% of all employment is agricultural sector related (Anonymous 2006). Murray (2008b) estimates that the agricultural sector in general, and the ostrich industry in particular, provides for as much as 50% of regional output of more than R900 million per annum.



Although there has been much research focus on stock farming impacts on Karoo vegetation (Campbell *et al.* 2006) very little quantitative data on vegetation degradation exists for the Succulent Karoo vegetation types of the Little Karoo. This study focuses on a distinct vegetation type within the Succulent Karoo, critically endangered Oudtshoorn Gannaveld. It is hypothesised that apart from natural patchiness, vegetation degradation has resulted in the occurrence of other distinct plant communities. It may be possible to interpret the characteristics of these communities as representing vegetation condition or state (Westoby *et al.* 1989). Changes in perennial plant composition and abundance between these states will provide new insight into degradation processes in this lowland habitat.

Although one could theoretically expect certain broad vegetation community responses to degradation in this area based on previous research on Succulent Karoo vegetation, the finer levels of degradation induced vegetation change have yet to be tested in the Little Karoo Gannaveld vegetation. No vegetation data quantified to the extent of the study exists for this vegetation type or habitat. In the Little Karoo the main threat to critically important biodiversity is the most important economic industry so understanding degradation patterns and processes is crucial to inform future land management practices.

# Chapter 2

## Quantitative vegetation description of Oudtshoorn Gannaveld

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## Introduction

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The vegetation of the Karoo-Namib region (Werger 1978) is divided into the Succulent Karoo (strongly winter rainfall area) and the Nama Karoo (non-seasonal rainfall area) regions (Jürgens 1991) based on phytogeographical divisions. The Succulent Karoo is one of South Africa's nine biomes (Rouget *et al.* 2004) and receives low but relatively predictable rainfall from cold fronts during the winter months. Minimum temperatures are higher than other parts of the Karoo (Desmet and Cowling 1999). The Little Karoo area of the Succulent Karoo biome lies in a transitional zone between winter and summer rainfall conditions (Desmet and Cowling 1999) with the largest rainfall events usually occurring in spring and autumn.



Succulent Karoo floral composition differs from the Nama Karoo and other arid areas in southern Africa (Cowling and Hilton-Taylor 1999) and contains the worlds richest succulent flora (Cowling *et al.* 1999a) having, at the 0.1ha scale, the third highest plant species richness of all biomes in southern Africa (Cowling and Hilton-Taylor 1999). The biome consists of short, scrubby vegetation (Milton 1990) dominated by leaf succulent dwarf shrubs associated with the Aizoaceae, Asteraceae, Liliaceae, Crassulaceae, Euphorbiaceae and Asclepiadaceae families (Cowling and Hilton-Taylor 1999). Grasses are rare (Low and Rebelo 1998).

There have been various descriptions of the vegetation of the Succulent Karoo (Acocks 1975, Rutherford and Westfall 1986, Low and Rebelo 1998, Mucina and Rutherford 2004, Rouget *et* *al.* 2004) and vegetation mapping has been carried out through the Succulent Karoo Ecosystem Programme (Driver *et al.* 2003) at a 1:250 000 scale. For the Little Karoo region of the Succulent Karoo a vegetation map at a finer scale of 1:50 000 (Vlok *et al.* 2005) reveals the complex pattern of vegetation in this area through a six-tier vegetation classification system. Using this system Vlok *et al.* (2005) identified 32 major habitat types, 56 habitat types, and 369 separate vegetation units in the Little Karoo (Figure 1).

According to Vlok *et al.* (2005) the first tier of the classification system comprises of a split between aquatic and terrestrial systems. The second tier splits the aquatic units into permanent fresh water and those that drain seasonally, while the terrestrial units are split at the biome level. The third level classifies the units according to one of the 32 major habitat types representing the structural characteristics of the vegetation. The fourth tier classifies units according to floristic components and the bio-geographical context using widespread species. Each of these units represents a regional bio-geographic unit. The fifth tier classifies units according to specific combinations of species dominant in the unit and limited local distributions recognizing local variance of regional habitat types. The sixth tier terrestrial habitat units are split into unfragmented solid units where elements of only one biome were present and those where elements of more than one biome are present (mosaic units). During the classification of the vegetation types (Vlok *et al.* 2005) each unit was sampled for dominant and abundant species as well as the occurrence of localized endemic species. Only the major species composition was noted and no quantitative data were collected for the vegetation units.

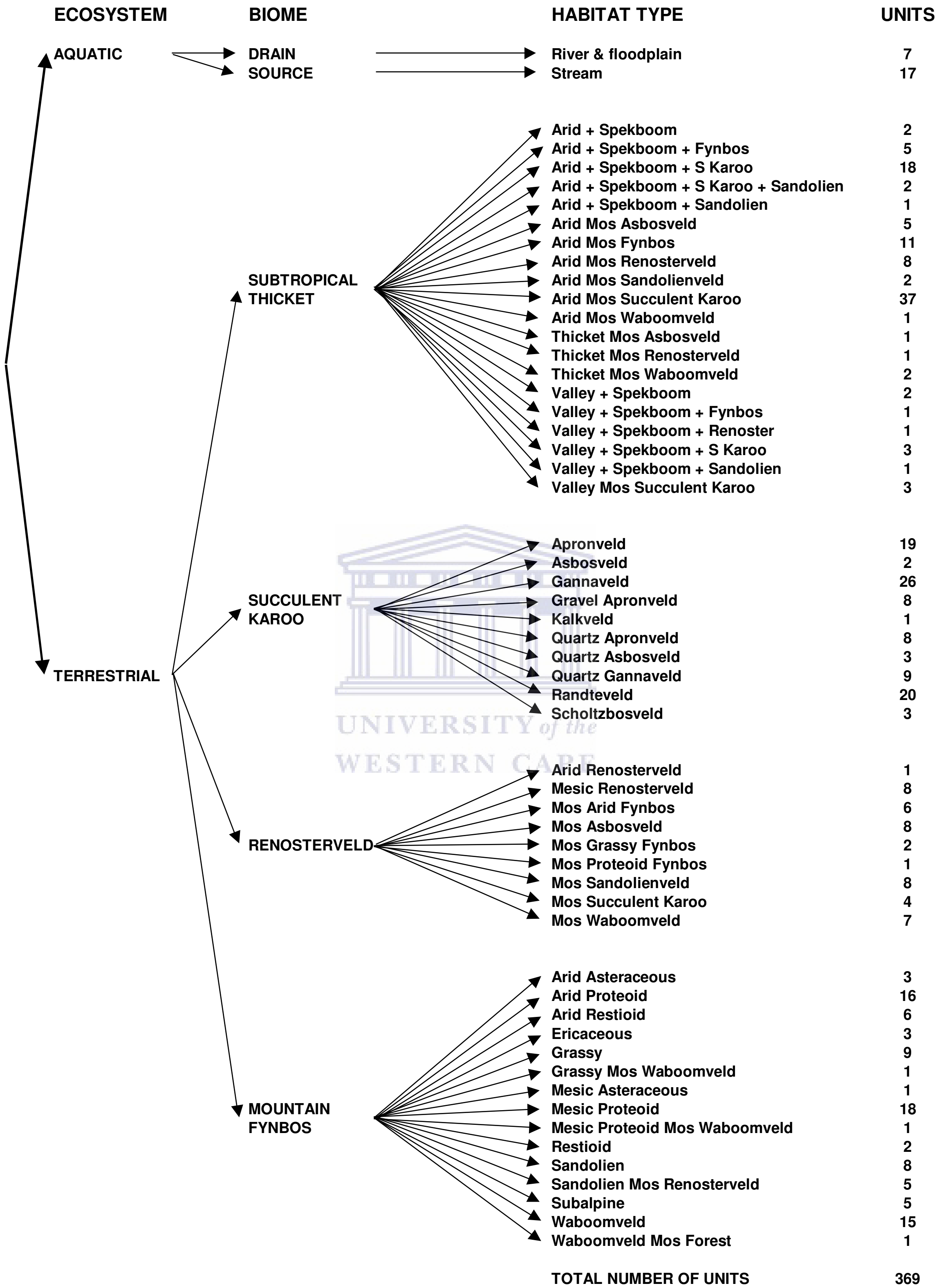




Figure 1

First 3-tiers of the final hierarchy for the Little Karoo vegetation (Vlok *et al.* 2005).

**The Succulent Karoo biome in the Little Karoo**

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Although the Succulent Karoo biome receives generally low but relatively predictable rainfall from cold fronts during the winter months, the Little Karoo lies in a transitional area between winter and summer rainfall conditions (Desmet and Cowling 1999) with the largest rainfall events usually occurring in spring and autumn. Vlok *et al.* (2005) found that only a small part of the Little Karoo area consists of true Succulent Karoo vegetation (Table 1). Of the six biomes identified in the Little Karoo by Vlok *et al.* (2005) only 17.4% of the total area of 2 343 900 hectares is made up of solid Succulent Karoo vegetation types, with sub-tropical thickets and Fynbos vegetation types accounting for more than 60% of the Little Karoo vegetation.

Table 1

The six biomes of the Little Karoo (Vlok *et al.* 2005) showing the percentage of the total area of the Little Karoo that mosaic and solid units of vegetation of each biome make up. The total percentage each biome contributes to the Little Karoo is shown in the last column.

| Biome | Mosaic units | Solid units | Total |
|---|---|---|---|
| River and floodplain | 0% | 5.50% | 5.50% |
| Perennial stream | 0% | 3.40% | 3.40% |
| Subtropical thicket | 32.70% | 2.50% | 35.30% |
| Succulent Karoo | 0% | 17.40% | 17.40% |
| Renosterveld | 10.30% | 2.30% | 12.60% |
| Fynbos | 2.80% | 23.10% | 25.90% |
| Total | 45.80% | 54.20% | 100% |

The Succulent Karoo habitats of the Little Karoo occur in lower lying areas, where soils are nutrient rich and where the rainfall is less than 350mm per annum (Vlok *et al.* 2005). In these areas leaf and stem succulent plants are abundant and shrubs less than one meter tall of the Aizoaceae, Amaranthaceae and Asteraceae families are predominant. Grasses and tall woody shrubs and trees are sparse (Vlok *et al.* 2005).

Adding to the exceptional plant diversity of these areas are the mima-like circular soil mounds that are largely believed to have been made by termites (Lovegrove and Siegfried 1989, Milton and Dean 1990). These termitaria coincide with the distribution of the Succulent Karoo biome (Lovegrove and Siegfried 1986) and support different vegetation to the surrounding matrix of vegetation (Midgley and Musil 1990), adding to the highly heterogeneous vegetation of the Succulent Karoo (Dean and Milton 1999).



There are 10 Succulent Karoo major habitat types in the Little Karoo; Apronveld, Asbosveld, Gannaveld, Gravel Apronveld, Kalkveld, Quartz Apronveld, Quartz Asbosveld, Quartz Gannaveld, Randteveld, Scholtzbosveld. The names used by Vlok *et al.* (2005) to describe these major habitat types are often used in general literature such as Le Roux *et al.* (1994) and Shearing (1994), but their exact origin is not known. Each of these major habitat types consists of a number of vegetation units. Gannaveld contains the most vegetation units for a single major habitat type in the Little Karoo Succulent Karoo biome. It varies greatly in species composition and structure and 26 separate vegetation types (Table 2) are recognized across the Little Karoo (Vlok *et al.* 2005).

Table 2

Little Karoo Gannaveld vegetation types (Vlok *et al.* 2005) showing the original extent of each vegetation type in hectares.

| Vegetation type | Ha | Vegetation type | Ha |
|---|---|---|---|
| Koeniekuils Gannaveld | 20387 | Nouga Gannaveld | 2648 |
| Oudtshoorn Gannaveld | 9993 | Hartbeesvlakte Gannaveld | 2513 |
| Ladismith Gannaveld | 7297 | Kruisrivier Gannaveld | 2444 |
| Volmoed Gannaveld | 6692 | Puts Gannaveld | 2400 |
| Grootrivier Gannaveld | 4771 | Doornkloof Gannaveld | 2274 |
| Calitzdorp Gannaveld | 4269 | Touws Gannaveld | 1833 |
| Vlakteplaas Gannaveld | 4086 | Kandelaars Gannaveld | 1634 |
| Boerboonleegte Gannaveld | 4063 | Sandfontein Gannaveld | 1315 |
| Ratelfontein Gannaveld | 3933 | Koktyls Gannaveld | 825 |
| Brakrivier Gannaveld | 3295 | Van Zylsdamme Gannaveld | 729 |
| Lemoenshoek Gannaveld | 2874 | Algerynskraal Gannaveld | 664 |
| Rheboksfontein Gannaveld | 2835 | Spreeufontein Gannaveld | 509 |
| Montagu Gannaveld | 2833 | Leopard Rock Gannaveld | 229 |

Vlok *et al.* (2005) provide a comprehensive description of the Gannaveld habitat in the Succulent Karoo biome of the Little Karoo. It is described as a habitat located in valley bottoms that often forms large open plains just above the river and floodplain habitat type. The soils are deep, loamy and saline and the vegetation type is denuded of trees, with the exception of one Gannaveld type, the Boerboonleegte Gannaveld type. Tall shrubs such as *Salsola* species and *Lycium* species are considered to be abundant and many smaller shrubs such as *Eriocephalus* species, *Pentzia incana*, *and Pteronia* species also occur. As in other parts of the Succulent Karoo grasses are considered to be uncommon.

The 26 vegetation units of the Gannaveld habitat differ in structure and composition making them unique vegetation types in the Little Karoo. While Vlok *et al.* (2005) have provided the most comprehensive descriptions of different Gannaveld types in the Little Karoo to date, detailed vegetation descriptions that include abundance measurements are lacking. The purpose of this chapter is to provide a detailed quantification of the perennial plant composition of one of the Gannaveld vegetation types, Oudtshoorn Gannaveld.



In this chapter I determine the composition of the persistent perennial plant component of critically endangered Oudtshoorn Gannaveld. The research question for this chapter is:

- What is the perennial plant composition of Oudtshoorn Gannaveld?

**Study area**

The study was carried out in the critically endangered (Kirkwood *et al.* 2007, Reyers 2008) Oudtshoorn Gannaveld vegetation type (Vlok *et al.* 2005) of the Gannaveld habitat type in the Succulent Karoo biome of the Little Karoo. The study area lies in the Oudtshoorn basin (300-400m above sea level) (Thompson *et al.* 2009) which is part of the Little Karoo inter-montane valley (Le Maitre and O'Farrel 2008) located in the Cape Floristic Region of South Africa.

The Oudtshoorn basin falls between two mountain ranges, the Swartberg mountain range in the north and the Outeniqua mountain range in the South and is situated approximately between the towns of Calitzdorp in the west and Oudtshoorn in the east. It falls within the rain shadow of the southern mountains (Le Maitre and O'Farrel 2008). The climate is warm-temperate and sub-Mediterranean with mean annual rainfall from 150mm to 250mm that falls mainly in spring (September-October) and autumn (April-May) (Thompson *et al.* 2009). Summers are hot and dry (Desmet and Cowling 1999).



The low lying vegetation in the Oudtshoorn basin consists of dwarf succulent shrublands associated with the Succulent Karoo biome predominantly of the Gannaveld and Apronveld vegetation types (Vlok *et al.* 2005, Thompson *et al.* 2009). Vlok *et al.* (2005) describe Oudtshoorn Gannaveld as vegetation in which *Salsola aphylla* is abundant and grows tall. Other locally abundant tall shrubs that may occur include *Carissa haematocarpa, Lycium cinereum, Lycium ferocissimum* and *Rhigozum obovatum*. *Pteronia pallens* is occasionally abundant and other shrub and succulent species such as *Aloe variegata, Cotyledon* *orbiculata, Drosanthemum giffenii, Phyllobolus splendens, Malephora lutea, Rosenia humilis, Senecio radicans* and *Tylecodon wallichii* may be present.

Within the Gannaveld of the Little Karoo, the Oudtshoorn Gannaveld vegetation type is the most critically endangered, with only 6.09% of it original extent of approximately 9 993 hectares considered to be in a near natural to natural state (Kirkwood *et al.* 2007). Despite including areas that were categorised as severely and moderately degraded by Thompson *et al.* (2005), these remnants are 17% below the recommended conservation target of 23% for this vegetation type. This conservation target was established through expert knowledge of the variability of this vegetation type and the degree of endemism of species (Reyers 2008).

The current study was carried out in the largest remaining extensive example of Oudtshoorn Gannaveld. The shape and location of this remnant is shown in Figure 2. The Figure also shows the original extent of the Oudtshoorn Gannaveld vegetation type (Vlok *et al.* 2005) and the area described by Thompson *et al.* (2005) as completely transformed. The natural to near natural areas (Kirkwood *et al.* 2007), which include areas classified by Thompson *et al.* (2005) as moderately or severely transformed and perceived intact, are also shown.

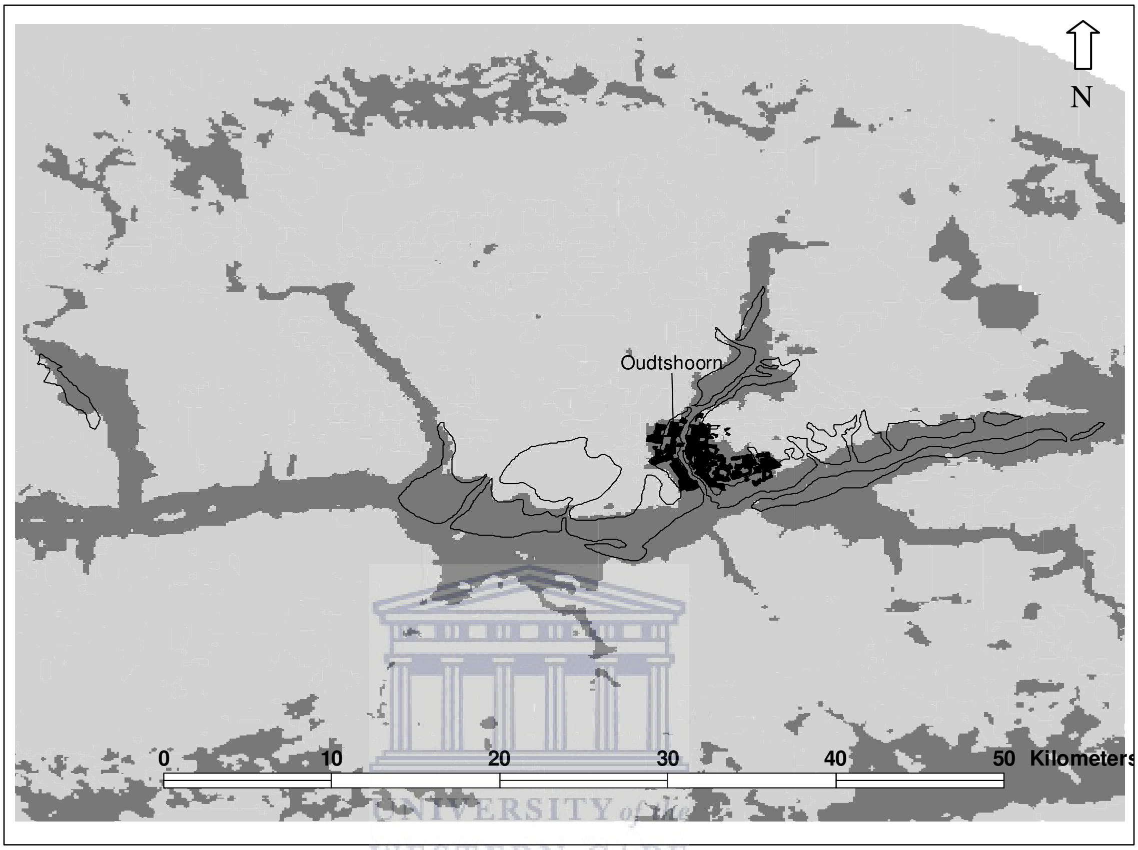




Figure 2

The original extent of Oudtshoorn Gannaveld (Vlok *et al.* 2005) is indicated by the black boundary line. The town of Oudtshoorn is indicted in black. Completely transformed vegetation is shown as dark grey. Areas containing vegetation termed as natural to near natural (Kirkwood *et al.* 2007) are shown in light grey. The light grey area includes areas classified by Thompson *et al.* (2005) as severely and moderately degraded and perceived intact.

**Methods**

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Data were collected from 200 10 x 10m$^2$ plots located in the core remnant of the Oudtshoorn Gannaveld vegetation type (Figure 3). The study site was determined using aerial photography and the Geographic Information System (Arcview 3.3) layers of Vlok (*et al.* 2005) and Thompson (*et al.* 2005). Pre-survey subjective vegetation assessments in the various Oudtshoorn Gannaveld remnants revealed that the largest remaining area contained vegetation in the perceived intact condition as well as vegetation in a perceived moderate and severely degraded condition (J. Vlok. pers. comm. 2004).

Sample plots were placed randomly throughout the core area regardless of perceived vegetation condition. The Geographic Information System was used to place 100 random plots throughout the study site and the coordinates for the random points were then located in the field using a global positioning system (GPS). The 100 sites were placed off termitaria and when the site fell onto a termite mound the nearest off termitaria site was selected. The 100 on termitaria plots were selected as the nearest termitaria to the random off termitaria plots.



Changes to the positioning of the sampling points in the field came about as a result of points falling within man made degradation areas such as dams, roads, borrow pits or other infrastructure. Areas at the edge the Oudtshoorn Gannaveld vegetation boundary were avoided as the vegetation changes to Grootkop Arid Spekboomveld, a vegetation type belonging to the Arid Spekboom Succulent Karoo habitat type of the Sub-tropical thicket biome (Vlok *et al.* 2005) that differs from Gannaveld vegetation in structure and composition.

The study area falls across land owned by four different land managers. Three are farmers and one is the South African National Defence Force (SANDF). No sampling points could be located in the SANDF live-fire training area to the north east of the core Oudtshoorn Gannaveld area and infrastructure areas to the east of the study area. The location of the 200 sampling plots and the areas in which sampling was restricted are shown in Figure 3.

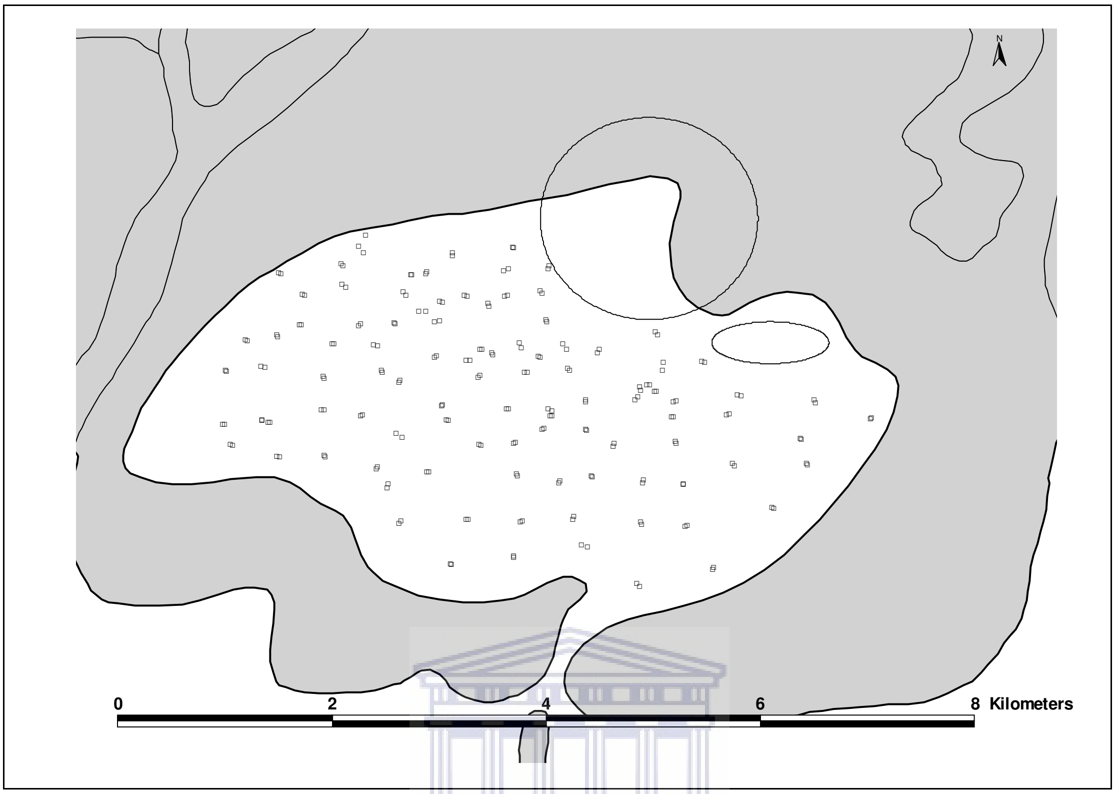




Figure 3

Map of the core Oudtshoorn Gannaveld remnant in the Little Karoo showing the location of 200 10 x 10m$^2$ vegetation sampling plots. The large circle shows the area excluded from sampling because of military training exercises and the small sphere indicates the area excluded because of military infrastructure.

A high number of plots were sampled to ensure that the true extent of the variability expected in this vegetation type as a result of natural and degradation induced patchiness (J. Vlok. pers. comm. 2004) was encountered. A high sampling intensity also increases the statistical ability to detect important finer differences in vegetation composition (Todd 2008).

As there is no standard sampling method to accurately and objectively measure species richness and abundance in Karoo rangelands (Todd 2008) the method was determined subjectively in the field based on the needs of this study. The sample plot size was required to cover the maximum area of individual termitaria without overlapping into off termitaria vegetation. The off termitaria sample plot needed to fit into the areas between termitaria without overlapping with termitaria vegetation. 10m x 10m square plots were determined to be a good fit and were large enough to adequately capture species richness and abundance data at a plot scale in this vegetation type for the purposes of this study.



Each 10m x 10m (100 square metre) plot was divided into 16 2.5m x 2.5m (6.25 square metre) subplots using highly visible yellow line attached to aluminium markers. This allowed for the thorough quantification of the specific variables required for this study in each subplot. 3 200 x 6.25 square metres subplots within 200 10m$^2$ plots were sampled over a period of one year (May 2006 to May 2007).

The following data were collected from each subplot.

1. Perennial plant species.
2. Number of individuals per species.
3. Canopy cover percentage per species.
4. Prostrate dead plant material cover percentage.
5. Bare ground percentage.
6. Soil.



Data were collected for plants with the basal part of the stem within the $6.25m^2$ subplot. Canopy cover percentage was calculated as the proportion of the ground occupied by a perpendicular projection to the ground from the outline of the aerial parts of the plant species (Brower *et al.* 1998) for that part of the plant that fell within the $6.25m^2$ subplot. If there was canopy cover in a plot from a species that had its basal cover outside the $100m^2$ plot, only the cover was recorded. Plant canopy cover falling outside the boundaries of the larger $100m^2$ plot was excluded. Canopy cover was estimated visually using the calculation that 1% of the 6.25 square metre subplot = 625 square centimetres. Canopy cover was then estimated by using a 25cm x 25cm board as a guide to 1% cover. Although estimating plant cover in this manner is to some extent subjective, all sites were assessed by the same observer in the same way, greatly reducing any potential variability inherent in the method. Litter percentage was estimated using the same system as for canopy cover and was considered to be all visible prostrate dead plant material within the $6.25m^2$ subplot.

Bare area was estimated using the same system and was considered to be the completely bare area of the plot not shaded by plants and where no dead plant material was present or in quantities sufficient to hold moisture for any significant length of time (Yeaton and Esler 1990). A soil sample was taken from each 100m$^2$ plot. Three random sites were selected within the plot and a soil sample taken from the top 10cm. The three samples were combined into one soil sample per plot.

**Data analysis**

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Data collected from the 200 10 x 10m$^2$ random sample plots were arranged in multiple measurement variable plot/species/abundance data set matrices with abundance measures of density and canopy cover. Data was placed into a raw data matrix (Microsoft Excel®) and data reduction was carried out using the SPSS software package (SPSS 16, 2007). Vegetation communities were defined using hierarchical cluster analysis based on the Sorensen distance measure and the Flexible Beta linkage method using the PC-ORD software package (McCune and Mefford 2006).

A plant functional type classification scheme to distinguish among succulent plant types in Succulent Karoo vegetation (Todd and Hoffman 2009) was applied and species were assigned to one of the following seven plant functional types.



1. Perennial forbs. Plants not having above-ground woody tissue but which survive for more than one year.
2. Perennial grasses.
3. Dwarf succulents. All globbose, mat and tuft forming succulent leaf or stem plants without conspicuous aerial branched stems.
4. Dwarf succulent shrubs. Stem or leaf succulent shrubs less than 0.3m tall.
5. Succulent shrubs. Stem and leaf succulent shrubs taller than 0.3m.
6. Dwarf Woody Shrubs. Woody shrub species without succulent leaves or stems and below 0.5 m tall.
7. Woody Shrubs. Woody shrub species without succulent leaves or stems taller than 0.5m

## Results

## Perennial plant composition of Oudtshoorn Gannaveld

72 species in 49 genera and 17 families were sampled in the 200 10 x 10$m^2$ Oudtshoorn Gannaveld sample plots. Table 3 provides the mean (±SD) density and canopy cover percentage for all species recorded across the study area.

Although some species such as *Crassula expansa* and a *Galenia* complex consisting of *Galenia fruticosa, Galenia papulosa and Galenia portulacacea* were recorded throughout the study, these were removed during the analysis because, although not strictly annual they are ephemeral by nature. They are not considered to be strictly persistent perennial plants in this environment (J. Vlok. pers. comm. 2008) and were therefore excluded for the purposes of this study. *Crassula expansa* accounted for 5.68% (n = 6 922 individuals in 20 000$m^2$) of the total number of plants recorded and 0.24% of the total canopy cover of plants recorded. The *Galenia* complex recorded accounted for 1.08% (n = 1 315 individuals in 20 000$m^2$) of the total number of plants recorded and 0.36% of the total canopy cover of plants recorded.

Table 3

Plant families, plant functional type (PFT) and species with mean (±SD) density (number of individuals) and canopy cover percentage data from 200 10m x 10m plots sampled in Oudtshoorn Gannaveld. Nomenclature follows Goldblatt and Manning (2000) and Goldblatt *et al.* (2008).

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Acanthaceae | Woody Shrub | *Justicia cuneata* | 0.02 ± 0.22 | 0.01 ± 0.11 |
| Aizoaceae | Dwarf Succulent | *Ruschia impressa* | 13.36 ± 50.93 | 1 ± 3.8 |
| Aizoaceae | Dwarf Succulent Shrub | *Leipoldtia schultzei* | 231.51 ± 304.93 | 14.82 ± 19.11 |
| Aizoaceae | Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | 49.61 ± 179.84 | 3.31 ± 10.12 |
| Aizoaceae | Dwarf Succulent Shrub | *Ruschia spinosa* | 38.35 ± 72.63 | 2.39 ± 4.96 |
| Aizoaceae | Perennial Forb | *Hermannia* sp. | 0.01 ± 0.07 | 0 ± 0 |
| Aizoaceae | Succulent Shrub | *Delosperma* sp. | 0.14 ± 1.77 | 0.03 ± 0.37 |
| Aizoaceae | Succulent Shrub | *Drosanthemum giffenii* | 9.59 ± 27.2 | 0.68 ± 1.85 |
| Aizoaceae | Succulent Shrub | *Drosanthemum hispidum* | 48.1 ± 83.89 | 7.77 ± 14.49 |
| Aizoaceae | Succulent Shrub | *Drosanthemum lique* | 8.71 ± 36.67 | 0.4 ± 1.99 |
| Aizoaceae | Succulent Shrub | *Lampranthus haworthii* | 0.76 ± 3.67 | 0.14 ± 0.72 |
| Aizoaceae | Succulent Shrub | *Malephora lutea* | 21.61 ± 58.24 | 3.4 ± 9.67 |

Table 3 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Aizoaceae | Succulent Shrub | *Phyllobolus splendens* | 4.58 ± 10.41 | 1.32 ± 3.06 |
| Aizoaceae | Succulent Shrub | *Psilocaulon junceum* | 26.95 ± 40.86 | 4.6 ± 7.49 |
| Aizoaceae | Succulent Shrub | *Ruschia ceresiana* | 28.58 ± 44.5 | 7.45 ± 11.44 |
| Aizoaceae | Succulent Shrub | *Ruschia crassa* | 0.17 ± 1.55 | 0.16 ± 1.49 |
| Aizoaceae | Succulent Shrub | *Tetragonia fruticosa* | 4.24 ± 7.34 | 0.52 ± 0.94 |
| Aizoaceae | Woody Shrub | *Galenia africana* | 0.62 ± 2.55 | 0.23 ± 0.94 |
| Amaranthaceae | Woody Shrub | *Manochlamys albicans* | 0.04 ± 0.44 | 0 ± 0.03 |
| Amaranthaceae | Woody Shrub | *Salsola aphylla* | 0.59 ± 1.51 | 1.19 ± 2.99 |
| Apocynaceae | Dwarf Succulent | *Duvalia caespitosa* | 0.07 ± 0.47 | 0 ± 0.01 |
| Apocynaceae | Dwarf Succulent | *Tridentea gemmiflora* | 0.02 ± 0.17 | 0 ± 0.01 |
| Asparagaceae | Woody Shrub | *Asparagus aethiopicus* | 0.03 ± 0.36 | 0.01 ± 0.09 |
| Asparagaceae | Woody Shrub | *Asparagus africanus* | 0.04 ± 0.37 | 0 ± 0.02 |
| Asparagaceae | Woody Shrub | *Asparagus recurvispinus* | 0.09 ± 0.38 | 0.02 ± 0.15 |
| Asteraceae | Dwarf Succulent | *Senecio radicans* | 0.09 ± 0.46 | 0 ± 0.02 |
| Asteraceae | Dwarf Succulent Shrub | *Othonna sp.* | 0.03 ± 0.2 | 0 ± 0.03 |
| Asteraceae | Dwarf Woody Shrub | *Chrysocoma ciliata* | 31.41 ± 42.71 | 1.56 ± 2.31 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum anomalum* | 0.1 ± 0.79 | 0.01 ± 0.11 |

Table 3 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Asteraceae | Dwarf Woody Shrub | *Helichrysum dregei* | 0.18 ± 2.34 | 0.01 ± 0.07 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum excisum* | 0.01 ± 0.14 | 0 ± 0.02 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum rosum* | 0.21 ± 1.02 | 0.01 ± 0.05 |
| Asteraceae | Dwarf Woody Shrub | *Pentzia incana* | 0.25 ± 1.34 | 0.06 ± 0.31 |
| Asteraceae | Dwarf Woody Shrub | *Senecio juniperinus* | 1.56 ± 5.16 | 0.04 ± 0.1 |
| Asteraceae | Dwarf Woody Shrub | *Tripteris sinuata* | 0.03 ± 0.36 | 0 ± 0.04 |
| Asteraceae | Succulent Shrub | *Senecio sp.* | 0.17 ± 1.29 | 0.04 ± 0.27 |
| Asteraceae | Woody Shrub | *Dicerothamnus rhinocerotis* | 0.01 ± 0.14 | 0 ± 0.06 |
| Asteraceae | Woody Shrub | *Eriocephalus brevifolius* | 1.78 ± 7.33 | 0.51 ± 2.21 |
| Asteraceae | Woody Shrub | *Eriocephalus ericoides* | 15.19 ± 29.43 | 1.81 ± 3.77 |
| Asteraceae | Woody Shrub | *Euryops lateriflorus* | 0.14 ± 0.97 | 0.02 ± 0.19 |
| Asteraceae | Woody Shrub | *Felicia filifolia* | 0.92 ± 4.42 | 0.22 ± 0.91 |
| Asteraceae | Woody Shrub | *Helichrysum zeyheri* | 0.86 ± 4.03 | 0.17 ± 0.8 |
| Asteraceae | Woody Shrub | *Pentzia dentata* | 0.87 ± 4.23 | 0.32 ± 1.7 |
| Asteraceae | Woody Shrub | *Pteronia glauca* | 1.13 ± 5.41 | 0.33 ± 1.67 |
| Asteraceae | Woody Shrub | *Pteronia incana* | 3.78 ± 9.59 | 0.92 ± 2.64 |
| Asteraceae | Woody Shrub | *Pteronia pallens* | 1.17 ± 5.08 | 0.42 ± 1.99 |

Table 3 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Asteraceae | Woody Shrub | *Pteronia paniculata* | 0.71 ± 4.99 | 0.16 ± 1.11 |
| Asteraceae | Woody Shrub | *Rosenia humilis* | 0.15 ± 0.84 | 0.02 ± 0.17 |
| Brassicaceae | Dwarf Woody Shrub | *Heliophila sauvissima* | 0.05 ± 0.52 | 0.01 ± 0.08 |
| Crassulaceae | Dwarf Succulent | *Crassula capitella* | 6.29 ± 30.34 | 0.04 ± 0.22 |
| Crassulaceae | Dwarf Succulent | *Crassula muscosa* | 0.92 ± 2.42 | 0.03 ± 0.06 |
| Crassulaceae | Dwarf Succulent Shrub | *Crassula subaphylla* | 5.12 ± 36.51 | 0.07 ± 0.19 |
| Crassulaceae | Succulent Shrub | *Cotyledon orbiculata* | 0.1 ± 0.52 | 0.01 ± 0.12 |
| Crassulaceae | Succulent Shrub | *Crassula tetragona* | 1.72 ± 5.26 | 0.06 ± 0.16 |
| Crassulaceae | Succulent Shrub | *Tylecodon ventricosus* | 0.01 ± 0.07 | 0 ± 0 |
| Euphorbiaceae | Dwarf Succulent Shrub | *Euphorbia fimbriata* | 0.52 ± 1.36 | 0.03 ± 0.1 |
| Molluginaceae | Dwarf Woody Shrub | *Limeum aethiopicum* | 0.01 ± 0.07 | 0 ± 0 |
| Molluginaceae | Perennial Forb | *Hypertelis salsoloides* | 0.01 ± 0.1 | 0 ± 0 |
| Poaceae | Perennial Grass | *Digitaria argyrograpta* | 0.26 ± 3.61 | 0.01 ± 0.2 |
| Poaceae | Perennial Grass | *Ehrharta calycina* | 0.28 ± 2.02 | 0.02 ± 0.2 |
| Portulacaceae | Dwarf Succulent | *Anacampseros arachnoides* | 0.11 ± 1.49 | 0 ± 0.01 |
| Rubiaceae | Perennial Forb | *Anthospermum ciliata* | 0.03 ± 0.23 | 0 ± 0.02 |
| Santalaceae | Dwarf Woody Shrub | *Thesium nudicaule* | 0.13 ± 0.63 | 0.01 ± 0.04 |

Table 3 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Scrophulariaceae | Dwarf Woody Shrub | *Selago albida* | 0.08 ± 1.13 | 0 ± 0.04 |
| Scrophulariaceae | Dwarf Woody Shrub | *Selago glutinosa* | 0.67 ± 3.96 | 0.02 ± 0.12 |
| Scrophulariaceae | Perennial Forb | *Aptosimum indivisum* | 0.14 ± 0.74 | 0 ± 0.02 |
| Scrophulariaceae | Perennial Forb | *Hebenstretia sp.* | 0.02 ± 0.28 | 0 ± 0.02 |
| Solanaceae | Woody Shrub | *Lycium cinereum* | 0.19 ± 0.64 | 0.06 ± 0.22 |
| Solanaceae | Woody Shrub | *Lycium oxycarpum* | 0.02 ± 0.16 | 0.04 ± 0.6 |
| Zygophyllaceae | Succulent Shrub | *Augea capensis* | 0.49 ± 2.86 | 0.04 ± 0.28 |
| Zygophyllaceae | Succulent Shrub | *Tetraena retrofracta* | 2.95 ± 8.67 | 0.72 ± 2.16 |
| Zygophyllaceae | Woody Shrub | *Roepera lichtensteiniana* | 0.01 ± 0.07 | 0 ± 0 |

Oudtshoorn Gannaveld is dominated in terms of perennial plant species richness by the Asteraceae (23 species, 31.94%), Aizoaceae (17 species, 23.61%) and Crassulaceae (6 species, 8.33%) families. This vegetation type is dominated in terms of perennial plant canopy cover percentage by species of the Aizoaceae (17 species and 84.20% of total cover), Asteraceae (23, species 11.59%) and Amaranthaceae (2 species, 2.09%) families. The families most dominant in terms of plant density (number of individual plants) are the Aizoaceae (17 species, 85.63%), Asteraceae (23 species, 10.67%) and Crassulaceae (6 species, 2.48%) families.

Dominant plant families in terms of species richness, plant canopy cover and number of individual plants in Oudtshoorn Gannaveld are shown in Table 4.

Table 4

Total species richness for all sample plots, mean (±SD) canopy cover percentage and mean (±SD) density (number of individuals) per 100m$^2$ with relative abundance shown in percentages, arranged according to dominance per family recorded in Oudtshoorn Gannaveld.

| Species richness | | | Cover | | | Density | | |
|---|---|---|---|---|---|---|---|---|
| Asteraceae | 23 | 31.94% | Aizoaceae | 48.19 ± 14.23 | 84.20% | Aizoaceae | 486.86 ± 261.89 | 85.64% |
| Aizoaceae | 17 | 23.61% | Asteraceae | 6.63 ± 7.58 | 11.59% | Asteraceae | 60.7 ± 64.13 | 10.68% |
| Crassulaceae | 6 | 8.33% | Amaranthaceae | 1.2 ± 2.99 | 2.09% | Crassulaceae | 14.15 ± 48.63 | 2.49% |
| Scrophulariaceae | 4 | 5.56% | Zygophyllaceae | 0.76 ± 2.16 | 1.32% | Zygophyllaceae | 3.44 ± 8.98 | 0.61% |
| Asparagaceae | 3 | 4.17% | Crassulaceae | 0.2 ± 0.4 | 0.35% | Scrophulariaceae | 0.9 ± 4.19 | 0.16% |
| Zygophyllaceae | 3 | 4.17% | Solanaceae | 0.1 ± 0.63 | 0.17% | Amaranthaceae | 0.63 ± 1.56 | 0.11% |
| Amaranthaceae | 2 | 2.78% | Poaceae | 0.03 ± 0.28 | 0.06% | Poaceae | 0.54 ± 4.12 | 0.09% |
| Apocynaceae | 2 | 2.78% | Euphorbiaceae | 0.03 ± 0.1 | 0.06% | Euphorbiaceae | 0.52 ± 1.36 | 0.09% |
| Molluginaceae | 2 | 2.78% | Asparagaceae | 0.03 ± 0.17 | 0.05% | Solanaceae | 0.21 ± 0.65 | 0.04% |
| Poaceae | 2 | 2.78% | Scrophulariaceae | 0.03 ± 0.13 | 0.05% | Asparagaceae | 0.16 ± 0.63 | 0.03% |
| Solanaceae | 2 | 2.78% | Acanthaceae | 0.01 ± 0.11 | 0.02% | Santalaceae | 0.13 ± 0.63 | 0.02% |
| Acanthaceae | 1 | 1.39% | Santalaceae | 0.01 ± 0.04 | 0.01% | Portulacaceae | 0.11 ± 1.48 | 0.02% |
| Brassicaceae | 1 | 1.39% | Brassicaceae | 0.01 ± 0.08 | 0.01% | Apocynaceae | 0.09 ± 0.5 | 0.01% |

| Table 4 continued | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species richness | | | Cover | | | Density | | |
| Euphorbiaceae | 1 | 1.39% | Apocynaceae | 0 ± 0.01 | 0% | Brassicaceae | 0.05 ± 0.52 | 0.01% |
| Portulacaceae | 1 | 1.39% | Rubiaceae | 0 ± 0.01 | 0% | Rubiaceae | 0.03 ± 0.23 | 0% |
| Rubiaceae | 1 | 1.39% | Portulacaceae | 0 ± 0.01 | 0% | Acanthaceae | 0.02 ± 0.22 | 0% |
| Santalaceae | 1 | 1.39% | Molluginaceae | 0 ± 0 | 0% | Molluginaceae | 0.02 ± 0.12 | 0% |

The dominant plant functional types of this vegetation type in terms of species richness are the woody shrub component with 22 species (31%), followed by the succulent shrub component 17 species (24%) and the dwarf woody shrub component 13 species (18%). The dominant plant functional type in terms of the number of individuals per $m^2$ is the dwarf succulent shrub component with a mean density of 325.1 (±328.4) per $100m^2$. Succulent shrubs in this vegetation type have a mean density of 158.8 (±118.2) plants per $100m^2$ and are the second most abundant plant functional type in terms of density.

Dwarf woody shrubs have a mean density of 34.7 (±43.4) per $100m^2$, while woody shrub density is 28.3 (±35.3), dwarf succulents 20.8 (±59.2), perennial grasses 0.5 (±4.1) and perennial forbs 0.2 (±0.8). The dominant dwarf succulent shrub component accounts for 57.2% of the total density of plants in Oudtshoorn Gannaveld. Succulent shrubs make up 27.94% of the total density of plants while dwarf woody shrubs make up 6.1%, woody shrubs 4.98%, dwarf succulents 3.66%, perennial grasses 0.09% and perennial forbs 0.03%.



The plant functional type dominance differs when one considers the canopy cover percentages. The dominant plant functional type in terms of cover is the succulent shrub group with a mean canopy cover percentage of 27.3% (±19.4) per $100m^2$. Dwarf succulent shrubs have a mean canopy cover percentage of 20.6% (±19.7) per $100m^2$, while woody shrubs cover 6.5% (±6.6), dwarf woody shrubs 1.7% (±2.3) and dwarf succulents 1.1% (±3.8). Perennial grasses (0.0±0.3) and forbs (0.0±0.0) account for less than 0.1% of the relative canopy cover percentage. Succulent shrubs account for 47.7% of the total cover of plants in Oudtshoorn Gannaveld.

The dwarf succulent shrub cover makes up 36.04% of the total cover of plants and woody shrubs 11.3%. Dwarf woody shrubs contribute 3.1%, dwarf succulents 1.88%, perennial grasses 0.06% and perennial forbs 0.01% to the total cover of plants in Oudtshoorn Gannaveld.

Table 5 shows the dominant plant functional types in Oudtshoorn Gannaveld in terms of total species richness for all plots sampled, mean (±SD) density (number of individuals) and mean (±SD) canopy cover percentage. Relative abundances are shown as percentages.

Table 5

The dominant plant functional types in Oudtshoorn Gannaveld in terms of total species richness for all plots sampled, mean (±SD) density (number of individuals) and mean (±SD) canopy cover percentage per $100m^2$. Relative abundances are shown as percentages.

| Species richness | | | Density | | | Cover | | |
|---|---|---|---|---|---|---|---|---|
| Woody Shrubs | 22 | 30.56% | Dwarf Succulent Shrubs | 325.14 ± 328.43 | 57.19% | Succulent Shrubs | 27.31 ± 19.4 | 47.75% |
| Succulent Shrubs | 17 | 23.61% | Succulent Shrubs | 158.84 ± 118.2 | 27.94% | Dwarf Succulent Shrubs | 20.61 ± 19.68 | 36.04% |
| Dwarf Woody Shrubs | 13 | 18.06% | Dwarf Woody Shrubs | 34.67 ± 43.36 | 6.10% | Woody Shrubs | 6.47 ± 6.55 | 11.30% |
| Dwarf Succulents | 7 | 9.72% | Woody Shrubs | 28.31 ± 35.28 | 4.98% | Dwarf Woody Shrubs | 1.72 ± 2.33 | 3.01% |
| Dwarf Succulent Shrubs | 6 | 8.33% | Dwarf Succulents | 20.84 ± 59.25 | 3.66% | Dwarf Succulents | 1.07 ± 3.79 | 1.88% |
| Perennial Forbs | 5 | 6.94% | Perennial Grasses | 0.54 ± 4.12 | 0.09% | Perennial Grasses | 0.03 ± 0.28 | 0.06% |
| Perennial Grasses | 2 | 2.78% | Perennial Forbs | 0.2 ± 0.82 | 0.03% | Perennial Forbs | 0.01 ± 0.03 | 0.01% |

*Leipoldtia schultzei* is the dominant plant species occurring in Oudtshoorn Gannaveld both in terms of density and cover. This species has a mean density of 231.51 (±304.93) individuals and a mean cover of 14.82% (±19.11) per 100m$^2$. It accounts for 40.72% of the total density of plants in this vegetation type and 25.89% of the total cover.

Although 72 perennial plant species were recorded throughout the Oudtshoorn Gannaveld study area, only 11 species make up 90.45% of the total density abundance of plants in this vegetation type (Table 6). These are: *Leipoldtia schultzei* 40.72%, *Mesembryanthemum crystallinum* 8.73%, *Drosanthemum hispidum* 8.46%, *Ruschia spinosa* 6.74%, *Chrysocoma ciliata* 5.52%, *Ruschia ceresiana* 5.03%, *Psilocaulon junceum* 4.74%, *Malephora lutea* 3.80%, *Eriocephalus ericoides* 2.67%, *Ruschia impressa* 2.35% *and Drosanthemum giffenii* 1.69%.

In terms of plant canopy cover (Table 6), 13 species make up 90% of the total cover abundance in Oudtshoorn Gannaveld; *Leipoldtia schultzei* 25.89%, *Drosanthemum hispidum* 13.58%, *Ruschia ceresiana* 13.01%, *Psilocaulon junceum* 8.03%, *Malephora lutea* 5.93%, *Mesembryanthemum crystallinum* 5.78%, *Ruschia spinosa* 4.17%, *Eriocephalus ericoides* 3.16%, *Chrysocoma ciliata* 2.73%, *Phyllobolus splendens* 2.31%, *Salsola aphylla* 2.09%, *Ruschia impressa* 1.75% *and Pteronia incana* 1.61%. Other species (61 for density and 59 for canopy cover) contribute minimally to the overall density and cover percentage of plants in Oudtshoorn Gannaveld. The density and cover percentages of species that contribute more than 1% are shown in Table 6.

Table 6

Mean (±SD) density (number of individuals) and canopy cover percentage per 100m$^2$ for species which contribute more than 1%, recorded throughout the Oudtshoorn Gannaveld vegetation type. Values are arranged from highest to lowest value for density and cover. The relative abundance of each species is shown in percentage in the Rel% column. The cumulative relative abundance of species is shown as a percentage in the Acc% column.

| Density | | | | Cover | | | |
|---|---|---|---|---|---|---|---|
| | | Rel % | Acc % | | | Rel % | Acc % |
| *Leipoldtia schultzei* | 231.51 ± 304.93 | 40.72% | 40.72% | *Leipoldtia schultzei* | 14.82 ± 19.11 | 25.89% | 25.89% |
| *Mesembryanthemum crystallinum* | 49.61 ± 179.84 | 8.73% | 49.45% | *Drosanthemum hispidum* | 7.77 ± 14.49 | 13.58% | 39.46% |
| *Drosanthemum hispidum* | 48.1 ± 83.89 | 8.46% | 57.91% | *Ruschia ceresiana* | 7.45 ± 11.44 | 13.01% | 52.48% |
| *Ruschia spinosa* | 38.35 ± 72.63 | 6.75% | 64.65% | *Psilocaulon junceum* | 4.6 ± 7.49 | 8.03% | 60.51% |
| *Chrysocoma ciliata* | 31.41 ± 42.71 | 5.52% | 70.18% | *Malephora lutea* | 3.4 ± 9.67 | 5.93% | 66.45% |
| *Ruschia ceresiana* | 28.58 ± 44.5 | 5.03% | 75.21% | *Mesembryanthemum crystallinum* | 3.31 ± 10.12 | 5.78% | 72.22% |
| *Psilocaulon junceum* | 26.95 ± 40.86 | 4.74% | 79.95% | *Ruschia spinosa* | 2.39 ± 4.96 | 4.17% | 76.40% |
| *Malephora lutea* | 21.61 ± 58.24 | 3.80% | 83.75% | *Eriocephalus ericoides* | 1.81 ± 3.77 | 3.16% | 79.56% |
| *Eriocephalus ericoides* | 15.19 ± 29.43 | 2.67% | 86.42% | *Chrysocoma ciliata* | 1.56 ± 2.31 | 2.73% | 82.29% |

Table 6 continued

| Density | | | | Cover | | | |
|---|---|---|---|---|---|---|---|
| *Ruschia impressa* | 13.36 ± 50.93 | 2.35% | 88.77% | *Phyllobolus splendens* | 1.32 ± 3.06 | 2.31% | 84.60% |
| *Drosanthemum giffenii* | 9.59 ± 27.2 | 1.69% | 90.45% | *Salsola aphylla* | 1.19 ± 2.99 | 2.09% | 86.69% |
| *Drosanthemum lique* | 8.71 ± 36.67 | 1.53% | 91.99% | *Ruschia impressa* | 1 ± 3.8 | 1.75% | 88.43% |
| *Crassula capitella* | 6.29 ± 30.34 | 1.11% | 93.09% | *Pteronia incana* | 0.92 ± 2.64 | 1.61% | 90.04% |
| | | | | *Tetraena retrofracta* | 0.72 ± 2.16 | 1.25% | 91.29% |
| | | | | *Drosanthemum giffenii* | 0.68 ± 1.85 | 1.18% | 92.48% |

Table 7 shows the frequency (percentage occurrence in all lots samples) of species recorded in 200 10 x 10m$^2$ sample plots in Oudtshoorn Gannaveld. The frequency of plant species occurring in the 200 sample plots in Oudtshoorn Gannaveld varies from 76.5% to 0.5% with only *Chrysocoma ciliata, Leipoldtia schultzei, Ruschia spinosa, Drosanthemum hispidum, Psilocaulon junceum, Eriocephalus ericoides, Tetragonia fruticosa* and *Ruschia ceresiana* having a frequency of more than 50%.

Table 7

The frequency of species occurring in 200 10m x 10m sample plots in the Oudtshoorn Gannaveld vegetation type.

| | Frequency | | Frequency | | Frequency |
|---|---|---|---|---|---|
| *Chrysocoma ciliata* | 76.5% | *Eriocephalus brevifolius* | 13.0% | *Helichrysum anomalum* | 2.0% |
| *Leipoldtia schultzei* | 67.0% | *Lycium cinereum* | 13.0% | *Anthospermum ciliata* | 1.5% |
| *Ruschia spinosa* | 63.5% | *Pteronia glauca* | 11.5% | *Asparagus africanus* | 1.5% |
| *Drosanthemum hispidum* | 61.0% | *Pentzia dentata* | 11.0% | *Delosperma sp.* | 1.5% |
| *Psilocaulon junceum* | 57.0% | *Helichrysum zeyheri* | 10.5% | *Heliophila sauvissima* | 1.5% |
| *Eriocephalus ericoides* | 54.5% | *Crassula capitella* | 10.0% | *Manochlamys albicans* | 1.5% |
| *Tetragonia fruticosa* | 52.5% | *Lampranthus haworthii* | 10.0% | *Ruschia crassa* | 1.5% |
| *Ruschia ceresiana* | 50.5% | *Felicia filifolia* | 9.0% | *Tridentea gemmiflora* | 1.5% |
| *Phyllobolus splendens* | 38.5% | *Helichrysum rosum* | 7.5% | *Asparagus aethiopicus* | 1.0% |
| *Mesembryanthemum crystallinum* | 37.5% | *Selago glutinosa* | 7.0% | *Helichrysum dregei* | 1.0% |
| *Drosanthemum lique* | 33.5% | *Asparagus recurvispinus* | 6.5% | *Hypertelis salsoloides* | 1.0% |

Table 7 continued

| | Frequency | | Frequency | | Frequency |
|---|---|---|---|---|---|
| *Malephora lutea* | 33.0% | *Augea capensis* | 6.0% | *Justicia cuneata* | 1.0% |
| *Pteronia incana* | 32.5% | *Cotyledon orbiculata* | 5.5% | *Lycium oxycarpum* | 1.0% |
| *Crassula subaphylla* | 30.5% | *Pentzia incana* | 5.5% | *Tripteris sinuata* | 1.0% |
| *Crassula muscosa* | 28.5% | *Aptosimum indivisum* | 5.0% | *Anacampseros arachnoides* | 0.5% |
| *Drosanthemum giffenii* | 26.5% | *Thesium nudicaule* | 5.0% | *Dicerothamnus rhinocerotis* | 0.5% |
| *Tetraena retrofracta* | 24.5% | *Rosenia humilis* | 4.5% | *Digitaria argyrograpta* | 0.5% |
| *Ruschia impressa* | 23.0% | *Ehrharta calycina* | 4.0% | *Hebenstretia sp.* | 0.5% |
| *Salsola aphylla* | 22.0% | *Senecio radicans* | 4.0% | *Helichrysum excisum* | 0.5% |
| *Euphorbia fimbriata* | 21.0% | *Duvalia caespitosa* | 3.5% | *Hermannia sp.* | 0.5% |
| *Crassula tetragona* | 18.0% | *Pteronia paniculata* | 3.5% | *Limeum aethiopicum* | 0.5% |
| *Senecio juniperinus* | 17.5% | *Euryops lateriflorus* | 3.0% | *Roepera lichtensteiniana* | 0.5% |
| *Galenia africana* | 14.5% | *Othonna sp.* | 2.5% | *Selago albida* | 0.5% |
| *Pteronia pallens* | 13.5% | *Senecio sp.* | 2.5% | *Tylecodon ventricosus* | 0.5% |

Cluster analysis revealed the two major vegetation communities occurring in Oudtshoorn Gannaveld, the on termitaria and off termitaria vegetation communities (Figure 4).

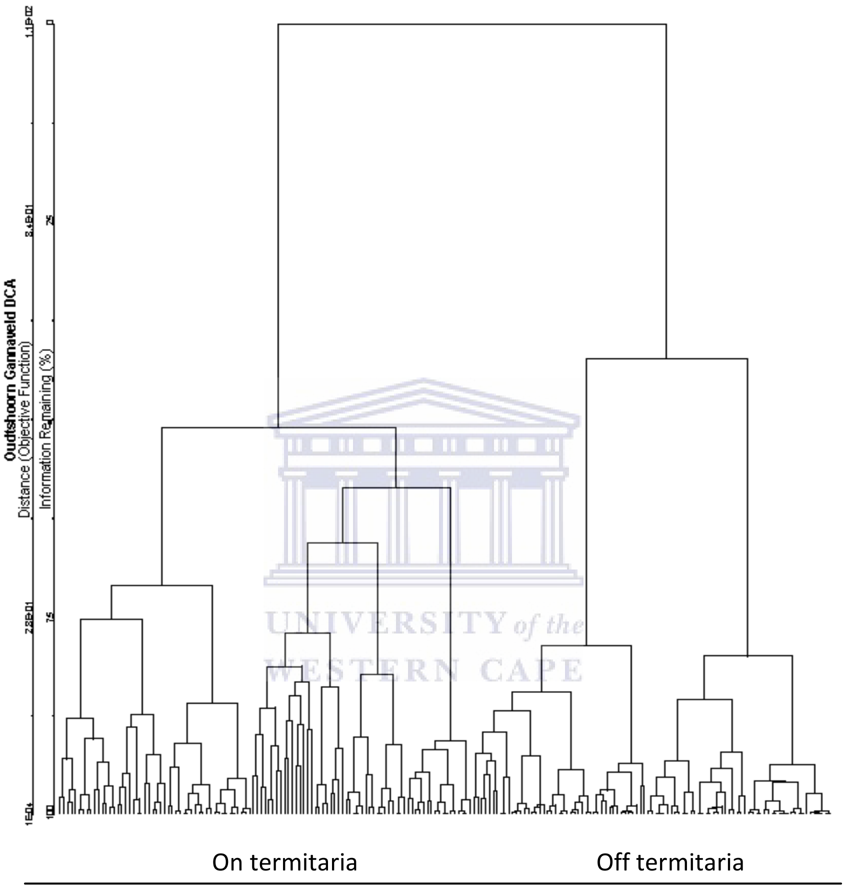




Figure 4

Cluster dendrogram of all sample plots based on the Sorensen distance measure and Wards' Flexible Beta linkage method. The first level division represents a division between the two major vegetation communities occurring in Oudtshoorn Gannaveld, predominantly on termitaria (left cluster) and predominantly off termitaria (right cluster) vegetation communities.

Of the 72 persistent perennial plant species recorded in Oudtshoorn Gannaveld, 46 species occurred both on and off termitaria, 68 species occurred off termitaria, 50 species occurred on termitaria, 22 species occurred only off termitaria and 4 species occurred only on termitaria (Table 8).

Table 8

Species richness of perennial plants from 200 10 x 10m$^2$ plots located on and off termitaria in Oudtshoorn Gannaveld vegetation.

| | |
|---|---|
| Species recorded both on and off termitaria | 46 |
| Species recorded off termitaria | 68 |
| Species recorded on termitaria | 50 |
| Species recorded only off termitaria | 22 |
| Species recorded only on termitaria | 4 |
| Total species recorded | 72 |

**Oudtshoorn Gannaveld off termitaria community**

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**Perennial plant composition**

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68 species in 46 genera and 17 families were sampled in 100 10 x 10m$^2$ sample plots off termitaria. Table 9 shows the mean (±SD) density and canopy cover percentage for all perennial plant species recorded in the off termitaria plant community.

The off termitaria perennial plant community of Oudtshoorn Gannaveld is dominated in terms of perennial plant species richness by the Asteraceae (23 species, 33.82%), Aizoaceae (17 species, 25%) and Crassulaceae (6 species, 8.82%) families (Table 10). This vegetation type is dominated in terms of perennial plant canopy cover percentage by species of the Aizoaceae (17 species, 79.66% of total cover off termitaria) and Asteraceae (23 species 19.02%) families. The families most dominant in terms of plant density (number of individual plants) are the Aizoaceae (17 species, 81.28%), Asteraceae (23 species, 14.34%) and Crassulaceae (6 species, 3.76%) families.

Table 9

Plant families, plant functional type (PFT) and species with mean (±SD) density (number of individuals) and canopy cover percentage data from 100 10m x 10m plots sampled in the off termitaria plant community of Oudtshoorn Gannaveld. Nomenclature follows Goldblatt and Manning (2000) and Goldblatt *et al.* (2008).

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Acanthaceae | Woody Shrub | *Justicia cuneata* | 0.01 ± 0.1 | 0.01 ± 0.12 |
| Aizoaceae | Dwarf Succulent | *Ruschia impressa* | 6.98 ± 53.75 | 0.45 ± 3.48 |
| Aizoaceae | Dwarf Succulent Shrub | *Leipoldtia schultzei* | 446.65 ± 302.77 | 28.6 ± 18.55 |
| Aizoaceae | Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | 0.55 ± 1.73 | 0.03 ± 0.1 |
| Aizoaceae | Dwarf Succulent Shrub | *Ruschia spinosa* | 37.35 ± 71.22 | 1.95 ± 4.05 |
| Aizoaceae | Perennial Forb | *Hermannia sp.* | 0.01 ± 0.1 | 0 ± 0 |
| Aizoaceae | Succulent Shrub | *Delosperma sp.* | 0.28 ± 2.51 | 0.05 ± 0.52 |
| Aizoaceae | Succulent Shrub | *Drosanthemum giffenii* | 0.12 ± 0.62 | 0.01 ± 0.03 |
| Aizoaceae | Succulent Shrub | *Drosanthemum hispidum* | 5.55 ± 24.36 | 0.38 ± 1.92 |
| Aizoaceae | Succulent Shrub | *Drosanthemum lique* | 17.31 ± 50.52 | 0.8 ± 2.76 |
| Aizoaceae | Succulent Shrub | *Lampranthus haworthii* | 1.51 ± 5.09 | 0.28 ± 1.01 |

Table 9 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Aizoaceae | Succulent Shrub | *Malephora lutea* | 7.36 ± 35 | 0.93 ± 4.96 |
| Aizoaceae | Succulent Shrub | *Phyllobolus splendens* | 1.53 ± 3.99 | 0.43 ± 1.36 |
| Aizoaceae | Succulent Shrub | *Psilocaulon junceum* | 0.93 ± 3.47 | 0.12 ± 0.46 |
| Aizoaceae | Succulent Shrub | *Ruschia ceresiana* | 56.26 ± 49.16 | 14.48 ± 12.57 |
| Aizoaceae | Succulent Shrub | *Ruschia crassa* | 0.04 ± 0.4 | 0.02 ± 0.23 |
| Aizoaceae | Succulent Shrub | *Tetragonia fruticosa* | 8.13 ± 8.76 | 0.99 ± 1.15 |
| Aizoaceae | Woody Shrub | *Galenia africana* | 0.94 ± 3.36 | 0.34 ± 1.24 |
| Amaranthaceae | Woody Shrub | *Salsola aphylla* | 0.08 ± 0.31 | 0.06 ± 0.3 |
| Apocynaceae | Dwarf Succulent | *Duvalia caespitosa* | 0.13 ± 0.66 | 0 ± 0.01 |
| Apocynaceae | Dwarf Succulent | *Tridentea gemmiflora* | 0.02 ± 0.14 | 0 ± 0.01 |
| Asparagaceae | Woody Shrub | *Asparagus aethiopicus* | 0.06 ± 0.51 | 0.02 ± 0.13 |
| Asparagaceae | Woody Shrub | *Asparagus africanus* | 0.07 ± 0.52 | 0 ± 0.03 |
| Asparagaceae | Woody Shrub | *Asparagus recurvispinus* | 0.13 ± 0.44 | 0.01 ± 0.06 |
| Asteraceae | Dwarf Succulent | *Senecio radicans* | 0.17 ± 0.64 | 0.01 ± 0.03 |
| Asteraceae | Dwarf Succulent Shrub | *Othonna sp.* | 0.05 ± 0.26 | 0.01 ± 0.04 |
| Asteraceae | Dwarf Woody Shrub | *Chrysocoma ciliata* | 51.67 ± 46.75 | 2.66 ± 2.67 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum anomalum* | 0.2 ± 1.11 | 0.03 ± 0.16 |

Table 9 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Asteraceae | Dwarf Woody Shrub | *Helichrysum dregei* | 0.33 ± 3.3 | 0.01 ± 0.09 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum excisum* | 0.02 ± 0.2 | 0 ± 0.03 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum rosum* | 0.39 ± 1.41 | 0.02 ± 0.07 |
| Asteraceae | Dwarf Woody Shrub | *Pentzia incana* | 0.08 ± 0.71 | 0.03 ± 0.24 |
| Asteraceae | Dwarf Woody Shrub | *Senecio juniperinus* | 1.51 ± 5.52 | 0.03 ± 0.1 |
| Asteraceae | Dwarf Woody Shrub | *Tripteris sinuata* | 0.06 ± 0.51 | 0.01 ± 0.06 |
| Asteraceae | Succulent Shrub | *Senecio sp.* | 0.32 ± 1.81 | 0.05 ± 0.29 |
| Asteraceae | Woody Shrub | *Dicerothamnus rhinocerotis* | 0.02 ± 0.2 | 0.01 ± 0.09 |
| Asteraceae | Woody Shrub | *Eriocephalus brevifolius* | 3.54 ± 10.09 | 1.02 ± 3.04 |
| Asteraceae | Woody Shrub | *Eriocephalus ericoides* | 28.69 ± 36.57 | 3.46 ± 4.77 |
| Asteraceae | Woody Shrub | *Euryops lateriflorus* | 0.27 ± 1.36 | 0.05 ± 0.26 |
| Asteraceae | Woody Shrub | *Felicia filifolia* | 1.8 ± 6.14 | 0.42 ± 1.25 |
| Asteraceae | Woody Shrub | *Helichrysum zeyheri* | 1.71 ± 5.58 | 0.33 ± 1.12 |
| Asteraceae | Woody Shrub | *Pentzia dentata* | 1.73 ± 5.87 | 0.64 ± 2.37 |
| Asteraceae | Woody Shrub | *Pteronia glauca* | 1.68 ± 6.84 | 0.49 ± 2.09 |
| Asteraceae | Woody Shrub | *Pteronia incana* | 6.66 ± 12.37 | 1.7 ± 3.5 |
| Asteraceae | Woody Shrub | *Pteronia pallens* | 1.76 ± 5.85 | 0.65 ± 2.36 |

| Table 9 continued | | | | |
|---|---|---|---|---|
| Family | PFT | Species | Density | Cover |
| Asteraceae | Woody Shrub | *Pteronia paniculata* | 1.42 ± 7 | 0.31 ± 1.56 |
| Asteraceae | Woody Shrub | *Rosenia humilis* | 0.29 ± 1.18 | 0.05 ± 0.24 |
| Brassicaceae | Dwarf Woody Shrub | *Heliophila sauvissima* | 0.1 ± 0.73 | 0.01 ± 0.11 |
| Crassulaceae | Dwarf Succulent | *Crassula capitella* | 12.52 ± 42.09 | 0.09 ± 0.3 |
| Crassulaceae | Dwarf Succulent | *Crassula muscosa* | 1.63 ± 3.22 | 0.04 ± 0.08 |
| Crassulaceae | Dwarf Succulent Shrub | *Crassula subaphylla* | 9.61 ± 51.26 | 0.12 ± 0.25 |
| Crassulaceae | Succulent Shrub | *Cotyledon orbiculata* | 0.17 ± 0.7 | 0.02 ± 0.17 |
| Crassulaceae | Succulent Shrub | *Crassula tetragona* | 3.39 ± 7.05 | 0.11 ± 0.21 |
| Crassulaceae | Succulent Shrub | *Tylecodon ventricosus* | 0.01 ± 0.1 | 0 ± 0 |
| Euphorbiaceae | Dwarf Succulent Shrub | *Euphorbia fimbriata* | 0.75 ± 1.57 | 0.04 ± 0.09 |
| Molluginaceae | Dwarf Woody Shrub | *Limeum aethiopicum* | 0.01 ± 0.1 | 0 ± 0 |
| Molluginaceae | Perennial Forb | *Hypertelis salsoloides* | 0.01 ± 0.1 | 0 ± 0 |
| Poaceae | Perennial Grass | *Digitaria argyrograpta* | 0.51 ± 5.1 | 0.03 ± 0.28 |
| Poaceae | Perennial Grass | *Ehrharta calycina* | 0.54 ± 2.84 | 0.04 ± 0.29 |
| Portulacaceae | Dwarf Succulent | *Anacampseros arachnoides* | 0.21 ± 2.1 | 0 ± 0.01 |
| Rubiaceae | Perennial Forb | *Anthospermum ciliata* | 0.05 ± 0.33 | 0 ± 0.02 |
| Santalaceae | Dwarf Woody Shrub | *Thesium nudicaule* | 0.25 ± 0.88 | 0.02 ± 0.05 |

Table 9 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Scrophulariaceae | Dwarf Woody Shrub | *Selago glutinosa* | 1.19 ± 5.43 | 0.04 ± 0.16 |
| Solanaceae | Woody Shrub | *Lycium cinereum* | 0.2 ± 0.71 | 0.05 ± 0.2 |
| Solanaceae | Woody Shrub | *Lycium oxycarpum* | 0.02 ± 0.2 | 0.08 ± 0.84 |
| Zygophyllaceae | Succulent Shrub | *Augea capensis* | 0.02 ± 0.14 | 0 ± 0 |
| Zygophyllaceae | Succulent Shrub | *Tetraena retrofracta* | 0.16 ± 0.86 | 0.03 ± 0.13 |
| Zygophyllaceae | Woody Shrub | *Roepera lichtensteiniana* | 0.01 ± 0.1 | 0 ± 0 |

Table 10

Total species richness for off termitaria plant community sample plots, mean (±SD) canopy cover percentage and mean (±SD) density (number of individuals) per 100m$^2$ with relative abundance shown in percentages, arranged according to dominance per family recorded in Oudtshoorn Gannaveld.

| Species richness | | | Cover | | | Density | | |
|---|---|---|---|---|---|---|---|---|
| Asteraceae | 23 | 33.8% | Aizoaceae | 591.5 ± 263.74 | 81.3% | Aizoaceae | 49.85 ± 11.44 | 79.7% |
| Aizoaceae | 17 | 25.0% | Asteraceae | 104.37 ± 59.14 | 14.3% | Asteraceae | 11.9 ± 7.08 | 19.0% |
| Crassulaceae | 6 | 8.8% | Crassulaceae | 27.33 ± 66.24 | 3.8% | Crassulaceae | 0.38 ± 0.5 | 0.6% |
| Asparagaceae | 3 | 4.4% | Scrophulariaceae | 1.19 ± 5.43 | 0.2% | Solanaceae | 0.13 ± 0.86 | 0.2% |
| Zygophyllaceae | 3 | 4.4% | Poaceae | 1.05 ± 5.79 | 0.1% | Poaceae | 0.07 ± 0.4 | 0.1% |
| Apocynaceae | 2 | 2.9% | Euphorbiaceae | 0.75 ± 1.57 | 0.1% | Amaranthaceae | 0.06 ± 0.3 | 0.1% |
| Molluginaceae | 2 | 2.9% | Asparagaceae | 0.26 ± 0.82 | 0.0% | Euphorbiaceae | 0.04 ± 0.09 | 0.1% |
| Poaceae | 2 | 2.9% | Santalaceae | 0.25 ± 0.88 | 0.0% | Scrophulariaceae | 0.04 ± 0.16 | 0.1% |
| Solanaceae | 2 | 2.9% | Solanaceae | 0.22 ± 0.73 | 0.0% | Asparagaceae | 0.03 ± 0.14 | 0.1% |
| Acanthaceae | 1 | 1.5% | Portulacaceae | 0.21 ± 2.1 | 0.0% | Zygophyllaceae | 0.03 ± 0.13 | 0.0% |
| Amaranthaceae | 1 | 1.5% | Zygophyllaceae | 0.19 ± 0.87 | 0.0% | Santalaceae | 0.01 ± 0.05 | 0.0% |

Table 10 continued

| Species richness | | | Cover | | | Density | | |
|---|---|---|---|---|---|---|---|---|
| Brassicaceae | 1 | 1.5% | Apocynaceae | 0.15 ± 0.67 | 0.0% | Brassicaceae | 0.01 ± 0.11 | 0.0% |
| Euphorbiaceae | 1 | 1.5% | Brassicaceae | 0.1 ± 0.73 | 0.0% | Acanthaceae | 0.01 ± 0.12 | 0.0% |
| Portulacaceae | 1 | 1.5% | Amaranthaceae | 0.08 ± 0.31 | 0.0% | Apocynaceae | 0 ± 0.01 | 0.0% |
| Rubiaceae | 1 | 1.5% | Rubiaceae | 0.05 ± 0.33 | 0.0% | Rubiaceae | 0 ± 0.02 | 0.0% |
| Santalaceae | 1 | 1.5% | Molluginaceae | 0.02 ± 0.14 | 0.0% | Portulacaceae | 0 ± 0.01 | 0.0% |
| Scrophulariaceae | 1 | 1.5% | Acanthaceae | 0.01 ± 0.1 | 0.0% | Molluginaceae | 0 ± 0 | 0.0% |

The dominant plant functional types off termitaria in terms of species richness are the woody shrub component with 21 species (30.88%), followed by the succulent shrub component 17 species (25%) and the dwarf woody shrub component 13 species (17.65%). The dwarf succulent component of this vegetation type comprises of 7 species (10.29%), the dwarf succulent shrubs component consists of 6 species (8.82), perennial forbs 3 species (4.41%) and perennial grasses 2 species (2.94%).

The dominant plant functional type in terms of density abundance (number of individuals) is the dwarf succulent shrub component with a mean density of 494.96 (±310.47) plants per 100m$^2$. Succulent shrubs in the off termitaria plant community have a mean density of 103.09 (±85.20) plants per 100m$^2$ and are the second most abundant plant functional type in terms of density. Dwarf woody shrubs have a mean density of 55.81 (±46.48) per 100m$^2$, while woody shrubs = 51.09 (±36.43), dwarf succulents = 21.66 (±69.27), perennial grasses = 1.05 (±0.58) and perennial forbs = 0.07 (±0.04).



The dominant dwarf succulent shrub component accounts for 68.01% of the total density of plants in the off termitaria plant community of Oudtshoorn Gannaveld. Succulent shrubs make up 14.17% of the total density of plants in this vegetation type while dwarf woody shrubs make up 7.67%, woody shrubs 7.02%, dwarf succulents 2.98%. Perennial grasses and perennial forbs are both less than 1%.

The plant functional type dominance differs in terms of canopy cover abundance. The dominant plant functional type in terms of cover is the dwarf succulent shrub group with a mean canopy cover percentage of 30.74% (±19.13) per 100m$^2$.

Succulent shrubs have a mean cover of 18.69% (±13.68) per 100m$^2$ and woody shrub cover is 9.69% (±6.47). Dwarf woody shrubs cover is 2.85% (±2.65). Dwarf succulent, perennial grass and perennial forb cover are all less than 1%. Dwarf succulent shrubs account for 49.08% of the total cover of plants in the off termitaria plant community of Oudtshoorn Gannaveld. The succulent shrub component makes up 29.84% of the total cover plants and woody shrubs 15.47%. Dwarf woody shrubs contribute 4.55%.

Table 11 shows the dominant plant functional types in the off termitaria plant community of Oudtshoorn Gannaveld in terms of total species richness for all plots sampled, mean (±SD) density (number of individuals) and mean (±SD) canopy cover percentage.

Table 11

The dominant plant functional types in the off termitaria plant community of Oudtshoorn Gannaveld in terms of total species richness for all plots sampled, mean (±SD) density (number of individuals) and mean (±SD) canopy cover percentage per 100m$^2$. Relative abundances are shown as percentages.

| Species richness | | | Density | | | Cover | | |
|---|---|---|---|---|---|---|---|---|
| Growth form | No of species | % contribution | Growth form | No of ind/100 m$^2$ | % contribution | Growth form | % of plot area | % contribution |
| Woody Shrubs | 21 | 30.9% | Dwarf Succulent Shrubs | 494.96 ± 310.47 | 68.0% | Dwarf Succulent Shrubs | 30.74 ± 19.13 | 49.1% |
| Succulent Shrubs | 17 | 25.0% | Succulent Shrubs | 103.09 ± 85.2 | 14.2% | Succulent Shrubs | 18.69 ± 13.68 | 29.8% |
| Dwarf Woody Shrubs | 12 | 17.7% | Dwarf Woody Shrubs | 55.81 ± 46.48 | 7.7% | Woody Shrubs | 9.69 ± 6.47 | 15.5% |
| Dwarf Succulents | 7 | 10.3% | Woody Shrubs | 51.09 ± 36.43 | 7.0% | Dwarf Woody Shrubs | 2.85 ± 2.65 | 4.6% |
| Dwarf Succulent Shrubs | 6 | 8.8% | Dwarf Succulents | 21.66 ± 69.27 | 3.0% | Dwarf Succulents | 0.59 ± 3.48 | 0.9% |
| Perennial Forbs | 3 | 4.4% | Perennial Grasses | 1.05 ± 5.79 | 0.1% | Perennial Grasses | 0.07 ± 0.4 | 0.1% |
| Perennial Grasses | 2 | 2.9% | Perennial Forbs | 0.07 ± 0.36 | 0.0% | Perennial Forbs | 0 ± 0.02 | 0.0% |

*Leipoldtia schultzei* is the most dominant plant species occurring in the off termitaria plant community of Oudtshoorn Gannaveld both in terms of density and cover. This species has a mean density of 446.65 (±302.77) individuals and a mean cover of 28.56% (±18.55) per 100m$^2$. It accounts for 61.38% of the total density of plants and 45.65% of the total cover of the off termitaria plant community in this vegetation type.

Although 68 perennial plant species were recorded in the off termitaria plant community, only 8 species make up 90.70% of the total density abundance of plants in the off termitaria community. These are: *Leipoldtia schultzei* 61.38%, *Ruschia ceresiana 7.73%, Chrysocoma ciliata 7.10%, Ruschia spinosa 5.13%, Eriocephalus ericoides 3.94%, Drosanthemum lique* 2.38%, *Crassula capitella* 1.72% and *Crassula subaphylla* 1.32%.

In terms of plant canopy cover, 10 plant species make up 90.32% of the total canopy cover abundance in Oudtshoorn Gannaveld. These are *Leipoldtia schultzei* 45.66%, *Ruschia ceresiana* 23.11%, *Eriocephalus ericoides* 5.52%, *Chrysocoma ciliata* 4.25%, *Ruschia spinosa* 3.11%, *Pteronia incana* 2.71%, *Eriocephalus brevifolius* 1.63%, *Tetragonia fruticosa* 1.58%, *Malephora lutea* 1.48% and *Drosanthemum lique 1.27*%.

Other species (60 species for density and 58 species for canopy cover percentage) contribute minimally to the overall density and cover percentage of plants off termitaria. The species recorded arranged according to density and cover dominance with relative percentages and the accumulation of percentages of density and cover are shown in Table 12.

Table 12

Mean (±SD) density (number of individuals) and canopy cover percentage per $100m^2$ for species that contribute more than 1%, recorded in the off termitaria plant community of the Oudtshoorn Gannaveld vegetation type. Values are arranged from highest to lowest value for density and cover. The relative abundance of each species is shown in percentage in the Rel% column. The cumulative relative abundance of species is shown as a percentage in the Acc% column.

| Density | | | | Cover | | | |
|---|---|---|---|---|---|---|---|
| | | Rel% | Acc% | | | Rel% | Acc% |
| *Leipoldtia schultzei* | 446.65±302.77 | 61.4% | 61.4% | *Leipoldtia schultzei* | 28.6±18.55 | 45.7% | 45.7% |
| *Ruschia ceresiana* | 56.26±49.16 | 7.7% | 69.1% | *Ruschia ceresiana* | 14.48±12.57 | 23.1% | 68.8% |
| *Chrysocoma ciliata* | 51.67±46.75 | 7.1% | 76.2% | *Eriocephalus ericoides* | 3.46±4.77 | 5.5% | 74.3% |
| *Ruschia spinosa* | 37.35±71.22 | 5.1% | 81.3% | *Chrysocoma ciliata* | 2.66±2.67 | 4.3% | 78.5% |
| *Eriocephalus ericoides* | 28.69±36.57 | 3.9% | 85.3% | *Ruschia spinosa* | 1.95±4.05 | 3.1% | 81.7% |
| *Drosanthemum lique* | 17.31±50.52 | 2.4% | 87.7% | *Pteronia incana* | 1.7±3.5 | 2.7% | 84.4% |
| *Crassula capitella* | 12.52±42.09 | 1.7% | 89.4% | *Eriocephalus brevifolius* | 1.02±3.04 | 1.6% | 86.0% |

Table 12 continued

| Density | | | | Cover | | | |
|---|---|---|---|---|---|---|---|
| | | Rel% | Acc% | | | Rel% | Acc% |
| *Crassula subaphylla* | 9.61±51.26 | 1.3% | 90.7% | *Tetragonia fruticosa* | 0.99±1.15 | 1.6% | 87.6% |
| *Tetragonia fruticosa* | 8.13±8.76 | 1.1% | 91.8% | *Malephora lutea* | 0.93±4.96 | 1.5% | 89.1% |
| *Malephora lutea* | 7.36±35 | 1.0% | 92.8% | *Drosanthemum lique* | 0.8±2.76 | 1.3% | 90.3% |
| | | | | *Pteronia pallens* | 0.65±2.36 | 1.0% | 91.4% |
| | | | | *Pentzia dentata* | 0.64±2.37 | 1.0% | 92.4% |

The frequency of species in the off termitaria community of Oudtshoorn Gannaveld varies from 96% to 1% with only *Chrysocoma ciliata, Leipoldtia schultzei, Tetragonia fruticosa, Eriocephalus ericoides, Ruschia ceresiana, Ruschia spinosa* and *Drosanthemum lique* having a frequency of occurrence across 100 sample plots of more than 50%. Table 13 shows the frequency of species recorded in 100 10 x 10m$^2$ sample plots off termitaria.

Table 13

The frequency of species occurring in 100 10m x 10m sample plots in the off termitaria plant community of the Oudtshoorn Gannaveld vegetation type.

| Frequency | | | | | |
|---|---|---|---|---|---|
| *Chrysocoma ciliata* | 96% | *Pteronia pallens* | 17% | *Anthospermum ciliata* | 3% |
| *Leipoldtia schultzei* | 93% | *Felicia filifolia* | 16% | *Asparagus africanus* | 3% |
| *Tetragonia fruticosa* | 89% | *Helichrysum rosum* | 14% | *Delosperma sp.* | 3% |
| *Eriocephalus ericoides* | 81% | *Lycium cinereum* | 13% | *Heliophila sauvissima* | 3% |
| *Ruschia ceresiana* | 81% | *Mesembryanthemum crystallinum* | 13% | *Asparagus aethiopicus* | 2% |
| *Ruschia spinosa* | 72% | *Pteronia glauca* | 12% | *Augea capensis* | 2% |
| *Drosanthemum lique* | 60% | *Selago glutinosa* | 12% | *Pentzia incana* | 2% |
| *Crassula subaphylla* | 54% | *Asparagus recurvispinus* | 10% | *Tridentea gemmiflora* | 2% |
| *Pteronia incana* | 47% | *Thesium nudicaule* | 10% | *Tripteris sinuata* | 2% |
| *Crassula muscosa* | 46% | *Cotyledon orbiculata* | 9% | *Anacampseros arachnoides* | 1% |
| *Drosanthemum hispidum* | 35% | *Ruschia impressa* | 9% | *Dicerothamnus rhinocerotis* | 1% |
| *Crassula tetragona* | 34% | *Rosenia humilis* | 8% | *Digitaria argyrograpta* | 1% |
| *Euphorbia fimbriata* | 32% | *Senecio radicans* | 8% | *Helichrysum dregei* | 1% |
| *Malephora lutea* | 28% | *Duvalia caespitosa* | 7% | *Helichrysum excisum* | 1% |

Table 13 continued

| | | | | | |
|---|---|---|---|---|---|
| | | Frequency | | | |
| *Phyllobolus splendens* | 28% | *Ehrharta calycina* | 7% | *Hermannia sp.* | 1% |
| *Eriocephalus brevifolius* | 25% | *Pteronia paniculata* | 7% | *Hypertelis salsoloides* | 1% |
| *Helichrysum zeyheri* | 21% | *Salsola aphylla* | 7% | *Justicia cuneata* | 1% |
| *Pentzia dentata* | 21% | *Tetraena retrofracta* | 7% | *Limeum aethiopicum* | 1% |
| *Galenia africana* | 20% | *Euryops lateriflorus* | 6% | *Lycium oxycarpum* | 1% |
| *Lampranthus haworthii* | 20% | *Drosanthemum giffenii* | 5% | *Roepera lichtensteiniana* | 1% |
| *Psilocaulon junceum* | 20% | *Helichrysum anomalum* | 4% | *Ruschia crassa* | 1% |
| *Senecio juniperinus* | 18% | *Othonna sp.* | 4% | *Tylecodon ventricosus* | 1% |
| *Crassula capitella* | 17% | *Senecio sp.* | 4% | | |

**Oudtshoorn Gannaveld on termitaria community**

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**Perennial plant composition**

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50 species in 34 genera and 13 families were sampled in the on termitaria plant community of the Oudtshoorn Gannaveld vegetation type. Table 14 provides the mean (±SD) density and canopy cover percentage for all species recorded in this plant community.

The on termitaria perennial plant community of Oudtshoorn Gannaveld is dominated in terms of perennial plant species richness by the Asteraceae (15 species, 30%), Aizoaceae (14 species, 28%) and Crassulaceae (5 species, 10%) families (Table 15).

The on termitaria community is dominated in terms of perennial plant canopy cover percentage by species of the Aizoaceae (14 species, 46.53%) and Amaranthaceae (2 species, 2.33%), Zygophyllaceae (2 species 1.49%) and Asteraceae (15 species, 1.32%) families. The families most dominant in terms of plant density (number of individual plants) are the Aizoaceae (14 species, 93.38%), Asteraceae (15 species, 4.16%) and Zygophyllaceae (2 species, 1.63%) families.

Table 14

Plant families, plant functional type (PFT) and species with mean (±SD) density (number of individuals) and canopy cover percentage data from 100 10m x 10m plots sampled in the on termitaria plant community of Oudtshoorn Gannaveld. Nomenclature follows Goldblatt and Manning (2000) and Goldblatt *et al.* (2008).

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Acanthaceae | Woody Shrub | *Justicia cuneata* | 0.03 ± 0.3 | 0.01 ± 0.09 |
| Aizoaceae | Dwarf Succulent | *Ruschia impressa* | 19.73 ± 47.37 | 1.55 ± 4.03 |
| Aizoaceae | Dwarf Succulent Shrub | *Leipoldtia schultzei* | 16.36 ± 41.45 | 1.04 ± 2.59 |
| Aizoaceae | Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | 98.67 ± 245.24 | 6.59 ± 13.56 |
| Aizoaceae | Dwarf Succulent Shrub | *Ruschia spinosa* | 39.35 ± 74.35 | 2.83 ± 5.71 |
| Aizoaceae | Succulent Shrub | *Drosanthemum giffenii* | 19.05 ± 36.14 | 1.35 ± 2.44 |
| Aizoaceae | Succulent Shrub | *Drosanthemum hispidum* | 90.65 ± 99.48 | 15.16 ± 17.55 |
| Aizoaceae | Succulent Shrub | *Drosanthemum lique* | 0.11 ± 0.45 | 0 ± 0.02 |
| Aizoaceae | Succulent Shrub | *Malephora lutea* | 35.85 ± 72 | 5.86 ± 12.29 |
| Aizoaceae | Succulent Shrub | *Phyllobolus splendens* | 7.63 ± 13.54 | 2.22 ± 3.92 |

Table 14 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Aizoaceae | Succulent Shrub | *Psilocaulon junceum* | 52.96 ± 44.47 | 9.08 ± 8.49 |
| Aizoaceae | Succulent Shrub | *Ruschia ceresiana* | 0.9 ± 3.94 | 0.42 ± 2.27 |
| Aizoaceae | Succulent Shrub | *Ruschia crassa* | 0.3 ± 2.15 | 0.29 ± 2.09 |
| Aizoaceae | Succulent Shrub | *Tetragonia fruticosa* | 0.35 ± 1.04 | 0.05 ± 0.15 |
| Aizoaceae | Woody Shrub | *Galenia africana* | 0.3 ± 1.25 | 0.11 ± 0.44 |
| Amaranthaceae | Woody Shrub | *Manochlamys albicans* | 0.08 ± 0.61 | 0 ± 0.04 |
| Amaranthaceae | Woody Shrub | *Salsola aphylla* | 1.09 ± 2 | 2.33 ± 3.91 |
| Apocynaceae | Dwarf Succulent | *Tridentea gemmiflora* | 0.02 ± 0.2 | 0 ± 0 |
| Asparagaceae | Woody Shrub | *Asparagus recurvispinus* | 0.05 ± 0.3 | 0.03 ± 0.2 |
| Asteraceae | Dwarf Succulent Shrub | *Othonna sp.* | 0.01 ± 0.1 | 0 ± 0.01 |
| Asteraceae | Dwarf Woody Shrub | *Chrysocoma ciliata* | 11.15 ± 25.53 | 0.46 ± 1.07 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum dregei* | 0.03 ± 0.3 | 0 ± 0.01 |
| Asteraceae | Dwarf Woody Shrub | *Helichrysum rosum* | 0.02 ± 0.2 | 0 ± 0.01 |
| Asteraceae | Dwarf Woody Shrub | *Pentzia incana* | 0.41 ± 1.74 | 0.09 ± 0.36 |

Table 14 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Asteraceae | Dwarf Woody Shrub | *Senecio juniperinus* | 1.61 ± 4.8 | 0.04 ± 0.1 |
| Asteraceae | Succulent Shrub | *Senecio sp.* | 0.01 ± 0.1 | 0.03 ± 0.25 |
| Asteraceae | Woody Shrub | *Eriocephalus brevifolius* | 0.02 ± 0.2 | 0 ± 0.01 |
| Asteraceae | Woody Shrub | *Eriocephalus ericoides* | 1.69 ± 5.99 | 0.16 ± 0.56 |
| Asteraceae | Woody Shrub | *Felicia filifolia* | 0.03 ± 0.22 | 0.02 ± 0.13 |
| Asteraceae | Woody Shrub | *Pentzia dentata* | 0.01 ± 0.1 | 0 ± 0.03 |
| Asteraceae | Woody Shrub | *Pteronia glauca* | 0.57 ± 3.39 | 0.18 ± 1.1 |
| Asteraceae | Woody Shrub | *Pteronia incana* | 0.89 ± 3.86 | 0.15 ± 0.71 |
| Asteraceae | Woody Shrub | *Pteronia pallens* | 0.57 ± 4.13 | 0.2 ± 1.52 |
| Asteraceae | Woody Shrub | *Rosenia humilis* | 0.01 ± 0.1 | 0 ± 0.01 |
| Crassulaceae | Dwarf Succulent | *Crassula capitella* | 0.06 ± 0.42 | 0 ± 0.01 |
| Crassulaceae | Dwarf Succulent | *Crassula muscosa* | 0.2 ± 0.67 | 0.01 ± 0.02 |
| Crassulaceae | Dwarf Succulent Shrub | *Crassula subaphylla* | 0.63 ± 3.34 | 0.02 ± 0.08 |
| Crassulaceae | Succulent Shrub | *Cotyledon orbiculata* | 0.03 ± 0.22 | 0 ± 0.01 |

Table 14 continued

| Family | PFT | Species | Density | Cover |
|---|---|---|---|---|
| Crassulaceae | Succulent Shrub | *Crassula tetragona* | 0.05 ± 0.41 | 0 ± 0.02 |
| Euphorbiaceae | Dwarf Succulent Shrub | *Euphorbia fimbriata* | 0.29 ± 1.09 | 0.03 ± 0.1 |
| Molluginaceae | Perennial Forb | *Hypertelis salsoloides* | 0.01 ± 0.1 | 0 ± 0 |
| Poaceae | Perennial Grass | *Ehrharta calycina* | 0.02 ± 0.2 | 0 ± 0.01 |
| Scrophulariaceae | Dwarf Woody Shrub | *Selago albida* | 0.16 ± 1.6 | 0.01 ± 0.06 |
| Scrophulariaceae | Dwarf Woody Shrub | *Selago glutinosa* | 0.14 ± 1.22 | 0 ± 0.03 |
| Scrophulariaceae | Perennial Forb | *Aptosimum indivisum* | 0.27 ± 1.03 | 0.01 ± 0.02 |
| Scrophulariaceae | Perennial Forb | *Hebenstretia sp.* | 0.04 ± 0.4 | 0 ± 0.03 |
| Solanaceae | Woody Shrub | *Lycium cinereum* | 0.18 ± 0.56 | 0.06 ± 0.24 |
| Solanaceae | Woody Shrub | *Lycium oxycarpum* | 0.01 ± 0.1 | 0 ± 0.03 |
| Zygophyllaceae | Succulent Shrub | *Augea capensis* | 0.96 ± 4 | 0.08 ± 0.39 |
| Zygophyllaceae | Succulent Shrub | *Tetraena retrofracta* | 5.73 ± 11.61 | 1.41 ± 2.89 |

Table 15

Total species richness for on termitaria plant community sample plots, mean (±SD) canopy cover percentage and mean (±SD) density (number of individuals) per 100m$^2$ with relative abundance shown in percentages, arranged according to dominance per family recorded in Oudtshoorn Gannaveld.

| Species richness | | | Cover | | | Density | | |
|---|---|---|---|---|---|---|---|---|
| Asteraceae | 15 | 30% | Aizoaceae | 46.53 ± 16.45 | 89.77% | Aizoaceae | 382.21 ± 214.9 | 93.38% |
| Aizoaceae | 14 | 28% | Amaranthaceae | 2.33 ± 3.91 | 4.49% | Asteraceae | 17.03 ± 30.27 | 4.16% |
| Crassulaceae | 5 | 10% | Zygophyllaceae | 1.49 ± 2.88 | 2.87% | Zygophyllaceae | 6.69 ± 11.83 | 1.63% |
| Scrophulariaceae | 4 | 8% | Asteraceae | 1.32 ± 2.87 | 2.54% | Amaranthaceae | 1.17 ± 2.06 | 0.29% |
| Amaranthaceae | 2 | 4% | Solanaceae | 0.07 ± 0.24 | 0.13% | Crassulaceae | 0.97 ± 3.81 | 0.24% |
| Solanaceae | 2 | 4% | Euphorbiaceae | 0.03 ± 0.1 | 0.05% | Scrophulariaceae | 0.61 ± 2.39 | 0.15% |
| Zygophyllaceae | 2 | 4% | Asparagaceae | 0.03 ± 0.2 | 0.05% | Euphorbiaceae | 0.29 ± 1.09 | 0.07% |
| Acanthaceae | 1 | 2% | Crassulaceae | 0.03 ± 0.1 | 0.05% | Solanaceae | 0.19 ± 0.56 | 0.05% |
| Apocynaceae | 1 | 2% | Scrophulariaceae | 0.02 ± 0.08 | 0.03% | Asparagaceae | 0.05 ± 0.3 | 0.01% |
| Asparagaceae | 1 | 2% | Acanthaceae | 0.01 ± 0.09 | 0.02% | Acanthaceae | 0.03 ± 0.3 | 0.01% |
| Euphorbiaceae | 1 | 2% | Poaceae | 0 ± 0.01 | 0% | Apocynaceae | 0.02 ± 0.2 | 0% |
| Molluginaceae | 1 | 2% | Apocynaceae | 0 ± 0 | 0% | Poaceae | 0.02 ± 0.2 | 0% |
| Poaceae | 1 | 2% | Molluginaceae | 0 ± 0 | 0% | Molluginaceae | 0.01 ± 0.1 | 0% |

The dominant plant functional types on termitaria in terms of species richness are the woody shrub component with 15 species (30%), the succulent shrub component 14 species (28%) and the dwarf woody shrub component 7 species (14%). The dwarf succulent shrub functional type consists of 6 species (12%), the dwarf succulents consists of 4 species (8%), perennial forbs 3 species (6%) and perennial grasses 1 species (2 %).

The dominant plant functional type in terms of density is the succulent shrub component with a mean density of 214.58 (±120.61) plants per $100m^2$. Dwarf succulent shrubs on termitaria have a mean density of 155.31 (±249.34) per $100m^2$ and are the second most abundant plant functional type in terms of density. Dwarf succulents have a mean density per $100m^2$ of 20.01 (±47.50), dwarf woody shrubs 13.52 (±26.75) woody shrubs 5.53 (±11.24), perennial forbs 0.32 (±1.10) and perennial grasses 0.02 (±020).



The dominant succulent shrub component accounts for 52.43% of the total density of plants in the on termitaria plant community of Oudtshoorn Gannaveld. Dwarf succulent shrubs make up 37.95% of the total density of plants in this vegetation type while dwarf succulents make up 4.89%, dwarf woody shrubs 3.30%, woody shrubs 1.35%, perennial forbs 0.08% and perennial grasses 0%.

The plant functional type dominance differs in terms of the canopy cover percentages. The dominant plant functional type in terms of cover in the on termitaria plant community is the succulent shrub group with a mean canopy cover percentage of 35.93% (±20.48) per $100m^2$. Dwarf succulent shrubs have a mean cover percentage of 10.49% (±14.33) per $100m^2$, while woody shrubs cover 3.24% (±4.85). Dwarf succulents cover 1.56% (±4.03), dwarf woody shrubs

O.60% (±1.14), perennial forb and perennial grass cover is less than 0.1%. Succulent shrubs account for 69.33% of the total cover of plants in the on termitaria plant community of Oudtshoorn Gannaveld. The dwarf succulent shrub component makes up 20.24% of the total cover plants and woody shrubs 6.26%. Dwarf succulents contribute 3.01%, dwarf woody shrubs 1.15%, perennial forbs and grasses make up less than 0.1%.

Table 16 shows the dominant plant functional types on termitaria in terms of total species richness for all plots sampled, mean (±SD) density (number of individuals) and mean (±SD) canopy cover percentage.

Table 16

The dominant plant functional types in the on termitaria plant community of Oudtshoorn Gannaveld in terms of total species richness for on termitaria plots sampled, mean (±SD) density (number of individuals) and mean (±SD) canopy cover percentage per 100m$^2$. Relative abundances are shown as percentages.

| Species richness | | | Density | | | Cover | | |
|---|---|---|---|---|---|---|---|---|
| Woody Shrub | 15 | 30% | Succulent Shrub | 214.58 ± 120.61 | 52.43% | Succulent Shrub | 35.93 ± 20.48 | 69.33% |
| Succulent Shrub | 14 | 28% | Dwarf Succulent Shrub | 155.31 ± 249.34 | 37.95% | Dwarf Succulent Shrub | 10.49 ± 14.33 | 20.24% |
| Dwarf Woody Shrub | 7 | 14% | Dwarf Succulent | 20.01 ± 47.5 | 4.89% | Woody Shrub | 3.24 ± 4.85 | 6.26% |
| Dwarf Succulent Shrub | 6 | 12% | Dwarf Woody Shrub | 13.52 ± 26.75 | 3.3% | Dwarf Succulent | 1.56 ± 4.03 | 3.01% |
| Dwarf Succulent | 4 | 8% | Woody Shrub | 5.53 ± 11.24 | 1.35% | Dwarf Woody Shrub | 0.6 ± 1.14 | 1.15% |
| Perennial Forb | 3 | 6% | Perennial Forb | 0.32 ± 1.1 | 0.08% | Perennial Forb | 0.01 ± 0.04 | 0.02% |
| Perennial Grass | 1 | 2% | Perennial Grass | 0.02 ± 0.2 | 0% | Perennial Grass | 0 ± 0.01 | 0% |

*Mesembryanthemum crystallinum* is the most dominant plant species occurring in the on termitaria plant community of Oudtshoorn Gannaveld in terms of density. The species has a mean density of 98.67 (±245.24) per 100m$^2$. *Mesembryanthemum crystallinum* accounts for 61.38% of the total density of plants and 45.65% of the total cover of the on termitaria plant community in this vegetation type. Although 50 perennial plant species were recorded on termitaria, only 8 species make up 91.04% of the total density of plants. These are: *Mesembryanthemum crystallinum* 24.1%, *Drosanthemum hispidum* 22.1%, *Psilocaulon junceum* 12.9%, *Ruschia spinosa* 9.6%, *Malephora lutea* 8.8%, *Ruschia impressa* 4.8%, *Drosanthemum giffenii* 4.7% and *Leipoldtia schultzei* 4%.

*Drosanthemum hispidum* is the dominant plant species on termitaria in terms of canopy cover percentage. This species has a mean canopy cover of 15.16% (±17.55). On termitaria 9 plant species make up 90.71% of the total canopy cover. These are *Drosanthemum hispidum* 29.25%, *Psilocaulon junceum* 17.52%, *Mesembryanthemum crystallinum* 12.71%, *Malephora lutea* 11.31%, *Ruschia spinosa* 5.46%, *Salsola aphylla* 4.49%, *Phyllobolus splendens* 4.27%, *Ruschia impressa* 2.99%, *and Tetraena retrofracta* 2.72%. The rest of the species (42 species for density and 41 species for canopy cover percentage) contribute minimally to the overall density and cover percentage of plants on termitaria.



Species contributing more than 1% arranged according to density and cover dominance with relative percentages and the accumulation of percentages of density and cover are shown in Table 17.

Table 17

Mean (±SD) density (number of individuals) and canopy cover percentage per $100m^2$ for species that contribute more than 1%, recorded in the on termitaria plant community of the Oudtshoorn Gannaveld vegetation type. Values are arranged from highest to lowest value for density and cover. The relative abundance of each species is shown in percentage in the Rel% column. The cumulative relative abundance of species is shown as a percentage in the Acc% column.

| | Density | | | | Cover | | |
|---|---|---|---|---|---|---|---|
| | | Rel% | Acc% | | | Rel% | Acc% |
| *Mesembryanthemum crystallinum* | 98.67 ± 245.24 | 24.11% | 24.11% | *Drosanthemum hispidum* | 15.16 ± 17.55 | 29.25% | 29.25% |
| *Drosanthemum hispidum* | 90.65 ± 99.48 | 22.15% | 46.26% | *Psilocaulon junceum* | 9.08 ± 8.49 | 17.52% | 46.76% |
| *Psilocaulon junceum* | 52.96 ± 44.47 | 12.94% | 59.2% | *Mesembryanthemum crystallinum* | 6.59 ± 13.56 | 12.71% | 59.47% |
| *Ruschia spinosa* | 39.35 ± 74.35 | 9.61% | 68.81% | *Malephora lutea* | 5.86 ± 12.29 | 11.31% | 70.79% |
| *Malephora lutea* | 35.85 ± 72 | 8.76% | 77.57% | *Ruschia spinosa* | 2.83 ± 5.71 | 5.46% | 76.24% |
| *Ruschia impressa* | 19.73 ± 47.37 | 4.82% | 82.39% | *Salsola aphylla* | 2.33 ± 3.91 | 4.49% | 80.73% |
| *Drosanthemum giffenii* | 19.05 ± 36.14 | 4.65% | 87.04% | *Phyllobolus splendens* | 2.22 ± 3.92 | 4.27% | 85% |
| *Leipoldtia schultzei* | 16.36 ± 41.45 | 4% | 91.04% | *Ruschia impressa* | 1.55 ± 4.03 | 2.99% | 88% |
| *Chrysocoma ciliata* | 11.15 ± 25.53 | 2.72% | 93.76% | *Tetraena retrofracta* | 1.41 ± 2.89 | 2.72% | 90.71% |

Table 17 continued

| | Density | Rel% | Acc% | | Cover | Rel% | Acc% |
|---|---|---|---|---|---|---|---|
| *Phyllobolus splendens* | 7.63 ± 13.54 | 1.86% | 95.63% | *Drosanthemum giffenii* | 1.35 ± 2.44 | 2.6% | 93.31% |
| *Tetraena retrofracta* | 5.73 ± 11.61 | 1.4% | 97.03% | *Leipoldtia schultzei* | 1.04 ± 2.59 | 2% | 95.31% |

The frequency of species in the on termitaria community of Oudtshoorn Gannaveld varies from 94% to 1% with only *Psilocaulon junceum, Drosanthemum hispidum, Mesembryanthemum crystallinum, Chrysocoma ciliata* and *Ruschia spinosa* having a frequency of occurrence across 100 sample plots of more than 50%. Table 18 shows the frequency of species recorded.

Table 18

The frequency of species occurring in 100 10m x 10m sample plots in the on termitaria plant community the Oudtshoorn Gannaveld vegetation type.

| Frequency | | | | | |
|---|---|---|---|---|---|
| *Psilocaulon junceum* | 94% | *Lycium cinereum* | 13% | *Ruschia crassa* | 2% |
| *Drosanthemum hispidum* | 87% | *Crassula muscosa* | 11% | *Selago glutinosa* | 2% |
| *Mesembryanthemum crystallinum* | 62% | *Pteronia glauca* | 11% | *Ehrharta calycina* | 1% |
| *Chrysocoma ciliata* | 57% | *Aptosimum indivisum* | 10% | *Eriocephalus brevifolius* | 1% |
| *Ruschia spinosa* | 55% | *Augea capensis* | 10% | *Hebenstretia sp.* | 1% |
| *Phyllobolus splendens* | 49% | *Euphorbia fimbriata* | 10% | *Helichrysum dregei* | 1% |
| *Drosanthemum giffenii* | 48% | *Pteronia pallens* | 10% | *Helichrysum rosum* | 1% |
| *Tetraena retrofracta* | 42% | *Galenia africana* | 9% | *Hypertelis salsoloides* | 1% |
| *Leipoldtia schultzei* | 41% | *Pentzia incana* | 9% | *Justicia cuneata* | 1% |
| *Malephora lutea* | 38% | *Crassula subaphylla* | 7% | *Lycium oxycarpum* | 1% |
| *Ruschia impressa* | 37% | *Drosanthemum lique* | 7% | *Othonna sp.* | 1% |
| *Salsola aphylla* | 37% | *Asparagus recurvispinus* | 3% | *Pentzia dentata* | 1% |
| *Eriocephalus ericoides* | 28% | *Crassula capitella* | 3% | *Rosenia humilis* | 1% |
| *Ruschia ceresiana* | 20% | *Manochlamys albicans* | 3% | *Selago albida* | 1% |

| Table 18 continued | | | | | |
|---|---|---|---|---|---|
| | | Frequency | | | |
| *Pteronia incana* | 18% | *Cotyledon orbiculata* | 2% | *Senecio sp.* | 1% |
| *Senecio juniperinus* | 17% | *Crassula tetragona* | 2% | *Tridentea gemmiflora* | 1% |
| *Tetragonia fruticosa* | 16% | *Felicia filifolia* | 2% | | |

**Discussion**

The Oudtshoorn Gannaveld vegetation type has been relatively recently described by Vlok *et al.* (2005). However, during the mapping of the vegetation types of the Little Karoo the descriptions of the composition of the 369 vegetation types were limited to the more abundant and endemic species and descriptions of structure. The Oudtshoorn Gannaveld vegetation type is described as having *Salsola aphylla* abundant, as well as species such as *Pteronia pallens, Aloe variegata, Cotyledon orbiculare, Drosanthemum giffenii, Phyllobolus splendens, Malephora lutea, Rosenia humilis, Senecio radicans and Tylecodon wallichii* (Vlok *et al.* 2005). This study found that many of the species described as being abundant were in fact quite rare in Oudtshoorn Gannaveld and that species such as *Ruschia ceresiana, Drosanthemum hispidum, Leipoldtia schultzei* and *Psilocaulon junceum* better represent the dominant composition of this community. One of the species thought to be abundant in Oudtshoorn Gannaveld probably because it is one of the larger and more conspicuous species, *Salsola aphylla*, accounts for only 2% of the total canopy cover of plants in this vegetation type.



Perennial species richness in this vegetation type is mainly found in the Asteraceae, Aizoaceae and Crassulaceae families, which is in line with what has been described for the broader Succulent Karoo biome (Cowling and Hilton-Taylor 1999) and consists mostly of species in the woody shrub plant functional type. The leaf succulent shrubs, characteristic of the Succulent Karoo (Cowling and Hilton-Taylor 1999), are dominant in Oudtshoorn Gannaveld both in the number of individual plants and in cover.

It was found that Oudtshoorn Gannaveld is not only highly dominated in terms of plant density by dwarf succulent shrubs, but that plant cover is dominated by the succulent shrub group. It was also found that the abundance of perennial forbs and perennial grasses was extremely low. Perennial grasses are known to be rare in the Succulent Karoo biome (Low and Rebelo 1998) and in the Gannaveld habitat (Vlok *et al.* 2005). The low abundance of perennial forbs may be the result of grazing and trampling.

The clear distinction between the two main plant communities in Oudtshoorn Gannaveld, the on termitaria and the off termitaria communities has been well documented in the Succulent Karoo (Lovegrove and Siegfried 1986, Knight *et al.* 1989, Milton and Dean 1990, Moore and Picker 1991, Esler and Cowling 1995) although the composition of these communities in the Oudtshoorn Gannaveld vegetation type of the Little Karoo had not been quantified before this study. It was found that the Oudtshoorn Gannaveld off termitaria community is dominated by the Asteraceae, Aizoaceae and Crassulaceae families, while the on termitaria community is dominated by the Asteraceae, Amaranthaceae and Zygophyllaceae families. While woody and succulent shrubs dominate both on and off termitaria plant communities in terms of species richness, the canopy cover and density of plants on termitaria is dominated by succulent shrubs and by dwarf succulent shrubs off termitaria. This supports the descriptions by Vlok *et al.* (2005) that succulent shrubs are abundant in this habitat type and that shrubs less than one meter tall of the Aizoaceae, Amaranthaceae and Asteraceae families are predominant.

The study shows that 72 perennial species in 49 genera and 17 plant families occur in Oudtshoorn Gannaveld with most of these species being woody shrubs and succulent shrubs and most species occurring in the Asteraceae, Aizoaceae and Crassulaceae families. Most of the cover in Oudtshoorn Gannaveld is made up by species of the Aizoaceae, Asteraceae and Amaranthaceae families. There were 68 species in 46 genera and 17 plant families recorded off termitaria and 50 species in 34 genera and 13 plant families recorded on termitaria. Of interest is that although 72 perennial plant species were recorded throughout the Oudtshoorn Gannaveld study area, only 11 species make up 90% of the total number of plants found here. In terms of canopy cover only 13 species make up 90% of the total cover.

Data such as these are important in understanding the dynamics of Oudtshoorn Gannaveld, especially within the context of the highly threatened status of Succulent Karoo habitats such as Gannaveld. Key species in this vegetation type are the dwarf succulent shrub *Leipoldtia schultzei*, the most abundant plant occurring in Oudtshoorn Gannaveld, *Drosanthemum hispidum* and *Psilocaulon junceum* in the on termitaria community and *Ruschia ceresiana* in the off termitaria community.

**Conclusions**

The research question for this chapter is: What is the perennial plant composition of Oudtshoorn Gannaveld?

The perennial plant composition of Oudtshoorn Gannaveld has been described in detail in this chapter. The quantification of the perennial plant composition of Oudtshoorn Gannaveld has also provided new information on the relative abundance of species in this vegetation type. This differs in some respects from contemporary descriptions (e.g. Vlok *et al.* 2005), where composition has been based on species that appear dominant in the landscape. It can be seen from the results that the two plant communities, the on and off termitaria plant communities, differ in composition. This confirms what has been found in numerous other studies across the Succulent Karoo. However this study provides new information on the composition of these two plant communities in Oudtshoorn Gannaveld. An important finding is that the spread of the abundance of plants in Oudtshoorn Gannaveld is made up by a few key species such as *Leipoldtia schultzei*, *Drosanthemum hispidum*, *Ruschia ceresiana*, *Psilocaulon junceum*, *Malephora lutea*, *Mesembryanthemum crystallinum* and *Ruschia spinosa*.

The data from this study adds to the knowledge of Succulent Karoo plant diversity in the Little Karoo and the quantification of the abundance of species will be useful for comparisons with other Gannaveld vegetation types over time.

# Chapter 3

## On and off termitaria perennial plant communities of Oudtshoorn Gannaveld

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## Introduction

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The expected differences in vegetation composition between the termitaria and the off termitaria or matrix vegetation are based on studies showing that the soils on termitaria are nutrient rich (Lovegrove 1991) and differ in moisture availability (Milton and Dean 1990) and that termitaria support plant communities associated with the high levels of animal activity (Armstrong and Siegfried 1990, Milton and Dean 1990, Milton *et al.* 1992). Plant species on termitaria tend to have more opportunistic life-history characteristics than those off termitaria (Esler and Cowling 1995) allowing them to survive in this highly disturbed environment. Plant communities occurring off termitaria tend to have a slower turnover of plants, with relatively stable populations and long lived adult plants, while on termitaria communities have a faster turn over of plants and species tend to be more short lived (Yeaton and Esler 1990, Esler and Cowling 1995). This results in a distinct vegetation composition that is different to that of the matrix vegetation (Knight *et al.* 1989, Midgley and Musil 1990, Yeaton and Esler 1990, Milton 1990, Milton and Dean 1990).



Earth mounds similar to the termitaria mounds found in the Succulent Karoo are found in numerous landscapes in North and South America and Africa (Cox *et al.* 1987, Moore and Picker 1991). In southern Africa the distribution of termitaria falls mainly within the Succulent Karoo biome (Lovegrove and Siegfried 1986, Lovegrove 1991) and in the Western

Cape Province they occupy between 14 and 25% of the land surface (Moore and Picker 1991). The origin of these mounds, called “heuweltjies” or “kraaltjies” locally (Knight *et al.* 1989), has been the centre of much debate in the past (Lovegrove and Siegfried 1986, Lovegrove and Siegfried 1989, Moore and Picker 1991, Midgley *et al.* 2002, Picker *et al.* 2007). The carbon in the petrocalcic horizons of termitaria in the Clanwilliam and Elandsbay area of the Western Cape Province has been dated to be between 24 600 and 29 800 years old (Midgley *et al.* 2002) and their origins have been ascribed to zoogenic (Lovegrove and Siegfried 1986, Lovegrove 1991, Milton and Dean 1990) and geological (Ten Cate 1966, Visser and Toerien 1971) factors. It has, however, been generally accepted that south of the Orange River the termite species *Microhodotermes viator* is responsible for the creation of termitaria through nest building and maintenance (Dean and Milton 1999, Picker *et al.* 2007). Fossorial mammals, such as the common molerat (*Cryptomys hottentottus*), also contribute to the development and maintenance of these mounds (Milton and Dean 1990, Lovegrove 1993).



These regularly spaced round or oval mounds (Dean and Milton 1999) have diameters of up to 30m (average = 17m) (Armstrong and Siegfried 1990) and a height of up to 1.45m (Moore and Picker 1991). They form a characteristic pock-marked appearance in the landscape (Lovegrove 1993) and have a mean density of 296.6 mounds per $km^2$ (Picker *et al.* 2007) (Figures 1 and 2).



Figure 1

An aerial photograph taken of part of the study area in Oudtshoorn Gannaveld. The termitaria are visible as lighter circles throughout the landscape. The darker areas between the termitaria consist of the matrix or off termitaria vegetation. The road to the right of the picture is a National Road (R62) and this can be used to show the scale.

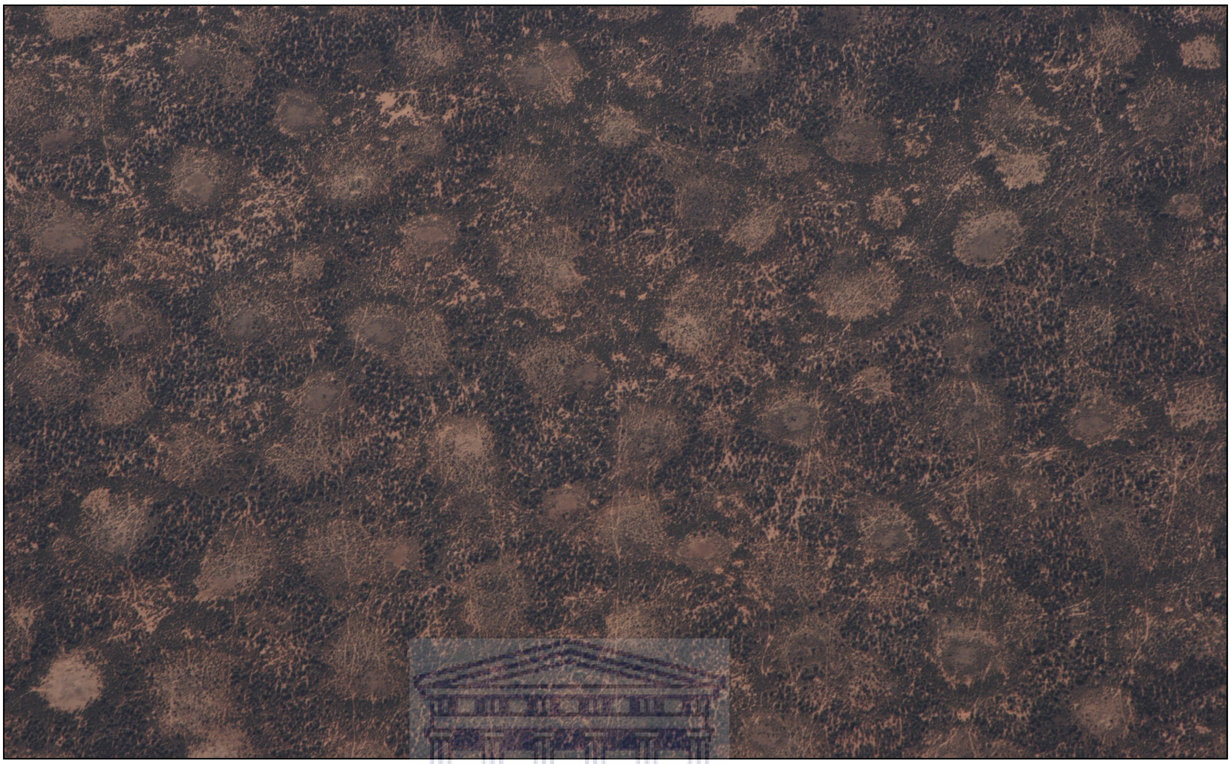



Figure 2

A close up aerial photograph of part of the study area in Oudtshoorn Gannaveld. The termitaria mounds are the lighter circular areas. The darker areas consist of the matrix or off termitaria vegetation. The diameter of the termitaria are approximately 15-20m and this shows the scale of the figure.

In the Succulent Karoo vegetation types of the Little Karoo, as with other areas in the Succulent Karoo, termitaria mounds are an important contributor to the botanical heterogeneity of the landscape (Yeaton and Esler 1990, Milton and Dean 1990, Esler and Cowling 1995, Vlok *et al.* 2005). Elements of on and off termitaria vegetation have been described in various studies (Knight *et al.* 1989, Yeaton and Esler 1990, Esler and Cowling 1995, Riginos *et al.* 2005, Rahlao *et al.* 2008) but no quantified comparison between these two plant communities exists for the Gannaveld habitat of Little Karoo (J. Vlok. pers. comm. 2004). In this chapter I quantify the differences in plant composition between the two main plant communities in Oudtshoorn Gannaveld, the on and off termitaria plant communities.

The research question for this chapter is:

- What are the differences in composition between on termitaria and off termitaria vegetation communities in Oudtshoorn Gannaveld?

**Study area**

The study area and methods have been described in detail in the previous chapter but are described again briefly here as a reference for this chapter. The study was carried out in the critically endangered (Kirkwood *et al.* 2007, Reyers 2008) Oudtshoorn Gannaveld vegetation type in the Succulent Karoo biome of the Little Karoo (Vlok *et al.* 2005). The study area is the only remaining extensive example of this vegetation type in the Little Karoo (Thompson *et al.* 2005).

**Methods**



Data were collected from two hundred 10 x 10m$^2$ plots. One hundred plots were placed off termitaria and 100 plots were placed on termitaria. Plots were placed randomly throughout the study area regardless of perceived vegetation condition. One hundred random points were placed on a Geographic Information System (ArcView 3.3) layer of the study site and the coordinates for the random points were then located in the field using a global positioning system (GPS).

In the field each site was located by GPS and placed in the inter-termitaria matrix vegetation. If a site fell onto a termite mound the nearest off termitaria site was selected. The 100 on termitaria plots were selected as the nearest termitaria to the random off termitaria plot. Each 100m$^2$ plot was divided into sixteen 2.5m x 2.5m (6.25m$^2$) subplots. 3 200 x 6.25m$^2$ subplots were sampled over a period of one year (May 2006 to May 2007).

The following data were collected from each subplot.

1. Perennial plant species.
2. Number of individuals per species.
3. Canopy cover percentage per species.
4. Prostrate dead plant material cover percentage.
5. Bare ground percentage.
6. Soil.

The soil samples were analysed for available phosphorus (P), exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$ and $Na^+$) and acidity (pH) (Gebremeskel and Pieterse 2007). Soil preparation was carried out using the conventional *aqua regia* digestion procedure consisting of digesting soil samples on a hotplate with a mixture of HCl and $HNO_3$ (Nieuwenhuize *et al.* 1991). The prepared soil samples were analysed for P using the Murphy and Riley (1962) method. The Unicam Solar M Series Atomic Absorption Spectrometer with air-acetylene flame system was used for K and Na and nitrousoxide-acetylene flame system was used for Ca and Mg. Soil analysis was carried out by the Science Faculty of the University of the Western Cape, Cape Town. Four of the most commonly used methods of expressing diversity (Clarke and Warwick 2001) in terms of species richness, equitability, or both, were compared for the two plant communities (on and off termitaria) in Oudtshoorn Gannaveld. These methods of expressing diversity are species richness (S) (Magurran 1988), Margalef's index (D*mg*) (Margalef 1958), the Shannon-Wiener diversity index (*H*') (Shannon and Wiener 1963) and Pielou's evenness index (*E)* (Pielou 1969).

**Data analysis**

Raw multivariate data was placed into a data matrix (Microsoft Excel®) and reduced using the SPSS software package (SPSS 16, 2007). The on and off termitaria data were tested for significant differences using paired t-tests in the SPSS software package. PRIMER statistical analysis software (Clarke and Warwick 2001) was used to determine diversity indices.

Results

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Of the 72 perennial plant species recorded across the study area 68 species were recorded off termitaria and 50 species were recorded on termitaria. Twenty two species were recorded only in the off termitaria vegetation and four species were recorded only on termitaria. Forty six species were common to both on and off termitaria communities. The off termitaria community of Oudtshoorn Gannaveld is dominated by the Asteraceae, Aizoaceae and Crassulaceae families while the on termitaria community is dominated by the Asteraceae, Aizoaceae, Crassulaceae families with relatively high abundances of a few species in the Amaranthaceae and Zygophyllaceae families.

Species richness differs between the on and off termitaria perennial plant communities of Oudtshoorn Gannaveld, with the on termitaria community having a significantly lower mean species richness than the off termitaria community (8.86 on and 12.82 off). The highest number of perennial plant species recorded in an individual sample plot off termitaria was 21 and the lowest 6. On termitaria the highest species richness recorded in an individual sample plot was 22 and the lowest 3.

The density and canopy cover of perennial plants differs significantly between termitaria and off termitaria sites. A total of 113 702 individual plants were recorded across the 20000m$^2$ of sample plots, 40 929 on termitaria and 72 773 off termitaria. There is significantly higher canopy cover off termitaria than on termitaria. The mean canopy cover percentages found on termitaria is 51.83% and off termitaria 62.63%.

The percentage of bare ground on termitaria is significantly higher than off termitaria. On termitaria the mean bare ground percentage is 40.22% while off termitaria it is 28.16%. Prostate plant litter (7% on and 9.33% off) was also found to be significantly different.

The mean (±SD) values and significant difference levels for species richness, density, canopy cover percentage, percentage prostrate dead plant material and percentage bare area are shown in Table 1.

Table 1

Mean (±SD) values for species richness (SR), canopy cover, density (number of individual plants per 100m$^2$), percentage prostrate plant litter and percentage bare area recorded in two hundred 10m x 10m plots (100 plots off and 100 plots on termitaria) in Oudtshoorn Gannaveld. Paired t-tests were used to determine significant differences. Significant difference is indicated by asterisks (***$P$<0.005).

| | Off termitaria | On termitaria |
|---|---|---|
| SR | 12.82 ± 3.55 | 8.86 ± 3.43*** |
| Cover | 62.63 ± 11.71 | 51.83 ± 15.23*** |
| Density | 727.73 ± 276.79 | 409.29 ± 215.49*** |
| Litter | 9.33 ± 5.16 | 7 ± 6.18*** |
| Bare | 28.16 ± 10.82 | 40.22 ± 14.01*** |



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Significant differences were also found in the density and canopy cover percentage of the various plant functional types on and off termitaria in this vegetation type. There are significant differences between the woody shrub, dwarf woody shrub, succulent shrub and dwarf succulent shrub density and canopy cover abundance between on and off termitaria plant communities. Woody shrubs, dwarf woody shrub and dwarf succulent shrubs were found to be significantly more abundant off termitaria than on termitaria. Succulent shrubs were significantly more abundant on termitaria than off termitaria.

Perennial forbs differ significantly between communities in terms of density but not canopy cover and perennial grass abundance does not differ significantly. Perennial forbs and grasses form an insignificant component in both on and off termitaria communities.



Table 2 shows the mean (SD) canopy cover percentage and density (number of individuals) per plant functional type on and off termitaria and the statistical significance of the difference between these values.

Table 2

Mean (±SD) canopy cover percentage and density (number of individual plants) of plant functional types recorded in 200 x 100m$^2$ sample plots in Oudtshoorn Gannaveld. Paired t-tests were used to determine significant differences. Significant difference is indicated by asterisks.

| | Cover | | Density | |
|---|---|---|---|---|
| | Off termitaria | On termitaria | Off termitaria | On termitaria |
| Woody Shrubs | 9.69 ± 6.47 | 3.24 ± 4.85*** | 51.09 ± 36.43 | 5.53 ± 11.24*** |
| Dwarf Woody Shrubs | 2.85 ± 2.65 | 0.6 ± 1.14*** | 55.81 ± 46.48 | 13.52 ± 26.75*** |
| Succulent Shrubs | 18.69 ± 13.68 | 35.93 ± 20.48*** | 103.09 ± 85.2 | 214.58 ± 120.61*** |
| Dwarf Succulent Shrubs | 30.74 ± 19.13 | 10.49 ± 14.33*** | 494.96 ± 310.47 | 155.31 ± 249.34*** |
| Dwarf Succulents | 0.59 ± 3.48 | 1.56 ± 4.03 | 21.66 ± 69.27 | 20.01 ± 47.5 |
| Perennial Forbs | 0 ± 0.02 | 0.01 ± 0.04 | 0.07 ± 0.36 | 0.32 ± 1.1* |
| Perennial Grasses | 0.07 ± 0.4 | 0 ± 0.01 | 1.05 ± 5.79 | 0.02 ± 0.2 |

*** $P < 0.005$
* $P < 0.05$

The significant differences between the plant functional types on and off termitaria can be better understood by analysing the relative abundance of the most common or dominant species making up each functional type. In the two most dominant functional types, the dwarf succulent shrub and succulent shrub functional types, the significant difference in cover between on and off termitaria is explained by the high abundance of the dwarf succulent shrub *Leipoldtia schultzei* off termitaria and the high abundance of the succulent shrub *Drosanthemum hispidum* on termitaria. The significant difference in the density of plants in the dominant functional types is explained by the dwarf succulent shrub *Leipoldtia schultzei* having a high density of plants off termitaria and the succulent shrubs *Drosanthemum hispidum* and *Psilocaulon junceum* having a high density of plants on termitaria.



Table 3 shows the plant functional type and mean (±SD) density per species. Table 4 shows the plant functional type and mean (±SD) canopy cover per species. These Tables also show whether species occurred only on or only off termitaria.

Table 3

Mean (±SD) density of species on and off termitaria recorded in 200 10m x 10m plots in Oudtshoorn Gannaveld. Values are in descending order. PFT indicates plant functional type. The on/off column indicates whether the species was recorded both on and off termitaria (ab), only off termitaria (a) or only on termitaria (b). Values in bold indicate abundance significantly higher off termitaria. Values in italics indicate abundance significantly higher on termitaria. Paired t-tests were used to determine significant differences. A significant statistical difference in density between species in the two communities is indicated by asterisks (*$P$<0.05, **$P$<0.01, ***$P$<0.005).

| Density | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Dwarf Succulent Shrub | *Leipoldtia schultzei* | *ab* | **446.65 ± 302.77*** ** | Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | *ab* | *98.67 ± 245.24**** |
| Succulent Shrub | *Ruschia ceresiana* | *ab* | **56.26 ± 49.16*** ** | Succulent Shrub | *Drosanthemum hispidum* | *ab* | *90.65 ± 99.48**** |
| Dwarf Woody Shrub | *Chrysocoma ciliata* | *ab* | **51.67 ± 46.75*** ** | Succulent Shrub | *Psilocaulon junceum* | *ab* | *52.96 ± 44.47**** |
| Dwarf Succulent Shrub | *Ruschia spinosa* | *ab* | 37.35 ± 71.22 | Dwarf Succulent Shrub | *Ruschia spinosa* | *ab* | 39.35 ± 74.35 |
| Woody Shrub | *Eriocephalus ericoides* | *ab* | **28.69 ± 36.57*** ** | Succulent Shrub | *Malephora lutea* | *ab* | *35.85 ± 72**** |
| Succulent Shrub | *Drosanthemum lique* | *ab* | **17.31 ± 50.52*** ** | Dwarf Succulent | *Ruschia impressa* | *ab* | 19.73 ± 47.37 |
| Dwarf Succulent | *Crassula capitella* | *ab* | **12.52 ± 42.09** ** | Succulent Shrub | *Drosanthemum giffenii* | *ab* | *19.05 ± 36.14**** |
| Dwarf Succulent Shrub | *Crassula subaphylla* | *ab* | 9.61 ± 51.26 | Dwarf Succulent Shrub | *Leipoldtia schultzei* | *ab* | **16.36 ± 41.45*** ** |
| Succulent Shrub | *Tetragonia fruticosa* | *ab* | **8.13 ± 8.76*** ** | Dwarf Woody Shrub | *Chrysocoma ciliata* | *ab* | **11.15 ± 25.53*** ** |

Table 3 continued

| Density | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Succulent Shrub | *Malephora lutea* | *ab* | *7.36 ± 35**** | Succulent Shrub | *Phyllobolus splendens* | *ab* | *7.63 ± 13.54**** |
| Dwarf Succulent | *Ruschia impressa* | *ab* | 6.98 ± 53.75 | Succulent Shrub | *Tetraena retrofracta* | *ab* | *5.73 ± 11.61**** |
| Woody Shrub | *Pteronia incana* | *ab* | **6.66 ± 12.37***** | Woody Shrub | *Eriocephalus ericoides* | *ab* | **1.69 ± 5.99***** |
| Succulent Shrub | *Drosanthemum hispidum* | *ab* | *5.55 ± 24.36**** | Dwarf Woody Shrub | *Senecio juniperinus* | *ab* | 1.61 ± 4.8 |
| Woody Shrub | *Eriocephalus brevifolius* | *ab* | **3.54 ± 10.09***** | Woody Shrub | *Salsola aphylla* | *ab* | *1.09 ± 2**** |
| Succulent Shrub | *Crassula tetragona* | *ab* | **3.39 ± 7.05***** | Succulent Shrub | *Augea capensis* | *ab* | *0.96 ± 4** |
| Woody Shrub | *Felicia filifolia* | *ab* | **1.8 ± 6.14***** | Succulent Shrub | *Ruschia ceresiana* | *ab* | **0.9 ± 3.94***** |
| Woody Shrub | *Pteronia pallens* | *ab* | 1.76 ± 5.85 | Woody Shrub | *Pteronia incana* | *ab* | **0.89 ± 3.86***** |
| Woody Shrub | *Pentzia dentata* | *ab* | **1.73 ± 5.87**** | Dwarf Succulent Shrub | *Crassula subaphylla* | *ab* | 0.63 ± 3.34 |
| Woody Shrub | *Helichrysum zeyheri* | *a* | **1.71 ± 5.58**** | Woody Shrub | *Pteronia glauca* | *ab* | 0.57 ± 3.39 |
| Woody Shrub | *Pteronia glauca* | *ab* | 1.68 ± 6.84 | Woody Shrub | *Pteronia pallens* | *ab* | 0.57 ± 4.13 |
| Dwarf Succulent | *Crassula muscosa* | *ab* | **1.63 ± 3.22***** | Dwarf Woody Shrub | *Pentzia incana* | *ab* | 0.41 ± 1.74 |
| Succulent Shrub | *Phyllobolus splendens* | *ab* | *1.53 ± 3.99**** | Succulent Shrub | *Tetragonia fruticosa* | *ab* | **0.35 ± 1.04***** |

Table 3 continued

| Density | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Succulent Shrub | *Lampranthus haworthii* | *a* | **1.51 ± 5.09**** | Woody Shrub | *Galenia africana* | *ab* | 0.3 ± 1.25 |
| Dwarf Woody Shrub | *Senecio juniperinus* | *ab* | 1.51 ± 5.52 | Succulent Shrub | *Ruschia crassa* | *ab* | 0.3 ± 2.15 |
| Woody Shrub | *Pteronia paniculata* | *a* | **1.42 ± 7*** | Dwarf Succulent Shrub | *Euphorbia fimbriata* | *ab* | **0.29 ± 1.09**** |
| Dwarf Woody Shrub | *Selago glutinosa* | *ab* | **1.19 ± 5.43*** | Perennial Forb | *Aptosimum indivisum* | *b* | *0.27 ± 1.03*** |
| Woody Shrub | *Galenia africana* | *ab* | 0.94 ± 3.36 | Dwarf Succulent | *Crassula muscosa* | *ab* | **0.2 ± 0.67***** |
| Succulent Shrub | *Psilocaulon junceum* | *ab* | *0.93 ± 3.47**** | Woody Shrub | *Lycium cinereum* | *ab* | 0.18 ± 0.56 |
| Dwarf Succulent Shrub | *Euphorbia fimbriata* | *ab* | **0.75 ± 1.57**** | Dwarf Woody Shrub | *Selago albida* | *b* | 0.16 ± 1.6 |
| Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | *ab* | *0.55 ± 1.73**** | Dwarf Woody Shrub | *Selago glutinosa* | *ab* | **0.14 ± 1.22*** |
| Perennial Grass | *Ehrharta calycina* | *ab* | 0.54 ± 2.84 | Succulent Shrub | *Drosanthemum lique* | *ab* | **0.11 ± 0.45***** |
| Perennial Grass | *Digitaria argyrograpta* | *a* | 0.51 ± 5.1 | Woody Shrub | *Manochlamys albicans* | *b* | 0.08 ± 0.61 |
| Dwarf Woody Shrub | *Helichrysum rosum* | *ab* | **0.39 ± 1.41*** | Dwarf Succulent | *Crassula capitella* | *ab* | **0.06 ± 0.42**** |
| Dwarf Woody Shrub | *Helichrysum dregei* | *ab* | 0.33 ± 3.3 | Woody Shrub | *Asparagus recurvispinus* | *ab* | 0.05 ± 0.3 |
| Succulent Shrub | *Senecio sp.* | *ab* | 0.32 ± 1.81 | Succulent Shrub | *Crassula tetragona* | *ab* | **0.05 ± 0.41***** |

Table 3 continued

| Density | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Woody Shrub | *Rosenia humilis* | *ab* | **0.29 ± 1.18*** | Perennial Forb | *Hebenstretia sp.* | *b* | 0.04 ± 0.4 |
| Succulent Shrub | *Delosperma sp.* | *a* | 0.28 ± 2.51 | Succulent Shrub | *Cotyledon orbiculata* | *ab* | 0.03 ± 0.22 |
| Woody Shrub | *Euryops lateriflorus* | *a* | **0.27 ± 1.36*** | Woody Shrub | *Felicia filifolia* | *ab* | **0.03 ± 0.22***** |
| Dwarf Woody Shrub | *Thesium nudicaule* | *a* | **0.25 ± 0.88**** | Dwarf Woody Shrub | *Helichrysum dregei* | *ab* | 0.03 ± 0.3 |
| Dwarf Succulent | *Anacampseros arachnoides* | *a* | 0.21 ± 2.1 | Woody Shrub | *Justicia cuneata* | *ab* | 0.03 ± 0.3 |
| Dwarf Woody Shrub | *Helichrysum anomalum* | *a* | 0.2 ± 1.11 | Perennial Grass | *Ehrharta calycina* | *ab* | 0.02 ± 0.2 |
| Woody Shrub | *Lycium cinereum* | *ab* | 0.2 ± 0.71 | Woody Shrub | *Eriocephalus brevifolius* | *ab* | **0.02 ± 0.2***** |
| Succulent Shrub | *Cotyledon orbiculata* | *ab* | 0.17 ± 0.7 | Dwarf Woody Shrub | *Helichrysum rosum* | *ab* | **0.02 ± 0.2*** |
| Dwarf Succulent | *Senecio radicans* | *a* | **0.17 ± 0.64**** | Dwarf Succulent | *Tridentea gemmiflora* | *ab* | 0.02 ± 0.2 |
| Succulent Shrub | *Tetraena retrofracta* | *ab* | *0.16 ± 0.86**** | Perennial Forb | *Hypertelis salsoloides* | *ab* | 0.01 ± 0.1 |
| Woody Shrub | *Asparagus recurvispinus* | *ab* | 0.13 ± 0.44 | Woody Shrub | *Lycium oxycarpum* | *ab* | 0.01 ± 0.1 |
| Dwarf Succulent | *Duvalia caespitosa* | *a* | 0.13 ± 0.66 | Dwarf Succulent Shrub | *Othonna sp.* | *ab* | 0.01 ± 0.1 |
| Succulent Shrub | *Drosanthemum giffenii* | *ab* | *0.12 ± 0.62**** | Woody Shrub | *Pentzia dentata* | *ab* | **0.01 ± 0.1**** |

Table 3 continued

| Density | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Dwarf Woody Shrub | *Heliophila sauvissima* | *a* | 0.1 ± 0.73 | Woody Shrub | *Rosenia humilis* | *ab* | 0.01 ± 0.1* |
| Dwarf Woody Shrub | *Pentzia incana* | *ab* | 0.08 ± 0.71 | Succulent Shrub | *Senecio sp.* | *ab* | 0.01 ± 0.1 |
| Woody Shrub | *Salsola aphylla* | *ab* | 0.08 ± 0.31*** | Dwarf Succulent | *Anacampseros arachnoides* | *a* | 0 ± 0 |
| Woody Shrub | *Asparagus africanus* | *a* | 0.07 ± 0.52 | Perennial Forb | *Anthospermum ciliata* | *a* | 0 ± 0 |
| Woody Shrub | *Asparagus aethiopicus* | *a* | 0.06 ± 0.51 | Woody Shrub | *Asparagus aethiopicus* | *a* | 0 ± 0 |
| Dwarf Woody Shrub | *Tripteris sinuata* | *a* | 0.06 ± 0.51 | Woody Shrub | *Asparagus africanus* | *a* | 0 ± 0 |
| Perennial Forb | *Anthospermum ciliata* | *a* | 0.05 ± 0.33 | Succulent Shrub | *Delosperma sp.* | *a* | 0 ± 0 |
| Dwarf Succulent Shrub | *Othonna sp.* | *ab* | 0.05 ± 0.26 | Woody Shrub | *Dicerothamnus rhinocerotis* | *a* | 0 ± 0 |
| Succulent Shrub | *Ruschia crassa* | *ab* | 0.04 ± 0.4 | Perennial Grass | *Digitaria argyrograpta* | *a* | 0 ± 0 |
| Succulent Shrub | *Augea capensis* | *ab* | 0.02 ± 0.14* | Dwarf Succulent | *Duvalia caespitosa* | *a* | 0 ± 0 |
| Woody Shrub | *Dicerothamnus rhinocerotis* | *a* | 0.02 ± 0.2 | Woody Shrub | *Euryops lateriflorus* | *a* | 0 ± 0* |
| Dwarf Woody Shrub | *Helichrysum excisum* | *a* | 0.02 ± 0.2 | Dwarf Woody Shrub | *Helichrysum anomalum* | *a* | 0 ± 0 |
| Woody Shrub | *Lycium oxycarpum* | *ab* | 0.02 ± 0.2 | Dwarf Woody Shrub | *Helichrysum excisum* | *a* | 0 ± 0 |

Table 3 continued

| | | | Density | | | | |
|---|---|---|---|---|---|---|---|
| | Off termitaria | | | | On termitaria | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Dwarf Succulent | *Tridentea gemmiflora* | *ab* | 0.02 ± 0.14 | Woody Shrub | *Helichrysum zeyheri* | *a* | **0 ± 0**** |
| Perennial Forb | *Hermannia sp.* | *a* | 0.01 ± 0.1 | Dwarf Woody Shrub | *Heliophila sauvissima* | *a* | 0 ± 0 |
| Perennial Forb | *Hypertelis salsoloides* | *ab* | 0.01 ± 0.1 | Perennial Forb | *Hermannia sp.* | *a* | 0 ± 0 |
| Woody Shrub | *Justicia cuneata* | *ab* | 0.01 ± 0.1 | Succulent Shrub | *Lampranthus haworthii* | *a* | **0 ± 0**** |
| Dwarf Woody Shrub | *Limeum aethiopicum* | *a* | 0.01 ± 0.1 | Dwarf Woody Shrub | *Limeum aethiopicum* | *a* | 0 ± 0 |
| Woody Shrub | *Roepera lichtensteiniana* | *a* | 0.01 ± 0.1 | Woody Shrub | *Pteronia paniculata* | *a* | **0 ± 0*** |
| Succulent Shrub | *Tylecodon ventricosus* | *a* | 0.01 ± 0.1 | Woody Shrub | *Roepera lichtensteiniana* | *a* | 0 ± 0 |
| Perennial Forb | *Aptosimum indivisum* | *b* | *0 ± 0*** | Dwarf Succulent | *Senecio radicans* | *a* | **0 ± 0**** |
| Perennial Forb | *Hebenstretia sp.* | *b* | 0 ± 0 | Dwarf Woody Shrub | *Thesium nudicaule* | *a* | **0 ± 0**** |
| Woody Shrub | *Manochlamys albicans* | *b* | 0 ± 0 | Dwarf Woody Shrub | *Tripteris sinuata* | *a* | 0 ± 0 |
| Dwarf Woody Shrub | *Selago albida* | *b* | 0 ± 0 | Succulent Shrub | *Tylecodon ventricosus* | *a* | 0 ± 0 |

Table 4

Mean (±SD) canopy cover percentage of species on and off termitaria recorded in 200 10m x 10m plots in Oudtshoorn Gannaveld. Values are in descending order. PFT indicates plant functional type. The on/off column indicates whether the species was recorded both on and off termitaria (ab), only off termitaria (a) or only on termitaria (b). Values in bold indicate abundance significantly higher off termitaria. Values in italics indicate abundance significantly higher on termitaria. A significant statistical difference in cover between species in the two communities is indicated by asterisks. (*$P$<0.05, **$P$<0.01, ***$P$<0.005).

| Cover | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Dwarf Succulent Shrub | *Leipoldtia schultzei* | *ab* | **28.6 ± 18.55*** ** | Succulent Shrub | *Drosanthemum hispidum* | *ab* | *15.16 ± 17.55**** |
| Succulent Shrub | *Ruschia ceresiana* | *ab* | **14.48 ± 12.57*** ** | Succulent Shrub | *Psilocaulon junceum* | *ab* | *9.08 ± 8.49**** |
| Woody Shrub | *Eriocephalus ericoides* | *ab* | **3.46 ± 4.77*** ** | Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | *ab* | *6.59 ± 13.56**** |
| Dwarf Woody Shrub | *Chrysocoma ciliata* | *ab* | **2.66 ± 2.67*** ** | Succulent Shrub | *Malephora lutea* | *ab* | *5.86 ± 12.29**** |
| Dwarf Succulent Shrub | *Ruschia spinosa* | *ab* | 1.95 ± 4.05 | Dwarf Succulent Shrub | *Ruschia spinosa* | *ab* | 2.83 ± 5.71 |
| Woody Shrub | *Pteronia incana* | *ab* | **1.7 ± 3.5*** ** | Woody Shrub | *Salsola aphylla* | *ab* | *2.33 ± 3.91**** |
| Woody Shrub | *Eriocephalus brevifolius* | *ab* | **1.02 ± 3.04*** ** | Succulent Shrub | *Phyllobolus splendens* | *ab* | *2.22 ± 3.92**** |
| Succulent Shrub | *Tetragonia fruticosa* | *ab* | **0.99 ± 1.15*** ** | Dwarf Succulent | *Ruschia impressa* | *ab* | *1.55 ± 4.03** |

Table 4 continued

| Cover | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Succulent Shrub | *Malephora lutea* | *ab* | *0.93 ± 4.96**** | Succulent Shrub | *Tetraena retrofracta* | *ab* | *1.41 ± 2.89**** |
| Succulent Shrub | *Drosanthemum lique* | *ab* | **0.8 ± 2.76**** | Succulent Shrub | *Drosanthemum giffenii* | *ab* | *1.35 ± 2.44**** |
| Woody Shrub | *Pteronia pallens* | *ab* | 0.65 ± 2.36 | Dwarf Succulent Shrub | *Leipoldtia schultzei* | *ab* | **1.04 ± 2.59***** |
| Woody Shrub | *Pentzia dentata* | *ab* | **0.64 ± 2.37**** | Dwarf Woody Shrub | *Chrysocoma ciliata* | *ab* | **0.46 ± 1.07***** |
| Woody Shrub | *Pteronia glauca* | *ab* | 0.49 ± 2.09 | Succulent Shrub | *Ruschia ceresiana* | *ab* | **0.42 ± 2.27***** |
| Dwarf Succulent | *Ruschia impressa* | *ab* | *0.45 ± 3.48** | Succulent Shrub | *Ruschia crassa* | *ab* | 0.29 ± 2.09 |
| Succulent Shrub | *Phyllobolus splendens* | *ab* | *0.43 ± 1.36**** | Woody Shrub | *Pteronia pallens* | *ab* | 0.2 ± 1.52 |
| Woody Shrub | *Felicia filifolia* | *ab* | **0.42 ± 1.25***** | Woody Shrub | *Pteronia glauca* | *ab* | 0.18 ± 1.1 |
| Succulent Shrub | *Drosanthemum hispidum* | *ab* | *0.38 ± 1.92**** | Woody Shrub | *Eriocephalus ericoides* | *ab* | **0.16 ± 0.56***** |
| Woody Shrub | *Galenia africana* | *ab* | 0.34 ± 1.24 | Woody Shrub | *Pteronia incana* | *ab* | **0.15 ± 0.71***** |
| Woody Shrub | *Helichrysum zeyheri* | *a* | **0.33 ± 1.12**** | Woody Shrub | *Galenia africana* | *ab* | 0.11 ± 0.44 |
| Woody Shrub | *Pteronia paniculata* | *a* | **0.31 ± 1.56*** | Dwarf Woody Shrub | *Pentzia incana* | *ab* | 0.09 ± 0.36 |
| Succulent Shrub | *Lampranthus haworthii* | *a* | **0.28 ± 1.01**** | Succulent Shrub | *Augea capensis* | *ab* | 0.08 ± 0.39 |

Table 4 continued

| Cover | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Dwarf Succulent Shrub | *Crassula subaphylla* | *ab* | **0.12 ± 0.25*** ** | Woody Shrub | *Lycium cinereum* | *ab* | 0.06 ± 0.24 |
| Succulent Shrub | *Psilocaulon junceum* | *ab* | *0.12 ± 0.46**** | Succulent Shrub | *Tetragonia fruticosa* | *ab* | **0.05 ± 0.15*** ** |
| Succulent Shrub | *Crassula tetragona* | *ab* | **0.11 ± 0.21*** ** | Dwarf Woody Shrub | *Senecio juniperinus* | *ab* | 0.04 ± 0.1 |
| Dwarf Succulent | *Crassula capitella* | *ab* | **0.09 ± 0.3** ** | Woody Shrub | *Asparagus recurvispinus* | *ab* | 0.03 ± 0.2 |
| Woody Shrub | *Lycium oxycarpum* | *ab* | 0.08 ± 0.84 | Dwarf Succulent Shrub | *Euphorbia fimbriata* | *ab* | 0.03 ± 0.1 |
| Woody Shrub | *Salsola aphylla* | *ab* | *0.06 ± 0.3**** | Succulent Shrub | *Senecio sp.* | *ab* | 0.03 ± 0.25 |
| Succulent Shrub | *Delosperma sp.* | *a* | 0.05 ± 0.52 | Dwarf Succulent Shrub | *Crassula subaphylla* | *ab* | **0.02 ± 0.08*** ** |
| Woody Shrub | *Euryops lateriflorus* | *a* | 0.05 ± 0.26 | Woody Shrub | *Felicia filifolia* | *ab* | **0.02 ± 0.13*** ** |
| Woody Shrub | *Lycium cinereum* | *ab* | 0.05 ± 0.2 | Perennial Forb | *Aptosimum indivisum* | *b* | *0.01 ± 0.02** |
| Woody Shrub | *Rosenia humilis* | *ab* | 0.05 ± 0.24 | Dwarf Succulent | *Crassula muscosa* | *ab* | **0.01 ± 0.02*** ** |
| Succulent Shrub | *Senecio sp.* | *ab* | 0.05 ± 0.29 | Woody Shrub | *Justicia cuneata* | *ab* | 0.01 ± 0.09 |
| Dwarf Succulent | *Crassula muscosa* | *ab* | **0.04 ± 0.08*** ** | Dwarf Woody Shrub | *Selago albida* | *b* | 0.01 ± 0.06 |
| Perennial Grass | *Ehrharta calycina* | *ab* | 0.04 ± 0.29 | Dwarf Succulent | *Anacampseros arachnoides* | *a* | 0 ± 0 |

Table 4 continued

| Cover | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Dwarf Succulent Shrub | *Euphorbia fimbriata* | *ab* | 0.04 ± 0.09 | Perennial Forb | *Anthospermum ciliata* | *a* | 0 ± 0 |
| Dwarf Woody Shrub | *Selago glutinosa* | *ab* | **0.04 ± 0.16*** | Woody Shrub | *Asparagus aethiopicus* | *a* | 0 ± 0 |
| Perennial Grass | *Digitaria argyrograpta* | *a* | 0.03 ± 0.28 | Woody Shrub | *Asparagus africanus* | *a* | 0 ± 0 |
| Dwarf Woody Shrub | *Helichrysum anomalum* | *a* | 0.03 ± 0.16 | Succulent Shrub | *Cotyledon orbiculata* | *ab* | 0 ± 0.01 |
| Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | *ab* | *0.03 ± 0.1**** | Dwarf Succulent | *Crassula capitella* | *ab* | **0 ± 0.01**** |
| Dwarf Woody Shrub | *Pentzia incana* | *ab* | 0.03 ± 0.24 | Succulent Shrub | *Crassula tetragona* | *ab* | **0 ± 0.02***** |
| Dwarf Woody Shrub | *Senecio juniperinus* | *ab* | 0.03 ± 0.1 | Succulent Shrub | *Delosperma sp.* | *a* | 0 ± 0 |
| Succulent Shrub | *Tetraena retrofracta* | *ab* | *0.03 ± 0.13**** | Woody Shrub | *Dicerothamnus rhinocerotis* | *a* | 0 ± 0 |
| Woody Shrub | *Asparagus aethiopicus* | *a* | 0.02 ± 0.13 | Perennial Grass | *Digitaria argyrograpta* | *a* | 0 ± 0 |
| Succulent Shrub | *Cotyledon orbiculata* | *ab* | 0.02 ± 0.17 | Succulent Shrub | *Drosanthemum lique* | *ab* | **0 ± 0.02**** |
| Dwarf Woody Shrub | *Helichrysum rosum* | *ab* | **0.02 ± 0.07**** | Dwarf Succulent | *Duvalia caespitosa* | *a* | **0 ± 0*** |
| Succulent Shrub | *Ruschia crassa* | *ab* | 0.02 ± 0.23 | Perennial Grass | *Ehrharta calycina* | *ab* | 0 ± 0.01 |
| Dwarf Woody Shrub | *Thesium nudicaule* | *a* | **0.02 ± 0.05**** | Woody Shrub | *Eriocephalus brevifolius* | *ab* | **0 ± 0.01***** |

Table 4 continued

| Cover | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Woody Shrub | *Asparagus recurvispinus* | *ab* | 0.01 ± 0.06 | Woody Shrub | *Euryops lateriflorus* | *a* | 0 ± 0 |
| Woody Shrub | *Dicerothamnus rhinocerotis* | *a* | 0.01 ± 0.09 | Perennial Forb | *Hebenstretia sp.* | *b* | 0 ± 0.03 |
| Succulent Shrub | *Drosanthemum giffenii* | *ab* | *0.01 ± 0.03**** | Dwarf Woody Shrub | *Helichrysum anomalum* | *a* | 0 ± 0 |
| Dwarf Woody Shrub | *Helichrysum dregei* | *ab* | 0.01 ± 0.09 | Dwarf Woody Shrub | *Helichrysum dregei* | *ab* | 0 ± 0.01 |
| Dwarf Woody Shrub | *Heliophila sauvissima* | *a* | 0.01 ± 0.11 | Dwarf Woody Shrub | *Helichrysum excisum* | *a* | 0 ± 0 |
| Woody Shrub | *Justicia cuneata* | *ab* | 0.01 ± 0.12 | Dwarf Woody Shrub | *Helichrysum rosum* | *ab* | **0 ± 0.01**** |
| Dwarf Succulent Shrub | *Othonna sp.* | *ab* | 0.01 ± 0.04 | Woody Shrub | *Helichrysum zeyheri* | *a* | **0 ± 0**** |
| Dwarf Succulent | *Senecio radicans* | *a* | **0.01 ± 0.03**** | Dwarf Woody Shrub | *Heliophila sauvissima* | *a* | 0 ± 0 |
| Dwarf Woody Shrub | *Tripteris sinuata* | *a* | 0.01 ± 0.06 | Perennial Forb | *Hermannia sp.* | *a* | 0 ± 0 |
| Dwarf Succulent | *Anacampseros arachnoides* | *a* | 0 ± 0.01 | Perennial Forb | *Hypertelis salsoloides* | *ab* | 0 ± 0 |
| Perennial Forb | *Anthospermum ciliata* | *a* | 0 ± 0.02 | Succulent Shrub | *Lampranthus haworthii* | *a* | **0 ± 0**** |
| Perennial Forb | *Aptosimum indivisum* | *b* | *0 ± 0** | Dwarf Woody Shrub | *Limeum aethiopicum* | *a* | 0 ± 0 |
| Woody Shrub | *Asparagus africanus* | *a* | 0 ± 0.03 | Woody Shrub | *Lycium oxycarpum* | *ab* | 0 ± 0.03 |

Table 4 continued

| Cover | | | | | | | |
|---|---|---|---|---|---|---|---|
| Off termitaria | | | | On termitaria | | | |
| PFT | Species | on/off | | PFT | Species | on/off | |
| Succulent Shrub | *Augea capensis* | *ab* | 0 ± 0 | Woody Shrub | *Manochlamys albicans* | *b* | 0 ± 0.04 |
| Dwarf Succulent | *Duvalia caespitosa* | *a* | **0 ± 0.01*** | Dwarf Succulent Shrub | *Othonna sp.* | *ab* | 0 ± 0.01 |
| Perennial Forb | *Hebenstretia sp.* | *b* | 0 ± 0 | Woody Shrub | *Pentzia dentata* | *ab* | **0 ± 0.03**** |
| Dwarf Woody Shrub | *Helichrysum excisum* | *a* | 0 ± 0.03 | Woody Shrub | *Pteronia paniculata* | *a* | **0 ± 0*** |
| Perennial Forb | *Hermannia sp.* | *a* | 0 ± 0 | Woody Shrub | *Roepera lichtensteiniana* | *a* | 0 ± 0 |
| Perennial Forb | *Hypertelis salsoloides* | *ab* | 0 ± 0 | Woody Shrub | *Rosenia humilis* | *ab* | 0 ± 0.01 |
| Dwarf Woody Shrub | *Limeum aethiopicum* | *a* | 0 ± 0 | Dwarf Woody Shrub | *Selago glutinosa* | *ab* | **0 ± 0.03*** |
| Woody Shrub | *Manochlamys albicans* | *b* | 0 ± 0 | Dwarf Succulent | *Senecio radicans* | *a* | **0 ± 0**** |
| Woody Shrub | *Roepera lichtensteiniana* | *a* | 0 ± 0 | Dwarf Woody Shrub | *Thesium nudicaule* | *a* | **0 ± 0**** |
| Dwarf Woody Shrub | *Selago albida* | *b* | 0 ± 0 | Dwarf Succulent | *Tridentea gemmiflora* | *ab* | 0 ± 0 |
| Dwarf Succulent | *Tridentea gemmiflora* | *ab* | 0 ± 0.01 | Dwarf Woody Shrub | *Tripteris sinuata* | *a* | 0 ± 0 |
| Succulent Shrub | *Tylecodon ventricosus* | *a* | 0 ± 0 | Succulent Shrub | *Tylecodon ventricosus* | *a* | 0 ± 0 |

Analysis of the soils showed a significant difference in mean pH between the off termitaria and on termitaria sites (4.81 off and 8.36 on). K, Ca, Mg and P all differed significantly between on and off termitaria sites. In all cases the higher values were recorded on termitaria. Table 5 shows the soil analysis results.

Table 5

Mean (±SD) pH value and Na, K, Ca, Mg and P micrograms per gram (µg/g) values from soil samples taken from 100 on and 100 off termitaria sites in Oudtshoorn Gannaveld. Paired t-tests were used to determine significant differences. Significant difference is indicated by asterisks.

| | Soil | |
|---|---|---|
| | Off termitaria | On termitaria |
| pH | 4.81 ± 1.41 | 8.36 ± 1.09*** |
| Na | 397.73 ± 493.58 | 365.19 ± 471.83 |
| K | 4717.3 ± 2037 | 6787.45 ± 2216.26*** |
| Ca | 215.3 ± 251.83 | 1023.55 ± 602.19*** |
| Mg | 121.38 ± 96.58 | 629.08 ± 293.87*** |
| P | 234.79 ± 146.41 | 640.91 ± 298.15*** |

***$P$< 0.005

Species diversity and diversity indices.

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Four of the most commonly used methods of expressing diversity (Clarke and Warwick 2001) in terms of species richness, equitability, or both, were compared for the two plant communities (on and off termitaria) in Oudtshoorn Gannaveld. These methods of expressing diversity are species richness (S) (Magurran 1988), Margalef's index (D*mg*) (Margalef 1958), the Shannon-Wiener diversity index (*H*') (Shannon and Wiener 1963) and Pielou's evenness index (*E)* (Pielou 1969).

Although species richness is significantly higher off termitaria than on termitaria, the Shannon diversity index does not differ significantly between the two habitats. As the Shannon-Wiener diversity index (*H*') is based on the proportional abundance of species, taking into account both equitability and richness, the results indicate that there are many rare species contributing to species richness off termitaria. The index value usually falls between 1.5 and 3.5.

Pielou's evenness index is significantly higher on termitaria than off. The Pielou evenness index (*E)* gives a value of the ratio of observed diversity to maximum diversity. Maximum diversity would be found where all species are equally abundant. This index is constrained between 0 and 1, 1 representing all species being equally abundant. The Margalef diversity index (D*mg*) incorporates both species richness and evenness and is a measure of the number of species present (*S*) for a given number of individuals (*N*). The Margalef diversity index indicates that diversity is significantly higher off termitaria.

Table 6 shows the species richness, Shannon diversity index, Pielou's evenness index and Margalef's diversity index values for canopy cover and density abundance on and off termitaria in Oudtshoorn Gannaveld.

Table 6

Mean (±SD) values for species richness, Shannon diversity index, Pielou's evenness index and Margalef's diversity index for canopy cover and density abundance on and off termitaria in Oudtshoorn Gannaveld. Paired t-tests were used to determine significant differences. Significant difference is indicated by asterisks.

| | Off termitaria | On termitaria |
|---|---|---|
| Species Richness | 12.82 ± 3.55 | 8.86 ± 3.43*** |
| Shannon Density | 1.26 ± 0.44 | 1.28 ± 0.45 |
| Shannon Cover | 1.29 ± 0.37 | 1.25 ± 0.44 |
| Pielou's evenness Density | 0.49 ± 0.15 | 0.6 ± 0.17*** |
| Pielou's evenness Cover | 0.51 ± 0.12 | 0.58 ± 0.16*** |
| Margalef Cover | 1.72 ± 0.51 | 1.19 ± 0.58*** |
| Margalef Density | 1.82 ± 5.75 | 1.33 ± 5.76*** |

*** < 0.005

**Discussion**

Species richness, the density of plants per $100m^2$, canopy cover, plant litter, soil pH and soil chemicals K, Ca, Mg, and P all differ significantly between the off termitaria and on termitaria plant communities of Oudtshoorn Gannaveld. Species richness, the density of plants, canopy cover and the percentage of plant litter were all found to be significantly higher in the off termitaria community. The percentage of bare ground, soil pH, K, Ca, Mg, and P were all found to be significantly higher on termitaria.

The soil chemistry results of this study supports findings in other areas of termitaria distribution in the Succulent Karoo such as Milton *et al.* (1992) that show higher pH alkaline soils and higher nutrient levels occur on termitaria than off termitaria. Knight *et al.* (1989) found that in the Clanwilliam area of the Western Cape soil nutrient availability and pH were higher on termitaria than off termitaria. Midgley and Musil (1990) found that termitaria in the Worcester-Robertson Valley of the Western Cape Province were enriched in nutrients especially P, Ca, Mg, and Fe. Ellis (2001) found significant differences in pH and phosphorus in the Vredendal area of the Western Cape where both were higher on termitaria. Soils of the off termitaria sites at the Tierberg Karoo Research Centre in the southern Karoo were found to generally have low nutrient status and pH, while soils on termitaria were strongly alkaline and organic matter, nutrients and salt levels were three to five times higher on termitaria than off termitaria (Milton 1990).

As in this study, numerous other studies have confirmed the differences between the on and off termitaria plant communities of the Succulent Karoo (Knight *et al.* 1989, Midgley and Musil 1990, Yeaton and Esler 1990, Milton 1990, Milton and Dean 1990, Esler and Cowling 1995, Rahlao *et al.* 2008). These differences have been primarily attributed to the heterogeneity in moisture and soil fertility on termitaria (Milton 1990, Milton and Dean 1990, Dean and Milton 1999) and the life-history characteristics of species (Esler and Cowling 1995). Short-lived succulent plants that are characteristic of termitaria mounds in the Succulent Karoo (Knight *et al.* 1989, Milton 1990, Esler and Cowling 1995) are abundant on termitaria in Oudtshoorn Gannaveld, such as the succulent shrubs *Drosanthemum hispidum*, *Psilocaulon junceum*, *Malephora lutea* and the dwarf succulent shrub *Mesembryanthemum crystallinum*.



The off termitaria plant community of Oudtshoorn Gannaveld is dominated by the dwarf succulent shrub *Leipoldtia schultzei* and the succulent shrub *Ruschia ceresiana*. However there is a higher abundance of dwarf woody shrubs and woody shrubs off termitaria than on termitaria. This is in line with the findings of Esler and Cowling (1995) and Rahlao *et al.* (2008) that species occurring in the off termitaria areas tend to be longer-lived woody shrubs with relatively stable populations (Yeaton and Esler 1990). The woody species growing off termitaria, where disturbance is less than on termitaria, germinate rapidly and have low levels of seed dormancy and seed retention (Esler and Cowling 1995). The chances of off termitaria species finding suitable recruitment sites are low (Yeaton and Esler 1990, Esler 1993). Therefore, off termitaria species are geared towards exploiting rainfall events and release their seeds during the first rain event of the season, their longevity allowing adult plants to risk the high probability of seedling mortality (Esler and Cowling 1995).

In this study most of the species occurring on termitaria were also recorded off termitaria and this can be explained by the life-history characteristics of on termitaria species. Plant species that occur on termitaria maintain canopy seed banks with high seed retention (Esler and Cowling 1995) and also have soil seed banks (Esler *et al.* 1992, Esler 1993). This strategy is used to address environmental uncertainty such as the high levels of disturbance that occur on termitaria (Esler and Cowling 1995). This allows the on termitaria species to colonise disturbed off termitaria areas (Esler 1993). Milton *et al.* (1992) found that 65% of all species recorded on termitaria also occurred in disturbed sites off termitaria. In this study 92% of the species recorded on termitaria were recorded off termitaria, while only 32% of the species recorded off termitaria were also recorded on termitaria.



The ability of predominantly on termitaria species to colonise disturbed areas explains the high number of on termitaria species occurring off termitaria in Oudtshoorn Gannaveld. Sampling was carried out over a large area that includes various levels of degradation. A more accurate indication of the naturally occurring species composition on and off termitaria would be obtained by using only the samples recorded in the more intact areas, where there are fewer disturbed areas off termitaria.

## Conclusions

The research question for this chapter is: What are the differences in composition between termitaria and off termitaria vegetation communities in Oudtshoorn Gannaveld?

This study confirms that in Oudtshoorn Gannaveld, as in other Succulent Karoo areas, there are significant differences between on and off termitaria vegetation in terms of composition and soil chemistry. In Oudtshoorn Gannaveld more species occur off termitaria than on termitaria and there are more individual plants off termitaria than on termitaria. Off termitaria areas have higher plant canopy cover and less bare ground than on termitaria sites. Off termitaria sites also have more plant litter than on termitaria sites. Off termitaria areas in Oudtshoorn Gannaveld are dominated by an abundance of woody shrubs, dwarf woody shrub and dwarf succulent shrubs which are significantly more abundant than on termitaria, while on termitaria areas are dominated by succulent shrubs, the only functional type that is more abundant on termitaria than off termitaria.

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**Section B**

**Chapter 4**

**Determining plant communities on and off termitaria**

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## Introduction

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Oudtshoorn Gannaveld is a vegetation type in the Gannaveld habitat of the Little Karoo (Vlok *et al.* 2005). This low lying vegetation type is critically endangered (Reyers 2008) as a result of transformation of large areas for planted crops, mainly lucerne for ostriches, and because of high stocking densities of ostriches in this habitat for more than 150 years (Cupido 2005).



It is estimated that less than 6% of this vegetation remains in a near pristine condition, and this is contained in small fragments across the landscape (Thompson *et al.* 2005). Although fine scale data is available on the complex diversity of vegetation at a vegetation unit level in the Little Karoo (Vlok *et al.* 2005), quantitative studies of plant community composition and structure and the finer levels of domestic stock induced vegetation change are lacking. The relatively recently described individual vegetation units constitute critical components of the Little Karoo environment and must be understood in order to inform decisions and actions necessary to conserve the biodiversity of the region (Vlok *et al.* 2005).

In Oudtshoorn Gannaveld different plant communities may have developed as a response to different grazing pressures. Determining changes in the perennial plant composition between these communities will provide new insight into degradation processes in this lowland habitat. Although some changes could theoretically be expected to occur as a response to degradation, based on previous research on Succulent Karoo vegetation (Milton 1994, Milton and Hoffman 1994, Esler *et al.* 2006), the finer levels of degradation induced vegetation change have yet to be tested in Little Karoo Gannaveld vegetation.

In this chapter I determine the different plant communities that occur in the broader on and off termitaria vegetation communities of Oudtshoorn Gannaveld and analyse the differences between them. The research question for this chapter is:

- Are there distinct perennial plant communities within the broader on and off termitaria plant communities of Oudtshoorn Gannaveld?

**Study area**

The study area has been described in detail in chapter two and is briefly described again here. The study was carried out in the critically endangered (Kirkwood *et al.* 2007, Reyers 2008) Oudtshoorn Gannaveld vegetation type of the Gannaveld habitat type (Vlok *et al.* 2005) in the Succulent Karoo biome of the Little Karoo, South Africa. The study area lies in the Oudtshoorn basin (300-400m above sea level) (Thompson *et al.* 2009) which is part of the Little Karoo inter-montane valley (Le Maitre and O'Farrel 2008). The study area covers the largest remaining remnant of the Oudtshoorn Gannaveld vegetation type (Vlok *et al.* 2005) and is the only remaining extensive example of this vegetation type where various vegetation conditions, ranging from the perceived pristine to perceived degraded can be sampled.



Although the detailed historical domestic animal stocking records for the study area are not known, discussions with landowners and managers indicate that the four properties falling within the study area have been stocked at various intensities with domestic animals, mostly ostriches, in the past. An exception is the Government military training area where domestic stock farming is not carried out but where donkeys and ostriches do occur. The historically high concentration of ostriches in the Oudtshoorn basin from about 1863 (Cupido 2005) makes it highly probable that all the properties in the study area were stocked with ostriches in the past.

**Methods**

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The vegetation sampling methods have been described in detail in chapter two.

Vegetation data collected from the two major vegetation communities of Oudtshoorn Gannaveld, the on and off termitaria plant communities, were analysed through agglomerative cluster analysis, using the Sørensen (Bray-Curtis) distance method and the flexible beta link method, and non-metric multidimensional scaling (NMS) ordination to determine distinct groups within both communities.

The cluster analysis and NMS ordinations were produced following the procedure described by McCune and Grace (2002). NMS ordination solutions were repeatedly sought, based on 100 runs of the data, for successively fewer dimensions (6d-1d), using the best solution from the previous number of dimensions as the initial configuration for the next solution. A scree plot and Monte Carlo test, based on 50 randomised runs, was used to assess the stress at each dimensionality and used to identify the appropriate number of dimensions for the final solution. Canopy cover and density data were both used for the ordination. Canopy cover data was found to be the most useful in interpreting the ordination. The procedure was also repeated several times to ensure that the different runs were converging on the same solution. Differences between the NMS ordination communities were tested using a Kruskal-Wallis One-Way ANOVA and Dunns' multiple comparisons test as the post-hoc test. The Kendall tau rank correlation coefficient statistic was used to measure the degree of correspondence between physical variable rankings and NMS axis rankings and assess the significance of this correspondence.

## Results

### Cluster analysis and ordination

### Off termitaria

The cluster analysis shows four distinct vegetation communities within the broader off termitaria plant community of Oudtshoorn Gannaveld. The dendrogram of the cluster analysis is shown as Figure 1. The ordination of the off termitaria vegetation community of Oudtshoorn Gannaveld produced a three dimensional non-metric multidimensional scaling (NMS) solution with a stress of 15.66 and instability of 0.00001. Although the NMS ordination plots do not show a clear and separation of groups of plots the ordination values are within the range of values required to provide an acceptable ordination solution (McCune and Grace 2002). The cumulative $R^2$ between ordination distances and distances in the original *n*–dimension space was 0.796. Of this, 0.100 was accounted for by the first axis and 0.531 and 0.165 by the following two axes.

The cluster analysis and ordination show four communities within the broader off termitaria vegetation community of Oudtshoorn Gannaveld. These were identified as communities one, three, five and six. These grouping names are used throughout this document for ease of identification.

The graphic representation of the NMS ordination is shown as Figure 2.

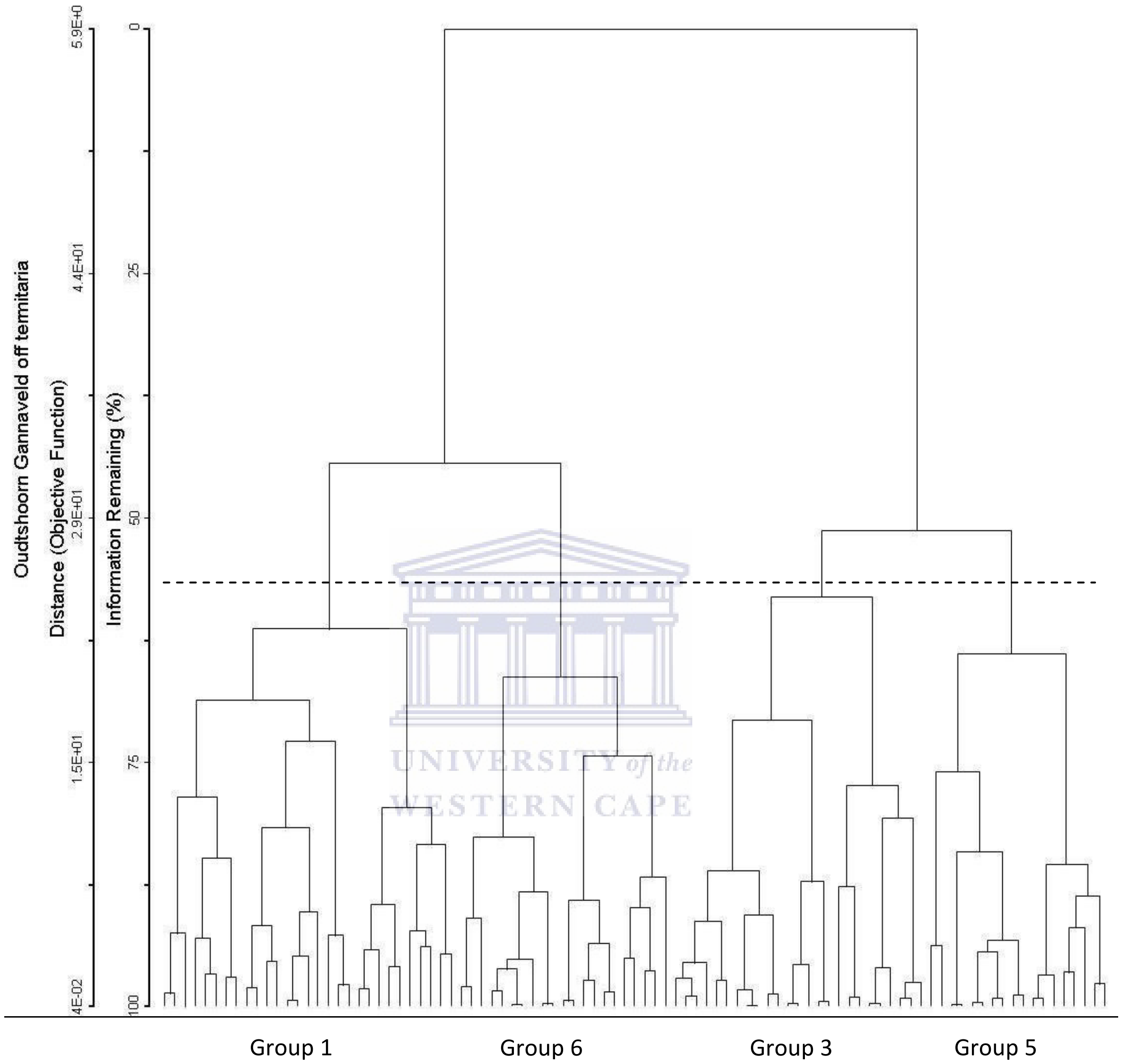


Figure 1

Cluster analysis dendrogram showing the four main vegetation communities occurring in the off termitaria vegetation community of Oudtshoorn Gannaveld.

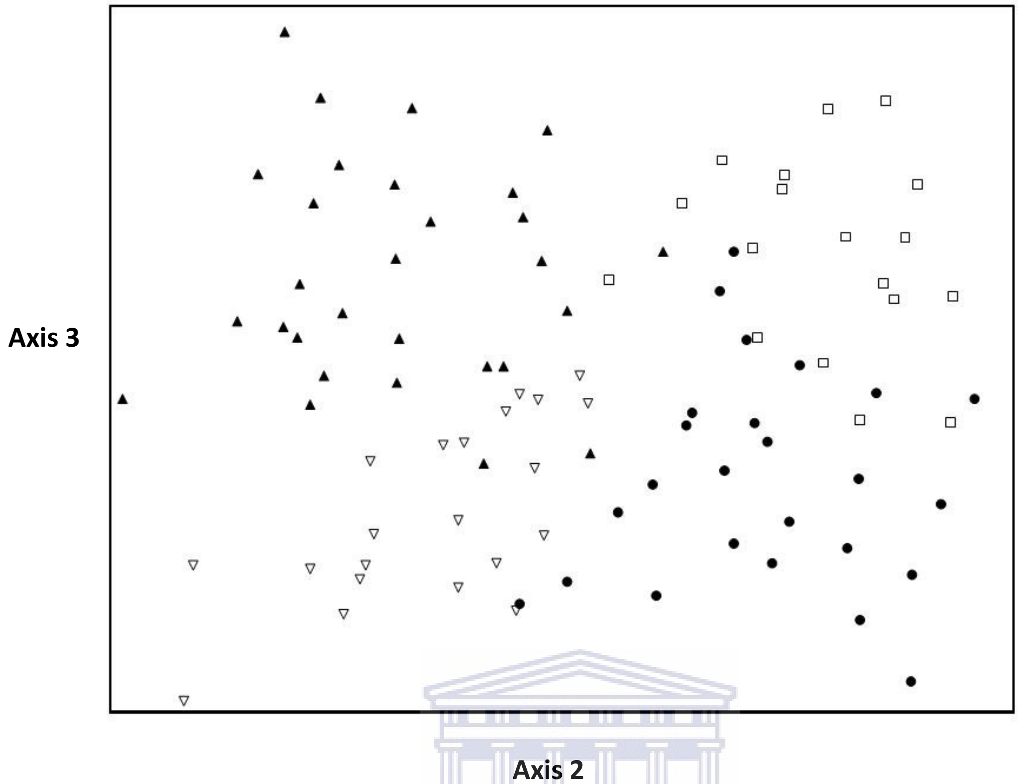




Figure 2

NMS ordination of the off termitaria plant community of Oudtshoorn Gannaveld. Groups derived from the cluster analysis are superimposed. Filled triangle symbols represent the group one community, filled circle symbols represent the group three community, empty square symbols represent the group five community and empty triangle symbols represent the group six community.

**Cluster analysis and ordination**

**On termitaria**

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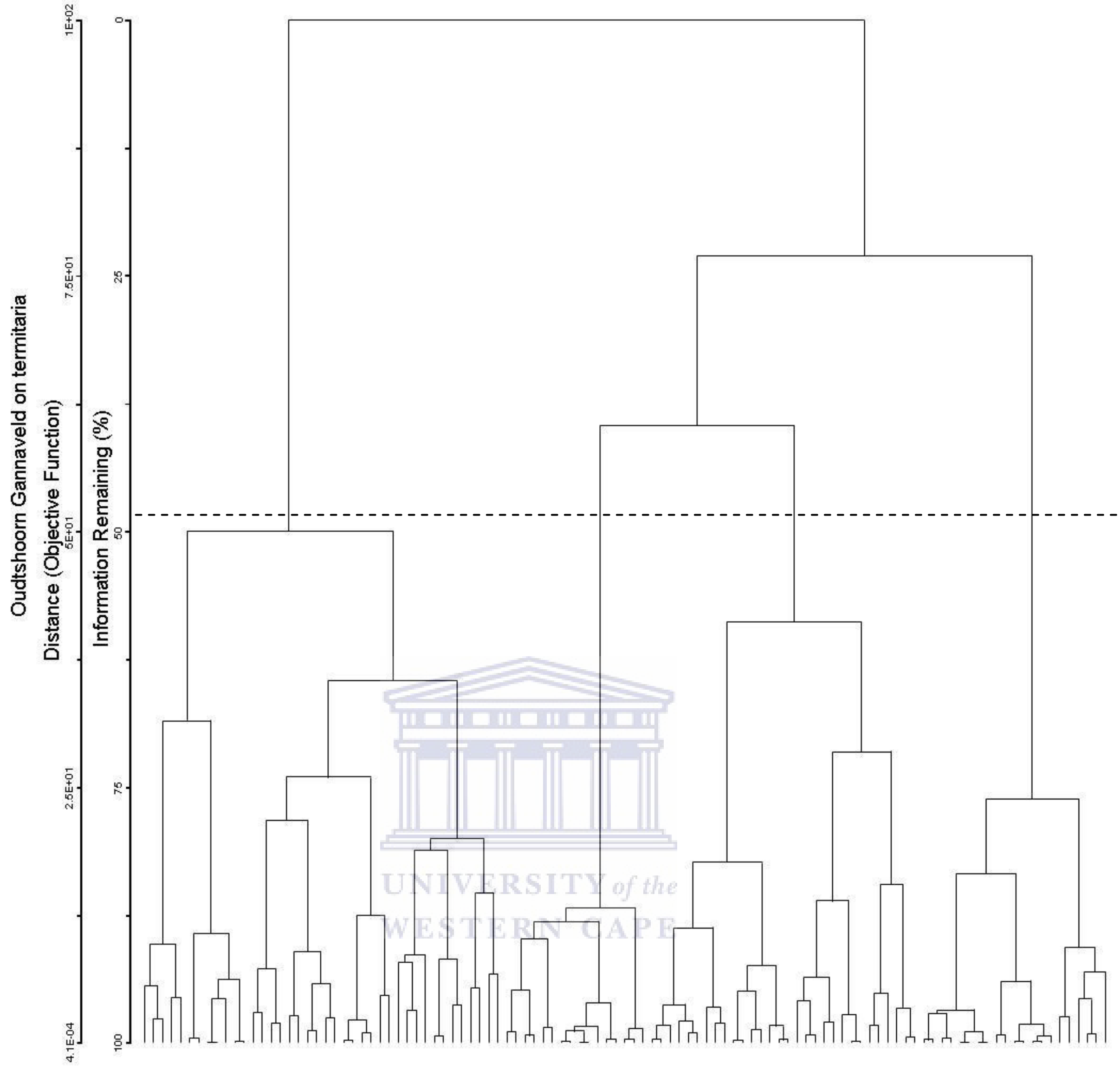
The cluster analysis of the on termitaria plant community of Oudtshoorn Gannaveld shows four distinct vegetation communities. The cluster analysis dendrogram is shown in Figure 3.

The ordination of on termitaria plots produced a three dimensional non-metric multidimensional scaling (NMS) solution with a stress of 17.95 and instability of 0.00001. Although the NMS ordination plots do not show a clear and separation of groups of plots the ordination values are within the range of values required to provide an acceptable ordination solution (McCune and Grace 2002). The cumulative $R^2$ between ordination distances and distances in the original *n*–dimension space was 0.710, of this, 0.209 was accounted for by the first axis and 0.233 and 0.269 by the following two axes. The cluster analysis and ordination show four distinct communities within the broader on termitaria vegetation community of Oudtshoorn Gannaveld. These groups were identified as groups one, four, eight and 13. These grouping names are used throughout the document for ease of identification.

The graphic representation of the NMS ordination for the on termitaria plant community is shown in Figure 4.




Group 1 Group 4 Group 8 Group 13

Figure 3

Cluster analysis dendrogram showing the four main vegetation communities occurring in the on termitaria vegetation community of Oudtshoorn Gannaveld.

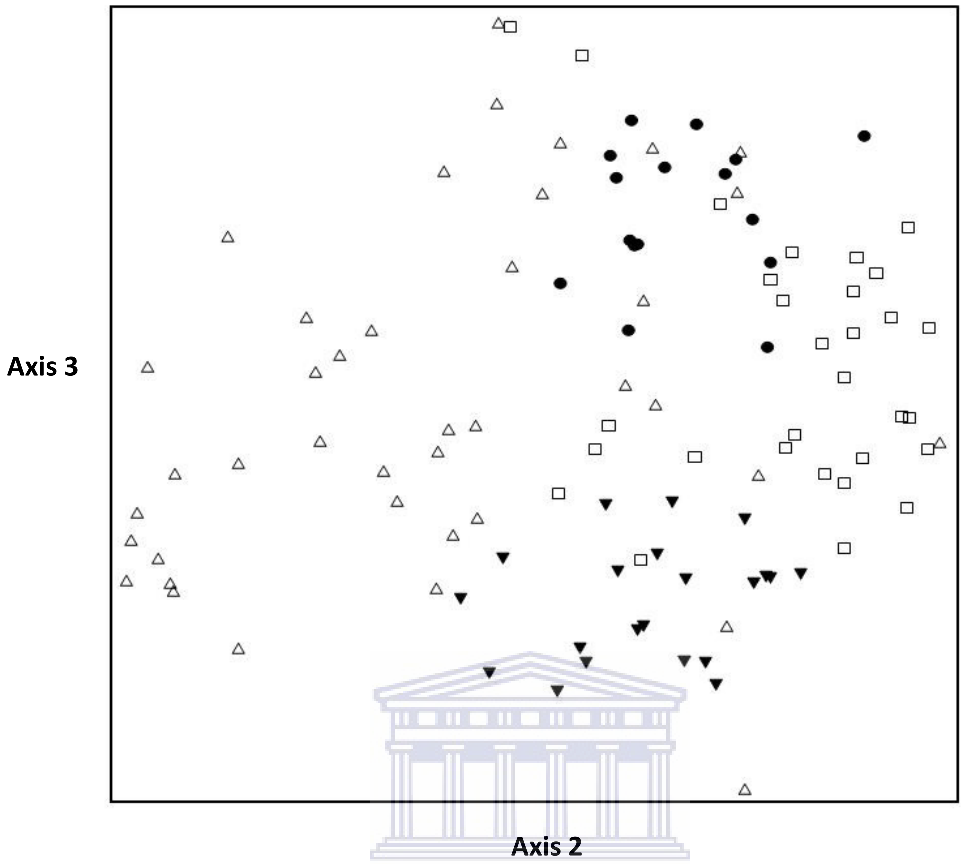





Figure 4

NMS ordination of the on termitaria plant community of Oudtshoorn Gannaveld. Groups derived from the cluster analysis are superimposed, empty triangle symbols represent the group one community, filled circle symbols represent the group four community, empty square symbols represent the group eight community and filled triangle symbols represent the group 13 community.

**Kruskal-Wallis One-Way ANOVA and Dunns' multiple comparisons test**

**Off termitaria**

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Kruskal-Wallis One-Way ANOVA and Dunns' multiple comparisons post hoc tests show several significant differences occur between the different plant communities off termitaria.

The highest mean species richness was recorded in group one. This was similar to the species richness in group six, but differed significantly from groups three and five. Although statistically significant, the difference in mean species richness between the groups is low. Group one and group six were found to be similar in plant density, but there was a significant increase in the density of plants in groups three and five, where the number of plants almost doubled. Interestingly, even with this significant increase in the number of plants the percentage of cover does not differ significantly between any of the groups. Also, the percentage of bare ground, although highest in group one and lowest in group five did not differ significantly between the groups. The percentage of dead prostrate litter that is expected to reduce as vegetation degrades (Milton and Hoffman 1994, Esler *et al.* 2006) did not differ between the off termitaria groups.



In terms of the plant functional type categories used in this study, the results show that the cover of dwarf succulents, perennial forbs and perennial grasses does not differ significantly between the ordination groups in the off termitaria community.

What was found was that dwarf succulent shrubs, dwarf woody shrubs, succulent shrubs and woody shrubs differed significantly in terms of canopy cover abundance between the four groups. The cover of dwarf succulent shrubs is significantly higher in groups three and five than in groups one and six and this corresponds well with the increased density of plants in these groups suggesting that the increased overall density is as a result of the increase in the number of dwarf succulent shrubs. In both group three and group five dwarf succulent shrubs are by far the most dominant plant functional type. The cover of dwarf woody shrubs is lowest in group five, significantly lower than in groups three and six.

Succulent shrub cover is highest in groups one and six, significantly higher than in groups three and five. This corresponds with the pattern of dwarf succulent shrub cover in these groups, where low dwarf succulent cover corresponds with high succulent shrub cover and high dwarf succulent cover corresponds with low succulent shrub cover. This pattern is interesting to note as the shift in community structure from the larger to the smaller perennial plants in the Karoo has been suggested as a response to continual overgrazing (Milton and Hoffman 1994, Thompson *et al.* 2009).



The result for the cover of woody shrubs between the off termitaria groups is also interesting. Woody shrub cover is similar for all groups except in group five, where there is a significant decrease in cover. Similar to the reduction in succulent shrubs, this decrease in woody shrub cover may be indicating a response to more intense stocking.

The patterns observed from these results indicate that although all four plants communities are similar in terms of cover, the percentage of bare ground and the percentage of litter, the functional type composition differs significantly and this corresponds with the significant differences seen in the density of plants. The group one and group six communities are dominated by succulent shrub cover. The group three and group five communities are dominated by dwarf succulent shrub cover. If these communities do represent different levels of degradation, the response has not been a reduction of cover or an increase in the percentage of bare ground, but rather a shift in the dominant plant functional type.

Table 1 shows the mean (±SD) values for density (number of individual plants), canopy cover percentage, bare area percentage, plant litter percentage, plant functional type cover percentage and species richness recorded in the off termitaria plant community of Oudtshoorn Gannaveld.

Table 1

Mean (±SD) values for species richness, density (number of individual plants), total canopy cover percentage, bare area percentage, percentage prostrate plant litter and plant functional type canopy cover percentage for all species recorded per ordination group in the off termitaria plant community of Oudtshoorn Gannaveld. Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test. ** indicates significance level p < 0.01. *** indicates significance level p < 0.001.

| | Group one | Group three | Group five | Group six |
|---|---|---|---|---|
| Species Richness*** | $15.31 \pm 3.13^{b}$ | $11.12 \pm 2.59^{a}$ | $11.94 \pm 4.21^{a}$ | $13.14 \pm 2.9^{ab}$ |
| Density*** | $579.59 \pm 189.69^{a}$ | $857.92 \pm 217.33^{b}$ | $1050.61 \pm 142.27^{b}$ | $544.48 \pm 186.94^{a}$ |
| Total canopy cover | 60.27 ± 10.71 | 65.92 ± 10.41 | 67.6 ± 7.59 | 64.61 ± 6.77 |
| Bare ground | 30.66 ± 10.94 | 25.75 ± 11.52 | 24.17 ± 7.63 | 27.03 ± 9.19 |
| Litter | 10.25 ± 4.71 | 8.12 ± 5.33 | 9.31 ± 4.51 | 11.02 ± 5.64 |
| Dwarf Succulents | 0.21 ± 0.38 | 0.16 ± 0.32 | 0.74 ± 1.43 | 0.04 ± 0.05 |
| Dwarf Succulent Shrubs*** | $19.2 \pm 11.64^{a}$ | $42.98 \pm 11.5^{b}$ | $54.6 \pm 9.3^{b}$ | $19.14 \pm 11.01^{a}$ |
| Dwarf Woody Shrubs** | $2.25 \pm 1.83^{ab}$ | $3.81 \pm 3.13^{b}$ | $1.64 \pm 1.68^{a}$ | $3.66 \pm 1.89^{b}$ |
| Perennial Forbs | 0.01 ± 0.03 | 0 ± 0 | 0.01 ± 0.04 | 0 ± 0 |
| Perennial Grasses | 0.21 ± 0.72 | 0.01 ± 0.05 | 0 ± 0 | 0.01 ± 0.07 |
| Succulent Shrubs*** | $25.44 \pm 7.07^{b}$ | $8.05 \pm 7.12^{a}$ | $6.21 \pm 5.26^{a}$ | $31.38 \pm 9.15^{b}$ |
| Woody Shrubs*** | $12.9 \pm 5.86^{b}$ | $10.92 \pm 6.79^{b}$ | $4.4 \pm 4.35^{a}$ | $10.33 \pm 5.37^{b}$ |

The analysis of differences in species abundance between the groups shows that the cover of many of the off termitaria species differs significantly. The more abundant species are discussed here while the significant differences in abundance of all individual species between the groups and the implication in terms of vegetation condition are discussed in more depth further on in this chapter. Individual perennial forb and grass species were recorded in extremely low abundance and differences between groups was not analysed. Table 2 shows the mean (±SD) cover percentages of species in each of the four ordination groups.

One of the important results is that *Leipoldtia schultzei* is significantly more abundant in groups three and five than in groups one and six. This species is the dominant species in the dwarf succulent shrub functional type and this explains the significantly higher cover of this functional type in groups three and five. *Leipoldtia schultzei* is mat forming in Oudtshoorn Gannaveld and its relatively high abundance is usually associated with degradation, especially where the larger perennial shrubs are reduced (Vlok *et al.* 2005, Thompson *et al.* 2009). This also corresponds well with the significantly lower abundance of woody shrubs in group five which has the highest abundance *of Leipoldtia schultzei.*



The high abundance of *Ruschia ceresiana* is responsible for the significantly higher cover of succulent shrubs in groups one and six and in both groups in which *Ruschia ceresiana* is dominant, *Leipoldtia schultzei* is significantly lower in abundance.

An interesting result is the high abundance of the dwarf succulent shrub *Ruschia spinosa* in group three, significantly higher than in groups one and six. The relative abundance of this spiny plant is also thought to be an indicator of degradation as it is avoided by livestock when other more palatable species are available (Esler *et al.* 2006). *Drosanthemum lique*, a palatable species, is significantly more abundant in group one than in any of the other groups. As palatable species are usually the first to be removed from systems due to continual heavy grazing (Milton *et al.* 1994a, Thompson *et al.* 2009) the abundance of this species in group one may be indicating that the group one community has been subjected to less intense grazing.

A pattern seen is that most woody shrub species are more abundant in group one and most succulent shrubs are more abundant in group one and six, than in the other groups. The woody shrubs *Pteronia incana, Helichrysum zeyheri, Felicia filifolia* and *Eriocephalus brevifolius* are highest in abundance in group one. *Eriocephalus ericoides* is the exception and is highest in abundance in group three. Most of the dwarf succulent shrubs and dwarf woody shrubs were found to be more abundant in groups three and five.



The results show some of the broader patterns that individual species follow in terms of difference in abundance between groups. There is a general pattern that succulent shrub and woody shrub species tend to be more abundant in groups one and six, while the dwarf succulent shrubs and dwarf woody shrubs tend to be more abundant in groups three and five.

There is also a noticeable pattern in species, as with the plant functional types, that in some cases a high abundance of certain species corresponds with the low abundance of other species. This is most evident in the abundances of *Ruschia ceresiana* and *Leipoldtia schultzei*.

Table 2

Mean (±SD) cover percentages for species used for the NMS ordination in the off termitaria plant community of Oudtshoorn Gannaveld. Plant functional type is indicated in the first column. Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test. ** indicates significance level $p < 0.01$. *** indicates significance level $p < 0.001$.

| Plant functional type | Species | Group one | Group three | Group five | Group six |
|---|---|---|---|---|---|
| Dwarf Succulent | *Crassula capitella* | 0.1 ± 0.35 | 0.03 ± 0.07 | 0.27 ± 0.51 | 0.01 ± 0.03 |
| Dwarf Succulent | *Crassula muscosa*** | 0.09 ± 0.11$^{b}$ | 0.03 ± 0.08$^{a}$ | 0.01 ± 0.02$^{a}$ | 0.02 ± 0.03$^{ab}$ |
| Dwarf Succulent Shrub | *Crassula subaphylla* *** | 0.24 ± 0.2$^{b}$ | 0.05 ± 0.08$^{a}$ | 0.04 ± 0.08$^{a}$ | 0.03 ± 0.04$^{a}$ |
| Dwarf Succulent Shrub | *Euphorbia fimbriata*** | 0.03 ± 0.09$^{a}$ | 0.08 ± 0.13$^{b}$ | 0.04 ± 0.07$^{ab}$ | 0.04 ± 0.07$^{ab}$ |
| Dwarf Succulent Shrub | *Leipoldtia schultzei**** | 18.08 ± 11.98$^{a}$ | 38.76 ± 12.08$^{b}$ | 52.67 ± 9.12$^{b}$ | 18.55 ± 10.97$^{a}$ |
| Dwarf Succulent Shrub | *Mesembryanthemum crystallinum*** | 0 ± 0.01$^{a}$ | 0.08 ± 0.17$^{b}$ | 0 ± 0.01$^{a}$ | 0.02 ± 0.08$^{ab}$ |
| Dwarf Succulent Shrub | *Ruschia spinosa**** | 0.52 ± 1.2$^{a}$ | 4.02 ± 5.21$^{b}$ | 1.86 ± 2.61$^{ab}$ | 0.5 ± 0.8$^{a}$ |
| Dwarf Woody Shrub | *Chrysocoma ciliata**** | 1.88 ± 1.73$^{a}$ | 3.78 ± 3.13$^{b}$ | 1.43 ± 1.64$^{a}$ | 3.45 ± 2.05$^{b}$ |
| Dwarf Woody Shrub | *Helichrysum rosum* | 0.02 ± 0.06 | 0 ± 0 | 0.02 ± 0.05 | 0.05 ± 0.12 |
| Dwarf Woody Shrub | *Selago glutinosa*** | 0.1 ± 0.29$^{b}$ | 0 ± 0$^{a}$ | 0.02 ± 0.07$^{ab}$ | 0.02 ± 0.08$^{ab}$ |
| Dwarf Woody Shrub | *Senecio juniperinus*** | 0.04 ± 0.11$^{ab}$ | 0.01 ± 0.02$^{a}$ | 0.11 ± 0.15$^{b}$ | 0 ± 0$^{a}$ |

Table 2 continued

| Plant functional type | Species | Group one | Group three | Group five | Group six |
|---|---|---|---|---|---|
| Dwarf Woody Shrub | *Thesium nudicaule*** | 0.04 ± 0.09$^{b}$ | 0 ± 0.01$^{ab}$ | 0 ± 0$^{a}$ | 0 ± 0.01$^{ab}$ |
| Succulent Shrub | *Crassula tetragona* *** | 0.12 ± 0.16$^{b}$ | 0.01 ± 0.03$^{a}$ | 0 ± 0$^{a}$ | 0.32 ± 0.33$^{b}$ |
| Succulent Shrub | *Drosanthemum hispidum* | 0.7 ± 3.17 | 0.04 ± 0.16 | 0.03 ± 0.08 | 0.07 ± 0.15 |
| Succulent Shrub | *Drosanthemum lique**** | 1.22 ± 1.46$^{b}$ | 0.13 ± 0.28$^{a}$ | 0.41 ± 0.95$^{a}$ | 0.23 ± 0.41$^{a}$ |
| Succulent Shrub | *Lampranthus haworthii*** | 0.46 ± 1.11$^{ab}$ | 0.01 ± 0.04$^{a}$ | 0 ± 0.02$^{a}$ | 0.67 ± 1.7$^{b}$ |
| Succulent Shrub | *Malephora lutea**** | 1.95 ± 8.05$^{bc}$ | 0.01 ± 0.03$^{ab}$ | 0.66 ± 1.49$^{c}$ | 0.01 ± 0.03$^{a}$ |
| Succulent Shrub | *Phyllobolus splendens** | 0.32 ± 0.65$^{b}$ | 0.01 ± 0.05$^{a}$ | 0.36 ± 0.79$^{ab}$ | 0.27 ± 0.84$^{ab}$ |
| Succulent Shrub | *Psilocaulon junceum* | 0.27 ± 0.8 | 0.07 ± 0.21 | 0.05 ± 0.18 | 0.04 ± 0.11 |
| Succulent Shrub | *Ruschia ceresiana**** | 20.06 ± 8.33$^{b}$ | 7.26 ± 7.11$^{a}$ | 2.8 ± 4.49$^{a}$ | 29 ± 9.16$^{b}$ |
| Succulent Shrub | *Tetragonia fruticosa**** | 1.33 ± 1.2$^{b}$ | 0.43 ± 0.58$^{a}$ | 1.6 ± 1.59$^{b}$ | 0.74 ± 0.7$^{ab}$ |
| Woody Shrub | *Asparagus recurvispinus* | 0.01 ± 0.02 | 0.01 ± 0.03 | 0.05 ± 0.13 | 0 ± 0 |
| Woody Shrub | *Eriocephalus brevifolius*** | 2.57 ± 4.94$^{b}$ | 0.02 ± 0.05$^{a}$ | 0.1 ± 0.4$^{a}$ | 1.2 ± 2.36$^{ab}$ |
| Woody Shrub | *Eriocephalus ericoides**** | 1.17 ± 1.74$^{a}$ | 7.96 ± 6.76$^{b}$ | 1.94 ± 2.22$^{a}$ | 3.09 ± 3.28$^{ab}$ |

Table 2 continued

| Plant functional type | Species | Group one | Group three | Group five | Group six |
|---|---|---|---|---|---|
| Woody Shrub | *Felicia filifolia*** | 1.03 ± 1.88[b] | 0.03 ± 0.16[a] | 0.14 ± 0.59[a] | 0.4 ± 1.24[ab] |
| Woody Shrub | *Galenia africana* | 0.13 ± 0.36 | 0.13 ± 0.28 | 0.82 ± 2.46 | 0.07 ± 0.34 |
| Woody Shrub | *Helichrysum zeyheri**** | 1.06 ± 1.89[b] | 0 ± 0[a] | 0.02 ± 0.05[a] | 0.08 ± 0.24[a] |
| Woody Shrub | *Lycium cinereum* | 0.03 ± 0.09 | 0.06 ± 0.2 | 0.04 ± 0.15 | 0.08 ± 0.34 |
| Woody Shrub | *Pentzia dentata* | 1.42 ± 3.95 | 0.04 ± 0.17 | 0.73 ± 1.96 | 0.4 ± 1 |
| Woody Shrub | *Pteronia glauca* | 0.98 ± 3.14 | 0.16 ± 0.73 | 0 ± 0 | 0.77 ± 2.51 |
| Woody Shrub | *Pteronia incana**** | 3.36 ± 4.93[c] | 0.21 ± 0.4[ab] | 0.1 ± 0.22[a] | 2.5 ± 3.34[bc] |
| Woody Shrub | *Pteronia pallens* | 0.02 ± 0.07 | 1.43 ± 3.04 | 0.33 ± 0.77 | 1.08 ± 3.77 |

There were several important differences in the soil chemistry of the different groups in the off termitaria community. Most notable of these include the higher pH in group five and the higher Na and Ca content in group one. Mg content was consistently highest in groups three and five.

The consistent pattern for group one sites to have higher mineral salt content than the other groups suggests that these sites are associated with more saline soil conditions. The spatial positioning of these sites however gives no indication that landscape position plays a role in determining the distribution of the these variables as the entire study area falls within the flat plains with which Gannaveld is associated. In Namaqualand Hoffman *et al.* (2003) found that soil pH and concentrations of P, Mg, Ca, K and Na, did not follow any pattern associated with plant cover. However, lower plant cover was usually associated with less heterogeneity in nutrient concentrations in soils. In the southern Karoo, Esler and Cowling (1993) found that soil pH and P, Mg and Ca levels were important in determining plant species distribution patterns. In this study there is a general pattern that indicates pH is lower in groups one and six than in groups three and five, and that all the soil minerals, except Mg, are higher in group one than in the other groups.

Table 3 shows soil pH, and Na, P, Ca, Mg and P content recorded in soil samples from the four ordination groups.

Table 3

Mean (±SD) values for pH, and Na, K, Ca, Mg and P recorded per ordination group in the off termitaria plant community of Oudtshoorn Gannaveld. Soil nutrient values are shown as micrograms per gram (µg/g). Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test.

** indicates significance level p < 0.01. *** indicates significance level p < 0.001.

| | Group one | Group three | Group five | Group six |
|---|---|---|---|---|
| pH** | 4.21 ± 0.69[a] | 4.79 ± 1.12[ab] | 5.02 ± 0.95[b] | 4.47 ± 1.53[a] |
| Na ** | 614.32 ± 427.29[b] | 278.87 ± 385.8[ab] | 281.27 ± 511.54[ab] | 309.63 ± 458.73[a] |
| K | 5112.4 ± 2306.6 | 4504.09 ± 1752.73 | 4340.98 ± 1461.62 | 4032.85 ± 1777.62 |
| Ca*** | 391.85 ± 262.58[b] | 148.16 ± 204.8[a] | 88.78 ± 171.01[a] | 142.79 ± 216.16[a] |
| Mg *** | 51.79 ± 57.57[a] | 153.21 ± 99.89[b] | 167.8 ± 77.09[b] | 111.98 ± 63.96[ab] |
| P | 264.82 ± 153.77 | 207.63 ± 158.75 | 200.24 ± 116.85 | 199.42 ± 102.97 |

**Kruskal-Wallis One-Way ANOVA and Dunns' multiple comparisons test**

**On termitaria**

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In the on termitaria community four groups of plots were determined by ordination. These are identified as groups one, four, eight and 13. Analysis revealed significant differences in a number of the variables between these groups and the main results are described below.

There was no statistically significant difference in the mean perennial plant species richness between the four on termitaria plant groups. There was a significant difference in the density of plants between group one and group eight, with group one having the highest density of plants. Cover differed between the groups, and was highest in group three and lowest in group one. Cover in groups four and 13 was consistently higher than that of groups one and eight. Of interest is that the group with the highest density of plants, group one, is also the group with the lowest cover. This indicates a number of smaller canopied plants that occur in this community. The very high cover in group 13 and the lower density of plants indicates a community made up of fewer but larger plants than group one.

As can be expected, the percentage of bare ground corresponded with the percentage of cover in each group. The highest percentage of bare ground was recorded for group one, which also has the lowest percentage of cover. The lowest percentage of bare ground is found in group 13 which has the highest cover. All groups follow this pattern.

The percentage of plant litter was lowest in group one, highest in group eight and consistently intermediate in groups four and 13. The cover of all plant functional types except perennial forbs and perennial grasses differed significantly between the four on termitaria plant communities. The cover of all plant functional types except perennial forbs and perennial grasses differed significantly between the four on termitaria plant communities. The cover of the dwarf succulents was significantly higher in group one than in any other group. Dwarf succulent shrubs were also highest in group one and consistently lower in groups eight and four. The cover of dwarf woody shrubs was highest in group one, significantly different to groups four and 13. From these results there is a clear pattern of a high abundance of smaller species that occur in the group one community and in most cases significantly higher than in the other communities.



The larger succulent shrubs are significantly more abundant in groups eight, four and 13 than in group one, corresponding well with the lower abundance of dwarf plants in these groups. Of importance in these results is the high abundance in group one of dwarf succulents, dwarf succulent shrubs and dwarf woody shrubs; and the dominance of the larger succulent shrubs in groups eight, four and 13. This combined with the high density of plants in group one indicates a similar pattern to the off termitaria community where larger shrubs dominate certain communities and smaller and more plants dominate other communities. This may indicate a response to continual high density stocking, where larger perennial shrubs have been reduced to the advantage of the smaller dwarf species.

One would expect the same pattern to apply for woody shrubs, however the cover of this functional type is lowest in group 13, not group one. This can be partly explained by the higher abundance of *Galenia africana* and *Pteronia pallens*, indicators of disturbance in this vegetation type, in group one.

Table 4 shows the mean (±SD) values for the species richness, density, canopy cover, bare area, plant litter and plant functional type cover recorded in the four ordination group of the on termitaria plant community of Oudtshoorn Gannaveld.

Table 4

Mean (±SD) values for species richness, density (number of individual perennial plants), total canopy cover percentage, bare area percentage, percentage prostrate plant litter and plant functional type canopy cover percentage for all species recorded per ordination group in the on termitaria plant community of Oudtshoorn Gannaveld. Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test. ** indicates significance level p < 0.01. *** indicates significance level p < 0.001.

| | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|
| Species richness | 9.5 ± 3.87 | 8.25 ± 2.77 | 9.33 ± 2.59 | 7.52 ± 3.34 |
| Density* | 501.4 ± 308.06$^{b}$ | 359.19 ± 116.08$^{ab}$ | 346.43 ± 139.48$^{a}$ | 424.05 ± 159.45$^{ab}$ |
| Cover*** | 41.89 ± 14.82$^{a}$ | 55.26 ± 7.83$^{bc}$ | 50.39 ± 12.04$^{ab}$ | 67 ± 11.88$^{c}$ |
| Bare*** | 47.9 ± 13.06$^{c}$ | 36.74 ± 7.49$^{ab}$ | 41.64 ± 11.55$^{bc}$ | 26.14 ± 10.14$^{a}$ |
| Litter** | 5.25 ± 5.17$^{a}$ | 7.32 ± 5.33$^{ab}$ | 8.5 ± 5.5$^{b}$ | 7.23 ± 8.23$^{ab}$ |
| Dwarf Succulents *** | 3.97 ± 7.56$^{b}$ | 0.26 ± 0.98$^{a}$ | 0.87 ± 2.19$^{a}$ | 0.07 ± 0.18$^{a}$ |
| Dwarf Succulent Shrubs*** | 19.3 ± 18.3$^{b}$ | 4.03 ± 6.08$^{a}$ | 2.79 ± 4.38$^{a}$ | 8.88 ± 9.35$^{ab}$ |
| Dwarf Woody Shrubs** | 1.17 ± 2.63$^{b}$ | 0.18 ± 0.38$^{ab}$ | 0.78 ± 1.03$^{b}$ | 0.22 ± 0.6$^{a}$ |
| Perennial Forbs | 0.02 ± 0.06 | 0.01 ± 0.02 | 0.01 ± 0.02 | 0 ± 0 |
| Perennial Grasses | 0 ± 0.02 | 0 ± 0 | 0 ± 0 | 0 ± 0 |
| Succulent Shrubs*** | 13.76 ± 11.54$^{a}$ | 47.17 ± 10.19$^{b}$ | 42.12 ± 12.3$^{b}$ | 56.38 ± 12.88$^{b}$ |
| Woody Shrubs* | 3.68 ± 5.31$^{ab}$ | 3.61 ± 2.75$^{b}$ | 3.83 ± 5.77$^{ab}$ | 1.45 ± 2.66$^{a}$ |

Analysis of the abundance of individual species between the four on termitaria groups showed a number of significant differences. The results for the more abundant species are discussed here while all individual species are discussed in more depth further on in this chapter.

The mat forming *Ruschia impressa* was most abundant in group one. This mat forming plant is the most abundant dwarf succulent on termitaria in this study and its significantly higher abundance in group one may be an indication of degradation (Vlok *et al.* 2005). The abundance of this species in group one accounts for the significantly higher cover of the dwarf succulent functional type in group one than in the other groups. The highest abundance of *Ruschia spinosa* was also recorded in group one, with an abundance of less than 1% in the other groups.



*Drosanthemum giffenii* was most abundant in group eight, significantly higher than in the other groups. The cover of *Drosanthemum hispidum* was extremely high in group 13 and this was significantly higher than in any other group. The succulent shrub *Malephora lutea* was most abundant in group four, significantly higher than the other groups. *Phyllobolus splendens* cover was highest in group eight, significantly higher than the other groups. The cover of *Psilocaulon junceum* was highest in group and lowest in group one. The abundance of this species was intermediate it groups four and 13. *Salsola aphylla*, probably the most prominent species on termitaria in Oudtshoorn Gannaveld was least abundant in group 13 and most abundant in group four.

Species that are most abundant in group one tend to be dwarf succulents, dwarf succulent shrubs and dwarf woody shrubs, while in the other groups the most abundant species are succulent shrubs. This indicates the difference in structure between the group one community and the other groups; with group one being a community consisting of mainly small plants. This corresponds well with the higher density of plants in this found in this community. Important species are *Drosanthemum hispidum* that dominates the cover in group 13 and *Malephora lutea* that is dominant in group four.

Table 5 shows the mean (±SD) cover percentages of species in each of the four ordination groups on termitaria.

Table 5

Mean (±SD) cover percentages for species used for NMS ordination in the on termitaria plant community of Oudtshoorn Gannaveld. Plant functional type is indicated in the first column. Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test. ** indicates significance level p < 0.01. *** indicates significance level p < 0.001.

| Plant functional type | Species | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|---|
| Dwarf Succulent | *Crassula muscosa** | $0.01 \pm 0.03^{b}$ | $0 \pm 0.01^{ab}$ | $0 \pm 0^{a}$ | $0 \pm 0.01^{ab}$ |
| Dwarf Succulent | *Ruschia impressa*** | $3.96 \pm 7.56^{b}$ | $0.26 \pm 0.98^{a}$ | $0.87 \pm 2.19^{ab}$ | $0.07 \pm 0.18^{a}$ |
| Dwarf Succulent Shrub | *Euphorbia fimbriata* | 0.03 ± 0.08 | 0.04 ± 0.14 | 0.01 ± 0.02 | 0 ± 0.02 |
| Dwarf Succulent Shrub | *Leipoldtia schultzei* | 1.94 ± 3.29 | 1.84 ± 6.48 | 0.77 ± 1.76 | 0.9 ± 3.63 |
| Dwarf Succulent Shrub | *Mesembryanthemum crystallinum* | 10.45 ± 19.13 | 3.52 ± 5.9 | 1.28 ± 4.13 | 6.98 ± 9.03 |
| Dwarf Succulent Shrub | *Ruschia spinosa**** | $6.81 \pm 8.36^{c}$ | $0.27 \pm 1.04^{a}$ | $0.73 \pm 1.46^{ab}$ | $0.92 \pm 1.5^{bc}$ |
| Dwarf Woody Shrub | *Chrysocoma ciliata*** | $1.13 \pm 2.62^{b}$ | $0.05 \pm 0.08^{a}$ | $0.47 \pm 0.83^{ab}$ | $0.2 \pm 0.6^{a}$ |
| Dwarf Woody Shrub | *Senecio juniperinus*** | $0.02 \pm 0.05^{ab}$ | $0.03 \pm 0.07^{ab}$ | $0.09 \pm 0.16^{b}$ | $0 \pm 0^{a}$ |
| Perennial Forb | *Aptosimum indivisum* | 0.01 ± 0.03 | 0.52 ± 0.17 | 0.58 ± 0.16 | 0.47 ± 0.21 |
| Succulent Shrub | *Augea capensis* | 0.03 ± 0.15 | 0.03 ± 0.08 | 0.2 ± 0.69 | 0 ± 0 |

Table 5 continued

| Plant functional type | Species | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|---|
| Succulent Shrub | *Drosanthemum giffenii**** | 0.56 ± 1.29$^{a}$ | 0.55 ± 1.17$^{a}$ | 3.33 ± 3.37$^{b}$ | 0.17 ± 0.47$^{a}$ |
| Succulent Shrub | *Drosanthemum hispidum**** | 2.62 ± 4.24$^{a}$ | 5.58 ± 5.43$^{ab}$ | 14.88 ± 10.11$^{b}$ | 43.08 ± 12.93$^{c}$ |
| Succulent Shrub | *Drosanthemum lique* | 0.7 ± 4.15 | 0.04 ± 0.14 | 0.01 ± 0.02 | 0 ± 0.01 |
| Succulent Shrub | *Malephora lutea**** | 0.67 ± 2.25$^{a}$ | 30.37 ± 13.67$^{b}$ | 3.91 ± 8.32$^{a}$ | 0.02 ± 0.04$^{a}$ |
| Succulent Shrub | *Phyllobolus splendens**** | 1.17 ± 2.34$^{a}$ | 0.89 ± 1.69$^{a}$ | 5.68 ± 5.31$^{b}$ | 0.26 ± 0.98$^{a}$ |
| Succulent Shrub | *Psilocaulon junceum**** | 4.85 ± 6.55$^{a}$ | 6.99 ± 4.43$^{ab}$ | 13.67 ± 10.71$^{b}$ | 9.14 ± 7.08$^{b}$ |
| Succulent Shrub | *Ruschia ceresiana* | 0.76 ± 3.41 | 0.19 ± 0 | 0.2 ± 0.82 | 0.04 ± 0.16 |
| Succulent Shrub | *Tetraena retrofracta*** | 2.23 ± 3.89$^{ab}$ | 0.25 ± 0.7$^{a}$ | 0.29 ± 1.26$^{a}$ | 1.86 ± 2.33$^{b}$ |
| Succulent Shrub | *Tetragonia fruticosa* | 0.13 ± 0.49 | 0.06 ± 0.14 | 0.06 ± 0.15 | 0.03 ± 0.1 |
| Woody Shrub | *Eriocephalus ericoides* | 0.55 ± 1.51 | 0.04 ± 0.14 | 0.01 ± 0.02 | 0 ± 0.01 |
| Woody Shrub | *Galenia africana** | 0.45 ± 1.1$^{b}$ | 0.02 ± 0.08$^{ab}$ | 0.02 ± 0.13$^{a}$ | 0.15 ± 0.51$^{ab}$ |
| Woody Shrub | *Lycium cinereum** | 0.03 ± 0.13$^{ab}$ | 0.02 ± 0.06$^{ab}$ | 0 ± 0$^{a}$ | 0.22 ± 0.47$^{b}$ |
| Woody Shrub | *Pteronia glauca* | 0.28 ± 1.6 | 0 ± 0 | 0.2 ± 0.82 | 0.04 ± 0.14 |

Table 5 continued

| Plant functional type | Species | Group 1 | Group 4 | Group 8 | Group 13 |
| --- | --- | --- | --- | --- | --- |
| Woody Shrub | *Pteronia incana* | 0.21 ± 1 | 0.06 ± 0 | 0.2 ± 0.82 | 0.04 ± 0.14 |
| Woody Shrub | *Pteronia pallens* | 0.46 ± 2.39 | 0.13 ± 0 | 0.2 ± 0.82 | 0.04 ± 0.15 |
| Woody Shrub | *Salsola aphylla** | 1.62 ± 3.18$^{ab}$ | 3.43 ± 2.79$^{b}$ | 3.07 ± 5.43$^{ab}$ | 0.99 ± 2.15$^{a}$ |

There were several important differences in the soil chemistry of the different groups in on termitaria community. Most noticeable is the high content of Na, P and Ca in group four and the correspondingly low content of these minerals in group one. Ca content is highest in group 13. P is highest in group 13 and lowest in group one. Soil pH did not differ between the groups.

The pattern that emerges from these results indicates that there is a depletion of soil nutrients in group one, where all soil minerals are shown to be lowest. Group four contains the highest levels of most of the minerals, but in most cases these do not differ significantly from the soils of group eight and 13. P however is significantly lower in group eight than in group 13.



Table 6 shows the pH, and Na, K, Ca, Mg and P content recorded in soil samples from the four ordination groups in the on termitaria plant community.

Table 6

Mean (±SD) values for pH, and Na, K, Ca, Mg and P recorded per ordination group in the on termitaria plant community of Oudtshoorn Gannaveld. Soil nutrient values are shown as micrograms per gram (µg/g). Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test. ** indicates significance level $p < 0.01$. *** indicates significance level $p < 0.001$.

| | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|
| pH | 8.15 ± 1.28 | 8.74 ± 0.52 | 8.28 ± 1.38 | 8.34 ± 0.83 |
| Na* | 236.81 ± 343.61$^{a}$ | 634.84 ± 719.24$^{b}$ | 441.59 ± 542.4$^{ab}$ | 302.65 ± 420.11$^{ab}$ |
| K ** | 6145.81 ± 2154.69$^{a}$ | 8132.01 ± 2294.51$^{b}$ | 7122.91 ± 2109.96$^{ab}$ | 6352.83 ± 2124.49$^{ab}$ |
| Ca *** | 652.19 ± 449.38$^{a}$ | 1204.9 ± 698.08$^{b}$ | 984.61 ± 547$^{ab}$ | 1369.11 ± 632.86$^{b}$ |
| Mg | 484.21 ± 221.9 | 694.75 ± 447.08 | 655.9 ± 272.2 | 677.83 ± 299.56 |
| P ** | 516.27 ± 224.48$^{a}$ | 728.32 ± 402.93$^{ab}$ | 586.57 ± 260.59$^{a}$ | 802.89 ± 285.48$^{b}$ |

**Correlation analysis**

**On and off termitaria**

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The Kendall's tau correlation analysis of data from the off termitaria vegetation community showed significant correlations between a number of variables and between variables and the ordination axes. Axis two and three were used for the correlation for both on and off termitaria data as these were found to explain the most variance in the ordination. Correlation analysis of the off termitaria data yielded a positive correlation for the number of individual plants to canopy cover percentage.

There was a negative correlation between the density of plants and bare ground and also a negative correlation between cover and bare ground. These results are to be expected, considering the analysis of total cover and bare ground show that in the groups with high cover the percentage of bare ground is low. The correlation analysis of on termitaria data shows a positive correlation between species richness and axis three of the ordination indicating an increase of species richness from group 13 to group one. However analysis shows no significant difference between the mean species richness of these groups. Between groups, the difference in mean species richness on termitaria is very low. The negative correlation between cover and bare ground is to be expected as groups with high cover have low bare ground percentages.

Table 7 shows the on and off termitaria correlation matrices for the NMS ordination axes two and three, density, canopy cover percentage, bare ground percentage, percentage of prostrate plant litter and species richness.

Table 7

Kendall's tau correlation matrix for off and on termitaria NMS ordination axes two and three, plant density, canopy cover, bare ground percentage, plant litter percentage and species richness (SR). Value is the correlation coefficient *r*. ** indicates correlation is significant at the 0.01 level. * indicates correlation is significant at the 0.05 level.

| Off termitaria | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Axis 2 | Axis 3 | Density | Cover | Bare | Litter | SR |
| Axis 2 | | | | | | | |
| Axis 3 | -0.036 | | | | | | |
| Density | -0.046 | 0.027 | | | | | |
| Cover | 0.081 | 0.047 | .411** | | | | |
| Bare | -0.036 | -.168* | -.335** | -.634** | | | |
| Litter | 0.068 | 0.132 | -0.078 | 0.110 | -.360** | | |
| SR | 0.132 | 0.003 | -0.127 | -0.009 | 0.036 | 0.074 | |

| On termitaria | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Axis 2 | Axis 3 | Density | Cover | Bare | Litter | SR |
| Axis 2 | | | | | | | |
| Axis 3 | 0.084 | | | | | | |
| Density | -.306** | -0.116 | | | | | |
| Cover | 0.105 | -.194** | .168* | | | | |
| Bare | -.205** | .234** | -0.075 | -.639** | | | |
| Litter | .242** | 0.120 | -.163* | -0.027 | -.184** | | |
| SR | 0.047 | .328** | 0.029 | -0.111 | .184** | 0.051 | |

Correlation analysis showed few significant correlations between the plant functional types off termitaria. The most significant was a negative correlation between dwarf succulent shrubs and succulent shrubs. This trend was clearly evident in the communities where succulent shrub cover was high, predominantly made up of *Ruschia ceresiana*. In these communities the abundance of dwarf succulent shrubs, mainly *Leipoldtia schultzei*, was low. There was also a negative correlation between dwarf succulent shrubs and woody shrubs. This is evident in the mean cover values of these functional types in the different groups, with a general trend showing an increase in dwarf succulent shrub cover with a decrease in woody shrub cover. These correlations support the analysis of variance results and show a shift from succulent and woody shrubs to dwarf succulent shrubs. These shifts indicate a change in community structure probably as a result of over stocking, where larger perennial shrubs are replaced by smaller dwarf shrubs over time (Milton and Hoffman 1994).



The correlation matrix for the off termitaria plant community NMS ordination axes two and three and plant functional type abundance is shown in Table 8.

Table 8

Kendall's tau correlation matrix for off termitaria NMS ordination axes two and three and cover abundance of plant functional types. Value is the correlation coefficient *r*. * indicates correlation is significant at the 0.05 level. ** indicates correlation is significant at the 0.01 level.

| | Axis 2 | Axis 3 | Dwarf Succulents | Dwarf Succulent Shrubs | Dwarf Woody Shrubs | Perennial Forbs | Perennial Grasses | Succulent Shrubs | Woody Shrubs |
|---|---|---|---|---|---|---|---|---|---|
| Axis 2 | | | | | | | | | |
| Axis 3 | -0.036 | | | | | | | | |
| Dwarf Succulents | -0.081 | 0.037 | | | | | | | |
| Dwarf Succulent Shrubs | -0.100 | 0.088 | 0.109 | | | | | | |
| Dwarf Woody Shrubs | 0.067 | -.226** | -0.043 | -0.079 | | | | | |
| Perennial Forbs | 0.102 | 0.011 | 0.057 | -0.014 | -0.104 | | | | |
| Perennial Grasses | 0.112 | 0.013 | -0.110 | -.296** | 0.010 | -0.071 | | | |
| Succulent Shrubs | 0.112 | -0.074 | -0.130 | -.661** | 0.093 | -0.034 | .214* | | |
| Woody Shrubs | 0.113 | 0.039 | -0.116 | -.241** | -0.017 | 0.030 | 0.082 | .151* | |

Correlation analysis of the on termitaria plant functional type data shows a number of significant correlations. There was a significant negative correlation between axis 2 of the ordination and dwarf succulent shrubs. There was also a significant positive correlation between axis two and succulent shrubs. This supports the results showing that in communities of high succulent shrub abundance there is generally a lower abundance of dwarf succulent shrubs. In communities of high dwarf succulent shrub abundance succulent shrub cover tends to be lower.

There was a positive correlation between axis three of the ordination and both dwarf woody shrubs and woody shrubs. This is evident in the low abundance of dwarf woody shrubs and woody shrubs in group 13, which generally increases in the other groups. Dwarf succulents are positively correlated with dwarf woody shrubs and this correspond with the higher abundance of these functional types in group one. Dwarf succulents and dwarf woody shrubs tend to be lower in abundance in the other groups. Dwarf succulent shrubs are also negatively correlated with succulent shrubs and this is clearly seen by the significantly lower abundance of dwarf succulents and dwarf succulent shrubs in communities where succulent shrubs are high in abundance.



This is the clearest pattern that emerges from the correlation analysis and shows that as the larger succulent shrubs decrease in abundance, the smaller dwarf succulents and dwarf succulent shrubs increase. This again indicates that some of the defined groups of the on termitaria plant community show response characteristics that become prevalent in overstocked semi-arid vegetation in the Succulent Karoo.

The correlation matrix for the on termitaria plant community NMS ordination axes two and three and plant functional type abundance is shown in Table 9.

Table 9

Kendall's tau correlation matrix for on termitaria NMS ordination axes two and three and cover abundance of plant functional types. Value is the correlation coefficient *r*. * indicates correlation is significant at the 0.05 level. ** indicates correlation is significant at the 0.01 level.

| | Axis 2 | Axis 3 | Dwarf Succulents | Dwarf Succulent Shrubs | Dwarf Woody Shrubs | Perennial Forbs | Perennial Grasses | Succulent Shrubs | Woody Shrubs |
|---|---|---|---|---|---|---|---|---|---|
| Axis 2 | | | | | | | | | |
| Axis 3 | 0.08 | | | | | | | | |
| Dwarf Succulent | -.188** | 0.13 | | | | | | | |
| Dwarf Succulent Shrub | -.551** | -.195** | 0.08 | | | | | | |
| Dwarf Woody Shrub | -0.01 | .263** | .259** | -0.05 | | | | | |
| Perennial Forb | -0.01 | .158* | 0.00 | 0.02 | 0.15 | | | | |
| Perennial Grass | -0.05 | 0.12 | 0.15 | 0.05 | -0.01 | -0.03 | | | |
| Succulent Shrub | .384** | -0.07 | -.280** | -.341** | -.135* | -0.07 | -0.11 | | |
| Woody Shrub | .159* | .325** | 0.11 | -0.10 | .152* | 0.09 | 0.08 | -0.10 | |

The correlation analysis showed several significant correlations between soil chemicals in the off termitaria community. pH was only correlated with Mg and this is evident in the high Mg content in group one. Group one has the highest pH of all on termitaria groups. Also notable is the positive correlation of Na with K and Ca. These minerals are all highest in group one and generally decrease in the other groups. Mg was negatively correlated with both Na and Ca and this is seen in the low Mg content in group one which increases significantly in groups three and five. P was positively correlated with K and Ca, however apart from a general trend that shows group one to have the highest P content, this was not significantly different to any of the other groups.

An interesting pattern is the negative correlation of Ca and Na with Mg. This suggests that the Mg content in the more saline sites is low. The pH level in the more saline sites is also lower than the sites of high Mg. As the more saline sites have been shown to support communities with a higher abundance of succulent and woody shrubs which may mean they are not severely degraded, the reduction of Mg in these sites may be as a result of the more active plant growth in these areas. However this needs to be more thoroughly investigated. An important issue is that if soil chemicals are depleted in certain more degraded groups this holds serious implications for any attempts at rehabilitation.



Table 10 shows the correlation matrix for off termitaria soils.

Table 10

Kendall's tau correlation matrix for the off termitaria plant community NMS ordination axes two and three, soil pH and soil nutrients. Value is the correlation coefficient *r*. * indicates correlation is significant at the 0.05 level. ** indicates correlation is significant at the 0.01 level.

| | Axis 2 | Axis 3 | pH | Na | K | Ca | Mg | P |
|---|---|---|---|---|---|---|---|---|
| Axis 2 | | | | | | | | |
| Axis 3 | -0.036 | | | | | | | |
| pH | -0.086 | 0.137 | | | | | | |
| Na | 0.071 | 0.077 | -0.128 | | | | | |
| K | 0.080 | 0.122 | -0.030 | .483** | | | | |
| Ca | 0.033 | 0.130 | 0.006 | .517** | .465** | | | |
| Mg | -0.131 | -0.010 | .209** | -.430** | -.172* | -.500** | | |
| P | .149* | .147* | 0.009 | .247** | .451** | .351** | -.185** | |

For the on termitaria plant community there were also a number of significant correlations between soil chemicals. An interesting result is the correlation of pH with Na and K. Although not significantly different to the other groups, pH was highest in group four and this group generally contained higher levels of Na and K than the other groups. Na was also correlated with Ca and K. These minerals are generally higher in group four than in the other groups, except Ca which is slightly higher but not significantly so in group 13. Ca was positively correlated with Mg and P, which correspond with the higher content of Ca, Mg and P in group 13 and relatively lower amounts in the other groups.

Mg was positively correlated with P. This correspond with the generally higher Mg and P content found in groups four and 13 compared to groups eight and one. K was positively correlated with axis three of the ordination and this can be seen in the significantly higher K content in group four than in group one, with groups eight and 13 being intermediate. These correlations show that most soil chemicals tend to increase or decrease together between groups and this is evident in the generally higher soil chemical content in group four as opposed to group one. The correlation analysis showed no significant negative correlations between the soil chemicals.



Table 11 show the correlation matrix for on termitaria soils.

Table 11

Kendall's tau correlation matrix for the on termitaria plant community NMS ordination axes two and three, soil pH and soil nutrients. Value is the correlation coefficient *r*. * indicates correlation is significant at the 0.05 level. ** indicates correlation is significant at the 0.01 level.

| | Axis 2 | Axis 3 | pH | Na | K | Ca | Mg | P |
|---|---|---|---|---|---|---|---|---|
| Axis 2 | | | | | | | | |
| Axis 3 | 0.084 | | | | | | | |
| pH | 0.116 | 0.123 | | | | | | |
| Na | 0.109 | .169** | .390** | | | | | |
| K | .168* | .229** | .357** | .545** | | | | |
| Ca | .150* | -0.062 | 0.086 | .219** | .209** | | | |
| Mg | 0.031 | -0.049 | -0.042 | -.137* | -0.082 | .411** | | |
| P | 0.028 | -.131* | 0.101 | 0.078 | .158* | .515** | .357** | |

Kendall's tau correlation analysis was used to determine the strength of the relationships of individual species recorded off termitaria to the axis values of NMS ordination. The highest significant correlation between species and the ordination axes occurs for *Chrysocoma ciliata* and *Lampranthus haworthii. Lampranthus haworthii* is positively correlated with axis two and *Chrysocoma ciliata* is negatively correlated with axis three. This is explained by the higher abundance of *Lampranthus haworthii* in groups one and six compared to groups three and five. The abundance of *Chrysocoma ciliata* is highest in groups six and three and these groups occur lower on axis three of the ordination. The low number of strong correlations between individual species and the ordination axes can be explained by the fluctuations of the abundances of species between the groups.

Table 12 shows the correlation matrix for the off termitaria plant community NMS ordination axes two and three and species.

Table 12

Kendall's tau correlation matrix for NMS ordination axes two and three and species recorded in the ordination groups of the off termitaria plant community of Oudtshoorn Gannaveld. Value is the correlation coefficient r. * indicates correlation is significant at the 0.05 level. ** indicates correlation is significant at the 0.01 level.

| | Axis 2 | Axis 3 | | Axis 2 | Axis 3 |
|---|---|---|---|---|---|
| *Asparagus recurvispinus* | 0.053 | 0.073 | *Leipoldtia schultzei* | -0.084 | 0.103 |
| *Chrysocoma ciliata* | 0.08 | -.222** | *Lycium cinereum* | 0.053 | -0.006 |
| *Crassula capitella* | -0.018 | 0.068 | *Malephora lutea* | -0.087 | 0.105 |
| *Crassula muscosa* | -0.044 | 0.098 | *Mesembryanthemum crystallinum* | -0.023 | -0.064 |
| *Crassula subaphylla* | 0.027 | 0.073 | *Pentzia dentata* | .189* | -0.143 |
| *Crassula tetragona* | 0.081 | -.158* | *Phyllobolus splendens* | -0.027 | 0.082 |
| *Drosanthemum hispidum* | 0.043 | -0.017 | *Psilocaulon junceum* | -0.038 | -0.06 |
| *Drosanthemum lique* | 0.046 | 0.103 | *Pteronia glauca* | -0.01 | 0.069 |
| *Eriocephalus brevifolius* | .206* | -0.025 | *Pteronia incana* | 0.126 | -0.094 |
| *Eriocephalus ericoides* | 0.069 | 0.122 | *Pteronia pallens* | 0.095 | -0.078 |
| *Euphorbia fimbriata* | 0.093 | -0.027 | *Ruschia ceresiana* | 0.066 | -0.05 |
| *Felicia filifolia* | -0.049 | -0.097 | *Ruschia spinosa* | -0.077 | -0.051 |
| *Galenia africana* | -0.147 | 0.1 | *Selago glutinosa* | 0.048 | 0.091 |
| *Helichrysum rosum* | 0.053 | 0.152 | *Senecio juniperinus* | 0.006 | -0.114 |
| *Helichrysum zeyheri* | 0.009 | -0.025 | *Tetragonia fruticosa* | 0.029 | 0.004 |
| *Lampranthus haworthii* | .228** | 0.036 | *Thesium nudicaule* | 0.124 | -0.028 |

Correlation analysis of individual species recorded on termitaria and the axis values of NMS ordination show several significant correlations. The majority of positive correlations with axis two are succulent shrub species. *Drosanthemum giffenii, Drosanthemum hispidum, Phyllobolus splendens* and *Psilocaulon junceum* are all positively correlated with axis two.

The highest negative correlations with axis two are the dwarf succulent shrub species *Mesembryanthemum crystallinum* and *Ruschia spinosa*. The succulent shrub *Tetraena retrofracta* is also negatively correlated with axis. This fits in well with the results showing that the groups containing the higher abundance of succulent shrub species generally exhibit low abundances of dwarf succulent shrub species. It is also interesting that *Tetraena retrofracta* is negatively correlated with axis two as this indicates that this species tends increase in the areas where dwarf succulent shrubs are more abundant. The relative abundance of this species may serve as an indication of the condition of vegetation.



The correlation with axis three of the ordination shows that all the stronger positive correlations are with the larger succulent and woody shrub species. *Drosanthemum giffenii, Senecio juniperinus, Malephora lutea, Phyllobolus splendens, Tetragonia fruticosa, Pteronia incana* and *Salsola aphylla* are all positively correlated with axis three. The highest abundance of most of these species occurs in groups eight and four. The stronger negative correlations with axis three are for *Drosanthemum hispidum Mesembryanthemum crystallinum, Tetraena retrofracta* and *Galenia africana.* These species are most abundant in groups one and thirteen.

The pattern that is probably the clearest from the correlation of species in the on termitaria community is the way in which the larger succulent and woody shrubs are positively correlated with the ordination axes and smaller dwarf succulent shrubs are negatively correlated. The exceptions are *Drosanthemum hispidum*, *Tetraena retrofracta* and *Galenia africana.* The negative correlation of *Drosanthemum hispidum* is explained by the extremely high abundance of this species in group 13, which is significantly higher than in any of the other groups. The relative high abundance of *Galenia africana*, a poisonous plant to stock, is usually a sign of overgrazing, and this may explain why this species correlates with the ordination axes in a similar manner to the dwarf succulent shrub species.

The negative correlation of the dwarf succulent species on the ordination axes, where there are positive correlations with succulent and woody shrubs, indicates the compositional changes that occur between the groups. A shift in structure from succulent and woody shrub dominated communities to dwarf succulent and dwarf succulent shrub communities is considered an indication of prolonged heavy grazing in the Karoo (Milton and Hoffman 1994).



Table 13 show the correlation matrix for the on termitaria plant community NMS ordination axes two and three and species.

Table 13

Kendall's tau correlation matrix for NMS ordination axes two and three and species recorded in the ordination groups of the on termitaria plant community of Oudtshoorn Gannaveld. Value is the correlation coefficient r. * indicates correlation is significant at the 0.05 level. ** indicates correlation is significant at the 0.01 level.

| | Axis 2 | Axis 3 | | Axis 2 | Axis 3 |
|---|---|---|---|---|---|
| *Aptosimum indivisum* | -0.01 | 0.151 | *Mesembryanthemum crystallinum* | -.344** | -.328** |
| *Augea capensis* | -0.048 | .173* | *Phyllobolus splendens* | .498** | .298** |
| *Chrysocoma ciliata* | 0.02 | .162* | *Psilocaulon junceum* | .304** | -0.03 |
| *Crassula muscosa* | -0.046 | .195* | *Pteronia glauca* | 0.042 | 0.013 |
| *Drosanthemum giffenii* | .415** | .250** | *Pteronia incana* | 0.065 | .243** |
| *Drosanthemum hispidum* | .315** | -.403** | *Pteronia pallens* | -0.071 | .167* |
| *Drosanthemum lique* | 0.005 | 0.068 | *Ruschia ceresiana* | -0.081 | -0.143 |
| *Eriocephalus ericoides* | 0.052 | .191* | *Ruschia impressa* | -.201** | 0.074 |
| *Euphorbia fimbriata* | -.177* | -0.023 | *Ruschia spinosa* | -.379** | -.160* |
| *Galenia africana* | -0.066 | -.222** | *Salsola aphylla* | .188** | .387** |
| *Leipoldtia schultzei* | -0.08 | .195** | *Senecio juniperinus* | 0.045 | .349** |
| *Lycium cinereum* | -0.075 | -0.096 | *Tetraena retrofracta* | -.311** | -.232** |
| *Malephora lutea* | 0.085 | .430** | *Tetragonia fruticosa* | 0.111 | .269** |

The results show that four distinct plant communities can be distinguished in each of the broader on termitaria and off termitaria plant communities in Oudtshoorn Gannaveld. The compositional differences between these communities vary, with similarities occurring between certain communities and significant differences in many variables between others. In the off termitaria community there are differences in species richness, the density of plants, plant functional type abundance and the abundance of a number of individual species. There are also differences in soil chemistry between the off termitaria communities.

In the on termitaria community there is no difference in species richness between the four communities, however there are significant differences in the abundance of a number of plant functional types and individual species. There are also significant differences in canopy cover and the percentage of bare ground as well as the percentage of plant litter. These results address the research question of this chapter by determining that there are distinctly separate vegetation communities that occur on and off termitaria and that these communities differ significantly in many respects.



The four communities that occur in the off termitaria communities are:

The group one community, a succulent shrub dominated community in which the dominant species is *Ruschia ceresiana.*

The group six community, which is also a succulent shrub dominated community with *Ruschia ceresiana* being the dominant species, however with significant differences in the abundance of other species and soil chemistry to the group one community.

The group three community is a dwarf succulent shrub dominated community, with the dominant species being *Leipoldtia schultzei.*

The group five community is also a dwarf succulent dominated community with *Leipoldtia schultzei* as the dominant species but differs from group three in the abundance of other functional types such as dwarf woody shrubs and woody shrubs.

The four on termitaria communities are:

The group one community, a community dominated by dwarf succulent shrubs with *Mesembryanthemum crystallinum* being the dominant species.

The group four community, which is dominated by succulent shrubs with *Malephora lutea* being the dominant species.

The group eight community is dominated by succulent shrubs with *Drosanthemum hispidum* as the dominant species but with *Psilocaulon junceum* also highly abundant.



The group 13 community is dominated by succulent shrubs and in this community *Drosanthemum hispidum* is highly abundant.

# Chapter 5

## Determining the vegetation condition of communities

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## Introduction

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In this chapter I determine the condition of the different vegetation communities identified in the on and off termitaria plant communities of Oudtshoorn Gannaveld. The research question for this chapter is:

- Do different vegetation communities on and off termitaria in Oudtshoorn Gannaveld represent different states of vegetation condition?



Based on a number of indications of degradation I have found that the different groups represent different states of vegetation degradation. In order for the chapter to be read more easily I have included these states at the beginning. I then explain the process of determining these states in the remainder of the chapter.

The condition of the four off termitaria plant communities were determined as:

- Group one community - least degraded.
- Group six community - moderately degraded.
- Group three community – degraded.
- Group five community – severely degraded.

The condition of the four on termitaria plant communities were determined as:

- Group eight community – least degraded.
- Group four community – moderately degraded.
- Group 13 community – degraded.
- Group one community – severely degraded.

Vegetation data for this study was collected in the only extensive example of Oudtshoorn Gannaveld thought to contain different vegetation conditions, from perceived pristine to moderately and severely degraded. Cluster analysis and NMS ordination of the on and off termitaria vegetation data identified four distinct plant communities in each broad plant community of the study area. The results of the analysis of this data are used here to determine whether the condition of the four communities in each of the two broader plant communities differs. In order to answer the research questions for this chapter, I consider how one could expect plant communities in this environment to respond to degradation based on available literature, and if these more typical degradation indicators differ significantly between the plant communities identified through ordination in this study.

The condition of vegetation in each community was assessed based on the following:

- Perennial plant diversity.
- Perennial plant cover.
- Community heterogeneity.
- Plant functional type diversity.
- Percentage of bare ground.
- Prostrate dead plant material.
- Disturbance indicating species.
- Vegetation condition index.
- Palatability indices.



The vegetation condition index (Esler *et al.* 2006) was calculated for each ordination group using the abundance value of each species recorded in the group multiplied by the grazing index value (Du Toit *et al.* 1995) for each species. Species that are not listed in the grazing index values described by Du Toit *et al.* (1995) and Esler *et al.* (2006) were allocated values based on appropriate equivalent species that are listed and through field observations. The presence or absence of disturbance indicating or palatable species recorded in the study but not suitable for analysis of variance because of low abundance, were also used to assess community condition. The condition determined for each community was then compared to the perceived condition of vegetation prior to this study in the different areas of the study site.

Although stocking intensity was not measured directly as part of this study the differences in the vegetation of the different communities are presumed to be as a result of increased grazing and trampling pressure, particularly by ostriches. This is supported by the fact that fences have historically separated the different areas of the study site making it highly probable that stock pressure over time has been different in each area.

The on and off termitaria plant communities are analyzed separately as they are recognized as separate plant communities in the Succulent Karoo biome (Knight *et al.* 1989, Midgley and Musil 1990, Yeaton and Esler 1990, Milton 1990, Milton and Dean 1990) and in Oudtshoorn Gannaveld (Vlok *et al.* 2005).

**Off termitaria**

**Diversity**

In Succulent Karoo habitats, intact vegetation is typically dominated by a diversity of perennial plants (Cowling *et al.* 1994, Milton *et al.* 1997). Overall species richness that includes annual species is usually not a good indicator of vegetation condition, as species richness may increase under heavy grazing pressure (Todd and Hoffman 1999, Cupido 2005, Esler *et al.* 2006) or may not differ under different grazing pressures (Anderson and Hoffman 2007). In the Succulent Karoo habitats of the Little Karoo there is a significant positive correlation between perennial plant species richness and vegetation condition (Cupido 2005) and perennial plant species richness is considered a accurate indicator of vegetation condition (Vlok *et al.* 2005, Thompson *et al.* 2009).



In the clearly delineated Oudtshoorn Gannaveld vegetation type of the Little Karoo (Vlok *et al.* 2005), one of the Succulent Karoo Gannaveld habitat vegetation types identified because of its unique structure and composition, changes in perennial plant species richness across the landscape cannot be attributed to a change in vegetation type. In this relatively small remnant of a distinct vegetation type where abiotic variables are unlikely to vary significantly across the landscape, changes in species richness are most likely to be associated with livestock pressure.

The high number of sample plots applied across the study site also addresses the issue of patchiness in this vegetation type, where individual plant communities may occur in patches smaller than one hectare (Vlok *et al.* 2005). The results show that the perennial plant species richness of the off termitaria community of Oudtshoorn Gannaveld differed significantly between the plant communities of ordination group one and ordination groups three and five. However species richness in group six did not differ significantly from group one or groups three and five. Groups three and five do not differ significantly. The mean species richness values for these groups show a decline from group one to group six, to group five to group three. This indicates that, in terms of perennial plant species richness, the plant communities of groups one and six are in a more intact condition than the communities of groups three and five.

**Cover**

There is ample evidence that continuous high-intensity defoliation through grazing in the Succulent Karoo results in a decline in perennial plant cover (Milton and Hoffman 1994, Todd and Hoffman 1999, Beukes and Ellis 2003, Cupido 2005, Anderson and Hoffman 2007). Even though intact vegetation of one type may have similar plant cover to the degraded state of another vegetation type in Little Karoo, depending on the species composition and the response of those species to overstocking (Thompson *et al.* 2009), in the Gannaveld habitat type of the Little Karoo, the reduction of perennial plant cover is considered an indicator of severe degradation (Vlok *et al.* 2005, Esler *et al.* 2006). The percentage of perennial plant cover therefore serves as a useful indicator of vegetation condition in Oudtshoorn Gannaveld.



Analysis of the canopy cover percentage recorded for each of the four ordination groups in the off termitaria plant community shows no significant difference in total perennial plant cover between the four groups, although the mean values do show an increase from group one through group six and group three to group five. The mean total canopy cover percentage thus gives no solid indication of any difference in vegetation condition between the four groups.

**Heterogeneity**

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An important indication of vegetation condition in the Succulent Karoo habitats of the Little Karoo is the degree of heterogeneity in community composition. One of the known mechanisms of vegetation change brought about by grazing in the Karoo is the loss of heterogeneity leading to the homogenization or the reduction and simplification of plant composition in communities (Hoffman and Cowling 1990, Milton 1994, O'Connor and Roux 1995, Todd and Hoffman 1999, Cupido 2005, Thompson *et al.* 2009). Determining the level of heterogeneity of the different Oudtshoorn Gannaveld communities would therefore give a good indication of the relative condition of the community.



The proportion of the total cover each species in a community contributes gives an indication of the extent to which each community is dominated by more or fewer species, showing the level of heterogeneity or homogeneity of the composition of each community. The results of this study show that although total perennial plant cover does not differ significantly statistically between the off termitaria ordination groups, the spread of the abundance of species between the groups differs greatly.

When considering the accumulation of cover of dominant species in each of the four off termitaria communities, the results show that 88.9% of the perennial plant cover of group five and 89.4% of the cover of group three is made up by just four species; *Leipoldtia schultzei, Ruschia ceresiana, Eriocephalus ericoides* and *Ruschia spinosa.*

88.8% of the cover of group six is made up by five species; *Ruschia ceresiana, Leipoldtia schultzei, Chrysocoma ciliata, Eriocephalus ericoides, Pteronia incana,* and *Eriocephalus brevifolius.* In group one 89.3% of the perennial plant cover is made up by ten species; *Ruschia ceresiana, Leipoldtia schultzei, Pteronia incana, Eriocephalus brevifolius, Malephora lutea, Chrysocoma ciliata, Pentzia dentata, Tetragonia fruticosa, Drosanthemum lique,* and *Eriocephalus ericoides.* The dominant species in groups one and six, *Ruschia ceresiana,* makes up only 33.8% and 45.5% respectively of the total cover of each group, while the dominant species in groups three and five, *Leipoldtia schultzei*, make up 59.8% and 79% of the total cover of the respective groups. This indicates that ordination group one represents a more heterogeneous plant community, in terms of the abundance of a variety of perennial plant species in off termitaria Oudtshoorn Gannaveld, than groups three, five and probably group six.



The cover percentage and the proportion of that cover of the total cover percentage for off termitaria species per ordination group is shown in Table 1.

Table 1

Canopy cover percentage for species recorded off termitaria per ordination group and arranged in order of dominance. Prop refers to the proportion of the total cover contributed by each species.

| Group 1 | | | Group 6 | | | Group 3 | | | Group 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover | Prop | | Cover | Prop | | Cover | Prop | | Cover | Prop |
| *Ruschia ceresiana* | 20.06 | 33.80 | *Ruschia ceresiana* | 29 | 45.52 | *Leipoldtia schultzei* | 38.76 | 59.76 | *Leipoldtia schultzei* | 52.67 | 79.02 |
| *Leipoldtia schultzei* | 18.08 | 30.46 | *Leipoldtia schultzei* | 18.55 | 29.12 | *Eriocephalus ericoides* | 7.96 | 12.27 | *Ruschia ceresiana* | 2.8 | 4.20 |
| *Pteronia incana* | 3.36 | 5.66 | *Chrysocoma ciliata* | 3.45 | 5.42 | *Ruschia ceresiana* | 7.26 | 11.19 | *Eriocephalus ericoides* | 1.94 | 2.91 |
| *Eriocephalus brevifolius* | 2.57 | 4.33 | *Eriocephalus ericoides* | 3.09 | 4.85 | *Ruschia spinosa* | 4.02 | 6.20 | *Ruschia spinosa* | 1.86 | 2.79 |
| *Malephora lutea* | 1.95 | 3.29 | *Pteronia incana* | 2.5 | 3.92 | *Chrysocoma ciliata* | 3.78 | 5.83 | *Tetragonia fruticosa* | 1.6 | 2.40 |
| *Chrysocoma ciliata* | 1.88 | 3.17 | *Eriocephalus brevifolius* | 1.2 | 1.88 | *Pteronia pallens* | 1.43 | 2.20 | *Chrysocoma ciliata* | 1.43 | 2.15 |
| *Pentzia dentata* | 1.42 | 2.39 | *Pteronia pallens* | 1.08 | 1.70 | *Tetragonia fruticosa* | 0.43 | 0.66 | *Galenia africana* | 0.82 | 1.23 |
| *Tetragonia fruticosa* | 1.33 | 2.24 | *Pteronia glauca* | 0.77 | 1.21 | *Pteronia incana* | 0.21 | 0.32 | *Pentzia dentata* | 0.73 | 1.10 |

Table 1 continued

| Group 1 | | | Group 6 | | | Group 3 | | | Group 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover | Prop | | Cover | Prop | | Cover | Prop | | Cover | Prop |
| *Drosanthemum lique* | 1.22 | 2.06 | *Tetragonia fruticosa* | 0.74 | 1.16 | *Pteronia glauca* | 0.16 | 0.25 | *Malephora lutea* | 0.66 | 0.99 |
| *Eriocephalus ericoides* | 1.17 | 1.97 | *Lampranthus haworthii* | 0.67 | 1.05 | *Drosanthemum lique* | 0.13 | 0.20 | *Drosanthemum lique* | 0.41 | 0.62 |
| *Helichrysum zeyheri* | 1.06 | 1.79 | *Ruschia spinosa* | 0.5 | 0.78 | *Galenia africana* | 0.13 | 0.20 | *Phyllobolus splendens* | 0.36 | 0.54 |
| *Felicia filifolia* | 1.03 | 1.74 | *Felicia filifolia* | 0.4 | 0.63 | *Euphorbia fimbriata* | 0.08 | 0.12 | *Pteronia pallens* | 0.33 | 0.50 |
| *Pteronia glauca* | 0.98 | 1.65 | *Pentzia dentata* | 0.4 | 0.63 | *Mesembryanthemum crystallinum* | 0.08 | 0.12 | *Crassula capitella* | 0.27 | 0.41 |
| *Drosanthemum hispidum* | 0.7 | 1.18 | *Crassula tetragona* | 0.32 | 0.50 | *Psilocaulon junceum* | 0.07 | 0.11 | *Felicia filifolia* | 0.14 | 0.21 |
| *Ruschia spinosa* | 0.52 | 0.88 | *Phyllobolus splendens* | 0.27 | 0.42 | *Lycium cinereum* | 0.06 | 0.09 | *Senecio juniperinus* | 0.11 | 0.17 |
| *Lampranthus haworthii* | 0.46 | 0.78 | *Drosanthemum lique* | 0.23 | 0.36 | *Crassula subaphylla* | 0.05 | 0.08 | *Pteronia incana* | 0.1 | 0.15 |
| *Phyllobolus splendens* | 0.32 | 0.54 | *Helichrysum zeyheri* | 0.08 | 0.13 | *Pentzia dentata* | 0.04 | 0.06 | *Eriocephalus brevifolius* | 0.1 | 0.15 |
| *Psilocaulon junceum* | 0.27 | 0.45 | *Lycium cinereum* | 0.08 | 0.13 | *Drosanthemum hispidum* | 0.04 | 0.06 | *Asparagus recurvispinus* | 0.05 | 0.08 |

Table 1 continued

| Group 1 | | | Group 6 | | | Group 3 | | | Group 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover | Prop | | Cover | Prop | | Cover | Prop | | Cover | Prop |
| *Crassula subaphylla* | 0.24 | 0.40 | *Galenia africana* | 0.07 | 0.11 | *Crassula muscosa* | 0.03 | 0.05 | *Psilocaulon junceum* | 0.05 | 0.08 |
| *Galenia africana* | 0.13 | 0.22 | *Drosanthemum hispidum* | 0.07 | 0.11 | *Felicia filifolia* | 0.03 | 0.05 | *Lycium cinereum* | 0.04 | 0.06 |
| *Crassula tetragona* | 0.12 | 0.20 | *Helichrysum rosum* | 0.05 | 0.08 | *Crassula capitella* | 0.03 | 0.05 | *Crassula subaphylla* | 0.04 | 0.06 |
| *Crassula capitella* | 0.1 | 0.17 | *Psilocaulon junceum* | 0.04 | 0.06 | *Eriocephalus brevifolius* | 0.02 | 0.03 | *Euphorbia fimbriata* | 0.04 | 0.06 |
| *Selago glutinosa* | 0.1 | 0.17 | *Euphorbia fimbriata* | 0.04 | 0.06 | *Asparagus recurvispinus* | 0.01 | 0.02 | *Drosanthemum hispidum* | 0.03 | 0.05 |
| *Crassula muscosa* | 0.09 | 0.15 | *Crassula subaphylla* | 0.03 | 0.05 | *Crassula tetragona* | 0.01 | 0.02 | *Helichrysum rosum* | 0.02 | 0.03 |
| *Thesium nudicaule* | 0.04 | 0.07 | *Crassula muscosa* | 0.02 | 0.03 | *Phyllobolus splendens* | 0.01 | 0.02 | *Helichrysum zeyheri* | 0.02 | 0.03 |
| *Senecio juniperinus* | 0.04 | 0.07 | *Selago glutinosa* | 0.02 | 0.03 | *Malephora lutea* | 0.01 | 0.02 | *Selago glutinosa* | 0.02 | 0.03 |
| *Lycium cinereum* | 0.03 | 0.05 | *Mesembryanthemum crystallinum* | 0.02 | 0.03 | *Lampranthus haworthii* | 0.01 | 0.02 | *Crassula muscosa* | 0.01 | 0.02 |
| *Euphorbia fimbriata* | 0.03 | 0.05 | *Crassula capitella* | 0.01 | 0.02 | *Senecio juniperinus* | 0.01 | 0.02 | *Lampranthus haworthii* | 0 | 0.00 |

Table 1 continued

| Group 1 | | | Group 6 | | | Group 3 | | | Group 5 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover | Prop | | Cover | Prop | | Cover | Prop | | Cover | Prop |
| *Helichrysum rosum* | 0.02 | 0.03 | *Malephora lutea* | 0.01 | 0.02 | *Thesium nudicaule* | 0 | 0.00 | *Mesembryanthemum crystallinum* | 0 | 0.00 |
| *Pteronia pallens* | 0.02 | 0.03 | *Thesium nudicaule* | 0 | 0.00 | *Helichrysum rosum* | 0 | 0.00 | *Crassula tetragona* | 0 | 0.00 |
| *Asparagus recurvispinus* | 0.01 | 0.02 | *Asparagus recurvispinus* | 0 | 0.00 | *Helichrysum zeyheri* | 0 | 0.00 | *Pteronia glauca* | 0 | 0.00 |
| *Mesembryanthemum crystallinum* | 0 | 0.00 | *Senecio juniperinus* | 0 | 0.00 | *Selago glutinosa* | 0 | 0.00 | *Thesium nudicaule* | 0 | 0.00 |

**Plant functional type diversity**

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In Succulent Karoo habitats, intact vegetation is typically dominated by a diversity of functionally differentiated perennial plants (Cowling *et al.* 1994) and sustained heavy grazing can result in significant shifts in plant functional type composition (Riginos and Hoffman 2003, Petersen *et al.* 2004). There is evidence from other studies in the Succulent Karoo (Todd and Hoffman 1999, Anderson and Hoffman 2007) that larger woody and succulent shrubs are replaced by smaller dwarf shrub species as a result of overgrazing. As the populations of the larger succulent and woody shrubs decline more open space becomes available. The release in competitive pressure results in an increase in abundance of the smaller dwarf shrubs (Esler and Cowling 1993). The relative density of the different plant functional types gives an indication of the evenness of the distribution of plant functional types within each ordination group.



The results show that in the off termitaria plant community the group one community is dominated in plant density by the dwarf succulent shrub plant functional type making up 56% of the total density of plants. Of the total density of plants in this group 24.6% is made up by the succulent shrub plant functional type and 8.7% by woody shrubs. The group six community is also dominated in terms of plant density by the dwarf succulent shrub plant functional type with 53.4% of the total density of plants. Of the total density of plants in group six 25.3% is made up by the succulent shrub functional type and 8.2% by woody shrubs.

The results of plant functional type density are quite different to groups one and six in group three and group five where 78% of the total density of plants in group three, and 85% of the total density of plants in group five, is made up by the dwarf succulent shrub plant functional type.

Figure 1 shows the proportional density of the seven plant functional types to the total density of plants in the four off termitaria ordination groups in Oudtshoorn Gannaveld.

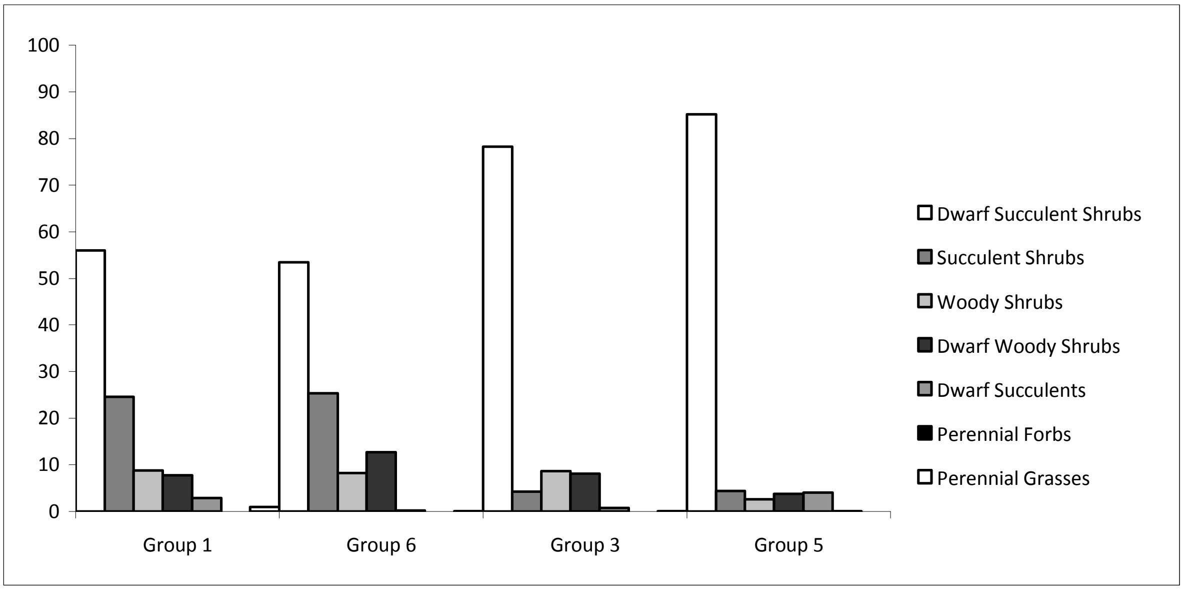


Figure 1

Proportional density percentage of seven plant functional types in the four off termitaria ordination groups of Oudtshoorn Gannaveld.

The results of this study indicate a more even spread of functional type abundance in the plant communities of groups one and six, while the communities of groups three and five are dominated by a single functional type, dwarf succulent shrubs. The vegetation communities of groups one and six are more heterogeneous in plant functional type abundance than the communities of groups three and five. This indicates that the vegetation of ordination groups one and six, with a significantly higher abundance of succulent shrubs, is less overgrazed than that of groups three and five. This is strongly supported by the significant increase in the abundance of the dwarf succulent shrub plant functional type in groups three and five.



In combination with the changes in plant functional type abundance mentioned above, the significant decrease in the abundance of the woody shrub functional group from groups one, six and three to group five, indicates that the vegetation of ordination group five is probably the most severely overgrazed. To support this further, it is known from studies in other semi-arid environments that in response to high grazing pressure there may be selection for low growing, prostrate growth forms (Milchunas and Lauenroth 1993, Hadar *et al.* 1999, Fensham *et al.* 1999). Mat forming succulent plants can dominate heavily overgrazed vegetation in the Succulent Karoo (Yeaton and Esler 1990, Milton and Dean 1990b, Fuls 1992, Dean and Milton 1999, Esler *et al.* 2006, Anderson and Hoffman 2007). These mat forming plants are disturbance indicators that can increase in abundance as vegetation degrades (Esler and Cowling 1993) and become dominant in degraded areas where perennial shrubs have been lost (Milton and Dean 1996).

It has been found that in the Succulent Karoo vegetation types of the Little Karoo, grazing-induced degradation results in an increase in the cover of creeping succulents and shallow-rooted mat forming plants (Vlok *et al.* 2005, Cupido 2005, Thompson *et al.* 2009). Although the dwarf succulent plant functional type in this study is dominated in all four off termitaria ordination groups by *Leipoldtia schultzei,* the abundance of this species is significantly higher in groups three (38.76% ± 12.08) and five (52.67% ± 9.12) than groups one (18.08% ± 11.98) and six (18.55% ± 10.97). *Leipoldtia schultzei* is a species that grows low and is mat forming in Oudtshoorn Gannaveld and when dominant on the ground it is considered to be an indicator of vegetation degradation (Vlok *et al.* 2005).

These results indicate that the vegetation of ordination groups three and five is more degraded than that of groups one and six. The high abundance of *Leipoldtia schultzei* also explains the significantly higher density of plants recorded for groups three and five than for groups one and six.

**Bare ground**

The percentage of bare ground is a good indicator of severe vegetation degradation in the Succulent Karoo habitats of the Little Karoo where vegetation is lost due to intensive grazing and trampling (Vlok *et al.* 2005, Thompson *et al.* 2005, Thompson *et al.* 2009). In this study no significant differences in bare ground percentage were recorded between the ordination groups off termitaria, even though there is significant reduction in the larger canopied succulent and woody shrub functional types from the group one plant community to the group five community.

The lack of significant increase in the bare area percentage as a result of this can best be explained by the significant increase in the abundance of the mat forming dwarf succulent shrub *Leipoldtia schultzei*. Hardy succulents such as these are known to serve as pioneers in degraded areas and establish more easily open sites than shrubs (Yeaton and Esler 1990, Fuls 1992).



Also, the fact that there is no significant difference in the percentage of bare ground between the ordination groups indicates that whatever the lowest ranking condition group of this study is, this does not necessarily represent an extreme extent of degradation in Gannaveld. For example, areas of very high ostrich concentrations in this habitat are predominantly denuded of vegetation and have very high percentages of bare ground (Dean and Milton 1999, Cupido 2005, Vlok *et al.* 2005, Esler *et al.* 2006, Reyers *et al.* 2009). These sites would represent extreme degradation.

**Prostrate dead plant material**

The amount of prostrate dead plant material, or mulch, that accumulates on the ground in the Succulent Karoo is important in creating microsites for seedling recruitment (Dean and Milton 1991, Esler 1993), reducing surface temperatures, water loss (du Preez and Snyman 1993) and soil erosion (Esler *et al.* 2006) and returning mineral nutrients to the soil by decay (Mills and Fey 2003). In terms of vegetation dynamics this indicates that plant litter is important during rare recruitment opportunities. Without suitable establishment sites recruitment would be inhibited. It is also known that in degraded sites of the Succulent Karoo very little plant litter protects or enters the soil (Milton and Dean 1996, Esler 1999). Therefore the differences in the percentage of dead plant material on the ground in the communities of Oudtshoorn Gannaveld may give an indication of the relative condition of each community.



The results however show that there is no significant difference in the percentage of dead prostrate plant litter between the four off termitaria groups, even though the mean values indicate a lower percentage of litter in groups three and five than in groups one and six. As with the percentage of bare ground between the groups, the lack of differences in plant litter percentage can possibly be explained by the fact that the degraded vegetation in this study does not necessarily represent an extreme level of degradation in this habitat, where it is highly likely that there will be a reduction in plant litter on the ground.

**Disturbance indicating species**

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The relative abundance of species that are indicators of disturbance or degradation in the Succulent Karoo is a good indication of vegetation condition as these species tend to become dominant in overgrazed or disturbed vegetation (Milton *et al.* 1994a, Milton and Dean 1999, Cupido 2005, Vlok *et al.* 2005). Some of the more commonly known species used to indicate degradation (Hoffman *et al.* 2003, Cupido 2005, Vlok *et al.* 2005, Esler *et al.* 2006, Thompson *et al.* 2009) and that have been recorded in this study in Oudtshoorn Gannaveld are used here to give an indication of the condition of the four off termitaria groups. These species are *Malephora lutea, Chrysocoma ciliata,* M*esembryanthemum crystallinum, Galenia africana, Pteronia pallens*, *Senecio juniperinus, Ruschia spinosa* and *Leipoldtia schultzei.*



The highest mean cover value for *Malephora lutea* was recorded in group one. This species was found to increase significantly in abundance from groups six and three to group five. The abundance of *Malephora lutea* did not differ significantly between groups six and three. A pattern appears to be the shift from a high abundance of plants in group one to a significantly lower abundance in group six, which stays similar in group three and then increases significantly in group five. A possible explanation for this could be that groups one and five in which there is a higher abundance of *Malephora lutea*, are more degraded than groups six and three.

The abundance of *Chrysocoma ciliata* increases significantly from group one to groups six and three, and decreases significantly again in group five. This species is significantly more abundant in groups three and six than in groups one and five. Using this species as an indicator of condition the pattern seems to indicate that group one and group five are in a less degraded condition than groups six and three.

The abundance of *Mesembryanthemum crystallinum* was not recorded off termitaria in groups one and five, probably because it is more commonly found on termitaria in Gannaveld (Vlok *et al.* 2005). However it was recorded in groups six and three in very low abundance (< 1%). The use of this species as an indicator of condition off termitaria for the purposes of this study is therefore considered to be unreliable.



*Galenia africana* showed no significant difference in abundance between the four groups, although the mean values indicate a decrease in abundance from group one to group five. *Pteronia pallens* also showed no significant difference between the groups. There was a significant difference between the abundance of *Senecio juniperinus* between groups three and five, with the species being more abundant in group five. This may indicate a worsening of condition from group three to group five. *Ruschia spinosa* was most abundant in groups three and five and lowest in groups one and six indicating that group three and five may be more degraded. *Leipoldtia schultzei* was significantly higher in groups three and five than in groups one and six, indicating that groups three and five are more degraded.

The pattern that emerges from these results indicates that most of the disturbance indicating species occur in the communities of groups three and five with the exception of *Malephora lutea* which is most abundant in group one. Based on these indicators the communities of groups three and five are more degraded than the communities of groups one and six.

**Vegetation condition index**

A vegetation condition index (Esler *et al.* 2006) was calculated for each off termitaria ordination group using the abundance value of each species recorded in the group multiplied by the grazing index value (Du Toit *et al.* 1995) for each species. Species that are not listed in the grazing index values described by Du Toit *et al.* (1995) and Esler *et al.* (2006) were allocated values based on appropriate equivalent species that are listed and through field observations. The grazing index value is a sum of the scores for four of the services that plants perform, forage production in and out of the growing season, accessibility to grazing animals, perenniality and the ability to protect soil (Du Toit *et al.* 1995).



Although this method may not be a reliable indicator of vegetation condition between different vegetation types because of natural differences in composition, it is acceptable for use in this study as all sites are located in a unique vegetation type. Also, the palatability of plants used to determine the grazing index values are based on palatability to large and small stock, not ostriches. Ostriches do however select and strip off leaves of palatable plants, in some cases removing small plants and seedlings completely and their feeding preferences bring them into direct competition with other mammalian herbivores such as sheep and goats (Milton *et al.* 1994b). It is therefore highly probable that palatable plant species will be removed first by ostriches in this vegetation type.

In the off termitaria plant community the highest vegetation condition index value was found for the group one plant community, followed by the group six community and the group three community. The lowest index value was shown for the group five community. This indicates that the group one and group six plant communities probably best represent better condition vegetation in this vegetation type, while the group three and group five plant communities probably represent Oudtshoorn Gannaveld vegetation in a more degraded condition.

The mean cover abundance percentages per species, species grazing index values (Du Toit *et al.* 1995) and vegetation condition scores (Esler *et al.* 2006) for each of the four off termitaria ordination groups are shown in Table 2.

Table 2

Grazing index values (GIV) (Du Toit *et al.* 1995), canopy cover percentage and vegetation condition index (VCI) (Esler *et al.* 2006), score for species recorded in four NMS ordination groups in the off termitaria plant community of Oudtshoorn Gannaveld. The total vegetation condition index score per group is given at the bottom of the Table.

| | | Group 1 | | Group 6 | | Group 3 | | Group 5 | |
|---|---|---|---|---|---|---|---|---|---|
| | GIV | Cover | VCI | Cover | VCI | Cover | VCI | Cover | VCI |
| *Asparagus recurvispinus* | 1 | 0.01 | 0.01 | 0 | 0 | 0.01 | 0.01 | 0.05 | 0.05 |
| *Chrysocoma ciliata* | 1.5 | 1.88 | 2.82 | 3.45 | 5.18 | 3.78 | 5.67 | 1.43 | 2.15 |
| *Crassula capitella* | 1 | 0.1 | 0.1 | 0.01 | 0.01 | 0.03 | 0.03 | 0.27 | 0.27 |
| *Crassula muscosa* | 1 | 0.09 | 0.09 | 0.02 | 0.02 | 0.03 | 0.03 | 0.01 | 0.01 |
| *Crassula subaphylla* | 1 | 0.24 | 0.24 | 0.03 | 0.03 | 0.05 | 0.05 | 0.04 | 0.04 |
| *Crassula tetragona* | 1 | 0.12 | 0.12 | 0.32 | 0.32 | 0.01 | 0.01 | 0 | 0 |
| *Drosanthemum hispidum* | 5.4 | 0.7 | 3.78 | 0.07 | 0.38 | 0.04 | 0.22 | 0.03 | 0.16 |
| *Drosanthemum lique* | 6.3 | 1.22 | 7.69 | 0.23 | 1.45 | 0.13 | 0.82 | 0.41 | 2.58 |
| *Eriocephalus brevifolius* | 5 | 2.57 | 12.85 | 1.2 | 6 | 0.02 | 0.1 | 0.1 | 0.5 |
| *Eriocephalus ericoides* | 5 | 1.17 | 5.85 | 3.09 | 15.45 | 7.96 | 39.8 | 1.94 | 9.7 |
| *Euphorbia fimbriata* | 2 | 0.03 | 0.06 | 0.04 | 0.08 | 0.08 | 0.16 | 0.04 | 0.08 |
| *Felicia filifolia* | 5.9 | 1.03 | 6.08 | 0.4 | 2.36 | 0.03 | 0.18 | 0.14 | 0.83 |
| *Galenia africana* | 2 | 0.13 | 0.26 | 0.07 | 0.14 | 0.13 | 0.26 | 0.82 | 1.64 |
| *Helichrysum rosum* | 3 | 0.02 | 0.06 | 0.05 | 0.15 | 0 | 0 | 0.02 | 0.06 |
| *Helichrysum zeyheri* | 4.1 | 1.06 | 4.35 | 0.08 | 0.33 | 0 | 0 | 0.02 | 0.08 |
| *Lampranthus haworthii* | 1 | 0.46 | 0.46 | 0.67 | 0.67 | 0.01 | 0.01 | 0 | 0 |
| *Leipoldtia schultzei* | 1 | 18.08 | 18.08 | 18.55 | 18.55 | 38.76 | 38.76 | 52.67 | 52.67 |
| *Lycium cinereum* | 3 | 0.03 | 0.09 | 0.08 | 0.24 | 0.06 | 0.18 | 0.04 | 0.12 |
| *Malephora lutea* | 3.5 | 1.95 | 6.83 | 0.01 | 0.04 | 0.01 | 0.04 | 0.66 | 2.31 |
| *Mesembryanthemum crystallinum* | 1.8 | 0 | 0 | 0.02 | 0.04 | 0.08 | 0.14 | 0 | 0 |

Table 19 continued

| | | Group 1 | | Group 6 | | Group 3 | | Group 5 | |
|---|---|---|---|---|---|---|---|---|---|
| | GIV | Cover | VCI | Cover | VCI | Cover | VCI | Cover | VCI |
| *Pentzia dentata* | 4.2 | 1.42 | 5.96 | 0.4 | 1.68 | 0.04 | 0.17 | 0.73 | 3.07 |
| *Phyllobolus splendens* | 5.7 | 0.32 | 1.82 | 0.27 | 1.54 | 0.01 | 0.06 | 0.36 | 2.05 |
| *Psilocaulon junceum* | 4.5 | 0.27 | 1.22 | 0.04 | 0.18 | 0.07 | 0.32 | 0.05 | 0.23 |
| *Pteronia glauca* | 3.4 | 0.98 | 3.33 | 0.77 | 2.62 | 0.16 | 0.54 | 0 | 0 |
| *Pteronia incana* | 2.7 | 3.36 | 9.07 | 2.5 | 6.75 | 0.21 | 0.57 | 0.1 | 0.27 |
| *Pteronia pallens* | 1.4 | 0.02 | 0.03 | 1.08 | 1.51 | 1.43 | 2 | 0.33 | 0.46 |
| *Ruschia ceresiana* | 2 | 20.06 | 40.12 | 29 | 58 | 7.26 | 14.52 | 2.8 | 5.6 |
| *Ruschia spinosa* | 2.7 | 0.52 | 1.4 | 0.5 | 1.35 | 4.02 | 10.85 | 1.86 | 5.02 |
| *Selago glutinosa* | 5.7 | 0.1 | 0.57 | 0.02 | 0.11 | 0 | 0 | 0.02 | 0.11 |
| *Senecio juniperinus* | 1.6 | 0.04 | 0.06 | 0 | 0 | 0.01 | 0.02 | 0.11 | 0.18 |
| *Tetragonia fruticosa* | 7.7 | 1.33 | 10.24 | 0.74 | 5.7 | 0.43 | 3.31 | 1.6 | 12.32 |
| *Thesium nudicaule* | 1.6 | 0.04 | 0.06 | 0 | 0 | 0 | 0 | 0 | 0 |
| Total vegetation condition index | | 143.7 | | 130.9 | | 118.8 | | 102.6 | |

**Palatability indices**

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There is evidence that overgrazing in the Succulent Karoo can reduce the fitness of palatable plant species to the advantage of unpalatable species (Milton and Dean 1990b, O'Connor 1991) resulting in a decrease of the abundance of palatable plants (Palmer *et al.* 1999, Todd and Hoffman 1999, Riginos and Hoffman 2003, Hendricks *et al.* 2005). The subjective palatability indices or star scores for Karoo plant species (Esler *et al.* 2006) differ from grazing index value (Du Toit *et al.* 1995) in that they are based purely on palatability, not a combination of factors. Species with palatability star scores of five are considered to be highly palatable and productive. Star score four species are considered to be palatable and productive, while star score three plants are less palatable or unproductive. Unpalatable plant species are assigned a star score of two and highly unpalatable species are assigned a star score of one.



The results of this study show significant statistical differences occur in the abundance of certain palatable species between the ordination groups. The highest star score species recorded off termitaria, *Drosanthemum lique*, was found to be significantly more abundant in group one than in the other groups. There is, however, no significant difference in the abundance of this species between groups three, five and six. *Helichrysum rosum*, with a palatability star score of four, although slightly more abundant in group six, did not differ significantly between the groups. *Tetragonia fruticosa*, also with a star score of four, is least abundant in group three and significantly different to groups one and five.

The abundance of *Crassula muscosa* with a star score of three, was highest in group one, and significantly different to groups three and five. Group six did not differ significantly in the abundance of *Crassula muscosa* from the other groups.

*Eriocephalus ericoides*, a species with a star score of three, was highest in group three, significantly different to groups one and five but not significantly different from group six. *Felicia filifolia* and *Helichrysum zeyheri*, both with palatability star scores of three, were most abundant in group one and significantly different to groups three and five. *Chrysocoma ciliata,* an unpalatable species with a star score of two, had a significantly higher abundance in group three than groups one and five, but did not differ significantly from group six. *Malephora lutea*, with a palatability star score of two, was found to be most abundant in group five and significantly different to groups six and three. *Phyllobolus splendens* with a star score of two was more abundant in group one and significantly different to group three.

The spiny species *Ruschia spinosa*, with a palatability star score of two, was significantly more abundant in group three than in both groups one and six, but although more abundant than in group five this difference was not statistically significant. The highest abundance of *Pteronia pallens*, a highly unpalatable species with a palatability star score of one, occurred in group three. However this was not shown to be significantly different statistically to the other groups. These results indicate that in terms of the abundance of palatable and unpalatable species the vegetation of group one is in a better condition than the vegetation of groups three, five and six.

The mean (±SD) cover abundance values for species with subjective palatability indices (star scores) (Esler *et al.* 2006) recorded in each off termitaria ordination group and the results of Kruskal Wallis ANOVA and Dunn multiple comparison tests are shown in Table 3.

Table 3

Cover abundance percentages and palatability star scores (Esler *et al.* 2006) that are available for species recorded in the four NMS ordination groups of the off termitaria plant community of Oudtshoorn Gannaveld. Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test. ** indicates significance level $p < 0.01$. *** indicates significance level $p < 0.001$.

| | Star score | Group 1 | Group 6 | Group 3 | Group 5 |
|---|---|---|---|---|---|
| *Drosanthemum lique**** | 5 | $1.22 \pm 1.46^{b}$ | $0.23 \pm 0.41^{a}$ | $0.13 \pm 0.28^{a}$ | $0.41 \pm 0.95^{a}$ |
| *Helichrysum rosum* | 4 | $0.02 \pm 0.06$ | $0.05 \pm 0.12$ | $0 \pm 0$ | $0.02 \pm 0.05$ |
| *Tetragonia fruticosa**** | 4 | $1.33 \pm 1.2^{b}$ | $0.74 \pm 0.7^{ab}$ | $0.43 \pm 0.58^{a}$ | $1.6 \pm 1.59^{b}$ |
| *Crassula muscosa*** | 3 | $0.09 \pm 0.11^{b}$ | $0.02 \pm 0.03^{ab}$ | $0.03 \pm 0.08^{a}$ | $0.01 \pm 0.02^{a}$ |
| *Eriocephalus ericoides**** | 3 | $1.17 \pm 1.74^{a}$ | $3.09 \pm 3.28^{ab}$ | $7.96 \pm 6.76^{b}$ | $1.94 \pm 2.22^{a}$ |
| *Felicia filifolia*** | 3 | $1.03 \pm 1.88^{b}$ | $0.4 \pm 1.24^{ab}$ | $0.03 \pm 0.16^{a}$ | $0.14 \pm 0.59^{a}$ |
| *Helichrysum zeyheri**** | 3 | $1.06 \pm 1.89^{b}$ | $0.08 \pm 0.24^{a}$ | $0 \pm 0^{a}$ | $0.02 \pm 0.05^{a}$ |
| *Chrysocoma ciliata**** | 2 | $1.88 \pm 1.73^{a}$ | $3.45 \pm 2.05^{b}$ | $3.78 \pm 3.13^{b}$ | $1.43 \pm 1.64^{a}$ |
| *Drosanthemum hispidum* | 2 | $0.7 \pm 3.17$ | $0.07 \pm 0.15$ | $0.04 \pm 0.16$ | $0.03 \pm 0.08$ |
| *Lycium cinereum* | 2 | $0.03 \pm 0.09$ | $0.08 \pm 0.34$ | $0.06 \pm 0.2$ | $0.04 \pm 0.15$ |
| *Malephora lutea**** | 2 | $1.95 \pm 8.05^{bc}$ | $0.01 \pm 0.03^{a}$ | $0.01 \pm 0.03^{ab}$ | $0.66 \pm 1.49^{c}$ |
| *Mesembryanthemum crystallinum*** | 2 | $0 \pm 0.01^{a}$ | $0.02 \pm 0.08^{ab}$ | $0.08 \pm 0.17^{b}$ | $0 \pm 0.01^{a}$ |

Table 3 continued

| | Star score | Group 1 | Group 6 | Group 3 | Group 5 |
|---|---|---|---|---|---|
| *Phyllobolus splendens** | 2 | 0.32 ± 0.65[b] | 0.27 ± 0.84[ab] | 0.01 ± 0.05[a] | 0.36 ± 0.79[ab] |
| *Pteronia glauca* | 2 | 0.98 ± 3.14 | 0.77 ± 2.51 | 0.16 ± 0.73 | 0 ± 0 |
| *Ruschia spinosa**** | 2 | 0.52 ± 1.2[a] | 0.5 ± 0.8[a] | 4.02 ± 5.21[b] | 1.86 ± 2.61[ab] |
| *Psilocaulon junceum* | 1 | 0.27 ± 0.8 | 0.04 ± 0.11 | 0.07 ± 0.21 | 0.05 ± 0.18 |
| *Pteronia pallens* | 1 | 0.02 ± 0.07 | 1.08 ± 3.77 | 1.43 ± 3.04 | 0.33 ± 0.77 |

**Other indicator species**

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A number of species recorded in the study area presented very low abundance values. This made the statistical analysis of significant differences of these species between groups unreliable. However, the presence or absence of some of the better known indicators of condition may give an indication of vegetation condition in the four ordination groups of the off termitaria plant community.

Interestingly, the highly palatable species *Tripteris sinuata*, with a palatability star score of five (Esler *et al.* 2006), was only recorded in group three. *Digitaria argyrograpta*, a palatable perennial grass with a palatability star score of four was only recorded in group one. *Ehrharta calycina,* a highly palatable perennial grass with a star score of five was only absent from group five. *Pentzia incana,* with a palatability star score of three, was recorded in groups one and six but was absent from groups three and five. *Salsola aphylla*, a five star score palatability species, was only absent from group five.



Because of the low abundances of these species it is difficult to draw any clear conclusions from their presence or absence, but group one does contain four of the five more palatable species mentioned above, possibly indicating better condition vegetation.

Table 4 shows the species occurrence of species not suitable for analysis of variance in each of the four off termitaria groups.

Table 4

Species with low abundance not suitable for analysis of variance recorded in the sample plots grouped by NMS ordination of the off termitaria plant community of the Oudtshoorn Gannaveld vegetation type. Presence is indicated by a 1 and absence is indicated by a 0.

| | Group 1 | Group 3 | Group 5 | Group 6 |
|---|---|---|---|---|
| *Anacampseros arachnoides* | 1 | 0 | 0 | 0 |
| *Anthospermum ciliata* | 1 | 0 | 1 | 0 |
| *Asparagus aethiopicus* | 0 | 0 | 0 | 1 |
| *Asparagus africanus* | 1 | 0 | 1 | 1 |
| *Augea capensis* | 0 | 1 | 1 | 0 |
| *Cotyledon orbiculata* | 1 | 0 | 1 | 1 |
| *Delosperma sp.* | 0 | 0 | 1 | 0 |
| *Dicerothamnus rhinocerotis* | 1 | 0 | 0 | 0 |
| *Digitaria argyrograpta* | 1 | 0 | 0 | 0 |
| *Drosanthemum giffenii* | 1 | 0 | 1 | 0 |
| *Duvalia caespitosa* | 1 | 1 | 1 | 1 |
| *Ehrharta calycina* | 1 | 1 | 0 | 1 |
| *Euryops lateriflorus* | 1 | 0 | 1 | 1 |
| *Helichrysum anomalum* | 1 | 0 | 1 | 0 |
| *Helichrysum dregei* | 0 | 0 | 1 | 0 |
| *Helichrysum excisum* | 0 | 0 | 0 | 1 |
| *Heliophila sauvissima* | 1 | 0 | 0 | 0 |
| *Hermannia sp.* | 1 | 0 | 0 | 0 |
| *Hypertelis salsoloides* | 0 | 0 | 1 | 0 |
| *Justicia cuneata* | 0 | 0 | 1 | 0 |
| *Limeum aethiopicum* | 0 | 1 | 0 | 0 |
| *Lycium oxycarpum* | 0 | 0 | 0 | 1 |

*Table 4 continued*

| | Group 1 | Group 3 | Group 5 | Group 6 |
|---|---|---|---|---|
| *Othonna sp.* | 1 | 0 | 0 | 0 |
| *Pentzia incana* | 1 | 0 | 0 | 1 |
| *Pteronia paniculata* | 1 | 1 | 0 | 1 |
| *Roepera lichtensteiniana* | 0 | 1 | 0 | 1 |
| *Rosenia humilis* | 1 | 1 | 1 | 0 |
| *Ruschia crassa* | 0 | 0 | 1 | 0 |
| *Ruschia impressa* | 1 | 1 | 1 | 0 |
| *Salsola aphylla* | 1 | 1 | 0 | 1 |
| *Senecio radicans* | 1 | 1 | 1 | 1 |
| *Senecio sp.* | 1 | 0 | 1 | 1 |
| *Tetraena retrofracta* | 0 | 1 | 1 | 1 |
| *Tridentea gemmiflora* | 0 | 0 | 1 | 1 |
| *Tripteris sinuata* | 0 | 1 | 0 | 0 |
| *Tylecodon ventricosus* | 1 | 0 | 0 | 0 |

**Vegetation condition of off termitaria ordination groups**

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The combination of the various indicators of vegetation condition used here indicates that the off termitaria groups determined through ordination represent different levels of degradation. The results show that the plant communities of groups one and six together, and the plant communities of groups three and five together, emerge as the two main communities best representing the most dissimilar conditions of vegetation in this vegetation type. The group one and group six combination represent a more intact vegetation condition than the group three and group five combination.

The vegetation of ordination group one is considered to be in the most intact condition, termed for the purposes of this study as least degraded. The vegetation of group six is considered to more degraded than group one, based on the higher dominance of a single species, a reduction in palatable plant abundance and an increase in disturbance indicating species. This community is termed moderately degraded. The vegetation of groups three and five are both considered to be degraded but group five is considered to be more degraded because of the extreme mono-dominance of *Leipoldtia schultzei*. Group three is therefore termed degraded and group five severely degraded.



Group one - least degraded.

Group six - moderately degraded.

Group three – degraded.

Group five – severely degraded.

It is important to place this result within the broader context of vegetation degradation in the Gannaveld habitat type of the Little Karoo. Broader spatial degradation assessments carried out for the area using remote sensing and GIS techniques show the study area as severely degraded (Thompson *et al.* 2005, Thompson *et al.* 2009). The vegetation considered to be in the least degraded condition in this study is therefore only an indication of the most intact condition of vegetation in the study area, and the vegetation considered to be severely degraded indicates the worst condition vegetation of the study site.

**Study results versus perceived condition of areas - off termitaria vegetation condition**

The perceived condition of the areas is based purely on a subjective observation of the study area and is used to show similarities between the subjective observations and the quantified survey. This spatial positioning of the NMS ordination group sample plots that represent different conditions of the off termitaria plant community of Oudtshoorn Gannaveld corresponds well with the subjective field observations and general perceptions of vegetation condition in difference parts of the study area prior to sampling. The terms used for the perceived condition of each area were near pristine, good, moderate and severely degraded. The term 'good' was used purely to describe a perceived condition between near pristine and moderately degraded as described in Milton *et al.* (1998) and Esler *et al.* (1996).



These results show that of the group one plots that are considered to be the least degraded, 41% fall within the area perceived to be near pristine and 45% fall within the area perceived to be in a good condition. Of the group six plots that are considered to be more degraded than group one plots and for the purposes of this study are termed moderately degraded, 57% lie within the area perceived to be moderately degraded. Of the group three plots that are considered to be more degraded than group six plots and are termed degraded, 56% fall within the area perceived to be moderately degraded. Of the group five plots, which are considered to be the most degraded plots, 44% fall within the area perceived to be degraded.

An interesting result is the higher percentage of least degraded plots that occur in area two, than in area one of the study area. Area one was thought to contain the near pristine vegetation of the study area partly because of its status as a Government military area and not an ostrich farm. Although the precise land management history of area was not established as part of this study, it is highly unlikely that this area has been totally excluded from ostrich farming in the past given that the Oudtshoorn basin has been the core of the ostrich farming industry in South Africa since about 1863 (Cupido 2005). The occurrence of wild donkeys in the Government military area may also have had an impact on the vegetation of area one.

Areas three and four of the study area were perceived to be in a similar moderately degraded condition. The results however show a high percentage of group six sample plots, that represent moderately degraded vegetation, in area three, and a high percentage of group three plots, representing degraded vegetation, in area four. This can be explained by the historical separation of these two areas by a road from the town of Oudtshoorn to the village of Volmoed, which has since been closed and the fences removed. The two areas have probably been subjected to different animal stocking regimes in the past and the results of this study indicate that area four was more heavily stocked historically, most probably with ostriches, than area three. These results also show the patchiness of degradation across the study site, with a spread, although uneven, of different vegetation condition plots across each area. Figure 2 shows the areas of perceived vegetation condition in the study area prior to data collection and analysis, and Figure 3 shows the actual condition of these areas based on the results of this study. Table 5 shows the percentage of sample plots from each ordination group that occur in the five perceived vegetation condition areas of the study area.

Table 5

Percentage of NMS ordination group sample plots located in areas of perceived vegetation condition in the off termitaria plant community of Oudtshoorn Gannaveld. Highest values per area are in bold.

| off | Group 1 (Least degraded) | Group 6 (Moderately degraded) | Group 3 (Degraded) | Group 5 (Most degraded) |
|---|---|---|---|---|
| Area 1 (Perceived near pristine) | **41** | 5 | 24 | 11 |
| Area 2 (Perceived good) | **45** | 19 | 0 | 22 |
| Area 3 (Perceived moderate) | 10 | **57** | 16 | 17 |
| Area 4 (Perceived moderate) | 0 | 14 | **56** | 6 |
| Area 5 (Perceived severe) | 3 | 5 | 4 | **44** |
| Total | 100 | 100 | 100 | 100 |

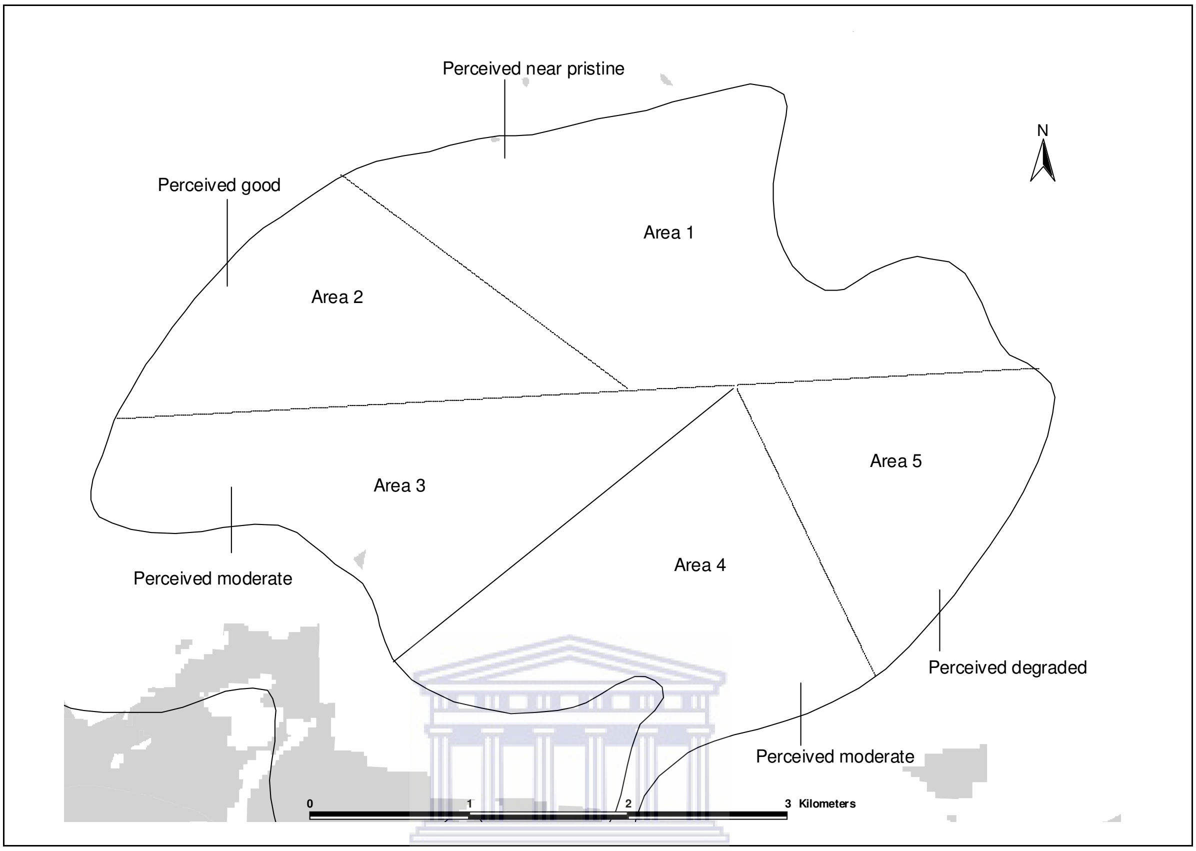




Figure 2

Perceived vegetation condition in areas of the study site prior to study. The black boundary line indicates Oudtshoorn Gannaveld. Dotted lines represent fencelines. The solid line between area three and four represents the old road from Oudtshoorn to Volmoed. The grey areas indicate transformed vegetation (Thompson *et al.* 2005).

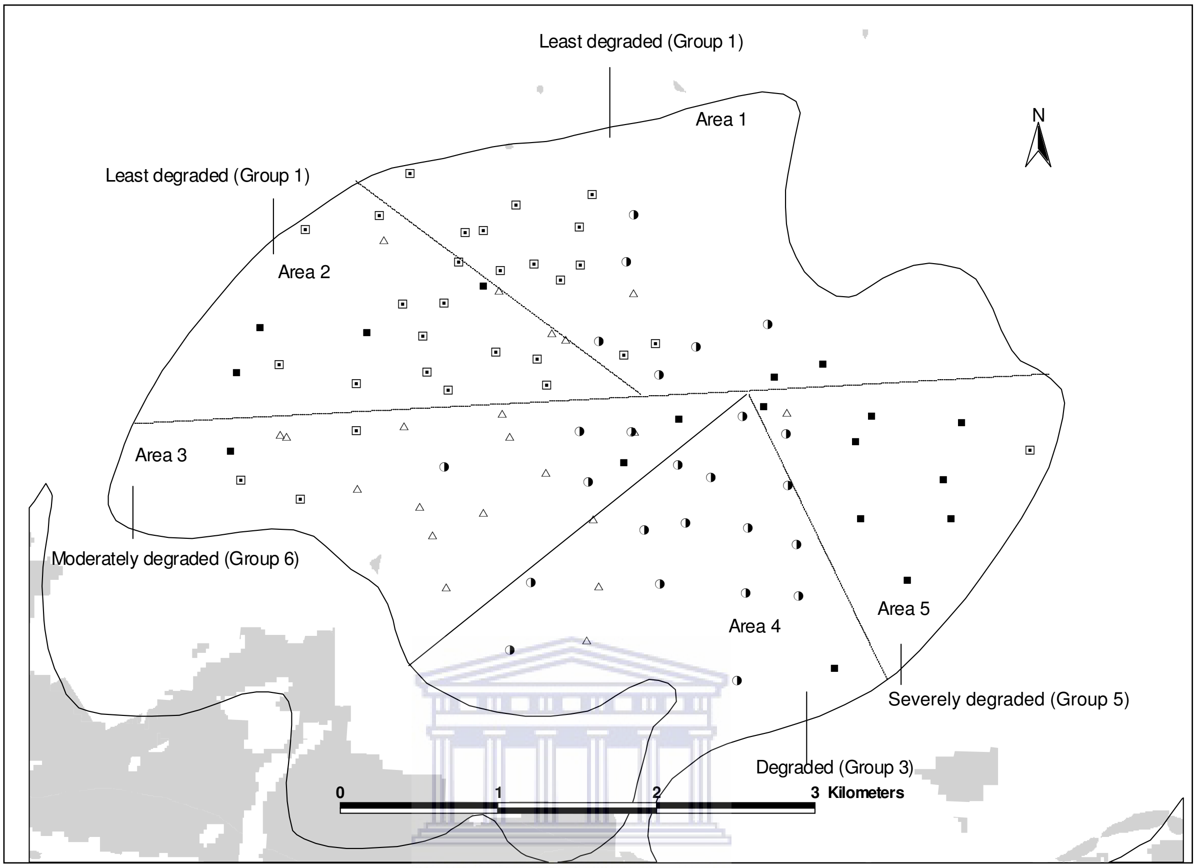




Figure 3

Off termitaria sample plots indicated by symbols representing different vegetation condition. Square with centre dot symbols indicate group 1 plots (least degraded). Half filled circle symbols indicate group 3 (degraded) plots. Filled square symbols indicate group 5 (severely degraded) plots. Empty triangles indicate group 6 (moderately degraded) plots. The black boundary indicates Oudtshoorn Gannaveld. The solid line between area three and four represents the old road from Oudtshoorn to Volmoed. The grey areas indicate transformed vegetation (Thompson *et al.* 2005).

**Determining the vegetation condition of ordination groups**

**On termitaria**

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The same methods applied in determining the condition of vegetation in the off termitaria plant community are applied here to determine the condition of the four on termitaria plant communities identified through NMS ordination.

This study has shown in chapter three that the composition of the on termitaria plant community in Oudtshoorn Gannaveld differs significantly in many ways from the off termitaria plant community and this is supported by similar findings in other parts of the Succulent Karoo (Knight *et al.* 1989, Midgley and Musil 1990, Yeaton and Esler 1990, Milton 1990, Milton and Dean 1990a, Rahloa *et al.* 2008). Disturbance levels on termitaria tend to be higher than in the off termitaria vegetation (Milton and Dean 1990a). This is due to termitaria being the focus of grazing by domestic stock (Armstrong and Siegfried 1990) and burrowing by rodents, and are used as dung middens by some mammal species (Milton and Dean 1990a).



In the Succulent Karoo habitats of the Little Karoo there is a concentrated selection of termitaria vegetation by ostriches for grazing and nest making (Cupido 2005). This results in the faster deterioration of the termitaria vegetation than the off termitaria communities and this can be used as an early indication of degradation especially in the Gannaveld habitat (Vlok *et al.* 2005).

**Diversity**

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Although the mean species richness was highest in group one followed by group eight group four and group 13, the results show that there is no significant difference in the mean species richness recorded for the four ordination groups on termitaria. The lack of significant statistical difference gives no real indication of any difference in the condition of the four on termitaria plant communities.

**Cover**

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The highest mean percentage of perennial plant cover was recorded in group 13. This is significantly different to the mean plant cover of group one and group eight, but not significantly different to group four. Based on perennial plant cover being an indicator of on termitaria vegetation condition these results indicate that the group 13 and group four communities are in a better condition than the group one and group eight communities.

**Heterogeneity**

In each group, the proportion of the total cover that each species contributes gives an indication of the level of heterogeneity of the composition of each community. The results of this study show that the spread of the abundance of species between the groups differs greatly. When considering the accumulation of cover of the dominant species in each of the four on termitaria communities, the results show that in the group one plant community, 90.1% of the total cover is made up by 11 species (*Mesembryanthemum crystallinum, Ruschia spinosa, Psilocaulon junceum, Ruschia impressa, Drosanthemum hispidum, Tetraena retrofracta, Leipoldtia schultzei, Salsola aphylla, Phyllobolus splendens, Chrysocoma ciliata* and *Ruschia ceresiana*).



In the group four community 90.4% of the total cover is made up by five species (*Malephora lutea, Psilocaulon junceum, Drosanthemum hispidum, Mesembryanthemum crystallinum* and *Salsola aphylla*). In group eight, 90.3% of the total plant cover is made up by seven species, (*Drosanthemum hispidum, Psilocaulon junceum, Phyllobolus splendens, Malephora lutea, Drosanthemum giffenii, Salsola aphylla* and *Mesembryanthemum crystallinum*). In group 13, 90.2% of the total plant cover is made up by just three species, (*Drosanthemum hispidum, Psilocaulon junceum* and *Mesembryanthemum crystallinum*).

The dominant species in group one, *Mesembryanthemum crystallinum* makes up 25.1% of the total cover. The dominant species in group four, *Malephora lutea* makes up 55% of the total cover of this community.

The dominant species in group eight, *Drosanthemum hispidum*, makes up 29.3% of the total cover of this community, and the dominant species in group 13, *Drosanthemum hispidum*, makes up 65.7% of the total cover of this community.

These results indicate that the group one plant community is more heterogeneous in composition than the group four, group eight and group 13 plant communities. The vegetation of the group eight community is also relatively heterogeneous when compared to the highly homogenous composition of the group four and group 13 plant communities. This indicates that the group one plant community probably best represents better condition on termitaria vegetation and the group 13 vegetation best represents vegetation in a degraded condition. The condition of vegetation in the group eight and group four plant communities seems to be best placed between the two extremes.



As described for the off termitaria vegetation community, the least and most degraded vegetation conditions in this study do not necessarily represent the extremes of vegetation condition in the Gannaveld habitat type. Termitaria in Gannaveld areas with very high ostrich stocking densities are mostly denuded of perennial vegetation (Vlok *et al.* 2005).

The cover percentage and the proportion of that cover of the total cover percentage for the on termitaria species per ordination group is shown in Table 6.

Table 6

Canopy cover abundance for species recorded on termitaria per ordination group and arranged in order of dominance. Prop refers to the proportion of the total cover contributed by each species.

| Group 1 | | | Group 4 | | | Group 8 | | | Group 13 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover | Prop | | Cover | Prop | | Cover | Prop | | Cover | Prop |
| *Mesembryanthemum crystallinum* | 10.45 | 25.07 | *Malephora lutea* | 30.37 | 55.04 | *Drosanthemum hispidum* | 14.88 | 29.33 | *Drosanthemum hispidum* | 43.08 | 65.65 |
| *Ruschia spinosa* | 6.81 | 16.34 | *Psilocaulon junceum* | 6.99 | 12.67 | *Psilocaulon junceum* | 13.67 | 26.95 | *Psilocaulon junceum* | 9.14 | 13.93 |
| *Psilocaulon junceum* | 4.85 | 11.64 | *Drosanthemum hispidum* | 5.58 | 10.11 | *Phyllobolus splendens* | 5.68 | 11.20 | *Mesembryanthemum crystallinum* | 6.98 | 10.64 |
| *Ruschia impressa* | 3.96 | 9.50 | *Mesembryanthemum crystallinum* | 3.52 | 6.38 | *Malephora lutea* | 3.91 | 7.71 | *Tetraena retrofracta* | 1.86 | 2.83 |
| *Drosanthemum hispidum* | 2.62 | 6.29 | *Salsola aphylla* | 3.43 | 6.22 | *Drosanthemum giffenii* | 3.33 | 6.56 | *Salsola aphylla* | 0.99 | 1.51 |
| *Tetraena retrofracta* | 2.23 | 5.35 | *Leipoldtia schultzei* | 1.84 | 3.33 | *Salsola aphylla* | 3.07 | 6.05 | *Ruschia impressa* | 0.92 | 1.40 |
| *Leipoldtia schultzei* | 1.94 | 4.65 | *Phyllobolus splendens* | 0.89 | 1.61 | *Mesembryanthemum crystallinum* | 1.28 | 2.52 | *Leipoldtia schultzei* | 0.90 | 1.37 |
| *Salsola aphylla* | 1.62 | 3.89 | *Drosanthemum giffenii* | 0.55 | 1.00 | *Ruschia ceresiana* | 0.87 | 1.71 | *Aptosimum indivisum* | 0.47 | 0.72 |
| *Phyllobolus splendens* | 1.17 | 2.81 | *Aptosimum indivisum* | 0.52 | 0.94 | *Leipoldtia schultzei* | 0.77 | 1.52 | *Phyllobolus splendens* | 0.26 | 0.40 |
| *Chrysocoma ciliata* | 1.13 | 2.71 | *Ruschia impressa* | 0.27 | 0.49 | *Ruschia impressa* | 0.73 | 1.44 | *Lycium cinereum* | 0.22 | 0.34 |
| *Ruschia ceresiana* | 0.76 | 1.82 | *Ruschia ceresiana* | 0.26 | 0.47 | *Aptosimum indivisum* | 0.58 | 1.14 | *Chrysocoma ciliata* | 0.20 | 0.30 |

Table 6 continued

| Group 1 | | | Group 4 | | | Group 8 | | | Group 13 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cover | Prop | | Cover | Prop | | Cover | Prop | | Cover | Prop |
| *Drosanthemum lique* | 0.70 | 1.68 | *Tetraena retrofracta* | 0.25 | 0.45 | *Chrysocoma ciliata* | 0.47 | 0.93 | *Drosanthemum giffenii* | 0.17 | 0.26 |
| *Malephora lutea* | 0.67 | 1.61 | *Ruschia spinosa* | 0.19 | 0.34 | *Tetraena retrofracta* | 0.29 | 0.57 | *Galenia africana* | 0.15 | 0.23 |
| *Drosanthemum giffenii* | 0.56 | 1.34 | *Pteronia pallens* | 0.13 | 0.24 | *Augea capensis* | 0.20 | 0.39 | *Ruschia ceresiana* | 0.07 | 0.11 |
| *Eriocephalus ericoides* | 0.55 | 1.32 | *Pteronia incana* | 0.06 | 0.11 | *Pteronia glauca* | 0.20 | 0.39 | *Pteronia glauca* | 0.04 | 0.06 |
| *Pteronia pallens* | 0.46 | 1.10 | *Tetragonia fruticosa* | 0.06 | 0.11 | *Pteronia incana* | 0.20 | 0.39 | *Pteronia incana* | 0.04 | 0.06 |
| *Galenia africana* | 0.45 | 1.08 | *Chrysocoma ciliata* | 0.05 | 0.09 | *Pteronia pallens* | 0.20 | 0.39 | *Pteronia pallens* | 0.04 | 0.06 |
| *Pteronia glauca* | 0.28 | 0.67 | *Drosanthemum lique* | 0.04 | 0.07 | *Ruschia spinosa* | 0.20 | 0.39 | *Ruschia spinosa* | 0.04 | 0.06 |
| *Pteronia incana* | 0.21 | 0.50 | *Eriocephalus ericoides* | 0.04 | 0.07 | *Senecio juniperinus* | 0.09 | 0.18 | *Tetragonia fruticosa* | 0.03 | 0.05 |
| *Tetragonia fruticosa* | 0.13 | 0.31 | *Euphorbia fimbriata* | 0.04 | 0.07 | *Tetragonia fruticosa* | 0.06 | 0.12 | *Malephora lutea* | 0.02 | 0.03 |
| *Lycium cinereum* | 0.03 | 0.07 | *Augea capensis* | 0.03 | 0.05 | *Galenia africana* | 0.02 | 0.04 | *Crassula muscosa* | 0.00 | 0.00 |
| *Euphorbia fimbriata* | 0.03 | 0.07 | *Senecio juniperinus* | 0.03 | 0.05 | *Drosanthemum lique* | 0.01 | 0.02 | *Drosanthemum lique* | 0.00 | 0.00 |
| *Augea capensis* | 0.03 | 0.07 | *Galenia africana* | 0.02 | 0.04 | *Eriocephalus ericoides* | 0.01 | 0.02 | *Eriocephalus ericoides* | 0.00 | 0.00 |
| *Senecio juniperinus* | 0.02 | 0.05 | *Lycium cinereum* | 0.02 | 0.04 | *Euphorbia fimbriata* | 0.01 | 0.02 | *Euphorbia fimbriata* | 0.00 | 0.00 |
| *Crassula muscosa* | 0.01 | 0.02 | *Crassula muscosa* | 0.00 | 0.00 | *Crassula muscosa* | 0.00 | 0.00 | *Augea capensis* | 0.00 | 0.00 |
| *Aptosimum indivisum* | 0.01 | 0.02 | *Pteronia glauca* | 0.00 | 0.00 | *Lycium cinereum* | 0.00 | 0.00 | *Senecio juniperinus* | 0.00 | 0.00 |

**Plant functional type diversity**

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The relative density of plants of the different plant functional types of this study gives an indication of the evenness of the distribution of plant functional types within each ordination group. The results show that group one is dominated in plant functional type density by the dwarf succulent shrubs that make up 61.1% of the total density of this community. 20.9% of the density of group one is made up by the succulent shrub functional type, while 10.6% is made up of the dwarf succulent plant functional type. Dwarf woody shrubs make up 4.8% of this community and woody shrubs 2.6% of the total plant density.



Group four is dominated by the succulent shrub plant functional type which makes up 81.9% of the total density of this community. The dwarf succulent shrub component makes up 15.7% of this community and the woody shrubs 0.9%. Dwarf succulent density makes up 0.8% of this community dwarf woody shrubs 0.7%. Perennial forb density makes up 0.1% of the total density of plants in this community.

Group eight is dominated by the succulent shrub plant functional type which makes up 74.7% of the total density of this community. Dwarf succulent shrubs contribute 14.8% of the total density, dwarf woody shrubs, 5.3%, dwarf succulents, 3.9%, woody shrubs, 1.2% and perennial forbs 0.1% of the total density of plants in this community.

Group 13 is also dominated by the succulent shrub plant functional type which makes up 73.46% of the total density of plants in this community. The dwarf succulent shrub plant functional type makes up 24.9% of the total density of plants in this community. Dwarf woody shrubs, woody shrubs, and dwarf succulents each contribute less than 1% of the total plant density of this community. Perennial forbs were not recorded in this community.

Figure 4 shows the proportional density of the seven plant functional types to the total density of plants in the four on termitaria ordination groups in Oudtshoorn Gannaveld.

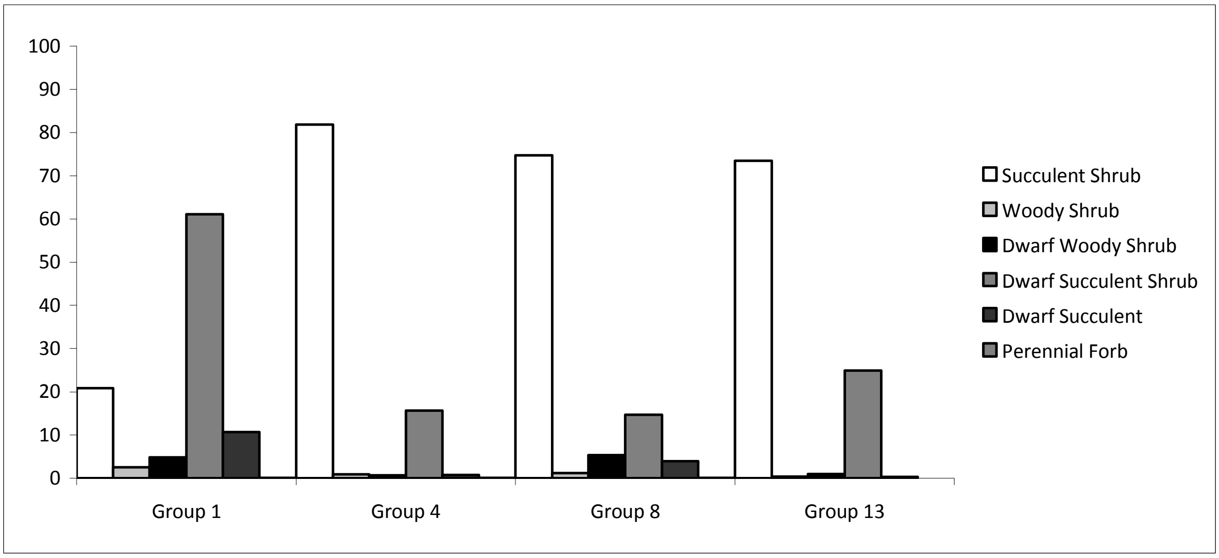


Figure 4

Proportional density in percentage of seven plant functional types in the four off termitaria ordination groups of Oudtshoorn Gannaveld.



These results indicate a more heterogeneous spread of functional type abundance in the plant communities of groups one and eight, with the group one community being the most heterogeneous community in terms of the evenness of plant functional type abundance. Based on the heterogeneity of plant functional type abundance the results indicate that group one is less degraded than the other three communities. The vegetation of group eight is also relatively heterogeneous, although dominated by the succulent shrub plant functional type. Groups four and 13 are thought to represent the more degraded vegetation. However the difference in dominant plant functional type between group one, which is dominated by dwarf succulent shrubs, and groups four, eight and 13, which are dominated by succulent shrubs, complicates the determination of community condition.

The evidence that in Succulent Karoo vegetation types of the Little Karoo, grazing-induced vegetation degradation results in an increase in the cover of creeping succulents and shallow-rooted mat forming plants and that larger woody and succulent shrubs are replaced by smaller dwarf shrub species (Vlok *et al.* 2005, Cupido 2005, Thompson *et al.* 2009) would indicate that the communities dominated by succulent and woody shrubs are in a less degraded condition than the communities dominated by dwarf succulent and dwarf woody shrubs. Groups four, eight and 13 are all dominated by the succulent shrub plant functional type, group four slightly more so, although not significantly different statistically from the other groups. In group one, succulent shrub abundance is significantly lower than in the other groups and is dominated by dwarf succulent shrub abundance. This indicates that group one is more degraded than groups four, eight and 13.



Therefore, although functional type diversity indicates that group one is more diverse, the high abundance of the dwarf succulent and dwarf succulent shrub functional types indicates that group one is in a more degraded condition than those groups with a high abundance of succulent and woody shrubs. Group eight with high functional type diversity and a higher abundance of succulent and woody shrubs than the smaller dwarf functional types represents vegetation in the least degraded condition.

**Bare ground**

The percentage of bare ground is a good indicator of severe vegetation degradation on termitaria where there is faster deterioration than in the off termitaria communities because of the focus of grazing by domestic stock (Armstrong and Siegfried 1990, Esler and Cowling 1995, Vlok *et al.* 2005).

Mean bare ground percentages show that group one has the highest percentage of bare ground followed by groups eight, four and 13. The bare ground percentage of group one was significantly higher than that of group four and 13, but not significantly different to group eight. This result indicates that groups one and eight are more degraded than groups four and 13.

**Prostrate dead plant material**

The highest percentage of dead prostrate plant material was recorded in group eight. This was significantly higher than in group one. The litter percentage of groups eight and 13 did not differ significantly from any group. Based on the mean percentage of prostrate plant litter, the on termitaria vegetation of group eight represents the community in the best condition, while the vegetation of the group one community represents the most degraded condition. Based on the mean values, the group four and 13 communities contain vegetation in a condition between the two extremes.

**Disturbance indicating species**



The species used here to indicate degradation of on termitaria vegetation are *Malephora lutea, Chrysocoma ciliata, Galenia africana, Pteronia pallens, Ruschia spinosa*, *Ruschia impressa,* M*esembryanthemum crystallinum, Augea capensis* and *Senecio juniperinus.* The relative abundance of these species indicates vegetation degradation in the Succulent Karoo habitats of the Little Karoo (Cupido 2005, Vlok *et al.* 2005, Esler *et al.* 2006, Thompson *et al.* 2009). The Gannaveld habitat in particular is also prone to invasion by the non-locally indigenous species *Augea capensis* and degraded termitaria in Gannaveld are known to be dominated by M*esembryanthemum crystallinum* (Vlok *et al.* 2005).

*Malephora lutea* was most abundant in terms of canopy cover in the group four plant community, significantly higher than in groups one, eight and 13. The cover of *Chrysocoma ciliata* was found to be highest in group one, significantly different to groups four and 13, but not significantly different from group eight. *Galenia africana* cover was found to be highest in group one, significantly different to group eight but not significantly different to groups four and 13. The cover of *Pteronia pallens* showed no significant differences between the four on termitaria plant communities.

The cover of *Senecio juniperinus* was highest in group eight, significantly different to group 13, but not significantly different to groups four and one. M*esembryanthemum crystallinum* and *Augea capensis* did not differ significantly in cover between the four communities. The abundance of *Ruschia spinosa* was found to be significantly higher in group one than in groups four, eight and 13. The mat forming species *Ruschia impressa* was highest in group one significantly higher than the groups four and 13.

These results show that the group one community contains a higher abundance of degradation indicating species than the other groups. This indicates that the group one community is the most degraded community.

**Vegetation condition index**

A vegetation condition index (Esler *et al.* 2006) was calculated for each on termitaria ordination group using the abundance value of each species recorded in the group multiplied by the grazing index value (Du Toit *et al.* 1995) for each species. The results show that the lowest vegetation condition index was recorded for the group one plant community, followed by the group four community, the group eight community, and the group 13 community with the highest vegetation condition index.

The mean cover abundance percentages per species, species grazing index values (Du Toit *et al.* 1995) and vegetation condition scores (Esler *et al.* 2006) for each of the four on termitaria ordination groups are shown in Table 7.

Table 7

Grazing index values (GIV) (Du Toit *et al.* 1995), canopy cover percentage and vegetation condition index (VCI) (Esler *et al.* 2006), score for species recorded in four NMS ordination groups in the on termitaria plant community of Oudtshoorn Gannaveld. The total vegetation condition index score per group is given at the bottom of the Table.

| | | Group 1 | | Group 4 | | Group 8 | | Group 13 | |
|---|---|---|---|---|---|---|---|---|---|
| | GIV | Cover | VCI | Cover | VCI | Cover | VCI | Cover | VCI |
| Aptosimum indivisum | 2.3 | 0.01 | 0.02 | 0.52 | 1.2 | 0.58 | 1.33 | 0.47 | 1.08 |
| Augea capensis | 2.1 | 0.03 | 0.06 | 0.03 | 0.06 | 0.2 | 0.42 | 0 | 0 |
| Chrysocoma ciliata | 1.5 | 1.13 | 1.7 | 0.05 | 0.08 | 0.47 | 0.71 | 0.2 | 0.3 |
| Crassula muscosa | 1 | 0.01 | 0.01 | 0 | 0 | 0 | 0 | 0 | 0 |
| Drosanthemum giffenii | 4 | 0.56 | 2.24 | 0.55 | 2.2 | 3.33 | 13.32 | 0.17 | 0.68 |
| Drosanthemum hispidum | 5.4 | 2.62 | 14.15 | 5.58 | 30.13 | 14.88 | 80.35 | 43.08 | 232.63 |
| Drosanthemum lique | 6.3 | 0.7 | 4.41 | 0.04 | 0.25 | 0.01 | 0.06 | 0 | 0 |
| Eriocephalus ericoides | 5 | 0.55 | 2.75 | 0.04 | 0.2 | 0.01 | 0.05 | 0 | 0 |
| Euphorbia fimbriata | 2 | 0.03 | 0.06 | 0.04 | 0.08 | 0.01 | 0.02 | 0 | 0 |
| Galenia africana | 2 | 0.45 | 0.9 | 0.02 | 0.04 | 0.02 | 0.04 | 0.15 | 0.3 |
| Leipoldtia schultzei | 1 | 1.94 | 1.94 | 1.84 | 1.84 | 0.77 | 0.77 | 0.9 | 0.9 |
| Lycium cinereum | 3 | 0.03 | 0.09 | 0.02 | 0.06 | 0 | 0 | 0.22 | 0.66 |
| Malephora lutea | 3.5 | 0.67 | 2.35 | 30.37 | 106.3 | 3.91 | 13.69 | 0.02 | 0.07 |
| Mesembryanthemum crystallinum | 1.8 | 10.45 | 18.81 | 3.52 | 6.34 | 1.28 | 2.3 | 6.98 | 12.56 |
| Phyllobolus splendens | 5.7 | 1.17 | 6.67 | 0.89 | 5.07 | 5.68 | 32.38 | 0.26 | 1.48 |
| Psilocaulon junceum | 4.5 | 4.85 | 21.83 | 6.99 | 31.46 | 13.67 | 61.52 | 9.14 | 41.13 |
| Pteronia glauca | 3.4 | 0.28 | 0.95 | 0 | 0 | 0.2 | 0.68 | 0.04 | 0.14 |
| Pteronia incana | 2.7 | 0.21 | 0.57 | 0.06 | 0.16 | 0.2 | 0.54 | 0.04 | 0.11 |
| Pteronia pallens | 1.4 | 0.46 | 0.64 | 0.13 | 0.18 | 0.2 | 0.28 | 0.04 | 0.06 |
| Ruschia ceresiana | 2 | 0.76 | 1.52 | 0.26 | 0.52 | 0.87 | 1.74 | 0.07 | 0.14 |

Table continued

| | | Group 1 | | Group 4 | | Group 8 | | Group 13 | |
|---|---|---|---|---|---|---|---|---|---|
| | GIV | Cover | VCI | Cover | VCI | Cover | VCI | Cover | VCI |
| Ruschia impressa | 2 | 3.96 | 7.92 | 0.27 | 0.54 | 0.73 | 1.46 | 0.92 | 1.84 |
| Ruschia spinosa | 2.7 | 6.81 | 18.39 | 0.19 | 0.51 | 0.2 | 0.54 | 0.04 | 0.11 |
| Salsola aphylla | 5.5 | 1.62 | 8.91 | 3.43 | 18.87 | 3.07 | 16.89 | 0.99 | 5.45 |
| Senecio juniperinus | 1.6 | 0.02 | 0.03 | 0.03 | 0.05 | 0.09 | 0.14 | 0 | 0 |
| Tetraena retrofracta | 3.7 | 2.23 | 8.25 | 0.25 | 0.93 | 0.29 | 1.07 | 1.86 | 6.88 |
| Tetragonia fruticosa | 7.7 | 0.13 | 1 | 0.06 | 0.46 | 0.06 | 0.46 | 0.03 | 0.23 |
| Total vegetation condition index | | | 126.17 | | 207.53 | | 230.76 | | 306.75 |

**Palatability indices**

The loss of palatable species due to grazing is pronounced on termitaria because of the nitrogen rich plants that are preferred by grazing animals (Armstrong and Siegfried 1990, Esler *et al.* 2006). Therefore the abundance of palatable and unpalatable plant species in the four groups of the on termitaria plant community serves as a good indicator of the level of degradation. The subjective palatability indices or star scores for Karoo plant species (Esler *et al.* 2006) have been discussed in the section regarding the off termitaria community, but are mentioned again here for context. Species with palatability star scores of five are considered to be highly palatable and productive. Star score four species are considered to be palatable and productive, while star score three plants are less palatable or unproductive. Unpalatable plant species are assigned a star score of two and highly unpalatable species are assigned a star score of one.



The most palatable species recorded on termitaria, *Salsola aphylla*, with a palatability star score of five was most abundant in group four, but this was only significantly different to group 13. The abundance of *Tetragonia fruticosa* did not differ significantly between the on termitaria communities. These results for the on termitaria plant community give very little insight into the condition of the four communities in terms of the abundance of palatable and unpalatable species. The fact that only two species recorded on termitaria are considered to be palatable, *Salsola aphylla* (five star) and *Tetragonia fruticosa* (four star), indicates that all of the on termitaria sites are in fact degraded to some extent.

The mean (±SD) cover abundance values for species with subjective palatability indices (star scores) (Esler *et al.* 2006) recorded in each on termitaria ordination group and the results of Kruskal Wallis ANOVA and Dunn multiple comparison tests are shown in Table 8.

Table 8

Mean (±SD) cover percentages and palatability star scores (Esler *et al.* 2006) that are available for species recorded in the four NMS ordination groups of the on termitaria plant community of Oudtshoorn Gannaveld. Dissimilar superscripts indicate significant differences based on a Kruskal-Wallis One-Way ANOVA and Dunn's multiple comparisons test. ** indicates significance level p < 0.01. *** indicates significance level p < 0.001.

| | Star score | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|---|
| *Salsola aphylla** | 5 | 1.62 ± 3.18ab | 3.43 ± 2.79b | 3.07 ± 5.43ab | 0.99 ± 2.15a |
| *Tetragonia fruticosa* | 4 | 0.13 ± 0.49 | 0.06 ± 0.14 | 0.06 ± 0.15 | 0.03 ± 0.1 |
| *Crassula muscosa** | 3 | 0.01 ± 0.03b | 0 ± 0.01ab | 0 ± 0a | 0 ± 0.01ab |
| *Eriocephalus ericoides* | 3 | 0.55 ± 1.51 | 0.04 ± 0.14 | 0.01 ± 0.02 | 0 ± 0.01 |
| *Chrysocoma ciliata*** | 2 | 1.13 ± 2.62b | 0.05 ± 0.08a | 0.47 ± 0.83ab | 0.2 ± 0.6a |
| *Drosanthemum hispidum**** | 2 | 2.62 ± 4.24a | 5.58 ± 5.43ab | 14.88 ± 10.11b | 43.08 ± 12.93c |
| *Lycium cinereum** | 2 | 0.03 ± 0.13ab | 0.02 ± 0.06ab | 0 ± 0a | 0.22 ± 0.47b |
| *Malephora lutea**** | 2 | 0.67 ± 2.25a | 30.37 ± 13.67b | 3.91 ± 8.32a | 0.02 ± 0.04a |
| *Mesembryanthemum crystallinum* | 2 | 10.45 ± 19.13 | 3.52 ± 5.9 | 1.28 ± 4.13 | 6.98 ± 9.03 |
| *Phyllobolus splendens**** | 2 | 1.17 ± 2.34a | 0.89 ± 1.69a | 5.68 ± 5.31b | 0.26 ± 0.98a |
| *Pteronia glauca* | 2 | 0.28 ± 1.6 | 0 ± 0 | 0.2 ± 0.82 | 0.04 ± 0.14 |
| *Ruschia spinosa**** | 2 | 6.81 ± 8.36c | 0.27 ± 1.04a | 0.73 ± 1.46ab | 0.92 ± 1.5bc |

Table 8 continued

| | Star score | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|---|
| *Tetraena retrofracta*** | 2 | 2.23 ± 3.89ab | 0.25 ± 0.7a | 0.29 ± 1.26a | 1.86 ± 2.33b |
| *Galenia africana** | 1 | 0.45 ± 1.1b | 0.02 ± 0.08ab | 0.02 ± 0.13a | 0.15 ± 0.51ab |
| *Psilocaulon junceum**** | 1 | 4.85 ± 6.55a | 6.99 ± 4.43ab | 13.67 ± 10.71b | 9.14 ± 7.08b |
| *Pteronia pallens* | 1 | 0.46 ± 2.39 | 0.13 ± 0 | 0.2 ± 0.82 | 0.04 ± 0.15 |

**Other indicator species**

A number of species recorded on termitaria were of very low abundance and made statistical analysis unreliable. The most palatable species *Ehrharta calycina* (five star palatability grass) was only recorded in group one. *Felicia filifolia* (three star palatability), was recorded in groups four and eight. *Pentzia incana* (three star palatability), was recorded in all four groups. These results add little to the determination of the degradation level of the four on termitaria groups.

A list of the species not suitable for analysis recorded in the sample plots of each ordination group is shown in Table 9.

Table 9

Species with low abundance not suitable for analysis of variance recorded in the sample plots grouped by NMS ordination of the on termitaria plant community of the Oudtshoorn Gannaveld vegetation type. Presence is indicated by a 1 and absence is indicated by a 0.

| | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|
| *Asparagus recurvispinus* | 1 | 0 | 1 | 0 |
| *Cotyledon orbiculata* | 1 | 0 | 0 | 0 |
| *Crassula capitella* | 1 | 1 | 1 | 0 |
| *Crassula subaphylla* | 1 | 0 | 1 | 1 |
| *Crassula tetragona* | 0 | 0 | 1 | 0 |
| *Ehrharta calycina* | 1 | 0 | 0 | 0 |
| *Eriocephalus brevifolius* | 0 | 0 | 1 | 0 |
| *Felicia filifolia* | 0 | 1 | 1 | 0 |
| *Hebenstretia sp.* | 1 | 0 | 0 | 0 |
| *Helichrysum dregei* | 1 | 0 | 0 | 0 |
| *Helichrysum rosum* | 1 | 0 | 0 | 0 |
| *Hypertelis salsoloides* | 0 | 0 | 1 | 0 |
| *Justicia cuneata* | 0 | 0 | 1 | 0 |
| *Lycium oxycarpum* | 1 | 0 | 0 | 0 |
| *Manochlamys albicans* | 0 | 0 | 1 | 1 |
| *Othonna sp.* | 0 | 0 | 0 | 1 |
| *Pentzia dentata* | 1 | 0 | 0 | 0 |
| *Pentzia incana* | 1 | 1 | 1 | 1 |
| *Rosenia humilis* | 1 | 0 | 0 | 0 |
| *Ruschia crassa* | 0 | 0 | 0 | 1 |
| *Selago albida* | 1 | 0 | 0 | 0 |
| *Selago glutinosa* | 0 | 1 | 1 | 0 |

Table 9 continued

| | Group 1 | Group 4 | Group 8 | Group 13 |
|---|---|---|---|---|
| *Senecio sp.* | 1 | 0 | 0 | 0 |
| *Tridentea gemmiflora* | 1 | 0 | 0 | 0 |

**Vegetation condition of on termitaria ordination groups**

The combination of the various indicators of on termitaria vegetation condition described shows that the four on termitaria communities are at different levels of degradation. This is mainly apparent in the way these communities differ in composition, heterogeneity and the dominance of plant function types. What emerges is that the communities of group one and group 13 tend to be in a more degraded condition than those of group four and group eight. What distinguishes the group one community from the group 13 community is the high percentage of bare ground on the termitaria of group one. A high percentage of bare ground on termitaria is a good indicator of overgrazing, especially where this is as a result of the loss of perennial species (Vlok *et al.* 2005, Esler *et al.* 2006).



Even though group one has a more even spread of functional type abundance than that of the other groups, the individual species making up this spread indicate degradation, and are more abundant in group one than in the other groups. The group one community is also significantly less abundant in the larger succulent shrub plant functional type, which has probably been reduced due to intensive overstocking (Milton and Dean 1996, Todd and Hoffman 1999, Anderson and Hoffman 2007). There is also very little plant litter in this community which may indicate increased degradation (Milton *et al.* 1994a, Esler *et al.* 2006).

The significantly higher abundance of mat forming and other disturbance indicating species that occur in group one, suggests that this group is the most degraded of the four groups. Group 13 with a high mono-dominance of *Drosanthemum hispidum*, indicates that this community is less degraded than group one but more degraded than the more heterogeneous groups four and eight.

Because of the heterogeneity and composition of communities four and eight these two communities are considered to be in the least degraded condition. The most important difference between them in terms of degradation is the dominance of *Malephora lutea* in group four. This indicates that group four is a more disturbed community than group eight (Cupido 2005, Vlok *et al.* 2005).



The most obvious conclusion from the results is that the vegetation of group one represents on termitaria vegetation in the most degraded condition in this study area. The vegetation of group eight represents the vegetation in the least degraded condition in this vegetation type. Group 13 and group four lie between the most and least degraded communities, with group 13 being more degraded than group four. For the purposes of this study group eight is termed least degraded, group four is termed moderately degraded, group 13 is termed degraded and group one is termed severely degraded.

Group eight – least degraded.

Group four – moderately degraded.

Group 13 – degraded.

Group one – severely degraded.

**Study results versus perceived condition of areas – on termitaria vegetation condition**

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The perceived condition of the areas is based purely on a subjective observation of the study area and is used to show similarities between the subjective observations and the quantified survey. The spatial positioning of the plots in each of the four ordination groups corresponds fairly well with the perceived condition of the vegetation in different areas of the study site prior to this study. However this is less distinct on termitaria than for the off termitaria plots. This is to be expected considering termitaria are generally more disturbed than off termitaria sites and degrade more quickly (Armstrong and Siegfried 1990, Vlok *et al.* 2005).

The terms used for the perceived condition of each area were near pristine, good, moderate and severely degraded. The term 'good' was used to describe a perceived condition between near pristine and moderately degraded as described in Milton *et al.* (1998) and Esler *et al.* (1996).



The results show (Table 10) that 30% of the group eight plots, which are considered to be the least degraded plots, lie within area one. Area one was perceived before the study to be in a near pristine condition. 30% of the least degraded plots also lie within area two, perceived to be in a good condition. Plots of the group eight community therefore fall mostly in the areas perceived to be in relatively good condition. Of the group four plots, considered to be moderately degraded and slightly more degraded than group eight plots, 81% fall within area two, which was perceived to be in a good condition. This reinforces the results that show group four represents a moderately degraded community.

Of the group 13 plots, which are considered to be in a degraded condition, 67% fall within area three, which was perceived to be in a moderately degraded condition. This corresponds well with the perceived condition, as area three was perceived to be in a slightly more degraded condition than area two. Of the group one plots considered to be the most degraded plots, 45% fall within area four, which was perceived before the study to be in a moderately degraded condition.

Of interest is that areas three and four of the study area were perceived to be in a similar moderately degraded condition. The results however show a high percentage of group 13 sample plots, that represent degraded vegetation, in area three, and a high percentage of group one plots, representing severely degraded vegetation, in area four. This is a similar pattern as in the off termitaria plant community, and is explained by the road that intersected these two areas in the past. The two areas are of different vegetation condition and have probably been subjected to different animal stocking regimes in the past, resulting in a higher level of degradation in area four than in area three.



It is also interesting that most on termitaria plots (57%) are in the degraded and severely degraded categories of this study. This is supported by other literature that shows on termitaria vegetation is targeted first by livestock and is more heavily grazed (Armstrong and Siegfried 1990, Milton *et al.* 1992) and in Gannaveld tends to be degraded more quickly than the surrounding off termitaria vegetation (Vlok *et al.* 2005). These results also show that the on termitaria vegetation is more susceptible to grazing than the off termitaria vegetation as can be seen by the relatively high number of degraded plots found in areas of least degraded off termitaria vegetation.

Figure 5 shows the areas of perceived vegetation condition in the study area prior to data collection and analysis, and Figure 6 shows the actual condition of these areas based on the results of this study. Table 10 shows the percentage of NMS ordination group sample plots located in areas of perceived vegetation condition in the on termitaria plant community of Oudtshoorn Gannaveld.

Table 10

Percentage of NMS ordination group sample plots located in areas of perceived vegetation condition in the on termitaria plant community of Oudtshoorn Gannaveld. Highest values per area are in bold.

| on | Group 8 (Least degraded) | Group 4 (Moderately degraded) | Group 13 (Degraded) | Group 1 (Severely degraded) |
|---|---|---|---|---|
| Area 1 (Perceived near pristine) | **30** | 0 | 10 | 23 |
| Area 2 (Perceived ) | **30** | **81** | 5 | 15 |
| Area 3 (Perceived moderate) | 13 | 0 | **67** | 10 |
| Area 4 (Perceived moderate) | 7 | 0 | 14 | **45** |
| Area 5 (Perceived severe) | 20 | 19 | 5 | 8 |
| Total | 100 | 100 | 100 | 100 |

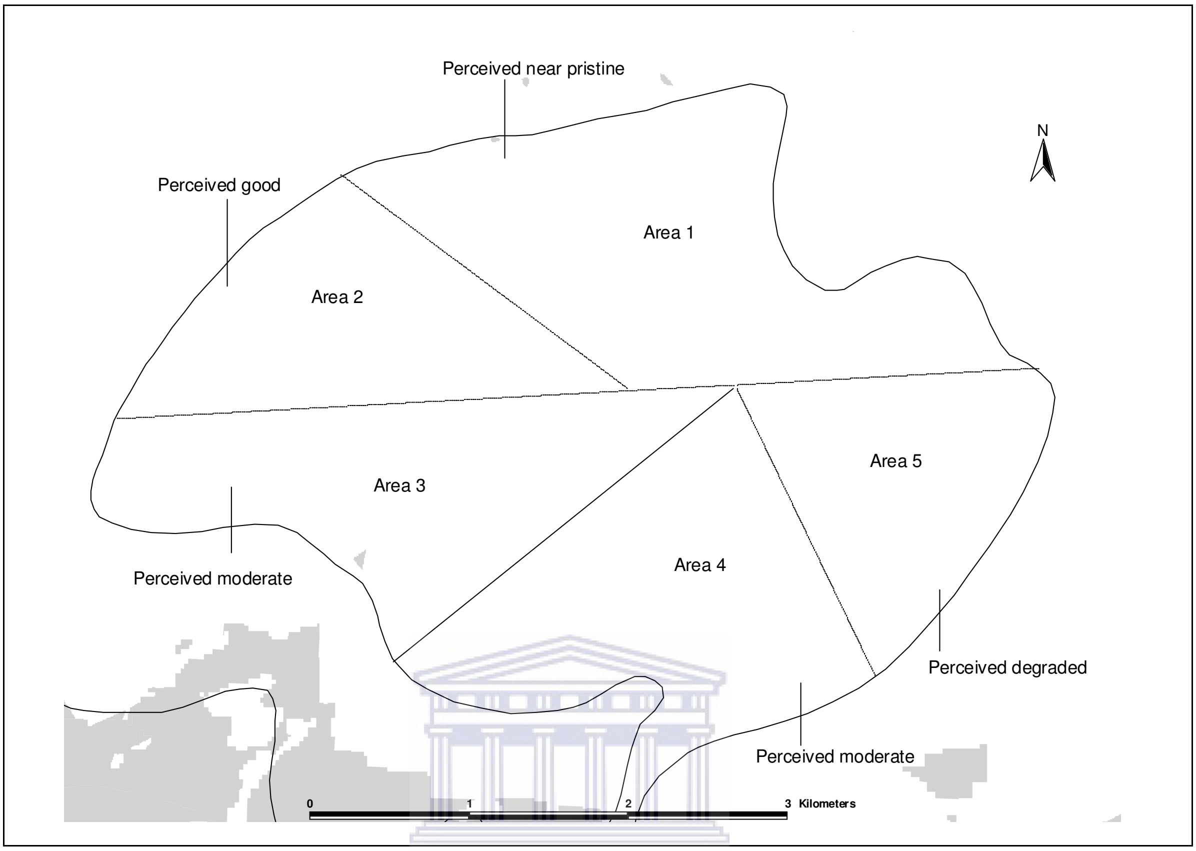




Figure 5

Perceived vegetation condition in areas of the study site prior to the study. The black boundary line indicates Oudtshoorn Gannaveld. Dotted lines represent fencelines. The solid line between area three and four represents the old road from Oudtshoorn to Volmoed. The grey areas indicate transformed vegetation (Thompson *et al.* 2005).

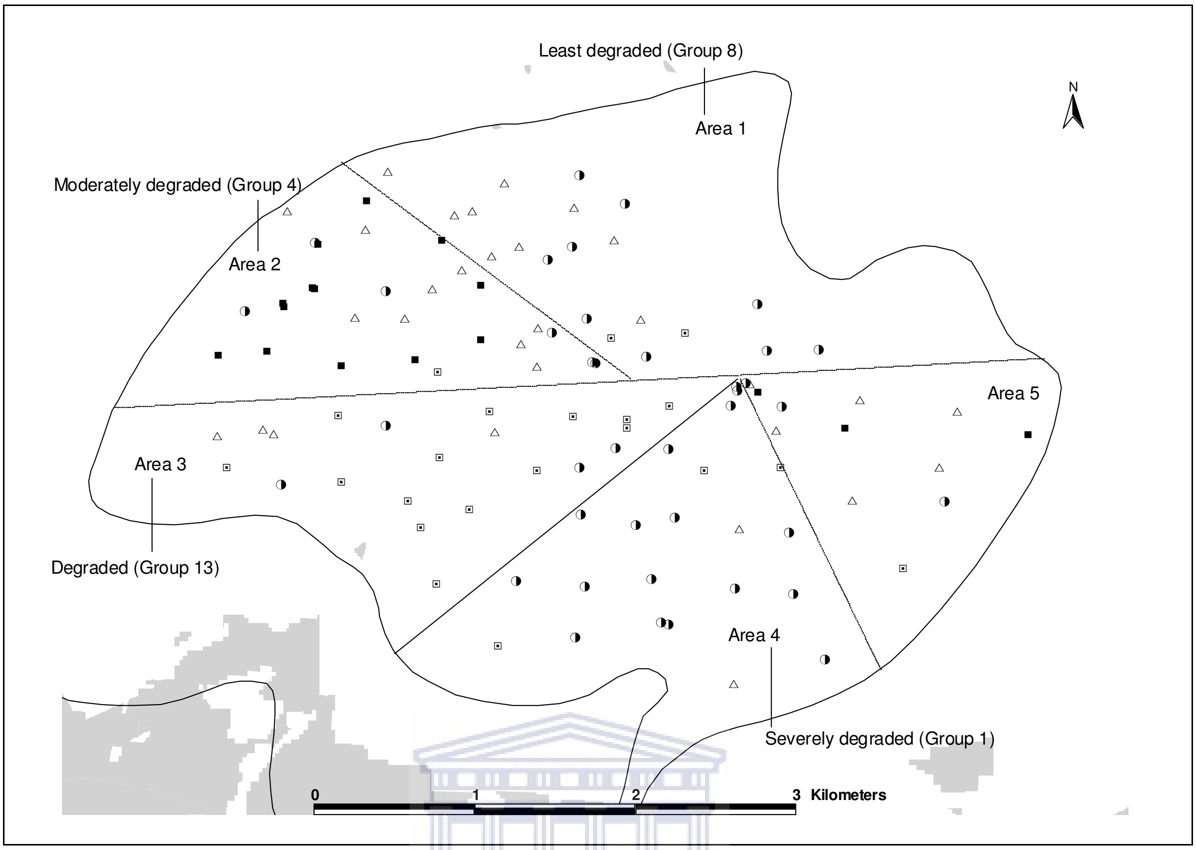


Figure 6



On termitaria sample plots indicated by symbols representing the vegetation condition. Square with centre dot symbols indicate group 13 plots (degraded). Half filled circle symbols indicate group 1 (severely degraded) plots. Filled square symbols indicate group 4 (moderately degraded) plots. Empty triangles indicate group 8 (least degraded) plots. The black boundary indicates Oudtshoorn Gannaveld. The solid line between area three and four represents the old road from Oudtshoorn to Volmoed. The grey areas indicate transformed vegetation (Thompson *et al.* 2005).

# Chapter 6

# Community characteristics

## Introduction

The study area for this study is categorised as severely degraded based on multi-seasonal and multi-resolution satellite imagery (Thompson *et al.* 2009) and expertly mapped vegetation units at the 1:50 000 scale (Vlok *et al.* 2005), using the Normalized Difference Vegetation Index (NDVI) and field evaluations to assess the condition of the Gannaveld habitat. However within this severely degraded area, this study shows that finer levels of degradation are discernable and that the plant communities representing these degradation levels can be distinguished by differences in perennial plant composition. The differences in composition between these communities give an indication of the shifts that take place as this vegetation type degrades and provides insight into how this critically endangered vegetation type responds to stocking pressure, particularly ostrich stocking.
The results show that while some communities may be in a relatively intact condition, others have been severely degraded.

In this chapter I describe the characteristics of the different vegetation communities identified on termitaria and off termitaria in Oudtshoorn Gannaveld and the processes of degradation in each.

The research questions for this chapter are:

- What are the characteristics of plant communities on and off termitaria that indicate Oudtshoorn Gannaveld in a least degraded condition?
- What are the characteristics of plant communities on and off termitaria that indicate Oudtshoorn Gannaveld in a degraded condition?
- What compositional shifts take place between the least degraded and degraded conditions of on and off termitaria vegetation in Oudtshoorn Gannaveld?

**Off termitaria communities**

**Group one plant community – least degraded condition**

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The least degraded Oudtshoorn Gannaveld maintains heterogeneity in the relative abundance of perennial species and plant functional types and is not significantly dominated by single species or functional type. The mean species richness in this community is higher than in the more degraded communities. The density of plants in this community is significantly lower than in the degraded and severely degraded communities. The dominant species in this community is *Ruschia ceresiana*.



The total perennial plant cover in this community does not differ significantly from the cover of the three more degraded communities. This is an important finding as it indicates that perennial plant cover is resilient to certain intensities of grazing pressure in this vegetation type. The unchanged cover percentage can be explained by the compositional changes that take place as this vegetation type degrades where the reduction in cover of larger succulent and woody shrubs results in an increase of dwarf succulents, dwarf succulent shrubs and dwarf woody shrubs. These prostrate plants are known to colonize open space opportunistically in the Succulent Karoo (Esler and Cowling 1995). In the Succulent Karoo habitats of the Little Karoo many severely degraded sites have a high cover percentage of longer-lived weedy species (Vlok *et al.* 2005, Thompson *et al.* 2009). Relative to the more degraded communities there is a higher abundance of palatable species in the least degraded community and disturbance indicating species are generally low in abundance.

Woody shrubs are relatively high in abundance in this community with species such as *Pteronia incana*, *Helichrysum zeyheri*, *Felicia filifolia* and *Eriocephalus brevifolius* being more abundant in the least degraded community than in the more degraded vegetation communities. Dwarf succulent shrubs are not high in abundance in this community especially species such as *Leipoldtia schultzei* and *Ruschia spinosa*. Dwarf succulents, perennial forbs and perennial grasses are not abundant throughout the off termitaria community of Oudtshoorn Gannaveld. The vegetation condition index (Du Toit *et al.* 1995) is highest in this community.

The mean soil pH for plots in this community is significantly lower than the pH of soils of the severely degraded community. The Na and Ca content are higher in this community than in the more degraded communities and Mg is lower.

Figure 1 shows an example of an off termitaria area in the least degraded condition.



Figure 1

Example of off termitaria Oudtshoorn Gannaveld vegetation in the least degraded condition. There is a variety of succulent and woody shrubs and very few mat forming dwarf succulents and dwarf succulent shrubs.

**Off termitaria communities**

**Group six plant community - moderately degraded condition**

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Oudtshoorn Gannaveld in a moderately degraded condition maintains a similar heterogeneity of perennial species and plant functional types to the least degraded community but tends to be more dominated by the succulent shrub species *Ruschia ceresana*. The mean species richness of this community is slightly lower but does not differ significantly from that of vegetation in the least degraded condition. The density of plants in this community is similar to that of the least degraded community but is significantly lower than the more degraded communities.



Cover in moderately degraded Oudtshoorn Gannaveld is dominated by succulent shrubs, with the dominant species being *Ruschia ceresiana.* The woody shrub cover in the moderately degraded community is similar to that of the least degraded community and is higher than in the severely degraded community. However there is a significant decrease in the abundance of a number of woody shrub species in this community. Although not statistically significant, the mean cover of succulent shrubs is slightly higher and the mean cover of woody shrubs is slightly lower in moderately degraded vegetation. The abundance of dwarf succulents, dwarf succulent shrubs, dwarf woody shrubs and succulent shrubs, does not differ significantly from the least degraded community. The abundance of dwarf succulent shrubs in the moderately degraded community is similar to that of the least degraded community, but is lower than in the degraded and severely degraded communities.

The least degraded and moderately degraded communities are similar in many respects. However the higher dominance of *Ruschia ceresiana* in the moderately degraded community, the reduction in the abundance of several woody shrub and palatable species and the increase in abundance of disturbance indicating species separates the moderately degraded community from the least degraded community.

Mean pH does not differ between the moderately degraded and the least degraded community soils, although pH of the moderately degraded community is lower than that of the severely degraded community soil. Ca and Na are significantly lower in this community than in the least degraded community.

Figure 2 shows an example of an off termitaria area in the moderately degraded condition.



Figure 2

An example of off termitaria Oudtshoorn Gannaveld in a moderately degraded condition. The vegetation is dominated by the succulent shrub *Ruschia ceresiana* and relatively few other succulent and woody shrub species are present.

**Off termitaria communities**

**Group three plant community – degraded condition**

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In this community there is a significant decrease in the abundance of succulent shrubs and this can be attributed to the significant decrease of the abundance of *Ruschia ceresiana*. Associated with this decrease in succulent shrub abundance is a significant increase in the density of plants in the degraded community. The increase in density is primarily as a result of the significant increase in the abundance of the dwarf succulent shrub *Leipoldtia schultzei*. Although dwarf succulent shrub abundance becomes dominant in degraded Oudtshoorn Gannaveld as a result of the increase in the abundance of *Leipoldtia schultzei*, there is still a relatively high abundance of woody shrubs. This abundance of woody shrubs remains similar to that of the moderately degraded community. Woody shrubs abundance, as a result of the abundance of *Eriocephalus ericoides* is significantly higher in degraded Oudtshoorn Gannaveld than in severely degraded Oudtshoorn Gannaveld.

The composition of the degraded Oudtshoorn Gannaveld community becomes more homogenous than the moderately degraded community, with approximately 90% of cover made up by four species, *Leipoldtia schultzei, Eriocephalus ericoides, Ruschia ceresiana* and *Ruschia spinosa.* A single species, *Leipoldtia schultzei,* makes up 60% of the cover in this community. Species richness in the degraded community is lower than in the least degraded community. Ca is lower and Mg is higher in degraded community than in the least degraded community.

Figure 3 shows an example of an off termitaria area in the degraded condition.



Figure 3

Example of off termitaria Oudtshoorn Gannaveld in a degraded condition. The community is dominated by dwarf succulents shrubs *Leipoldtia schultzei* and *Ruschia spinosa* and there are few succulent shrubs. However there are still woody shrubs present mostly *Eriocephalus ericoides*.

**Off termitaria communities**

**Group five - severely degraded condition**

The perennial plant composition of severely degraded Oudtshoorn Gannaveld is highly homogenous with almost 80% of the total plant cover made up by one species, *Leipoldtia schultzei.* Species richness is lower than in the least degraded community. Severely degraded Oudtshoorn Gannaveld is significantly higher in dwarf succulent shrub abundance and significantly less abundant in succulent shrub abundance than the least degraded community. In the severely degraded community woody shrub abundance is significantly reduced compared to the less degraded communities.

The abundance of dwarf woody shrubs and woody shrubs decrease significantly in the severely degraded community. The decrease in dwarf woody shrub abundance is as a result of the decrease of *Chrysocoma ciliata*, a species that indicates degradation. This may well be as a result of a higher trampling intensity by ostriches in severely degraded vegetation. The significant decrease in woody shrub abundance is mainly as a result of a significant decrease in the abundance of *Eriocephalus ericoides.* As in the degraded community, there is a low abundance of succulent shrubs in severely degraded Oudtshoorn Gannaveld and this is lower than in the least degraded and moderately degraded communities.

There is an increase in the abundance of the dwarf woody shrub *Senecio juniperinus* in the severely degraded community, a species that indicates degradation in the Gannaveld habitat. The abundance of palatable species is low in the severely degraded community and disturbance indicating species become more abundant than in the less degraded communities.

Soils of the severely degraded plant community have a higher soil pH than in the least degraded or moderately degraded communities. Soils of the severely degraded community have the lowest Ca content and the highest Mg content of all off termitaria communities. Figure 4 shows an example of an off termitaria area in the severely degraded condition.



Figure 4

Example of off termitaria Oudtshoorn Gannaveld in a severely degraded condition. The community is highly dominated by the dwarf succulent shrub *Leipoldtia schultzei* and there are few other species. The woody shrub component has been reduced.

**Degradation processes off termitaria**

It can be seen from the differences in the vegetation characteristics of the four off termitaria plant communities that certain distinct changes occur from the least degraded community to the severely degraded community of Oudtshoorn Gannaveld. The most obvious shift is the change in plant functional type abundance and the associated change in community structure. This shift is seen in the change from a heterogeneous, relatively species rich least degraded community, dominated by succulent shrubs and a variety of woody shrubs, to a severely degraded community with fewer species and dominated by a high density and cover of dwarf succulent shrubs.

These changes are similar to what has been reported in other semi-arid regions of the world (Hadar *et al.* 1999, Fensham *et al.* 1999) and in the Succulent Karoo of South Africa (Stokes 1994, Todd and Hoffman 1999, Riginos and Hoffman 2003, Anderson and Hoffman 2007). However, in the off termitaria plant community of Oudtshoorn Gannaveld, increasing stock pressure has not yet reduced perennial plant cover, a response to intensive and prolonged herbivory that has been reported from other Succulent Karoo areas (Milton *et al.* 1994a, Todd and Hoffman 1999, Anderson and Hoffman 2007) and the Little Karoo (Vlok *et al.* 2005, Esler *et al.* 2006, Thompson *et al.* 2009). This indicates that the perennial plant composition of the severely degraded off termitaria community is highly resilient to the impacts of grazing and trampling.

This is supported by the changes in species composition that occur from the least degraded to the severely degraded communities. In Oudtshoorn Gannaveld the reduction of succulent and woody shrub cover is replaced by the cover of dwarf succulent shrubs, mainly *Leipoldtia schultzei*. This mat forming species is dominant in degraded vegetation off termitaria making up 80% of the cover in the severely degraded community. Mat forming succulents species such as *Leipoldtia schultzei* tend to colonize open space in the Succulent Karoo (Milton and Hoffman 1994) and dominate heavily overgrazed vegetation. They also tend to be resilient to grazing and trampling (Milchunas and Lauenroth 1993).
In Gannaveld high intensity stocking with ostriches results in the loss of trampling resistant species resulting in the almost total loss of cover (Cupido 2005, Vlok *et al.* 2005, Esler *et al.* 2006) Figure 5 shows a photograph of Gannaveld that has been subjected to intensive ostrich stocking.



The significant reduction in the abundance of the succulent shrub functional type as Oudtshoorn Gannaveld degrades is a response that has also been observed in other parts of the Succulent Karoo (Todd and Hoffman 1999, Anderson and Hoffman 2007). In Oudtshoorn Gannaveld most of the succulent shrub species follow this pattern, with some responding more rapidly to higher stock pressure than others. The palatable species *Drosanthemum lique* for example, decreases significantly from least degraded to moderately degraded vegetation, indicating sensitivity to increased stock pressure.



Figure 5

An area of Oudtshoorn Gannaveld that has been intensively stocked with ostriches. Vegetation cover has been almost entirely removed.

Some succulent shrub species are able to tolerate a higher stock pressure than occurs in the least degraded community and remain stable or even increase slightly as stock pressure increases. However these species cannot tolerate the higher stock pressure in the degraded and severely degraded communities and are significantly reduced. These are species such as *Crassula tetragona*, *Lampranthus haworthii*, *Phyllobolus splendens* and *Ruschia ceresiana*.

There is a relatively stable abundance of woody shrubs in the least degraded, moderately degraded and degraded communities of Oudtshoorn Gannaveld indicating a relative resilience to increasing stocking pressure. However there is a significant decrease in woody shrubs under the higher stock pressure of the severely degraded community indicating the low tolerance of these species to the increase in stock pressure.



The significant reduction of *Eriocephalus ericoides* in severely degraded vegetation explains the decrease in the abundance of the woody shrub functional type in the severely degraded community. As this species shows remarkable resilience to increased grazing pressure its reduction in severely degraded vegetation may be as a result of increased trampling. It may also be that increased stock pressure in the severely degraded community has resulted in the removal of emerging *Eriocephalus ericoides* seedlings by ostriches (Milton *et al.* 1994b) resulting in a change in population demographics. When the older *Eriocephalus ericoides* die there is limited new recruitment resulting in the population decline.

Other woody shrub species such as *Eriocephalus brevifolius*, *Felicia filifolia* and *Pteronia incana* seem to decline more rapidly as stock pressure increases and become less abundant in the degraded community. All of these species are significantly less abundant in severely degraded vegetation. This indicates a steadier decline than for some of the other woody shrub species. For example, *Helichrysum zeyheri* seems to be highly sensitive to increased stock pressure and is reduced significantly in moderately degraded vegetation.

Apart from the species already mentioned, the results of this study show that there are several other species that show a response to increasing stock pressure in the different communities. Some of these species decline rapidly under increased stock pressure and the loss of these species can be used as good indicators of a decline in vegetation condition. The dwarf succulent species *Crassula muscosa* and *Crassula subaphylla* decrease as vegetation degrades, with *Crassula subaphylla* decreasing significantly in moderately degraded vegetation. This indicates that this species is highly sensitive to an increase in stocking. *Crassula muscosa* decreases significantly at stock pressure associated with the degraded vegetation community.



The decrease of these species may be associated with a decrease in the abundance of a number of the larger succulent and woody shrub species. Carrick (2003) found that in the Namaqualand region of the Succulent Karoo, *Crassula muscosa* and *Crassula subaphylla* occur almost exclusively under the canopies of larger shrubs. This suggests a level of facilitation of *Crassula muscosa* and *Crassula subaphylla* by succulent and woody shrubs in the less degraded communities.

In the Succulent Karoo, no evidence of facilitation has been found under moderate browsing intensities of commercial rangelands (Milton 1994, Milton 1995) but it is evident under the extremely high browsing and trampling intensities of communal rangelands (Todd 2001). The limited evidence that facilitation may be more prevalent in communities that are subject to high levels of herbivory (Carrick 2003) indicates that the least degraded community of this study may be in a more severe state of degradation than considered in this study.

Although Na decreases in the moderately degraded site from the least degraded community and the trend seems to be a general decrease of Na as vegetation degrades, the lack of statistical evidence to support this makes drawing any clear conclusions difficult and further investigation is required. There is however a marked increase in the Mg content of soil as vegetation degrades and a significant decrease in Ca. These findings and the significantly higher pH in the severely degraded community together with the general reduction of soil chemicals, indicate that soil chemical content changes occur as vegetation degrades. The increase in pH and Mg is supported by Beukes *et al.* (1994) who found that changes to soil chemistry as a result of overgrazing in the Karoo tend to include increased salinity, nutrient status and pH. The changes in soil chemistry as Oudtshoorn Gannaveld degrades hold serious implications for the rehabilitation of degraded Oudtshoorn Gannaveld as these changes are considered to be a major constraint of vegetation recovery in the Succulent Karoo (Beukes and Cowling 2003).

Degradation of off termitaria Oudtshoorn Gannaveld results in the significant reduction in the abundance of a number of species and these can serve as important indicators of vegetation degradation. These species are: *Crassula muscosa, Crassula subaphylla, Crassula tetragona, Drosanthemum lique, Lampranthus haworthii, Phyllobolus splendens, Ruschia ceresiana, Tetragona fruticosa, Eriocephalus brevifolius, Eriocephalus ericoides, Felicia filifolia, Helichrysum zeyheri* and *Pteronia incana.* The increase in the relative abundance of *Leipoldtia schultzei, Ruschia spinosa, Chrysocoma ciliata* and *Senecio juniperinus* indicates an increase in degradation in Oudtshoorn Gannaveld.

**Community characteristics**

**On termitaria communities**

**Group eight plant community – least degraded condition**

Although species richness does not differ significantly between the four on termitaria communities, the vegetation of the least degraded community is characterised by a relatively more heterogeneous spread of functional type abundance and species, with no one species or functional type being highly dominant. The perennial plant cover in this community is similar to that of the moderately degraded community, but it is significantly lower than the cover of the degraded community. This can be explained by the high cover of *Drosanthemum hispidum* in the degraded community which increases the total cover of the degraded community significantly. The percentage of bare ground in this community follows a similar but opposite pattern to cover and is only higher in the least degraded community than in the degraded community.



In terms of plant functional types, the least degraded community is dominated by succulent and woody shrubs. The abundance of succulent shrubs is higher than in the severely degraded community and this functional type is dominated by *Drosanthemum hispidum* and *Psilocaulon junceum*. These two species are the most dominant species in this community. Perennial forbs and grasses are extremely low in abundance in this community as is the case across all the on termitaria communities. This is a general pattern found throughout the Gannaveld habitat (Vlok *et al.* 2005).

The abundance of dwarf succulents and dwarf succulent shrubs in this community is relatively low, lower than in severely degraded vegetation. Dwarf woody shrubs are higher in abundance in this community than in the degraded vegetation.

*Drosanthemum giffenii* and *Phyllobolus splendens* are more abundant in the least degraded community than in the more degraded communities indicating that these species show early signs of a response to increased stock pressure. The cover of *Psilocaulon junceum* is relatively high in this community and decreases significantly in severely degraded vegetation. The percentage of prostrate plant litter is relatively high in this community, higher than in severely degraded vegetation. Although the soil pH in this community does not differ from any other community, soil P content is lower here than in the degraded community.

Figure 6 shows an example of an on termitaria area in the least degraded condition.



Figure 6

Example of on termitaria Oudtshoorn Gannaveld vegetation in the least degraded condition. This community is dominated by the succulent shrubs *Drosanthemum hispidum* and *Psilocaulon junceum, w*ith species such as *Phyllobolus splendens* and *Drosanthemum giffenii* abundant. The woody shrub *Salsola aphylla* is also relatively abundant.

**On termitaria communities**

**Group four plant community – moderately degraded condition**

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This community is similar in many respects to the least degraded community except that it is less heterogeneous in the spread of species abundance, being dominated by *Malephora lutea* which makes up 55% of the total cover. The abundance of *Malephora lutea* increases significantly from the least degraded community in this community, indicating an increase in disturbance (Cupido 2005, Vlok *et al.* 2005, Thompson *et al.* 2009). As in the least degraded community, cover in this community is dominated by succulent shrubs. However in the moderately degraded community there is a less heterogeneous spread of the abundance of species than in the least degraded community.



Perennial plant cover increases slightly and bare ground decreases slightly in this community, but analysis shows these differences not to be statistically significant. However, cover is significantly higher and the percentage of bare ground significantly lower than in the severely degraded community. Although the density of plants in this community is lower than in the more degraded communities this difference is not significant. Dwarf succulents and dwarf succulent shrubs are relatively low in abundance in this community, lower than in the more degraded communities.

The abundance of woody shrubs in this community is similar to that of the least degraded community. There is a decrease in the abundance of *Drosanthemum giffenii* and *Phyllobolus splendens* from the least degraded to the moderately degraded community indicating the sensitivity of these species to this level of degradation.

Other dominant plants in this community are the succulent shrubs *Psilocaulon junceum* and *Drosanthemum hispidum*, the dwarf succulent shrub *Mesembryanthemum crystallinum* and the woody shrub *Salsola aphylla*. Na, K and Ca tend to be highest in this community, significantly higher than in the severely degraded community.

Figure 7 shows an example of an on termitaria area in the moderately degraded condition.

Figure 7

On termitaria Oudtshoorn Gannaveld vegetation in a moderately degraded condition. Dominated by *Malephora lutea* and *Psilocaulon junceum,* but with woody shrubs such as *Salsola aphylla* present.

**On termitaria communities**

**Group 13 plant community – degraded condition**

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The most significant characteristic of this community is the dominance by the succulent shrub *Drosanthemum hispidum* which makes up 66% of the total perennial plant cover. Together with *Psilocaulon junceum* and *Mesembryanthemum crystallinum* these species contribute 91% of the total cover in this community. The high abundance of *Drosanthemum hispidum* accounts for the dominance of the succulent shrub functional type in this community.

Although species richness and the density of plants in this community do not differ from any of the other groups, cover is higher here than in both the least degraded and the severely degraded communities. This explains the lower percentage of bare ground in this community compared to the least degraded and the severely degraded communities. There is a decrease in the abundance of the woody shrubs in this community which is lower than in the moderately degraded community. This is mainly the result of the decrease in the abundance of *Salsola aphylla* which decreases in abundance from the moderately degraded community. The abundance of *Ruschia spinosa* and *Tetraena retrofracta* increases in this community. Soil pH of the degraded community does not differ from any of the other groups. The Ca and P content in the soil of the degraded community are higher than that of severely degraded vegetation. P is also higher in this community than in the least degraded community. Figure 8 shows an example of an on termitaria area in the least degraded condition.

Figure 8

Example of on termitaria Oudtshoorn Gannaveld in a degraded condition. The high cover is dominated by *Drosanthemum hispidum* with *Psilocaulon junceum* abundant.

**On termitaria communities**

**Group one community – severely degraded condition**

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The major characteristics of this community are the significant increases in the abundance of dwarf succulents, dwarf succulent shrubs and dwarf woody shrubs. There is also an associated decrease in the abundance of succulent shrubs. Other characteristics include a high density of plants, low cover, a high percentage of bare ground and a low percentage of prostrate plant litter.

The severely degraded community is dominated by the dwarf succulent shrub functional type which is made up primarily of *Mesembryanthemum crystallinum* and *Ruschia spinosa*. The significant increase in the abundance of the dwarf succulent shrub functional type is explained by the significant increase in the mat forming species *Ruschia impressa.* The increase in dwarf woody shrubs is as a result of an increase in the cover of *Chrysocoma ciliata*. The lower cover of succulent shrubs in this community is attributed to the decrease in cover of *Drosanthemum giffenii, Drosanthemum hispidum, Malephora lutea, Phyllobolus splendens* and *Psilocaulon junceum.* The abundance of *Galenia africana*, an indicator of disturbance, is highest in the severely degraded community and is more abundant than in the least degraded community. Species richness does not differ significantly between the severely degraded community and the other communities. Soil chemical are generally lowest in this community, with Na, K, and Ca being significantly lower here than in moderately degraded vegetation. The amount of Ca and P is also significantly lower in this community than in the degraded community.

Figure 9 shows an example of an on termitaria area in the least degraded condition.



Figure 9

Example of on termitaria Oudtshoorn Gannaveld in a severely degraded condition. The dominant species in these communities are *Mesembryanthemum crystallinum*, *Ruschia spinosa* and *Psilocaulon junceum*. Plant cover is low and the percentage of bare ground is high. Woody shrubs such as *Salsola aphylla* have been replaced by species such as the disturbance indicating species *Galenia africana*.

**Degradation processes on termitaria**

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It can be seen from the characteristics of each of the on termitaria communities that there are several changes that take place as this vegetation degrades. As in the off termitaria plant community, the most obvious change in the on termitaria community is the distinct shift in community composition. This is as result of a shift from succulent shrub dominated communities to a community dominated by dwarf succulent shrubs and in which there is a significantly higher abundance of dwarf succulents and dwarf woody shrubs. This change is associated with a significant increase in the density of plants.



Another pattern that is evident on termitaria is that of increasing cover and decreasing percentage of bare ground as a response to increasing stock pressure. This is similar to the pattern observed in the off termitaria community. However, when even more degraded than the severely degraded condition of this study, vegetation cover on termitaria decreases and the percentage of bare ground increases (Figure 10). In the Little Karoo, the decrease of perennial plant cover and the increase of the percentage of bare ground on termitaria usually signify intense overgrazing by ostriches (Cupido 2005, Esler *et al.* 2006). This indicates that in severely degraded Oudtshoorn Gannaveld the effect of stocking pressure on termitaria has been higher than off termitaria. This finding corresponds well with other studies in the Succulent Karoo (Armstrong and Siegfried 1990, Milton *et al.* 1992) that have shown higher herbivory occurs on termitaria than off termitaria and that in the Gannaveld habitat termitaria tend to be more prone to degradation than the off termitaria areas (Vlok *et al.* 2005).



Figure 10

On termitaria Oudtshoorn Gannaveld vegetation that has degraded as a result of high ostrich stocking pressure.

An important degradation process as a response to increasing stock pressure that occurs on termitaria is an increase in the abundance of dwarf succulent shrubs and succulent shrubs. However when stock pressure increases to a level which results in severely degraded vegetation, succulent shrub abundance decreases significantly. This in turn results in an abundance of dwarf succulents, dwarf succulent shrubs and dwarf woody shrubs. This process is known to occur in degraded Succulent Karoo vegetation, where mat forming succulent plants tend to dominate heavily overgrazed vegetation (Yeaton and Esler 1990, Milton and Dean 1996, Dean and Milton 1999, Esler *et al.* 2006).

The key species in the degradation process on termitaria are the succulent shrub *Drosanthemum hispidum* and the dwarf succulents *Ruschia impressa* and *Ruschia spinosa*. *Drosanthemum hispidum* increases to become highly dominant in degraded vegetation, a pattern of mono-dominance in the shrub layer described for Succulent Karoo vegetation types in the Little Karoo (Thompson *et al.* 2009), but is significantly reduced in severely degraded vegetation.



Whereas *Ruschia spinosa* tends to increase gradually as vegetation degrades and becomes highly abundant in severely degraded vegetation, *Ruschia impressa* increases more abruptly in severely degraded vegetation. This is a result of the increase in the available open space created by the reduction of succulent shrubs, predominantly *Drosanthemum hispidum* and *Psilocaulon junceum*. *Ruschia impressa* establishes more easily in open eroded sites than shrubs (Yeaton and Esler 1990) and is also more resistant to trampling (Acocks 1988).

The ability of the dwarf succulent and dwarf succulent shrub species to withstand trampling by ostriches in Oudtshoorn Gannaveld is important as this probably plays an important role in the prevention of soil erosion on termitaria.

The reduction of the abundance of perennial shrubs and the increase in the smaller dwarf species is known to occur in other parts of the Succulent Karoo as a result of overgrazing (Milton 1994, Todd and Hoffman 1999, Hoffman *et al.* 2003). This is mainly as a result of continual removal of new growth of shrubs (Esler *et al.* 2006) and the reduction of reproductive potential through reduced seed output (Wiegand and Milton 1996).



This study shows that some on termitaria species such as *Drosanthemum giffenii, Phyllobolus splendens* and *Salsola aphylla* show a negative response to increasing stock pressure earlier than other species, indicating a higher sensitivity to grazing and trampling. Species such as *Drosanthemum hispidum* and *Psilocaulon junceum* tolerate higher levels of stock pressure, but cannot tolerate levels that result in severely degraded vegetation.

Species such as *Malephora lutea* seem to respond well in moderately degraded vegetation but this species is reduced significantly as stock pressure increases. The increase of *Malephora lutea* in moderately degraded vegetation is probably as a result of the decreasing abundance of more sensitive succulent shrub species such as *Drosanthemum giffenii, Phyllobolus splendens* and *Psilocaulon junceum* in moderately degraded vegetation which results in open space.

As the relative abundance of *Malephora lutea* is considered an indicator of disturbance in Gannaveld (Vlok *et al.* 2005) an explanation for its sudden decline in more degraded vegetation is difficult to interpret. However the significant increase in cover of succulent shrubs in degraded vegetation is likely to play a role in competition for space (Esler 1999).

This study shows that in the on termitaria plant community of Oudtshoorn Gannaveld species such as *Ruschia impressa, Mesembryanthemum crystallinum, Ruschia spinosa, Chrysocoma ciliata, Tetraena retrofracta* and *Galenia africana* are extremely resilient to stock pressure. These species increase in abundance on termitaria as stock pressure increases, being able to tolerate even the high stock pressure that results in severely degraded vegetation and the relative abundance of these species can be considered an indication of degradation.



The increase in the abundance of species such as these, in particular *Galenia africana* and *Chrysocoma ciliata,* is a trend that has been frequently observed in heavily, or over-grazed Succulent Karoo vegetation in Namaqualand (Macdonald 1989, Hoffman *et al.* 2003). Although this study shows that there are numerous shifts in the populations of individual species, species richness on termitaria is not affected by degradation.

This can be explained by the high number of short lived, disturbance tolerant species usually associated with termitaria (Esler and Cowling 1995). These species have specific life-history characteristic such the maintenance of a high degree of seed dormancy and canopy and soil seed banks (Esler 1993). This allows these species to spread or confine the risk of recruitment failure in disturbed environments (Esler and Cowling 1995) increasing the chances of survival.

Although soil pH remains unchanged as on termitaria vegetation degrades there is a tendency for the soil nutrients to be lower in severely degraded sites, especially Na, Ca and P. This is an interesting finding in that changes to soil chemistry as a result of overgrazing tend to include elevated salinity, nutrient status and pH (Beukes *et al.* 1994, Palmer *et al.* 1999). It may be speculated that the changes in soil chemistry observed in this study are the result of the influence of soil crusting on water infiltration. Trampling by ostriches, especially on fine textured soil such as in Gannaveld (Vlok *et al.* 2005) results in mineral crusting (Mills and Fey 2003). Mineral crusting can reduce infiltration and evaporation of water in soil (Le Maitre *et al.* 2007) and may therefore prevent soil salts being brought to the surface by the evaporation of water.



The reasons for the changes in soil chemical composition observed in Oudtshoorn Gannaveld require further investigation. However these soil chemistry differences hold serious implications for the recovery of degraded Oudtshoorn Gannaveld as in other areas of the Succulent Karoo (Beukes and Cowling 2003, Mills and Fey 2003).

Vegetation recovery may become extremely difficult if soil quality deteriorates to such an extent that plant growth and germination are adversely affected (Du Preez and Snyman 1993, Allsopp 1999).

The significant reduction in the amount of prostrate dead plant material on the ground in severely degraded on termitaria vegetation is also of concern. This material is important in creating microsites for seedling recruitment (Dean and Milton 1991, Esler 1993, Esler 1999), reducing surface temperatures, water loss (Snyman and du Preez 2005) and soil erosion (Esler *et al.* 2006) and returning mineral nutrients to the soil by decay (Mills and Fey 2003). In degraded sites of the Succulent Karoo habitats of Little Karoo little organic matter protects or enters the soil (Thomson *et al.* 2009). The reduction of plant litter therefore reduces the number of suitable microsites for seedling recruitment, further inhibiting vegetation recovery.



It is apparent from the differences observed between the Oudtshoorn Gannaveld plant communities that degradation is more complex than the loss of cover and the increase in bare ground. Perennial cover remains unaltered off termitaria while on termitaria cover is only significantly reduced in severely degraded vegetation. Degradation in Oudtshoorn Gannaveld results in significant shifts in species populations and functional type abundance and these changes hold implications for agriculture and biodiversity conservation.

**Chapter 7**

# General discussion

## Degradation processes

Understanding the causes of land degradation and determining the roles of climate and grazing in driving vegetation change in semi-arid ecosystems has been the focus of much research in South Africa (Archer 2004). There is still much debate around semi-arid rangeland dynamics in terms of the long term negative effects of grazing (Campbell *et al.* 2006). Directional or range succession models predict that in the absence of grazing or other disturbance, vegetation develops through succession to a single, persistent state or climax (Weaver and Clements 1929). These succession models are based on an equilibrium perspective that overgrazing or other disturbance causes the system to regress along a predictable pathway to earlier successional stages and a reduction in grazing pressure allows a return to a climax stage. These models are however considered to be of little value in semi-arid areas (Behnke and Scoones 1993) and do not explain why many grazing induced changes in the Karoo cannot be reversed by resting (Milton and Hoffman 1994).

It has been suggested that in semi-arid systems, described as disequilibrial (Behnke and Scoones 1993), grazing has very little long term impact on vegetation, being overridden by abiotic factors such as rainfall and drought (Ellis and Swift 1988). But according to (Todd and Hoffman 2009) the disequilibrium dynamics associated with other semi-arid areas such as the grasslands of East Africa and the Sahel (Ellis and Swift 1988), do not fit well with the dynamics of the Karoo shrublands of southern Africa because of the fundamental differences in the dynamics of the vegetation as well as the more intensive type of livestock farming practiced. There has also been recognition that there are probably elements of both equilibrium and non-equilibrium dynamics in semi-arid rangelands (Vetter 2005, Gillson and Hoffman 2007, Todd and Hoffman 2009). Campbell *et al.* (2006) have suggested a move beyond polarization of this debate towards a more integrative and flexible approach to grazing management in semi-arid areas where an optimal grazing regime is likely to vary depending on the specific conditions of the site in question.

However, models such as state and transition models (Westoby *et al.* 1989), suggest that unpredictable climate and disturbance such as grazing can shift vegetation from one state of community structure and composition to another and that these states may be irreversible through natural succession processes alone. In a conceptual model Milton *et al.* (1994a) describe a stepwise process of degradation of semi-arid vegetation whereby, at the first step perennial vegetation varies with weather, and biomass and composition of vegetation varies with climatic cycles and stochastic events. When grazing reduces the recruitment of palatable plants, populations of unpalatable species become more abundant. This results in demographic changes in the populations of the community. When plant species that fail to recruit are lost there is reduced secondary productivity. Biomass and productivity of vegetation may then fluctuate as ephemerals benefit from the loss of perennial cover. As the biomass of perennial species is reduced, short lived plants increase. Continued degradation then results in the denudation of vegetation and desertification. This results in changes in soil function, and increase in bare ground, increased soil erosion and aridification.

The state and transitional model (Westoby *et al.* 1989) applied to the Karoo regions of South Africa by Milton and Hoffman (1994), show that transitions can be rapid through overgrazing to a low cover community dominated by annual grasses and succulents, or by slow system rundown to a system dominated by unpalatable dwarf shrubs. In this model a hypothetical mechanisms for transitions between states of vegetation in the southern Succulent Karoo suggests that a perennial shrubland with a mixed composition of palatable and unpalatable shrubs of similar age could be transformed to a shrubland where all species were represented by plants of different ages. This would occur as a result of occasional disturbances that reduce the competitive abilities of established plants.

When herbivory becomes sufficient to prevent seeding of palatable plants, palatable shrubs will be replaced by seedlings of unpalatable plants. Continual grazing that prevents palatable species from reproducing will result in the eventual disappearance of palatable species. Long lived unpalatable species and thorny shrubs will become dominant. More intense herbivory will destroy most perennial seedlings before they set seed. Few of the longer lived shrubs have dormant seeds so there is no soil stored seed bank. This results in the loss of perennial species from the system and ephemeral species with dormant seed emerge (Esler *et al.* 1992, Esler 1993).



Steps of degradation in the Succulent Karoo have also been described elsewhere. Esler *et al.* (2006) describe the characteristics of five vegetation states, from an excellent state where perennial plant cover and diversity is high with an abundance of palatable species, to a severely degraded state where plant cover is minimal and little organic matter protects the soil and soil erosion occurs.

Similarly, Thompson *et al.* (2009) describe the basic characteristics of three states of degradation in the Succulent Karoo areas of the Little Karoo. In this description, intact Succulent Karoo vegetation is high in perennial cover and diversity. Palatable species are abundant and disturbance indicating species are absent or rare. In moderately degraded vegetation Thompson *et al.* (2009) consider all the characteristics to be intermediate between the intact and severe states and can revert to the intact state through the implementation of an appropriate management strategy. In the severely degraded state perennial cover is low, plant diversity is reduced and there is mono-dominance of unpalatable and disturbance indicating species.

The overarching process of degradation apparent from these models and descriptions is the reduction of perennial plant diversity and cover; the reduction of palatable species abundance and the increase in disturbance indicating species; and the increasing risk of soil erosion. These broader degradation patterns are apparent in Oudtshoorn Gannaveld and the different communities identified can be considered to be separate vegetation states (Westoby *et al.* 1989) that have developed as a result of a stock pressure transition mechanism as suggested by Milton and Hoffman (1994).

**Mechanisms of degradation**

These mechanisms of change in Oudtshoorn Gannaveld that have occurred mainly as a result of grazing and trampling by ostriches are primarily linked to plant mortality and recruitment. Large periodic mortality and recruitment events are known to be key processes driving the dynamics of semi-arid plant communities and establishment events can determine the composition of plant communities for long periods (Jeltsch *et al.* 1999). The major cause of plant mortality in these communities is drought, especially after high rainfall periods (Wiegand *et al.* 1995). Mortality and recruitment in these communities also depends on the drought tolerance of species, their longevity and their competitive ability (Milton *et al.* 1999). However, domestic livestock grazing may be able to override weather patterns and influence the dynamics of the plant populations (Milton and Hoffman 1994, O'Connor and Roux 1995).



In the Karoo, the availability of establishment sites for seedlings and the competition between emerging species, and between the emerging species and the established species, are important factors in determining community composition (Midgley and van der Heyden 1999). However livestock activity that alters establishment sites and reduces seed availability and seed set can play a major role in changing the abundance of species and the structure of communities (Milton *et al.* 1994a, Stokes 1994, Milton *et al.* 1999). Seed reduction is mainly caused by grazing where the reproductive success of plants is inhibited through the reduction of flowers (Milton 1994). Where grazing is intense enough to prevent palatable plants from seeding, they are replaced by the seedlings of unpalatable species (Milton and Hoffman 1994).

Also, continual grazing of new growth (Esler *et al.* 2006) and the limited re-growth because of the loss of apical meristems and the lack of secondary meristems (van der Heyden and Stock 1999) can considerably weaken or kill plants. This impact is compounded by the fact that Karoo shrubs do not exhibit fast re-growth rates or compensatory re-growth responses to grazing such as some grasses do (van der Heyden 1992). It has also been found that the ability of palatable Karoo species to regenerate is considerably reduced by continuous grazing (Todd 2001). Continual grazing therefore reduces palatable plant species reproductive success resulting in the loss of the species from the system.

However certain inherent physiological abilities (Roux and Vorster 1983) or compensatory mechanisms that operate only at intense levels of herbivory (Midgley and van der Heyden 1999) may give certain plant functional types a competitive advantage when the community is subjected to high intensity grazing. For example, van der Heyden and Stock (1999) showed that heavily grazed *Pteronia tricephala* plants were able to maintain carbohydrate status unchanged, while the carbohydrate status of *Eriocephalus ericoides* decreased. Shrubs such as *Eriocephalus ericoides* without compensatory mechanisms are therefore not able to survive continuous heavy grazing. In Oudtshoorn Gannaveld this is evident in the off termitaria community where *Eriocephalus ericoides* is able to tolerate the stock pressure of the moderately degraded and degraded communities, but declines significantly in severely degraded vegetation, unable to tolerate the higher grazing intensity.

Although the specific compensatory mechanisms for functional types in Gannaveld are not part of this study, it is interesting to note that in the off termitaria community, a number of species of the woody shrub functional type follow a similar pattern to *Eriocephalus ericoides* and also decrease significantly in moderately degraded, degraded or severely degraded communities, indicating that these species have no inherent compensatory mechanism to survive the continual grazing that has resulted in the degradation of Oudtshoorn Gannaveld.

Although Gannaveld in an intact state (Thompson *et al.* 2009) should contain a high abundance of palatable species (Vlok *et al.* 2005) there is a relatively low proportion of palatable species recorded even in the least degraded vegetation condition of this study area. This indicates that prolonged herbivory in this area, probably over more than 150 years (Cupido 2005), has reduced the fitness of palatable plant species to the point where unpalatable species have had the competitive advantage (O'Connor 1991) and certain palatable species have probably become extinct. Seed reduction through inhibited reproductive success and continual grazing of new growth explain the reduction of palatable species abundance off termitaria. These species also tend to be longer lived than species that occur off termitaria and do not maintain seed dormancy or seed banks (Esler and Cowling 2005) increasing the risk of recruitment failure.



Even though the shorter lived on termitaria species (Yeaton and Esler 1990) that are associated with high levels of disturbance (Armstrong and Siegfried 1990) maintain a high degree of seed dormancy and seeds in capsules to spread the risk of recruitment failure (Esler and Cowling 1995) even fewer palatable species were recorded on termitaria. This is not surprising as nutrient rich termitaria are known to be targeted by grazing animals (Armstrong and Siegfried 1990).

However, it is not only the more palatable species that have been reduced by grazing. Species that are considered to be less palatable have also decreased significantly as Oudtshoorn Gannaveld has degraded. The same mechanisms of reduced reproductive success and grazing of new growth probably also impact on the less palatable species especially when ostriches are stocked at high densities and grazing is not selective (Esler *et al.* 2006).

The dominant species in the least degraded vegetation both on and off termitaria in this study are not considered to be palatable (J. Vlok. pers. com. 2009) yet the continuous impact of grazing and trampling by ostriches in particular, that tend to strip leaves off plants or pull young plants and seedlings out of the ground (Milton *et al.* 1994b), has reduced the abundance of these species significantly. Reduced recruitment results in populations of older plants. As the older shrubs die there is an increase in open space and a release in competitive pressure which is to the advantage of disturbance indicating unpalatable mat forming and spiny species (Milton and Dean 1996).



As an example, in a simulation model based on field data from the Tierberg Karoo Research Centre in the southern Karoo, Wiegand and Milton (1996) found that sudden increases in the density of colonizer mat forming species such as *Brownanthus ciliatus* and *Ruschia spinosa,* species that need large gaps in open vegetation to establish, occurred when rains suitable for germination and recruitment followed long periods of rainfall not favourable for recruitment. Failure of plant populations to replace natural mortality during these prolonged periods led to a decrease in the density of established plants, and consequently to an increase in the size and abundance of gaps that served as safe establishment sites for colonizers.

This is clearly evident in Oudtshoorn Gannaveld where there is a significant shift of plant functional type abundance from the larger woody and succulent shrubs to a community dominated by a high abundance of unpalatable mat forming and spiny species. These hardy succulents serve as pioneers, as they establish more easily in open eroded sites than shrubs (Yeaton and Esler 1990) and are also more resistant to trampling (Acocks 1988). This is an important survival mechanism especially in ostrich farming areas where trampling is known to impact on more sensitive plants (Cupido 2005). Although these mat forming species are unpalatable disturbance indicating species they probably play a critical role in the prevention of soil erosion and the creation of microsites for the re-establishment of other species.



The dynamic mortality and recruitment processes that occur in Oudtshoorn Gannaveld have undoubtedly been impacted on by grazing and trampling induced degradation and this explains the significant changes in vegetation composition that have taken place in the different on and off termitaria communities. Reversing these compositional changes to increase diversity, improve forage quality and ecosystem functioning is obviously desirable, especially in a critically endangered vegetation type (Reyers 2008) of an internationally recognized biodiversity hotspot (Mittermeier *et al.* 2005). However major changes in vegetation composition such as have occurred in Oudtshoorn Gannaveld are unlikely to be reversible through the reduction of stock pressure.

**Reversing degradation**

In the Karoo it has been widely observed that neither precipitation nor withdrawal of grazing pressure invariably lead to a reversal of degradation (Novellie 1999). Although it has been reported in the Succulent Karoo (Rahlao *et al.* 2008) that a release from grazing can result in a significant and predictable directional vegetation response, improvement of overgrazed vegetation in semi-arid environments has seldom been achieved by withdrawal of livestock alone. This is evident from studies in the Karoo region of South Africa and in similar Australian and American semi-arid areas (Westoby *et al.* 1989, Fuls 1990, Bahre 1991, Milton *et al.* 1994a). Simulation results by Wiegand and Milton (1996) indicate that little improvement in degraded Karoo rangeland condition was likely to occur during a period of 60 years. After 60 years there was a 54% probability that overgrazed rangeland would remain in an overgrazed condition or even deteriorate, and only a 7% probability that there would be a substantial improvement in condition.



The removal of stock in an attempt to rehabilitate degraded vegetation where there have been major compositional shifts such as in Oudtshoorn Gannaveld can be stalled by compositional or demographic inertia (Westoby *et al.* 1989). When longer lived shrub species become dominant in degraded vegetation they tend to persist through longevity and during rare establishment events, where recruitment is proportional to seed input (Wiegand and Milton 1996) these dominant shrubs have the advantage resulting in new recruitment in that population. This would explain the dominance of the succulent shrub *Ruschia ceresiana* in the least degraded and moderately degraded communities off termitaria.

Although not statistically significant, there appears to be an increase in the abundance of *Ruschia ceresiana* from the least degraded community to the moderately degraded community. This increase in abundance of *Ruschia ceresiana* and the reduction of the abundance of a number of other succulent and woody shrubs in the moderately degraded community suggests that compositional inertia has been a process in altering community composition. This is also apparent on termitaria where the succulent shrub *Drosanthemum hispidum* increases significantly in the degraded community and is highly dominate. According to Todd and Hoffman (2009) compositional inertia may be responsible for the greater than expected susceptibility (Milchunas *et al.* 1988) of arid and semi arid shrublands to grazing-induced impacts. It therefore seems highly likely that, notwithstanding the role of climate, stocking induced reduction in reproductive success has altered the dynamics of Oudtshoorn Gannaveld resulting in separate communities or states from which transition to a different state is constrained by compositional inertia.



Milton and Hoffman (1994) consider there to be four major constraints on passive transitions between vegetation states. An inadequate supply of seed (O'Connor 1991, Milton and Dean 1990b, Milton 1992) of palatable species prevents a passive transition from a community dominated by unpalatable plants to a community with mixed species. Ungrazed species produce more seed which therefore have a higher probability of reaching suitable sites than the few seeds produced by overgrazed plants. High densities of long lived well established plants of unpalatable species compete with new seedlings for above and below ground resources and do not disappear abruptly when vegetation is rested (Moore 1989, Milton 1994). Competition from these established plants prevents a passive transition from one shrub guild to another.

It has also been suggested (Yeaton and Esler 1990) that reversal of grazing induced degradation is seldom achieved by the removal of livestock because of the removal of certain key species in the degradation process. The absence of these species prevents colonisation of associated species and the vegetation remains in the degraded state (Dean and Milton 1999). In addition, changes in soil chemistry are known to occur under heavy grazing in the Karoo (Allsopp 1999, Beukes *et al.* 1994, Mills and Fey 2003) and vegetation recovery may become extremely difficult if soil quality deteriorates to such an extent that plant growth and germination are adversely affected (Du Preez and Snyman 1993, Beukes and Cowling 2003).

In Oudtshoorn Gannaveld there are communities of long lived, well established unpalatable species. Passive transition from these communities to mixed species communities is restricted by competition from the established long lived plants. There are also communities dominated by short lived and shallow rooted, mat forming dwarf succulent shrubs where an inadequate supply of palatable species seed and an abundance of unpalatable plant seed and continued stock pressure contributes to preventing passive recovery.



There are numerous species of different functional types that have been reduced or removed that may be key species. The absence of these species from communities may be preventing the colonization of associated species as suggested by (Yeaton and Esler 1990). There are soil chemistry changes that take place both on and off termitaria and although an explanation for these changes needs further investigation the implications for vegetation recovery are apparent.

Passive recovery from any of the states of Oudtshoorn Gannaveld both on and off termitaria is unlikely, and any recovery would require active rehabilitation. Active rehabilitation can be costly and success levels low. Milton *et al.* (1994a) anticipate that for every step descending in their stepwise model of rangeland degradation, rehabilitation becomes more costly in terms of the loss of secondary productivity, labour, material, and machinery. Even attempts to increase densities of natural palatable plants by reseeding are rarely successful in the Karoo (Wiegand and Milton 1996).

In the Little Karoo Herling *et al.* (2009) found that the rehabilitation of Gannaveld to a condition where the abundance of palatable species would support sheep farming as an alternative to ostrich farming, the costs were restrictively high. The rehabilitation of Gannaveld was not considered to be financially feasible for a period of at least 20 years, making the investment in such actions unlikely considering this requires the removal of ostriches during the rehabilitation period. The Herling *et al.* (2009) study and others such as Milton *et al.* (2003) highlighted the fact that financial factors hinder effective restoration of degraded areas.



The broader compositional shifts that take place in Oudtshoorn Gannaveld as a result of stock pressure and the associated constraints on dynamic processes are likely to be similar in other Gannaveld vegetation types of the Little Karoo. The impact of degradation can generally be expected to be seen in shifts in the relative abundance of palatable and unpalatable species, the relative abundance of degradation indicating and mat forming species as the dominant plant functional type. As ostriches are the most common domestic livestock species farmed in the Gannaveld habitat of Little Karoo and the major cause of degradation in this highly threatened habitat (Cupido 2005, Vlok *et al.* 2005, Thompson *et al.* 2009) the degradation of Gannaveld holds implications for both agriculture and biodiversity conservation.

**Agriculture**

The Little Karoo has been the centre of the ostrich industry since 1865 (Beinart 2003, Cupido 2005). Currently, most of the farms in the Oudtshoorn area of the Little Karoo are involved in ostrich farming with 150 000 to 200 000 ostriches kept on approximately 500 farms (Murray 2008).

A report on the economic importance of ostrich farming in the Little Karoo (Murray 2008) shows that regional agriculture (predominantly ostriches and related lucerne production) small stock, seed production and tourism are the main sources of income. It is suggested by Murray (2008) that Little Karoo ostrich production represents up to 72% of total farm output and that the ostrich industry provides for as much as 50% of Little Karoo regional economic output, providing for 21% of all employment. This illustrates the important role ostrich farming plays in the socio-economic circumstances of the Little Karoo.



However to sustain this industry ostriches are usually stocked at much higher levels than their natural stocking density, estimated at one ostrich per 100 ha (Esler *et al.* 2006), or the levels recommended by the Department of Agriculture. Ostrich stocking densities in the Little Karoo have been shown to be far in excess, currently at 8.1 ha per ostrich, of the 22.8 ha per ostrich recommended by the Department of Agriculture (Murray 2008). Reyers *et al.*

(2009) estimated that ostrich numbers in the Little Karoo are more than five times the total potential capacity.

Maintaining these high ostrich densities in natural Gannaveld is made possible by supplementary feeding. Unlike mammalian livestock farmers in the Little Karoo, ostrich farmers are not dependent on the natural grazing resource to sustain ostrich production. However, even though supplementary feeding is provided for ostriches they still have the greatest negative impact on Gannaveld vegetation condition, more so than large and small stock (Cupido 2005).

This degradation is attributed to the active, territorial behaviour and trampling effects of ostriches (Cupido 2005) and the removal of seedlings (Milton *et al.* 1994b) but also to the foraging of ostriches even when supplied with full rations (Esler *et al.* 2006). Anecdotal evidence from farmers in the area indicates that up to 25% of supplementary feed costs can be saved after good rains when young shoots are available for ostriches to utilize.



Degradation of Gannaveld has consequences for the provision of ecosystem services considered crucial in the Little Karoo. Two of the important ecosystem services impacted on by vegetation degradation in Gannaveld are water-flow regulation and forage production. Forage production is the most expansive ecosystem service in the Little Karoo (O'Farrell *et al.* 2008) and is crucial in an area where the most important economic activity and employer is agriculture (Murray 2008). Water-flow regulation is considered to impact on the whole Little Karoo ecosystem and underpins the entire agricultural economy (Reyers *et al.* 2009).

In terms of water-flow regulation in the Little Karoo, overgrazing results in increases in surface water runoff, changes in water flow and groundwater regimes, decreases in water quality, and increases in the severity and frequency of floods (Le Maitre *et al.* 2007). There may also be reduced water infiltration into soil as the result of surface crusting (Mills and Fey 2004) which reduces vegetation productivity and increases erosion (Le Maitre *et al.* 2007). The deep, fine-fractured soils of Gannaveld are particularly vulnerable to soil erosion when vegetation is overgrazed (Vlok *et al.* 2005) and intact vegetation plays an important role in mitigating erosion by protecting soil. Under dry conditions topsoil with a fine texture such as Gannaveld, is also extremely vulnerable to wind erosion when vegetation cover is reduced (Todd *et al.* 2004).



The ecosystem service of water flow regulation and associated soil erosion control, depend mainly on the structural aspects of ecosystems, especially vegetation cover and root systems (Reyers *et al.* 2009). Therefore, large changes in community composition and structure, particularly in plant functional types such as observed in Oudtshoorn Gannaveld, will impact on the ability of ecosystems to provide this service.

Gannaveld degradation also impacts on the production of forage for livestock grazing (Reyers *et al.* 2009). With agriculture being the dominant industry in the Little Karoo forage production is an important ecosystem service provided to ostrich farmers and farmers of other mammalian livestock. Although ostriches are the most common domestic livestock species farmed in the Little Karoo (Cupido 2005) a number of other livestock are also farmed in the area, including dorper sheep, merino sheep, angora goats, boer goats and a variety of cattle breeds (Le Maitre and O'Farrell 2008) that rely more on natural forage production than ostriches.

Even though ostrich farming does not necessarily rely heavily on natural forage for grazing, changes in community composition and the loss of palatable species in degraded Gannaveld reduces options for ostrich farmers. Rehabilitating degraded Gannaveld for example, to provide enough forage to sustain a comparatively conservation compatible and sustainable land-use such as sheep farming is not financially feasible (Herling *et al.* 2009).

Changes in plant composition associated with overgrazing in the Little Karoo also hold implications for system resilience as the loss of species will reduce the capacity of these plant communities to respond to environmental fluctuation (Cowling *et al.* 1994, Anderson and Hoffman 2007) especially in terms of predicted climate change (Hoffman and Ashwell 2001). Livestock induced degradation in the Succulent Karoo vegetation of the Little Karoo is considered a serious threat (Lombard *et al.* 1999, Driver *et al.* 2003) and decisions regarding management of rangelands therefore have important implications for a global biodiversity asset (Le Maitre and O'Farrell 2008).

**Biodiversity conservation**

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The Gannaveld habitat of the Little Karoo forms part of the Succulent Karoo biodiversity hotspot (Mittermeier *et al.* 2005) of southern Africa and is highly threatened by unsustainable land use practices such as ostrich farming (Driver *et al.* 2003). A study by Thompson *et al.* (2009) shows that 59% of the Gannaveld habitat has been moderately degraded and 39% severely degraded mainly as a result of ostrich farming (Cupido 2005). This has resulted in most of the Gannaveld vegetation types in this habitat being either critically endangered, endangered or threatened (Kirkwood *et al.* 2007, Reyers 2008).

Stocking densities of ostriches in Gannaveld remain high (Murray 2008) increasing the risk of further degradation to intact or moderately degraded areas or the complete transformation of severely degraded areas. This holds serious implications for the conservation of Succulent Karoo vegetation (Desmet and Cowling 2005) and ecosystem functioning and services in the Little Karoo (Le Maitre *et al.* 2007, Reyers *et al.* 2009, Le Maitre and O'Farrel 2008). The increasing concern regarding the conservation of biodiversity in the Little Karoo is seen in the formation of multi-stakeholder groups such as the Gouritz Initiative, a biodiversity conservation based initiative that recognise the significant conservation and governance challenges that face the region and coordinates strategies and facilitates co-governance (Reyers *et al.* 2009).



In the ostrich industry, the establishment of the South African Ostrich Business Chamber (SAOBC) Biodiversity Management Project indicates that this industry recognizes the importance of biodiversity in the Little Karoo and the need for internationally acceptable environmental assurance (Pahl and Sharp 2007). As part of this commitment the SAOBC Biodiversity Management Project has initiated a process through which it aims to have farmers in the Little Karoo adopt land management practices that ensure the conservation of biodiversity and the sustainability of the ostrich farming industry (Botha *et al.* 2008). To achieve this requires that overstocking of free range ostriches for breeding, which is the main cause of degradation (Hoffman 1996, Cupido 2005, Vlok *et al.* 2005), be reduced.

To determine appropriate ostrich stocking densities an evaluation of the Little Karoo vegetation (Vlok and Schutte-Vlok 2008, Vlok and Coetzee 2008) based on the fine scale vegetation mapping of Vlok *et al.* (2005) and vegetation transformation mapping (Thompson *et al.* 2005) was carried out. It was recommended that all ostrich stocking be excluded from areas classified as critically endangered or endangered (Kirkwood *et al.* 2007, Reyers 2008) and that ostriches are stocked only at ecological carrying capacities in less threatened habitats. Ostrich farmers in the Little Karoo have subsequently been encouraged to shift from a free range breeding system to a pen based breeding system where breeding ostriches are removed from the range and placed in fenced breeding pens. This system is purported to improve selective breeding and greatly improve economic benefits to the farmer (Murray 2008).

Although the removal of ostriches from severely degraded rangeland may not result in passive recovery (Wiegand and Milton 1996), a reduction of stocking density will reduce the risk of further vegetation degradation (Milton and Hoffman 1994) and the resulting loss of biodiversity and diminished ecosystem services provision (Reyers *et al.* 2009).

In a study by O'Farrell *et al.* (2008) to examine the interconnectivity of the social-ecological system of the Little Karoo, it is suggested that natural resource management approaches which adopt a holistic outlook focusing on the integrated nature of social and ecological systems hold promise for sustainable land-use development in the Little Karoo.

This seems particularly pertinent in areas such as the Little Karoo, where the major impact on critically important biodiversity is also the most important socio-economic driver.

**Conclusions**

The study of the perennial plant composition of Oudtshoorn Gannaveld has provided a detailed description of the composition of the most critically endangered Gannaveld vegetation type in the Little Karoo, Oudtshoorn Gannaveld. The study has also quantified the composition of Oudtshoorn Gannaveld through determining the relative abundance of plant families, plant functional types and species. This quantification has provided new insight into the plant composition of Oudtshoorn Gannaveld.

The determination of the two broader communities that occur in Oudtshoorn Gannaveld, the on termitaria community and the off termitaria community, confirms the findings of other studies in Succulent Karoo vegetation that these two communities support distinctly different plant assemblages. These assemblages have been quantified for Oudtshoorn Gannaveld. The results presented in chapter three lend further support to the fact that the on and off termitaria plant communities are separated through composition by showing that in Oudtshoorn Gannaveld there are significant differences in a number of variables between them such as the diversity of perennial plants, plant cover and the density of plants, bare ground, plant functional type composition, the abundance of individual species and soil chemistry.



The results of the study have also shown that distinct plant communities occur within the broader on termitaria and off termitaria communities of Oudtshoorn Gannaveld and that these can be distinguished mainly by differences in perennial plant composition. There are also other variables that distinguish these communities from one another such as the percentage of bare ground, the density of plants, the percentage of plant litter and soil chemistry.

These different vegetation communities have in all likelihood developed as a response to different levels of livestock pressure, mainly ostrich stocking which is the predominant agricultural activity in the area. This has been shown by the determination of the condition of vegetation in each of the communities within the on and off termitaria communities, whereby it is evident that the communities vary in condition from a least degraded condition to moderately degraded, degraded and severely degraded conditions. The compositional shifts that take place between these communities are similar to those found in other areas of the Succulent Karoo biome and the Little Karoo that have been subjected to prolonged, heavy livestock impacts.



The characteristics of each of these separate communities have provided insight into the changes that have taken place in Oudtshoorn Gannaveld as this vegetation type degrades. Apart from the significant changes that occur in the relative abundance of individual species between these communities both on and off termitaria there have been significant shifts in plant functional type abundance. The most striking of these changes in both the on and off termitaria plant communities is the shift in composition and structure from diverse communities dominated by succulent shrubs to less diverse communities dominated by dwarf succulent shrubs.

While it appears that Oudtshoorn Gannaveld perennial vegetation cover off termitaria is relatively resilient to grazing and trampling, species richness, functional type composition and the abundance of numerous individual species are not as resilient. Species richness, succulent shrubs and woody shrubs are more sensitive to grazing and trampling off termitaria than cover and this is evident in the number of grazing and trampling sensitive species that are significantly reduced even in moderately degraded vegetation. These species are likely to be the first to respond to increasing grazing pressures and they represent indicator species in determining changes in off termitaria Oudtshoorn Gannaveld condition.

On termitaria cover is not as resilient to grazing and trampling as off termitaria vegetation and is reduced in severely degraded areas. In the on termitaria community diversity in terms of species richness seems to be resilient to grazing and trampling, however the evenness and abundance of plant functional types and several species are not resilient to these impacts. Some species on termitaria are highly sensitive to grazing and trampling pressure and are significantly reduced in moderately degraded vegetation. These species serve as indicators of declining condition of on termitaria Oudtshoorn Gannaveld vegetation. In Oudtshoorn Gannaveld, termitaria tend to be more degraded than off termitaria sites with higher levels of bare ground and lower cover especially in the severely degraded vegetation. This was evident in the high percentage of degraded and severely degraded termitaria found in areas of least degraded and moderately degraded off termitaria vegetation.



The determination that perennial plant cover is relatively resilient but that species richness is not resilient to grazing and trampling by ostriches in the off termitaria vegetation of Oudtshoorn Gannaveld holds implications for agriculture and biodiversity, especially as ostrich farmers in the Little Karoo mainly assess the condition of rangeland based on cover. The resilience of cover to grazing and trampling has probably resulted in ostrich farmers maintaining ostrich stocking at levels that can be tolerated by the grazing and trampling tolerant species, but which cannot be tolerated by many other species with the resultant loss of diversity. The changes that occur in soil chemistry between the different communities both on and off termitaria is off concern because of the implications this has for the recovery or rehabilitation of Oudtshoorn Gannaveld and further research into this aspect is critical.

The mechanisms and processes involved in the degradation of Oudtshoorn Gannaveld are primarily the grazing and trampling effects of ostriches on the recruitment and mortality of perennial plants. Grazing and trampling activities kill established plants and seedlings, and cause repeated reproductive failure which has resulted in the reduction of the abundance of palatable and trampling sensitive species and the increase in the abundance of unpalatable and disturbance indicating species in Oudtshoorn Gannaveld. The compositional inertia in the degraded communities makes passive reversal unlikely within a human lifespan. Active rehabilitation methods are expensive and chances of success are limited. As this study has shown, although the whole of the study area has been categorised as severely degraded through remote sensing, there are finer levels of degradation within this area. In critically endangered Oudtshoorn Gannaveld and in other threatened Gannaveld habitats further degradation needs to be prevented in the least degraded areas. These least degraded areas are relatively diverse and contain species compositions and abundances that can serve as vital seed sources for any rehabilitation of vegetation. The least degraded areas are also more likely to rehabilitate naturally over time than the more degraded areas. Allowing these areas to further degrade will probably result in vegetation crossing critical thresholds to states from which reversal is far less probable even under suitable climatic conditions owing to processes such as compositional inertia. The study has provided a number of indicator species that show increases in degradation in Oudtshoorn Gannaveld and these can be used to monitor vegetation condition.

The degradation of vegetation in habitats such as Gannaveld in the Little Karoo have implications for the provision of eco-system services such as forage production and water-flow regulation and impacts on these have far reaching effects on social and economic conditions in the Little Karoo. The loss of plant diversity in vegetation types that are already critically endangered and that are within internationally important biodiversity hotspots is also an issue that require serious attention. Although there is much evidence of detrimental impact ostrich farming has had over the past 150 years and continues to have on vegetation in the Gannaveld habitat of the Little Karoo, there have been few successful attempts at reconciling agricultural and biodiversity conservation objectives in the area. Current projects such as the Gouritz Initiative and the South African Ostrich Business Chamber Biodiversity Project are making progress in this regard, however there is a huge need for information regarding alternatives to unsustainable ostrich farming practices in the Little Karoo to be passed on to ostrich farmers. The least degraded and moderately degraded areas of Oudtshoorn Gannaveld need to be included in formal conservation stewardship strategies to safeguard the remaining biodiversity of this critically endangered vegetation type.

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