The impacts of indigenous herbivore grazing over five years (2004-2008) on vegetation dynamics in four distinct vegetation types of the winter-rainfall Little Karoo

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Abstract

Vegetation in semi-arid regions is subject to change when heavily utilised by herbivores. Changes in species richness, species and growth form composition, total cover and plant palatability in response to rest (fenced) and grazing (open) treatments was investigated in Sanbona Wildlife Reserve over five years (2004-2008). This reserve is over 55 000 ha and has four dominant vegetation types: Little Karoo Quartz Vygieveld, Western Little Karoo, Montagu Shale Renosterveld and previously transformed Renosterveld classified here as Old Lands. There was no significant change in vegetation dynamics between the fenced or open plots. There were significant differences between years in some vegetation types. All vegetation types showed both treatments having similar shifts in floristic composition. Floristic composition deviated the greatest in 2008 in all vegetation types. This was attributed to an increase in summer and winter rainfall in 2008, as all plots were similarly affected. There was no observed impact of herbivores although disturbance from small rodents and baboons was observed in a few plots. The lack of detectable difference between the fenced and open sites was attributed to low stocking rates, good rainfall and insufficient time.

Keywords: Rangeland ecology, grazing, stocking rates, rainfall, Little Karoo

1. Introduction

1.1 *Importance of Rangelands*

Rangelands are vital assets for national and global economies, supplying approximately 16% of the world's food supply (Miller 2005). Occupying about 41% of the world's land surface, rangelands play an important role in providing essential ecosystem goods, especially basic sources of meat and proteins, as well as hides, timber, fuelwood and medicinal plants. They also provide important services such as carbon and water storage, soil stabilization, habitat for wildlife and micro-organisms and recreational opportunities (Williams *et al.* 1968). If rainforests are described as 'the lungs of the world', rangelands are the 'the bread baskets'. Rangelands are inhabited by approximately 38% of the global population, who are some of the most ecologically, socially and politically marginalised peoples on Earth (Reynolds *et al.* 2007). According to the American Society of Range Management (1964) rangelands consist primarily of natural vegetation and changes in ecosystem health have direct consequences for range production (Harrington *et al.* 1984). The economic returns derived from indigenous plant communities are dependent on ecosystem health, and threaten the livelihoods and sustainability of rangeland inhabitants if degraded (Reynolds *et al.* 2007).

On a local scale, rangelands function as watersheds, replenishing spring and ground water reservoirs. Well-managed and non-degraded rangelands protect also soil from erosion. This promotes infiltration and increases microbial activity, which decompose organic compounds making them available for nutrient uptake in plants (Kröner 2003). Rangelands also provide habitat for native fauna and flora (Williams *et al.* 1968). On a global scale they function as carbon sinks, although they do emit methane (CH_4) and the urine and dung from animals are reported to leach the soil (Mannetje 2002). Despite their local and global importance in securing food and capital, rangelands are increasingly under threat of degradation, and on occasion desertification, due to increased population pressure, over-use, mismanagement and destruction. Rangeland degradation is a top concern for owners and people who depend on this resource for their livelihood, as it threatens economic stability and ecological integrity (Milton *et al.* 1994). In summary rangelands are vital to local and global economies and environments as they buffer food insecurities, provide alternative livelihoods for the poor, protect the culture of approximately 2.5 billion people whilst safeguarding biodiversity (Reynolds *et al.* 2007).

1.2 *State of global Rangelands*

Many rangelands occur outside the arid zone, however, sub-Saharan rangelands are subject to varying degrees of aridity, from sub-humid to arid conditions, and occur where the abiotic environment is unsuitable for agriculture, i.e. too steep, rocky, saline or seasonally wet (Friedel 2000). Despite these regions often being characterised by sparse populations, high rainfall variability and impoverished soils with low organic matter content aggravate the effects from exploitation by agriculture and grazing (Mannetje 2002, Reynolds *et al.* 2007). The poor nutrient status coupled with unpredictable and low rainfall of dry rangelands mean that they are especially susceptible to degradation through unsustainable grazing pressures (Reynolds *et al.* 2007). Arid rangelands are therefore sensitive to changes induced by grazing pressures and once transformed, are not always reversible (Westoby 1989, Reynolds *et al.* 2007). The impacts of grazing induced degradation is related to the notoriously slow restoration rates of dryland systems, which become increasingly costly with time and severity of degradation (Williams *et al.* 1968, Milton *et al.* 1994, Rahlao *et al.* 2008). Given their socio-economic importance, it is imperative to ensure that ecosystem services do not diminish as a result of overuse.

Semi-arid rangelands are particularly susceptible to grazing pressure because vegetation recruitment and growth is largely dependent on timing and amount of rainfall, which is characteristically low and erratic. The unpredictable rain is likely to delay new growth and coupled with prolonged grazing, can retard vegetation recovery. Continuous heavy, selective grazing

slowly induces compositional changes by reducing the reproductive potential of preferred species (Milton 1992). The progressive loss of vegetation cover and composition and its associated productivity is attributed to the over-utilisation of herbivores, particularly domestic ungulates (Milton *et al.* 1994, Kraaij and Milton 2006). Although semi-arid rangelands are more sensitive to domestic livestock, especially goats, which reduce overall diversity and rapidly degrade ecosystems (Stuart-Hill 1992, Kerley 1999), overstocking with indigenous herbivores has parallel effects. In southern Africa, indigenous ungulates are generally confined to relatively small reserves or farms by fences (Kraaij and Milton 2006). Such confinement results in greater pressure on the environment by preventing grazer movements, thus increasing the vulnerability of those systems to landscape degradation (Mentis *et al.* 1989). Once the capacity of the vegetation to sustain herbivores decreases, a positive feedback response can result where the vegetation supporting grazers decreases in density, size or growth rate, thus further limiting forage production (Milton *et al.* 1994). Disturbances from herbivore grazing in such semi-arid systems can thus have significant effects on the vegetation diversity and composition (Rahlao *et al.* 2008).

The majority of the world's rangelands are in poor condition, with 10-20% of these lands being severely degraded (Reynolds *et al.* 2007, Williams *et al.* 1968). The bulk of rangelands are producing less than half their potential produce. This is believed to be a result of insufficient forage production and overstocking. A case study in Saudi Arabia demonstrates the importance of forage production in optimising animal products, as lamb production was 85% when well-nourished, as opposed to 35% in overgrazed rangelands (Williams *et al.* 1968). Vetter (2005) demonstrates how managing a rangeland below the ecological carrying capacity can reduce livestock mortality during droughts, as the livestock are buffered by greater food source and body fat reserves. Unfortunately, most reserves operate well above the carrying capacity probably due to the short-term economic gains at the cost of a long-term sustainability. Cupido (2005) found the knowledge of farmers in the Little Karoo to be fairly optimistic in terms of their estimations of grazing capacity, veld condition and stocking rates. This is largely due to the lack of proper vegetation assessments and monitoring studies on private farms, especially in a winter rainfall regime.

1.3. *Previous Case Studies*

A popular tool to determine the role of herbivores and their impact on vegetation is the fenced exclusion of herbivores from grazing sites (Ryerson and Parmenter 2001). Long term observations of vegetation dynamics allows ecologists to both evaluate the impacts of grazers as well as to assess whether there is a systematic, and therefore predictable, response of plant communities to

grazing pressure. Several studies, of different plant communities and time scales, have shown the effects of continuous grazing pressure in driving vegetation change (Table 1). However, these vary in the response from positive, neutral and negative impacts on vegetation dynamics (Ryerson and Parmenter 2001). For example, Rahlao *et al.* (2008) found a consistent directional shift with 67 years of herbivore release in the Succulent Karoo, South Africa, whereas Ryerson and Parmenter (2001) found non-uniform, yet multi-directional changes in response to grazing from native prairie dog (*Cynomys* spp.) and European cattle (*Bos* spp.) in both enclosures and open sites over 20 years in New Mexico. In the Naukluft Mountains, Namibia, Burke (1997) found non-significant changes in both height and cover between grazed and non-grazed sites over 18 and 19 years of rest, although there was a noticeable reduction in leaf-succulents with grazing. Gallacher and Hill (2006) investigated the impacts of camel grazing in Dubai over 5 years and found a significant, three-fold plant cover decrease in camel grazed sites, showing the rapid degradation in response to overgrazing in arid environments.

Despite differences in vegetation responses, there are general trends that occur with overgrazing in semi-arid and arid environments. The most prominent response is influenced by the role of selective herbivory on specific plant species (Ryerson and Parmenter 2001). Different plant species are preferred by grazers, and the most palatable species tend to disappear at a greater rate with increased stocking rates and associated grazing pressure. Herbivore preference alters plant demography (Kraaij and Milton 2006), as palatable species are frequently defoliated, resulting in less seed production and fewer seedlings to replace senescent individuals, thus skewering the age structure toward older size classes (Milton *et al.* 1994). Shifts in plant assemblages occur, as unpalatable species gain a competitive advantage thus facilitating their establishment (Milton *et al.* 1994). The disruption of plant demography through herbivore selection, and the decline in palatable perennial species, allows the colonisation of toxic, spinecent and annual or other ephemeral species (Milton *et al.* 1994, Kraaij and Milton 2006). This reduces the supply of forage production, particularly during droughts, and decreases the overall secondary productivity of the system (Milton *et al.* 1994).

Degradation is a significant issue in rangelands. It not only lowers the productivity of the system affecting the herbivores, it also has consequences for the physical properties and biological diversity. Milton *et al.* (1994) demonstrates how the biodiversity is affected with grazing disturbances, as forage and nesting sites decline with diminishing plant cover. For example, rodents decrease with severe degradation, cicadas decline paralleling the reduction in plant cover, as they depend on the roots of long-lived species during the nymphal period, and entire termite

colonies have been reported to disappear. This has repercussions for the species that feed on these organisms as well as the vegetation communities that are defined by them (Milton *et al.* 1994). The impacts on the soil properties are especially crucial for semi-arid systems. The single most useful and reliable indictor for the loss of sustainability is the increase in bare patches due to their role in ecosystem function (Weltz *et al.* 2003). An increase in bare patches raises the risk of soil erosion and redistributes water (Weltz *et al.* 2003), reduced infiltration of water and increases runoff, which then reduces the rain-use efficiency (Le Houérou 1983).

1.4 *Rangeland Monitoring at Sanbona*

The economic survival of rangelands is dependent on their environmental sustainability and health, as this determines primary productivity, which in turn determines the capacity of the vegetation to support herbivores (Milton *et al.* 1994, Weltz *et al.* 2003). The direct cause of rangeland degradation is overstocking. However the underlying cause of degradation is the lack of early warning systems identified through indicators and monitoring systems, which inform managers of current or impending vegetation change. For example, Anderson and Hoffman (2007) found the loss of perennial grass cover in Leliefontein communal lands as an indication that the ecosystem experiencing greater pressure in response to over-stocking. To have a statistically defensible estimation of the status and trends of community change, an appropriate baseline study with sensitive indicators followed by long term repeated measures, need to be implemented (James *et al.* 1999). Baseline studies are temporal reference points that enable comparisons in vegetation dynamics (De Soyza *et al.* 1998, James *et al.* 1999). This allows managers to re-design an effective management plan. This adaptive management serves to direct future management plans according to the observed trends (James *et al.* 1999).

Sanbona Wildlife Reserve (SWR) is situated in the semi-arid Little Karoo, South Africa and forms part of the Succulent Karoo biome (Mucina & Rutherford 2006). Not only is this biome home to the richest succulent flora in the world (van Jaarsveld 1987) its winter-rainfall is low, yet predictable, separating it from other global arid regions (Hoffman 1989). This predictable winter-rainfall has profound influences on vegetation structure and function, as well as evolutionary processes, as seen in the explosive radiation of the genera such as the *Mesembryanthema* (Cowling & Rundel 1998). However, the consequences of winter-rainfall coupled with aridity have complicated repercussions for rangeland management largely because this ecosystem functions differently to other arid winter-rainfall regions in terms of growing and flowering. Coupled with low productivity, Sanbona is especially sensitive to overgrazing because most perennial species are short-lived and incapable of re-sprouting after droughts and intense grazing, unlike other arid

perennials (Gotzmann *et al.* 1999). Once the shrub component is destroyed, it is not replaced by grass (Erasmus unpublished), which is an added threat to disrupting the food supply if reduced by overgrazing. Resources are thus scarce, and vary temporally and spatially. Dean and Milton (1999) suggest that historically, animal numbers were relatively low for the Karoo and would migrate with forage availability and remain in regions with year-round rainfall. Characteristic species such as Ostrich (*Struthiolus camelus*) and Springbuck (*Antidorcas marsupialis*) are believed to survive seasonal resource deletion by moving to localised rainfall patches with new plant growth (Skinner 1993). However, fencing constraints by farms obviously prevent mobility and force animals to make do with available resources. The maintenance of the veld is thus vital because irreparable damage will occur with incorrect stocking rates

Two models exist to explain the function of rangeland systems and depending on which model the system best suites determine the way it needs to be managed. The equilibrium model emphasises that stocking rates are regulated by density dependent factors (e.g. disease and resource competition) and that the feedback effects of stock drive vegetation dynamics (Vetter 2005). The non-equilibrium model suggests that semi-arid rangelands are driven by stochastic environmental events, especially drought, where primary productivity is limited thus preventing stocking rates to reach carrying capacity (Vetter 2005). Managers should, however, be cautious when distinguishing between natural vegetation fluctuations and climate or human-induced fluctuation, as it is important to correctly recognise when vegetation change is an indication of degradation. Gillson and Hoffman (2007) stress that the boundaries are blurred between normal variation and degradation if there is no basis on which to distinguish them. Recent developments in the non- and equilibrium theory has been resolved by largely favouring a dynamic and non-equilibrium state of rangelands (Gillson and Hoffman 2007, Reynolds *et al.* 2007). Although systems are likely to have both elements, SWR is being managed on the assumption that productivity is driven by stocking rates due to the fairly predictable rainfall and known stocking rates (i.e. according to the equilibrium model).

Only 5.8% of the Succulent Karroo is formally protected, which substantially under represents the biome (Mucina and Rutherford 2006). With over 5% of the biome being irreversible transformed, reserves such as SWR provide an essential refuge and protection for these unique and regionally endemic plant communities. SWR is thus in the process of signing a Stewardship Agreement with Cape Nature, the provincial conservation authority. This will help to ensure that the reserve is managed under strict conservation ethics over the next 30 years. This requires SWR to adopt a monitoring plan, with clear objectives and goals, to inform management of the trends and status of

the reserves' resources, communities and biological diversity. The Management Plan, complied by the former Manager of Sanbona, Ryno Erasmus, has detailed descriptions of the types and numbers of animals the vegetation can support and must be adhered to if long-term grazing capacity is to be maintained.

The objective of this study was to create a baseline analysis for the SWR from data collected over the last five years (2004-2008). The effects of indigenous herbivore grazing on i) species richness, ii) growth form composition, iii) plant cover and iv) palatability in four distinct vegetation types were investigated using field surveys and multivariate ordination techniques. The aim was to investigate whether a consistent directional change in vegetation composition has taken place as a result of indigenous herbivore grazing (open sites), as well as recovery from transformed lands (fenced sites) over a five year period (2004-2008).

2. Study Site

2.1 *Sanbona's History*

Sanbona is currently in the process of officially being proclaimed a Wildlife Reserve. Land-use options have changed at different temporal and spatial scales. The reserve incorporated the Cape Wildlife Reserve in 2000-2001, which was over 24-25 000 ha of land. The Cape Wildlife Reserve had previously been used for cultivation purposes but this practice was abandoned in 1997 prior to the establishment of the Reserve. In 2002 extra property (an additional 25 000 ha) was purchased by Sanbona, which included neighbouring farmlands in the south with differing levels of veld condition. Nineteen farms were present in that area. Prior to 2004 when the monitoring started, some sections were heavily utilised for cultivation, predominantly wheat, and for supporting livestock, mainly sheep and goats. After the land was purchased, the land-use options changed from domestic livestock and agriculture to game farming and eco-tourism.

2.2 *Site Description*

The reserve includes 55 000 ha of land in which three major biomes meet; Fynbos/Renosterveld, Thicket and Succulent Karoo. The Succulent Karoo flora has a highly specialised habitat, characterised by quartz beds on the soil surface, and is the only arid region recognised globally as a biodiversity hotspot (Mucina and Rutherford 2006). This reserve is an important center for biodiversity, providing indigenous and rare fauna and flora with natural habitat. For example, Sanbona Wildlife Reserve (SWR) has six recorded individuals of the critically endangered riverine rabbit (*Bunolagus monticularis*) and is currently the only reserve that provides sufficient space and protection for this species. Semi-arid regions are also notorious for their invertebrate and reptile

diversity (Mucina and Rutherford 2006) and this protection of biodiversity alone justifies the protection from degradation.

The study was conducted at the Sanbona Wildlife Reserve which is situated in the Warmwaterberg and the Langeberg valley (GPS 33°43'24" S, 20°36'55" E). There is a gradient of decreasing rainfall from the southern (420 mm per annum) to the northern (350 mm per annum) boundary of the reserve which is associated with a decrease in altitude from 720 m in the south to 220 m in the north. Rainfall occurs throughout the year, although there is a tendency for rain to fall in the winter months (Mucina and Rutherford 2006).

There are several vegetation communities within the three biomes in SWR, however the scope of the project only includes the four dominant vegetation types. These vegetation types are influenced by the rainfall gradient but also by the underlying geology and soils. In the northern part of SWR there are about 1,000 ha of Little Karoo Vygieveld which is characterized by quartz patches on the soil surface but is underlain by shale in places (Fig. 1A). The dominant growth forms are dwarf leaf succulents, such as *Gibbaeum* spp. and members within the family Crassulaceae. The Western Little Karoo (covering about 22, 000 ha) is similar in climate and geology to the Little Karoo Quartz Vygieveld. However, it is dominated by succulent shrub genera such as (*Crassuala, Ruschia* and *Tylecodon*) and non-succulent shrub genera such as (*Chrysocoma, Pentzia* and *Pteronia*) particularly on the northern slopes and hot dry valleys in the South of Sanbona (Fig. 1B). Included in this study is the Montagu Shale Renosterveld, which occurs on clays derived from the Bokkeveld and some Witteberg shales. A characteristic species is renosterbos (*Elytropappus rhinocerotis*) (Fig. 1C). The last vegetation type is previously transformed Renosterveld. This vegetation type was cleared for wheat production in the past and is therefore classified here as Old Lands (Fig. 1D). Together, the Montagu Shale Renosterveld and the Old Lands make up 26 000 ha. A more detailed summary of the vegetation types is depicted in Table 2.

3. Methods

3.1 *Vegetation Sampling*

Paired plots 30 x 30 m^2 in extent and five metres apart from each other were located in each of the four vegetation types shown in Table 2. One of the pairs was fenced with a 1.5 – 2 m high fence preventing medium and large ungulates from grazing the vegetation. The other plot was subject to grazing. Six pairs of plots were located in the Little Karoo Quartz Vygieveld (LKQV), 20 in the Western Little Karoo (WLK), four in the Montagu Shale Renosterveld (MSR) and four in the Old Lands (OL) giving a total of 68 plots.

Drop-point surveys (Roux 1963) were conducted to determine the vegetation composition and percentage cover for each species in each plot. In each plot 500 points were surveyed. These points were located 1 m apart along 20 lines which were 25 m in length in each plot. This approach follows Du Toit (1997) and reduces the degree of error versus the sampling time (Kraaij and Miltom 2006). Below each point on the line, the species name was recorded and the percentage hits were determined as a proportion of the total number of points in the survey. A palatability index was assigned to each species, based on the grazing potential of that species. Two field ecologists, as well as members from the Department of Agriculture carried out the field surveys, and identified the species. In the case of unidentified species, reference books were consulted and a sample was pressed and sent to the Bolus herbarium for positive identification. The recorded data was entered into a spreadsheet, where the percentage of hits for each species was calculated. Sampling started in 2004, with 20 plots being distributed in the four vegetation types. In 2005, 14 additional plots were added between LKQV and WLK . The LKQV and WLK analyses started in 2005 to minimise statistical errors in calculating ANOVA with repreated measures.

3.2 *Growth Form Composition*

Growth forms were assigned for each species based on the categories used by Schmiedel (1999) namely: annuals, grasses, geophytes, leaf-succulent shrubs (<50cm), stem-succulent shrubs, non-succulent shrubs and trees (>50cm). The mean cover for each growth form was recorded in each plot and tabulated in Table 6. One-way ANOVA's were conducted to test for significance between and within treatments for each growth.

3.4 *Palatability and Grazing Capacity*

Palatability indexes were assigned to each species based on an unpublished formula developed by Bruce Beyer, an experienced ecologist with 30 years experience in the region. The formula is based on the palatability preference of domestic livestock for different species but also takes environmental variables into account such as rainfall, ground cover and species composition.

Each species has an assigned index value, based on the amount of the plant generally consumed by animals. Highly palatable species have an index value of 90%, moderately palatable species have an index value of 50%. Slightly palatable species have an index value of 20% and are those species that are only consumed in certain seasons and only a limited portion of the species is

consumed by animals. Unpalatable species have no forage potential and therefore have an index value of 0%.

The empirical equation used to derive the palatability index is:

1) Percentage cover x Index Value = Product

The Product for all species in the plots are summed, to give the Useable Production.

2) Potential Production = (yearly rainfall – 20) x RUE

Where RUE (Rain Use Efficiency) = the quotient of the annual primary production (kg/DM/ha/year) by rainfall (mm/year) (Le Houérou *et al.* 1988).

3) Actual Production = (Useable Production/ 100) x Potential Production

4) Grazing Capacity for small livestock (ha/SSU) = 650/Actual Production

5) Grazing Capacity for large livestock (ha/LSU) = Grazing capacity x 7.14

This provides a good estimate of how many LSU (large stocking units) can be supported on the rangeland. The RUE relates the mean annual primary production to annual rainfall in order to predict fluctuations in carrying capacity from the variation in rainfall. RUE is described as a good indicator for range condition and productivity (Le Houérou *et al.* 1988). The state of the rangeland can therefore be assessed and monitored over time to detect trends in rangeland condition.

3.5 Grazing impact and dung biomass

In 2008 the potential grazing impact of indigenous herbivores was assessed in each plot by noting the type of dung and counting the number of pellets at each drop-point within each transect. Since dung size and shape is different for different species, the relative density of specific indigenous herbivores at each plot could be estimated by calculating a dung biomass index. A regression equation relating the number of pellets to mass (g) was developed for the dung of each herbivore species (Table 3). This was used to calculate the mass of dung for each herbivore species within each plot and provided an estimation of species utilisation within the different vegetation types.

3.6 *Data Analysis*

Differences in species richness and growth form cover between open and fenced plots and between years were assessed using analysis of variance (ANOVA) with repeated measures in STATISTICA version 8.

3.6 *Reciprocal Averaging Ordination*

The compositional change over time was depicted using summary data of all plots for 2004-2008. Using Community Analysis Package 2.13 (Pisces Conservation©) Reciprocal Averaging (RA) analyses were carried out for each vegetation type over the five years. The ordinations showed the movement of community composition through time, and provided an estimate of the degree of change within communities. Dominant species were recorded at each point, to indicate which species influenced the change in species composition.

4. Results

4.1 *Rainfall Data*

The mean annual precipitation (MAP) is 385mm, with winter receiving more rainfall (212mm) than summer (173mm) (Fig. 2). The highest recorded MAP is in 2005, with 617mm falling in that year. This year is preceded by below average rainfall in both winter and summer, and thus also below average for yearly precipitation. Rainfall in 2008 was above average in both winter and summer, with summer receiving 301mm.

4.1. *Vegetation Types*

The ordination of the 2005 data set clearly grouped sample sites into four distinct clusters (Fig. 3). which closely matched the vegetation type units defined by Mucina and Rutherford (2006). Surprisingly, the northern slopes and valleys in the Western Little Karoo were not distinctly separated, and a separate ordination with only this community type showed no separation of plant communities between the slopes and valleys. We therefore justify grouping the northern slopes and valleys into a single vegetation type, as there was no observable clustering. In addition, the Old Lands and the Montagu Shale Renosterveld clusters are more closely related to each other than they are to the Little Karoo Quartz Vygieveld. The Western Little Karoo and the Little Karoo Quartz Vygieveld are relatively closely related, which could be attributed to their similar geologies, rainfall and altitude.

4.2 *Vegetation change from 2004-2008*

The RA ordinations depict vegetation compositional change within a vegetation type, derived from the average cover of all species.

Little Karoo Quartz Vygievld

The species composition in the fenced and open plots did not diverge from each other during 2005-2007 (Fig. 4a). However, both paired plots diverged considerably from the previous sample periods and from each other in 2008. The species which most influenced the directional change in the open plots in 2008 were *Felicia muricata*, *Osteospermum clandestinum* and *Tylecodon walichii.* The fenced plots were dominated by *Ruschia sp.*, *Maytenus heterophylla* and *Anacampceros albidiflora* in 2008. These species reflect a mix of both palatable (e.g. *F. muricata*, *M. heterophylla*) and unpalatable (e.g. *Tylecodon wallichii*) or less useful fodder species (e.g. *A. albidiflora*).

Western Little Karoo

The floristic composition between fenced and open plots has not diverged significantly throughout the years (2004-2008) and show directional movement (Fig. 4b). Although the composition was similar in both fenced and open plots, the fenced plot composition in 2006 slightly diverged from the composition in 2005 and 2007. The greatest divergence is the floristic composition in 2008. Both fenced and open plots in 2008 diverged from the composition in previous years. The shift in composition in 2008 from previous years is due to *Sutera uncinata, Bulbine sp., Gibbeaum velutinum* and *Oesteospermum clandestinum*. These species are not functionally different from those dominating in previous years with *Tetragonia fruticosa, Berkheya cuneata* and *Crassula subphylla* and other *Gibbeaum* and *Mesembryantheceae* species.

Montagu Shale Renosterveld

The floristic composition in the MSR showed similar trends as the WLK and LKQV, where both paired plots did not deviate from one another (Fig. 4c). Again, a large change in composition in 2008 was depicted. The species responsible for the change in composition in 2008 include *Pteronia, Helichrysum* and *Felicia* species.

Old Lands

The paired plots in the OL have moved closely together throughout the years (Fig. 4d). In contrast to the other vegetation communities, the Old Lands' composition is curling in on itself between 2005-2007, and shows weak progressive change in composition prior to 2008. The species

predominantly responsible for the composition in 2004 are *Delospermum pageanum* and *Selago sp.*. In 2008, the main species causing directional change are *Pteronia* and *Viscum sp.* The open and fenced plots show no significant differences in compositional change between treatments throughout the years.

4.3 *Changes in Species Richness and Cover*

Little Karoo Quartz Vygieveld

Species richness showed non-significant differences between the two treatments (Fig. 5a). There was a significant difference in species richness between years within treatments ($p<0.001$, $n=4$, $F=18.29$) (Table 4). The combined effect of year and treatment expressed as the interaction term was non-significant (Table 4). The total plant cover in the LKQV was non-significant between treatments (Fig. 6a). However, there was a significant difference within treatments between years ($p<0.001$, $n=4$, $F=6.94$). The interaction effect of year and treatment combined was significant ($p<0.001$, $n=4$, $F=10.23$).

Western Little Karoo

There were no differences in species richness between the fenced and open plots in the WLK, although species richness differed significantly between the years ($p<0.001$, $n=4$, $F=38.23$) (Fig. 5a., Table 4) There was no interaction effect of year and treatment on species richness. In terms of total plant cover, there were no differences between treatments. The total plant cover changed between years within a treatment ($p<0.01$, $n=4$, $F=3.32$) and the interaction of year and treatment was significant ($p<0.001$, $n=4$, $F=6.78$).

Montagu Shale Renosterveld

There was no significant difference in species richness between treatments (Fig. 5c). There were, however, significant differences within a treatment between the years ($p<0.001$, $n=5$, $F=23.2$) (Table 4). There was no significant difference in species richness when the effects of year and treatment were combined. Total cover was non-significant between treatments (Fig. 6c). Total cover was statistically significant between years with a treatment ($p<0.01$, $n=5$, $F=3.95$), with the fenced plots in 2005 (Table 4). The interaction variable was significant ($p<0.05$, $n=5$ $F=3.04$). This community type also had a significant difference between treatments in 2005, with the open plots having 70% total species cover, as opposed to 50% in the exclosures ($p=0.01$, $n=32$, $F=13.297$). This MSR had the highest total cover from all four vegetation types, with the total cover of fenced and open plots being 65.6% and 60.8% respectively.

Old Lands

Species richness was not different between the fenced and open plots (Fig. 5d). There was a significant difference in species richness between years within a treatment ($p<0.001$, n=5, F=6.14) (Table 4). The interaction effect of year and treatment was non-significant. There was no difference in plant cover between the fenced and open plots (Fig. 6d, Table 4). Total cover between years within a treatment was significant ($p<0.001$, n=5, F=6.69). There was a significant effect on total cover when treatment and year was combined ($p<0.01$ n=5, F=5.1).

4.4 *Changes in Growth Form Assemblages (2004-2008)*

Little Karoo Quartz Vygieveld

The dominant growth forms in the Quartz Vygieveld are leaf-succulent (LS) and non-succulent (NS) shrubs, which is a characteristic growth form for this vegetation type. Growth form composition for all growth forms did not change between treatments in the LKQV (Table 4). Only non-succulent shrubs showed significant differences in growth form composition between the years ($p<0.01$, n=4, F=4.19). The only intercept variable that showed significant differences in growth form is for non-succulent shrubs ($p<0.001$, n=4, F=4.5). Geophytes and grasses were completely absent in this vegetation type.

Western Little Karoo

There was no difference in growth form composition between the fenced and open sites for any growth form (Table 4). Annuals were significantly different between years within a treatment ($p<0.001$, n=4, F=8.90), with an increase to 3% in the fenced plot and 5% in the open plots in 2006. Although non-significant between treatments or the combined interaction variables, grasses were significantly different between years ($p<0.01$, n=4, F=4.75) (Table 4). Leaf-succulent shrubs were significant between years within a treatment ($p<0.001$, n=4, F=7.23) (Table 4) and the interaction effect of year and treatment also resulted in a significant difference is LS growth form composition ($p<0.001$, n=4, F=11.02), with the fenced plots noting a decrease in LS from 23% in 2004 to 14% in 2007 (Table 4). Differences in stem-succulent shrubs were statistically significant between years ($p<0.001$, n=4, F=6.4) and when treatment and year was combined ($p<0.001$, n=4, F=3.7).

Montagu Shale Renosterveld

Growth form compositional differences were non-significant between treatments for all growth forms (Table 4). The most dominant growth forms are non-succulent shrubs, contributing over 40% of the total cover. Annuals showed a significant difference between years within a treatment

($p<0.001$, $n=5$, $F=5.90$) with an increase in 2006 to 3% and 5% in fenced and open sites respectively (Table 4). Trees showed significant differences between years ($p<0.01$, $n=5$, $F=4.15$). Geophytes and stem-succulent shrubs were completely absent from this vegetation type.

Old Lands

There was no difference in growth form composition between treatments in the Old Lands (Fig. 6d). Annuals increased from 5% and 8% in 2006 and grasses appeared in both treatments from 2007 (Table 4). These findings were supported by the ANOVA, as there was a significant difference between years ($p<0.01$, $n=5$, $F=4.05$ and $p<0.01$, $n=5$, $F=3.81$) (Table 4). Although leaf-succulent shrubs showed no difference between treatments or between years, the interaction of these two variables was significant ($p<0.05$, $n=5$, $F=3.08$) (Table 4). Non-succulent shrubs and trees differed between years ($p<0.001$, $n=5$, $F=6.59$ and $p<0.01$, $n=5$, $F=3.80$).

4.5 *Changes in Grazing Capacity between treatments (2004-2007)*

Grazing capacities were calculated as ha/LSU, thus providing managers with an estimate of the amount of land needed to support one stocking unit. There were, however, stark differences between the vegetation types to support grazers and browsers.

Little Karoo Quartz Vygieveld

There was no difference between treatments or between years within a treatment in the LKQV (Fig. 7a). However, this vegetation type has the lowest grazing capacity, with exclosures sites needing 100 ha/LSU (SD±8.5) and the open sites needing 98 ha/LSU (SD±5.9). This vegetation types is therefore the least productive.

Western Little Karoo

The Western Little Karoo had an intermediate grazing capacity compared to the other vegetation types. There were no significant differences between fenced and open growth form compositions (Fig 7b, Table 5). Although there were significant differences between years ($p<0.001$, $n=4$, $F=7.28$) obvious increase or decreases in grazing capacity between years were not depicted (Fig. 6b). The interaction effect of year and treatment showed a significant difference ($p<0.001$, $n=4$,$F=6.71$) (Table 5). The fenced plots were surprisingly less productive, with 48 ha/LSU (SD±3.6) needed as opposed to 39.3 ha/LSU (SD±2.1) in the open sites.

Montagu Shale Renosterveld

The highest grazing capacity was not surprisingly the Montagu Shale Renosterveld. The open sites had a mean grazing capacity of 21 ha/LSU (SD±0.7), while the fenced plots had 19.5 ha/LSU (SD±2). There were no significant differences between treatments, years or interaction variable (Fig. 7c, Table 5).

Old Lands

The mean ha/LSU is 21 (SD±2.8) for the fenced and 23 (SD±2.8) for the open sites. There was no significant difference between treatments, although there was a significant difference in grazing capacity between years within a treatment ($p<0.05$, $n=4$, $F=3.42$) (Fig. 7d, Table 5).

4.5 *Dung Counts*

Little Karoo Quartz Vygieveld

The dung counts provide an estimated biomass index and vegetation preference of grazers. Although the Little Karoo Quartz Vygieveld had the least number of grazer species, (only three species: Steenbok, Springbuck and Eland), there was a strong preference of Springbuck on this vegetation type with over 103g of Springbuck dung being recorded. The LKQV had the least total biomass recorded (103g) (Table 6).

Western Little Karoo

Conversely, the Western Little Karoo had the highest total biomass (603g) and the greatest species diversity, with faeces from all seven species (Steenbok, Springbuck, Haartebeest, Gemsbok, Eland, Zebra and Elephant) being collected from the sites (Table 6). Although Eland visited 85% of the plots, the amount of biomass was the highest (159g) for a single species. Springbuck dung was found on all fenced plots.

Montagu Shale Renosterveld

The Montagu Shale Renosterveld had the greatest frequency of species (Table 6). However, the total biomass of these species was lower than other vegetation types, with Springbuck 37g, Eland 120g and Zebra 45 g.

Old Lands

The Old Lands depicted the same species preference to MSR, with Springbuck, Eland and Zebra dung occurring in all plots (Table 6). The Old Lands had the greatest total biomass index (735g).

5. Discussion

The influence of indigenous herbivores on the Little Karoo

5.1 Differences between fenced and open plots

Opinions on the effects of grazing on plant communities differs amongst researchers, where the degree of grazing can have positive feedback effects, such as stimulating plant diversity (Shaltout *et al.* 1996) to the adverse effects of reduced cover, decline in diversity and compositional shifts (Anderson & Hoffman 2007). This study aimed to investigate plant community responses to grazing of indigenous ungulates in a previously farmed, winter-rainfall region. Our key finding is that vegetation composition, species richness, total cover, growth form composition and grazing capacity did not differentiate between the fenced and open plots. The impacts of grazing are therefore not detected in this study.

The lack of significant differences between fenced and open plots can be attributed to the very low stocking rates of indigenous ungulates on SWR. Up to present, the stocking rates have been maintained at very low densities, with a maximum number of animals being reported in 2006, with 2227 individuals, however the stocking rates are increasing in winter 2008. Exact numbers are not known. Stocking rates are derived from vehicle and foot surveys, as well as aerial counts. The low densities are therefore adequate and encouraged because the veld has the capacity to support current grazers. However, Sanbona is currently in the process of a significant re-introduction programme, with an additional 3000 head of animals being introduced in the winter of 2008. The effects of the increase in stocking rates on the vegetation will therefore only be identified in the September 2009 survey, thus reiterating that this is a baseline study for the potential impacts of future stock increases.

Semi-arid regions such as the Little Karoo recover slowly from grazing-mediated disturbances and can take between 20-50 years for original vegetation to recolonise after prolonged heavy grazing (Allen-Diaz and Bartolome 1998). In comparison to our study, Gallacher and Hill (2006) found a significant difference in plant cover between rangelands subjected to camel and only wildlife grazing in just five years in Dubai. Five years in this region was therefore sufficient to cause significant compositional change. However, this was attributed to the loss of cover in the camel sites, and not due to the recovery of vegetation in the wildlife reserve. Also, Dubai is a lot more arid than the Karoo, receiving an average of 93.8mm annually, compared to an average 300 mm in SWR. The vegetation is also compositionally and functionally dissimilar in Dubai. Mobile sand dunes, which makes vegetation establishment difficult and the camels were grossly overstocked (960 camels in 225km^2) for the amount of vegetation. Burke (1997) also found a significant

difference in composition between grazed and non-grazed sites over 18 years in Namibia. The region is similar to Dubai, with 50-100mm MAP and mobile sand dunes probably affected vegetation establishment. The two studies suggests that the difference in aridity may be the underlining cause for the large differences in change in Dubai, and the lack of change over 5 years in our study.

Case studies of similar aridity (230-300 mm MAP) show significant changes in vegetation cover and/or composition. This suggests that studies of local and global comparisons have other fundamental processes that govern vegetation productivity and change other than rainfall. While we found no significant changes, Kraaij and Milton (2006) found that changes in composition, cover and species richness was greater in exclosures over 10 years. The vegetation and climate is very similar to our study site, and both regions were grazed by wild ungulates. However, the stocking rates were above the recommended values for 9 of the 10 years in the Karoo National Park (Kraaij and Milton 2006). The incorrect stocking rate is likely to add increased pressure on the Karoo vegetation and change is likely to be more rapid. Thus, the grazing intensity is the primary factor contributing to vegetation change as high densities in this environment caused significant vegetation change in only 10 years.

The study of Rahlao *et al.* (2008) was similar in principle to our study by investigating the effect of rest from grazing over 67 years on and off termitaria. The study showed that greater changes of cover and species composition termitaria. Given similar vegetation types and rainfall regime to our study, we suggest that our timescale (5 years) is unlikely to be sufficient to depict vegetation change. But, it is imperative to acknowledge the time it takes to detect recovery is determined by a multitude of factors, (e.g. stocking rates, aridity, level of vegetation degradation) and a 'long enough' study of 10 years will not necessarily depict compositional change. For example, Gardner (1950) found no difference in species composition over a 30 year period of livestock exclusion in New Mexico. Similarly, Ryerson and Parmenter (2001) found no directional change in New Mexico between grazed and non-grazed vegetation by cattle and prairie dogs over 20 years. The lack of change could be due to several reasons, including the resilience of that specific vegetation to grazing or low animal densities, or a combination of the two.

The underlying cause for these differences in vegetation response to grazing between case studies is outlined by the state-and-transition model. Succession theory as a means of understanding vegetation dynamics has been replaced in favour of the non-equilibrium state-and-transition model (Westoby *et al.* 1989, Milton *et al.* 1994, Gillson & Hoffman 2007). This is largely because

responses in the vegetation dynamics of semi-arid rangelands are rarely linear or reversible (Vetter 2005). Semi-arid rangelands also have multiple ecological states as a result from a complex interaction between slow (e.g. soil fertility) and fast (e.g. rainfall variation) variables operating at different temporal and spatial scales (Reynolds *et al.* 2007). Because several thresholds exist in non-equilibrium systems, crossing a threshold of one variable can alter the state of the system. Thus, rangelands have many potential 'states' (e.g. plant assemblages) and the transitions between these states suggests that thresholds exist between these different state changes (Vetter 2005, Friedel 2000, Reynolds *et al.* 2007).

Friedel (1991) defines a threshold as the boundary in space and time between two states where the initial shift across the boundary is irreversible without management intervention. An added complexity to rangeland management is the degree of variation within a system before such a threshold is crossed. Thresholds are clearly different between systems, as depicted by the aforementioned case studies where, for example, significant cover reduction was observed within 5 years in response to Camel grazing in Dubai, but livestock grazing in New Mexico showed no differences in 30 years (Gardner 1950). Gillson and Duffin (2007) developed the concept of thresholds of potential concern (TPC), which are monitoring end-points that define the upper and lower limits of a threshold. In other words, rangelands are variable at different scales and the ecological state depends on the thresholds of the multiple variables. Rangelands therefore are not at equilibrium, where several states and transition possibilities result in a multitude of ecological states. Therefore, the different vegetation responses to grazing across rangelands can be explained by Westoby *et al.* (1989) state-and-transition model, as each ecological state is a product of the complex interactions between variables, and their respective thresholds.

There was no observed significant difference between fenced and open treatments in vegetation composition or growth from within the four plant communities. This suggests that the stocking densities are low enough to cause no detectable impact on the vegetation. Although the ordinations did depict a dynamic nature of the vegetation, the state of the vegetation did not show a distinct transition from one state to another. It is important to acknowledge that the Little Karoo vegetation is not static, and is notorious for its variety of plant species (Shearing 1994). However, the changes in composition and growth form remains within range of the natural variability in those vegetation types. There is no indication that the vegetation has gradually improved, or worsened, as the species present are functionally similar and still largely the ones present prior to monitoring.

5.2 Changes between years

There was a large difference in floristic composition in 2008 in all four vegetation types. Karoo communities are characterised by leaf succulents with a short life history of 5-15 years (Gotzmann *et al.* 1999). The study has been ongoing for 5 years and therefore it is possible that recruitment and/or mortality have caused the change in composition. However, the same consistent trend was observed across all vegetation types, and such consistent mortality and recruitment is unlikely to occur on all vegetation types simultaneously. Because the stock introduction is still in process and all four vegetation types showed the same response, the increase in ungulate density is unlikely to cause such a significant change. There was, however, a large increase in total rainfall in 2008, with the summer rainfall being exceptionally high (301mm). The previous two years had poor rainfall and the change in composition in 2008 may be a vegetation response to good rainfall after a two-year drought. Vegetation responses, such as the opportunistic establishment of short-lived species, to increased rainfall is depicted by the increase in annuals in all vegetation types, except the LKQV, in 2006 after the high rainfall event in 2005.

The differences in species composition in 2008 may have been due to opportunistic seedling establishment or growth in response to rain. In the Succulent Karoo the above-ground growing season is predominantly during the winter months (April-September) because precipitation below 10 mm during summer inhibits growth (Esler and Rundel 1999). This winter growth and flowering is likely to have impacts on forage production and availability. Productivity of the landscape is low, and animals will consume year-long accumulated growth in a short period if forced to do so (Erasmus unpublished). In Sanbona, total summer rainfall was only 36mm in 2006, and was 125mm in 2007. Although this rainfall was not below 10mm and thus may not have inhibited growth as in the Succulent Karoo, the rainfall was far below summer average (173mm) and could have inhibited growth of species intolerant to drought. Our findings suggest that it is both the timing and amount of rainfall that is important for driving species composition. This is in accord with water availability during the growing season significantly limiting growth, flowering and seed production in the Karoo shrub *Pteronia pallens* and *P. empetrifolia* (Milton 2005).

In most semi-arid regions, vegetation composition can be altered with a single rainfall event (Hoffman 1989). The large compositional change in 2008 is attributed to the large increase in summer rainfall because all four vegetation types were affected in the same way (i.e. all had large differences in 2008) and rainfall in both winter and summer was above average. Compositional change was therefore attributed to increased rainfall event preceding a two-year drought.

5.3 Animal Behaviour

The dung counts provide an estimated biomass index and vegetation preference of grazers. Results were different to what was expected. Renosterveld occurs on moderately fertile, fine-grained soils (Walton 2006) and it is therefore not surprising that this high fertility couples with higher productivity in terms of grazing capacity. However, dung biomass was weakly correlated with grazing capacity, where the MSR, the most productive, had the second least biomass, despite the greatest number of grazer species visiting the vegetation type. Old Lands, despite their former overutilization, support a high proportion of palatable plan species. The high grazing capacity for the Old Lands is not surprising, as it is transformed Renosterveld and the grazing capacity is an indication of this regions productivity, which is likely to be the reason why previous owners used this vegetation as a rangeland. However, despite being previously transformed, the Old Lands have the most biomass index which suggests that animals are heavily utilising this vegetation type.

Interestingly was the large presence of Springbuck in the LKQV with the number of visits accounting for over 70% from all vegetation types. There was noticeable although isolated disturbance from springbuck on these plots, with patches of bare soils sporadically distributed (Appendix A). Springbuck are known to use pans for social interactions and dust baths, and their trampling may play a role in maintaining the low canopy cover by uprooting small plants (Milton *et al.* 1992). This may explain why the total cover in the open plots in the LKQV is approximately 5% lower than the fenced sites.

An interesting finding was that Karoo bush rats (*Otomys unisulcatus*) and the Whistling rats (*Parotomys brantsii*) preferred to build their nests in the fenced plots, possibly due to the protection or lack of trampling disturbance. Rats only occurred in 3 plots (13, 14, 19), however, they were always more frequent in the fenced plots (e.g. plot 14 had three nests in the fenced and one in the open). The disturbance by these rats was noticeable, with all the palatable species (e.g *Tripseris sinuata*) in plot 19 being completely overgrazed (Appendix A). Baboons also disturbed the species composition and cover by uprooting *Gibbeaum pubescence* and other succulents to eat the bulbs, corms and insects that live in them, although this never occurred within the fenced plots (Dean and Milton 1999) (Appendix A). The fenced plots are therefore not resistant to disturbance, and management cannot ignore the effects of small herbivores.

6. Conclusion

According to the Management Plan, Sanbona's objectives are to manage the vegetation to ensure maximum productivity for wildlife utilisation, while simultaneously maintaining ecological integrity. Overstocking is seen as one of the three main threats, along with illegal harvesting of

succulents and off road driving. This study functions as a baseline study with which the impacts of future overstocking will be compared against. This study shows that five years with the current (low) stocking rate is insufficient to detect significant vegetation change between grazed and protected sites in the semi-arid Little Karoo rangeland. However, the potential impacts on vegetation dynamics should be considered when introducing more stocks, as grazing capacity can be significantly reduced within 10 years in the Karoo with inappropriate stocking rates (Kraaij and Milton 2006). Our results reflect the notoriously slow response of vegetation to rest from grazing but also demonstrate the rapid compositional change in response to an abnormally high summer and winter rainfall event following a two-year drought. Although vegetation is changing, statistically significant differences were not found. SWR is in good condition and the grazing capacity is sufficient to support an increase in stocking rates. We suggest that it is crucial that the owner of Sanbona adheres to the guidelines in the Management Plan, as literature has demonstrated the effects of inappropriate stocking rates on this vegetation (e.g. Rahlao *et al.* 2008, Kraaij and Milton 2006).

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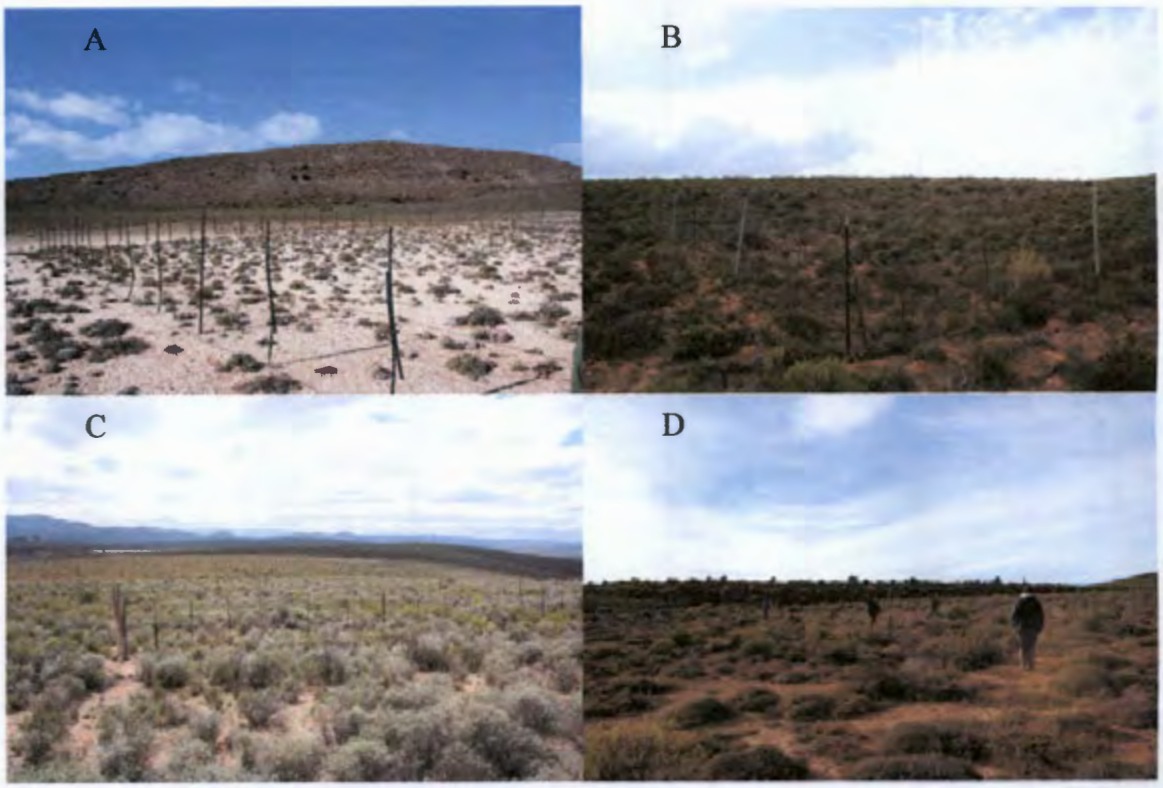

Figure 1: Fenced plots on the four vegetation types, a) Little Karoo Quartz Vygieveld, b) Western Little Karoo, c) Montagu Shale Renosterveld, d) Old Lands. The vegetation of these four types is distinctly different, with a) quartz fields with mesembs and dwarf succulents, b) dominated by knee-high shrubs, c) having many palatable species, including *Pentzia incana* and d) degraded Renosterveld, with more noticeable bare patches

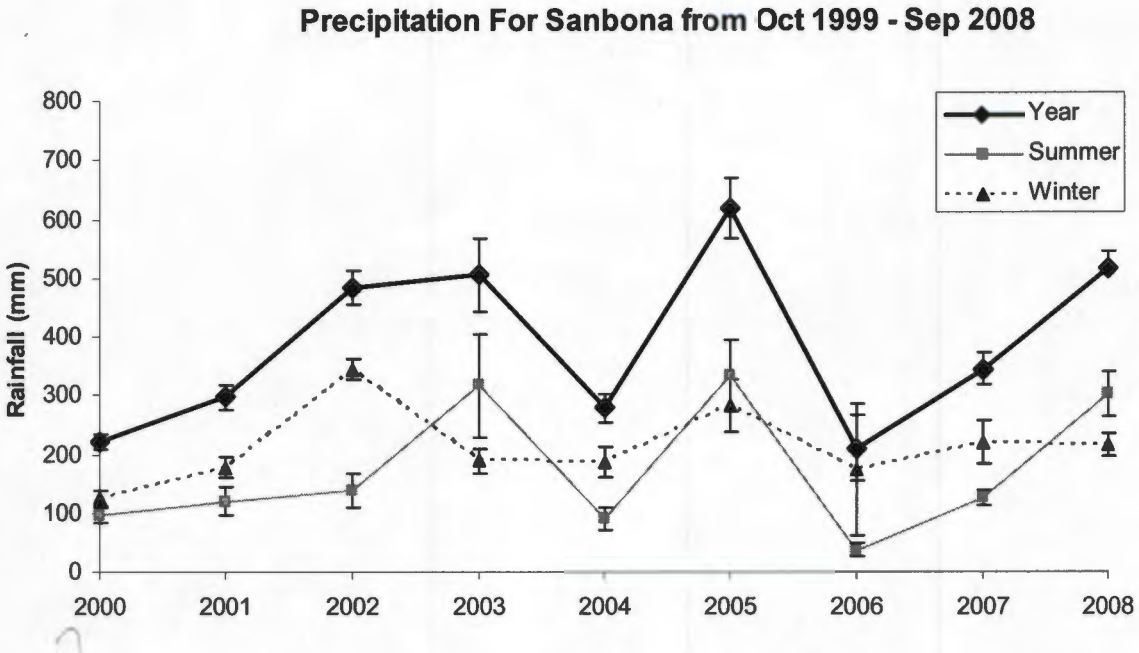

Figure 1: Mean and Seasonal rainfall data from October 1999 to September 2008 in Sanbona Wildlife Reserve. Symbols and bars represent means and ±SD. Summer is defined as October to March and Winter from April to September. There was a peak in rainfall in 2005, with drought occurring between 2006 and 2007. Rainfall in 2008 was above average both total and seasonally.

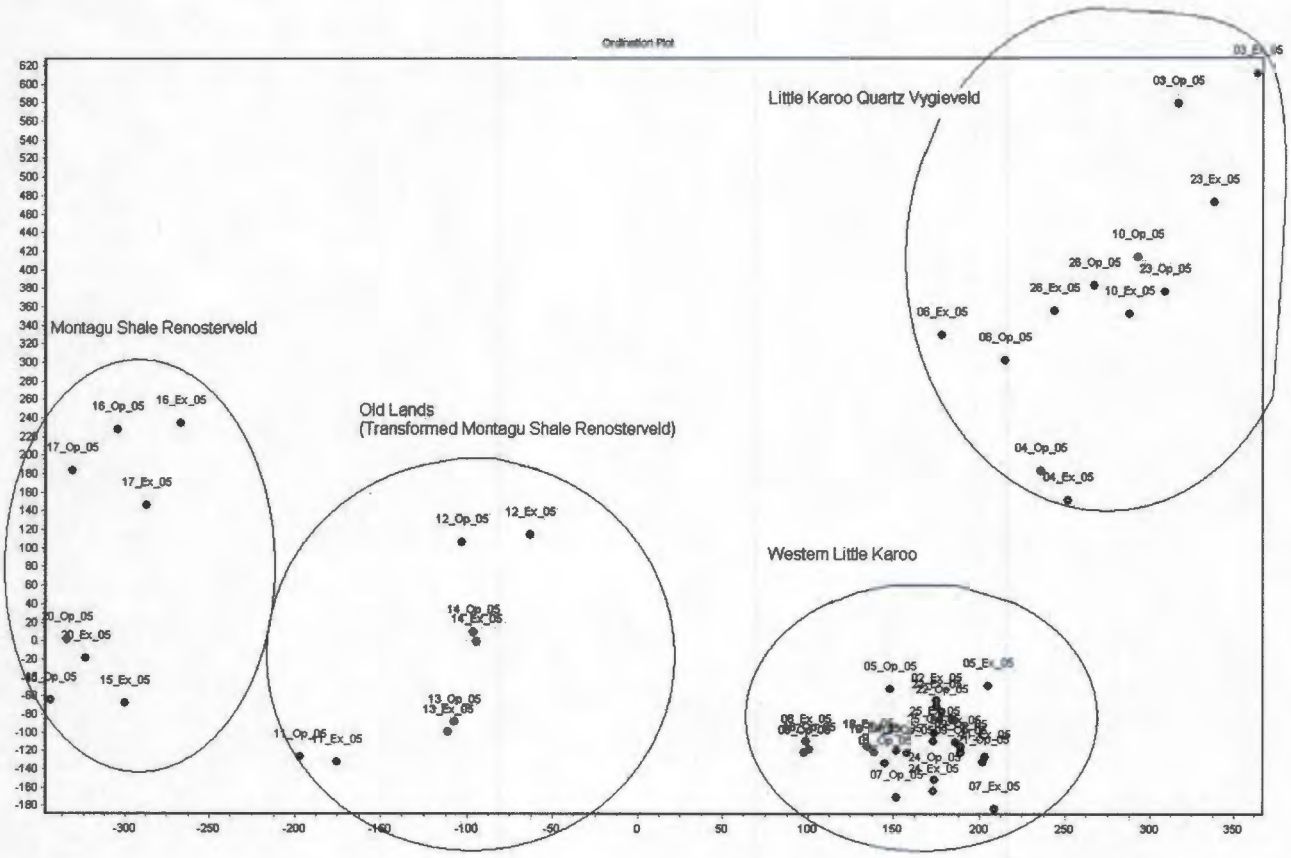

Figure 2: Ordination of sample sites in 2005 into separate communities using Reciprocal Averaging. Increased distance between plots represents greater dissimilarities. The four vegetation communities showed distinct clustering and are marked on the ordination.

Fig. 3 a

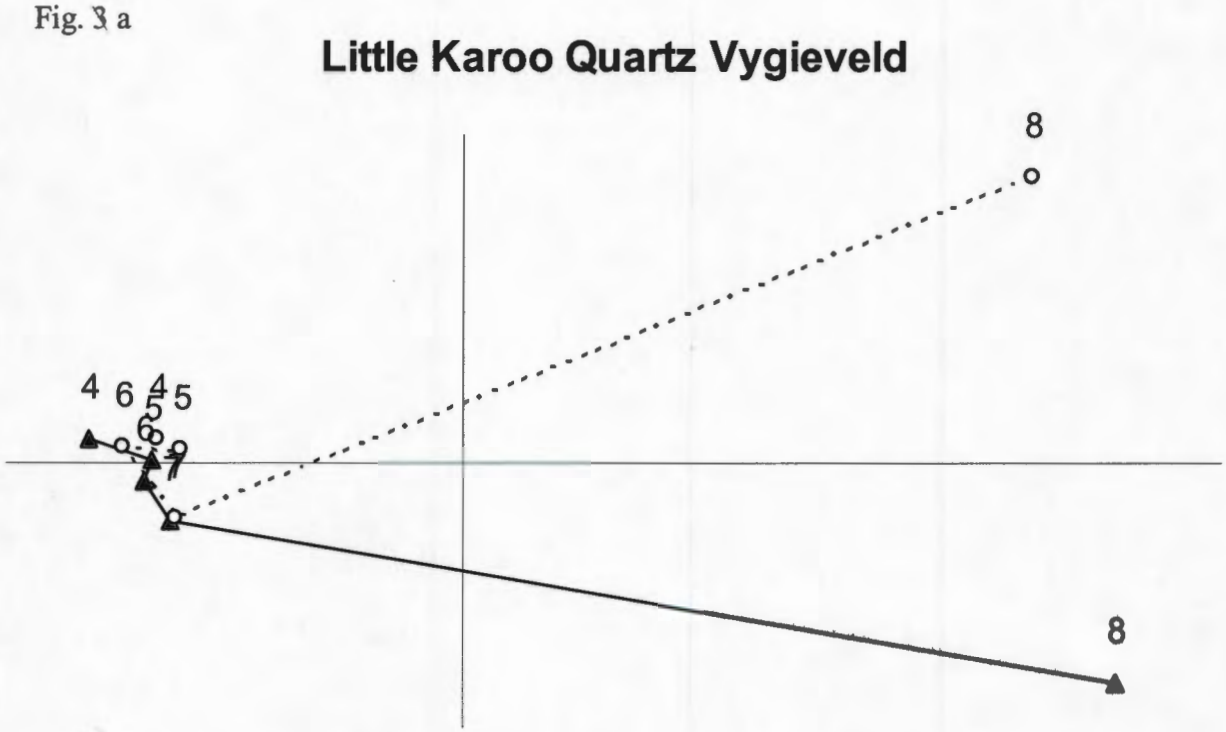
Little Karoo Quartz Vygieveld
8
4 6 4 5
8

Fig. 3 b

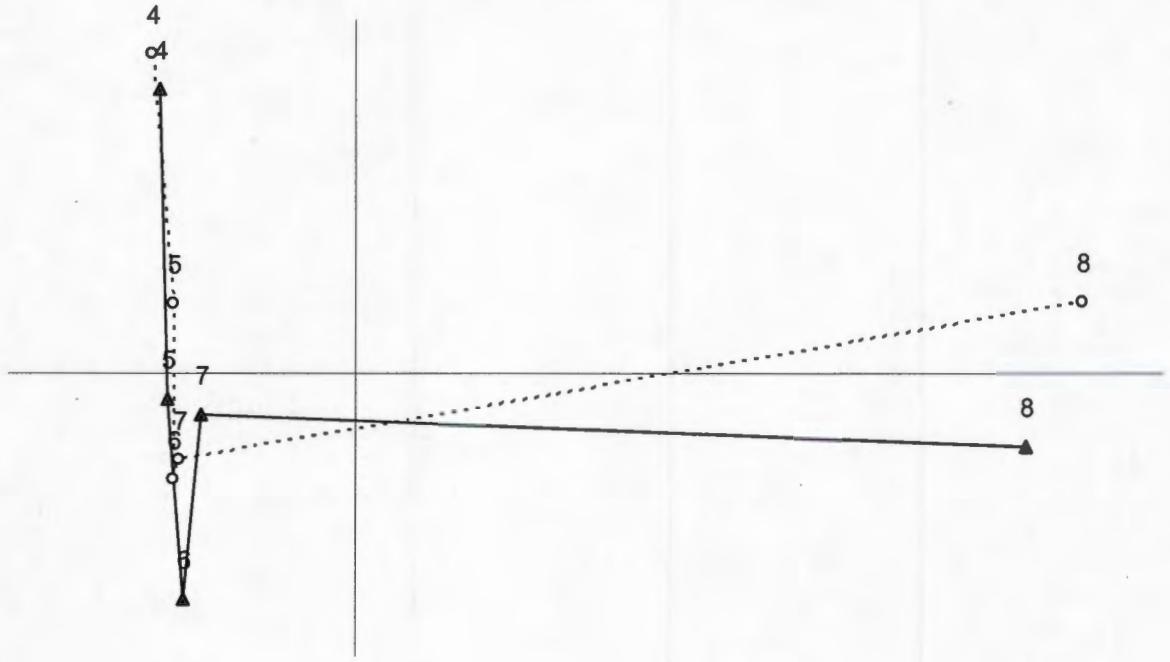
Western Little Karoo
4
4
8
7
8

Fig. 3 c

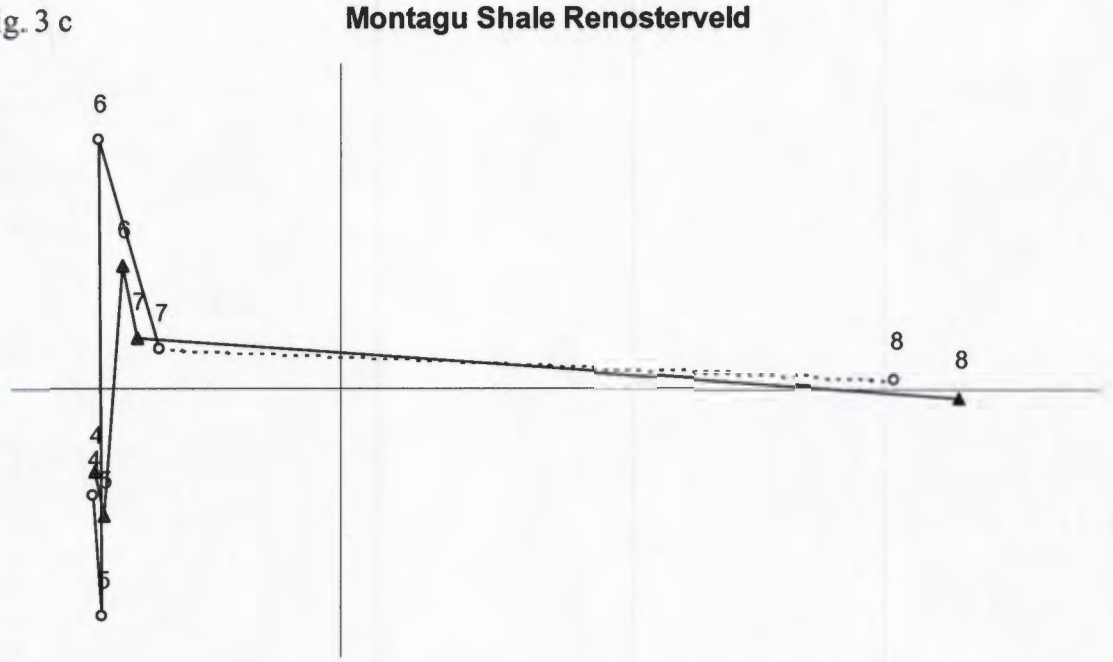

Fig. 3 d

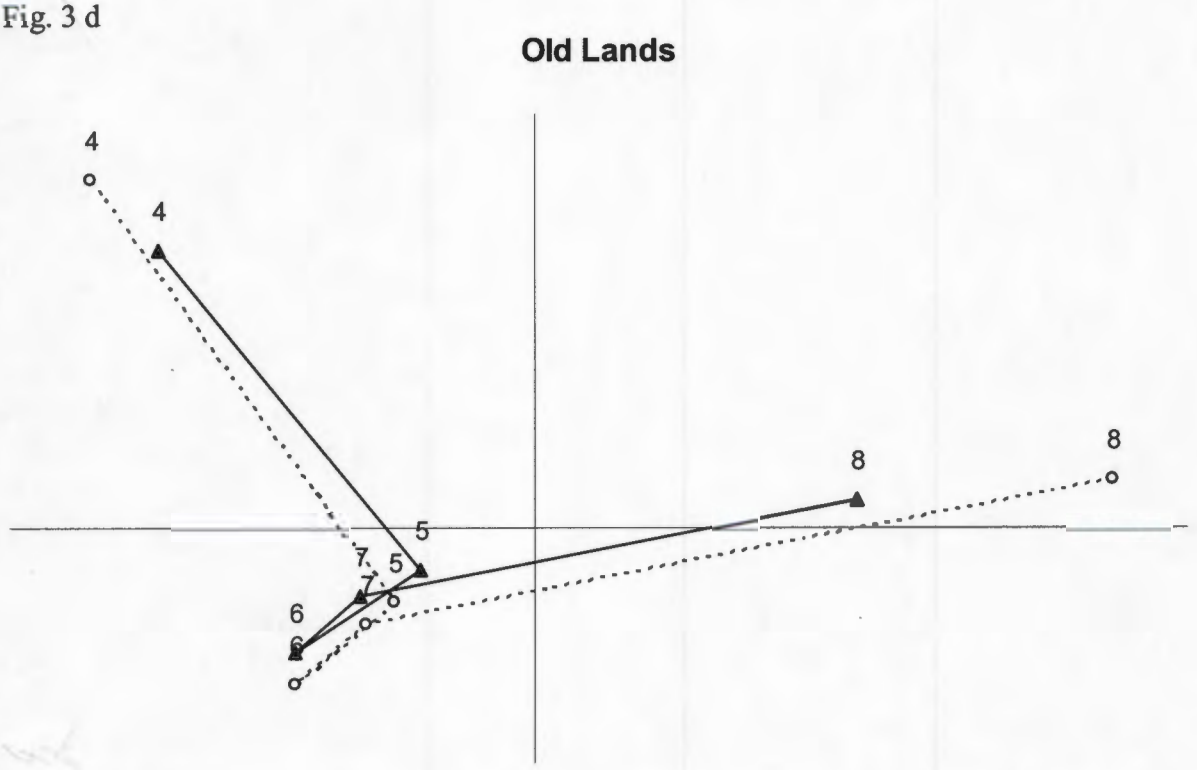

Figure 3: Ordinations of compositional change over time using summary data for all plots for 2004-2008. Numbers represent the year (4 = 2004, 5 = 2005, 6 = 2006, 7 = 2007, 8 = 2008). Open circles with dashed lines represent the open plots and the solid triangles with solid lines represent the fenced plots. Symbols and bars represent means and ±SD. Both fenced and open plots moved closely together, although there is a noticeable deviation in floristic composition in 2008 amongst all vegetation types.

Fig. 4 a

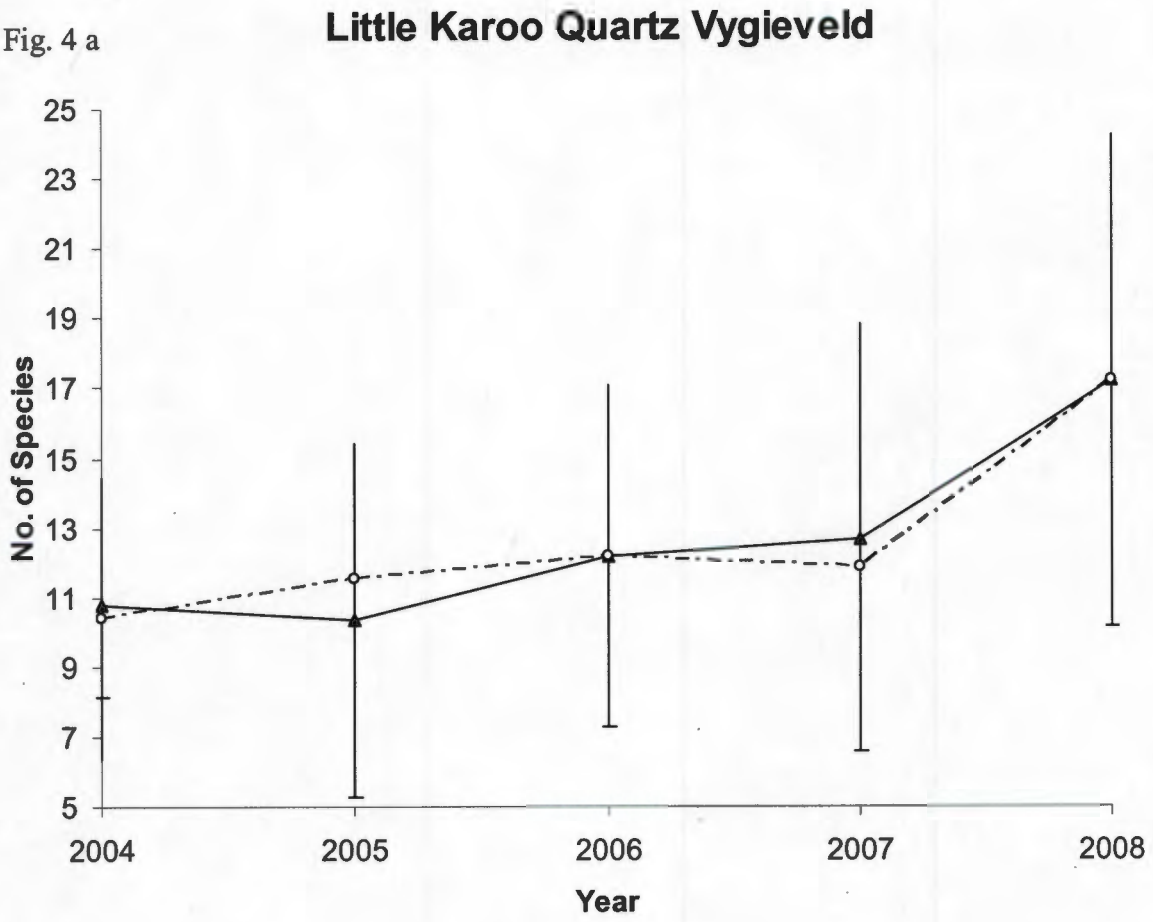
Little Karoo Quartz Vygieveld
No. of Species
25
23
21
19
17
15
13
11
9
7
5
2004
2005
2006
2007
2008
Year

Fig. 4 b

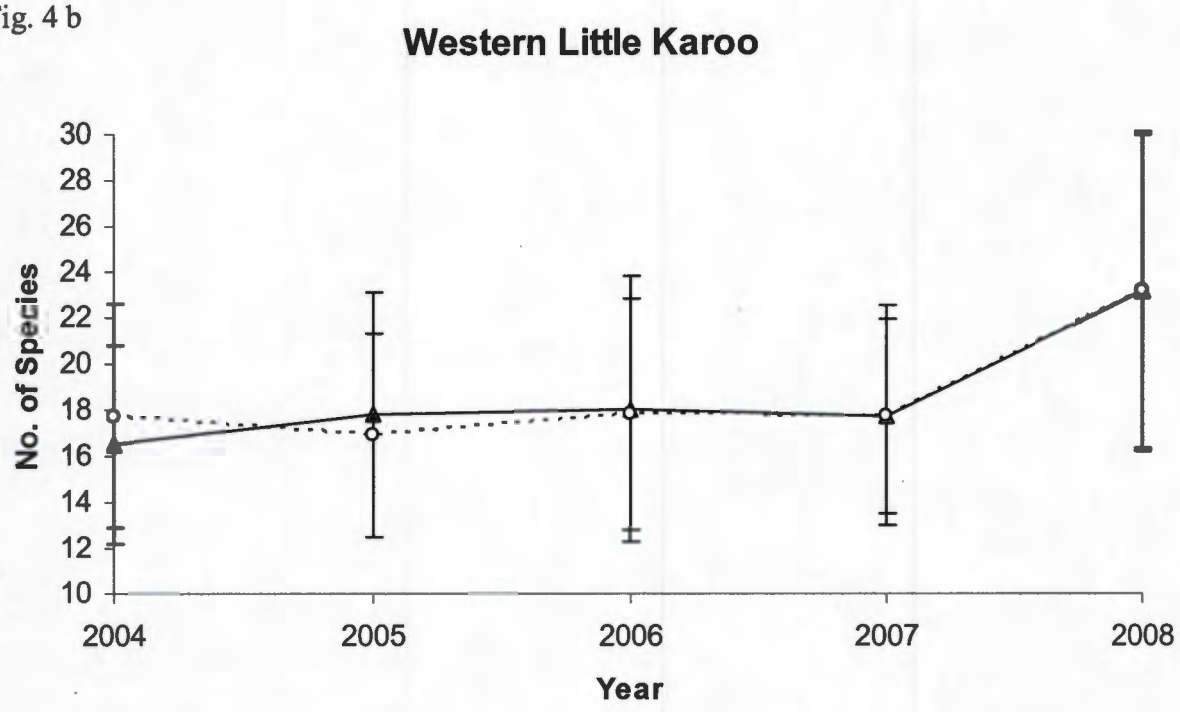
Western Little Karoo
No. of Species
30
28
26
24
22
20
18
16
14
12
10
2004
2005
2006
2007
2008
Year

Fig. 4 c

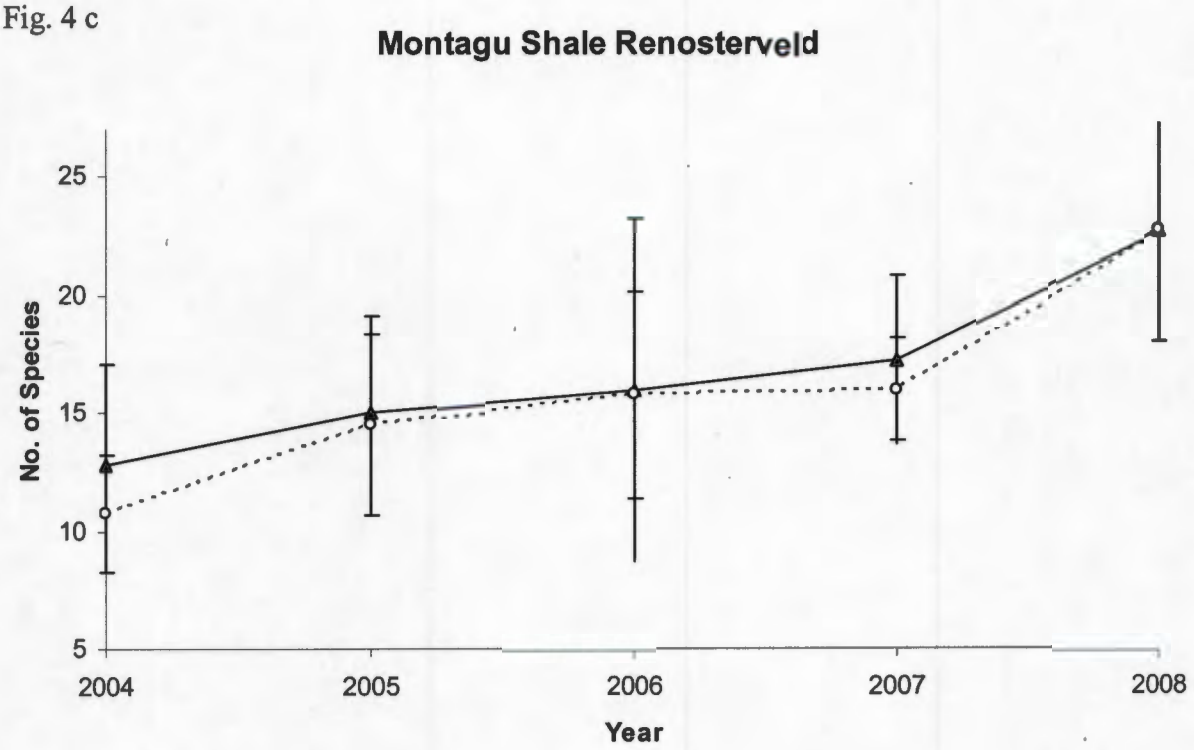

Fig. 4 d

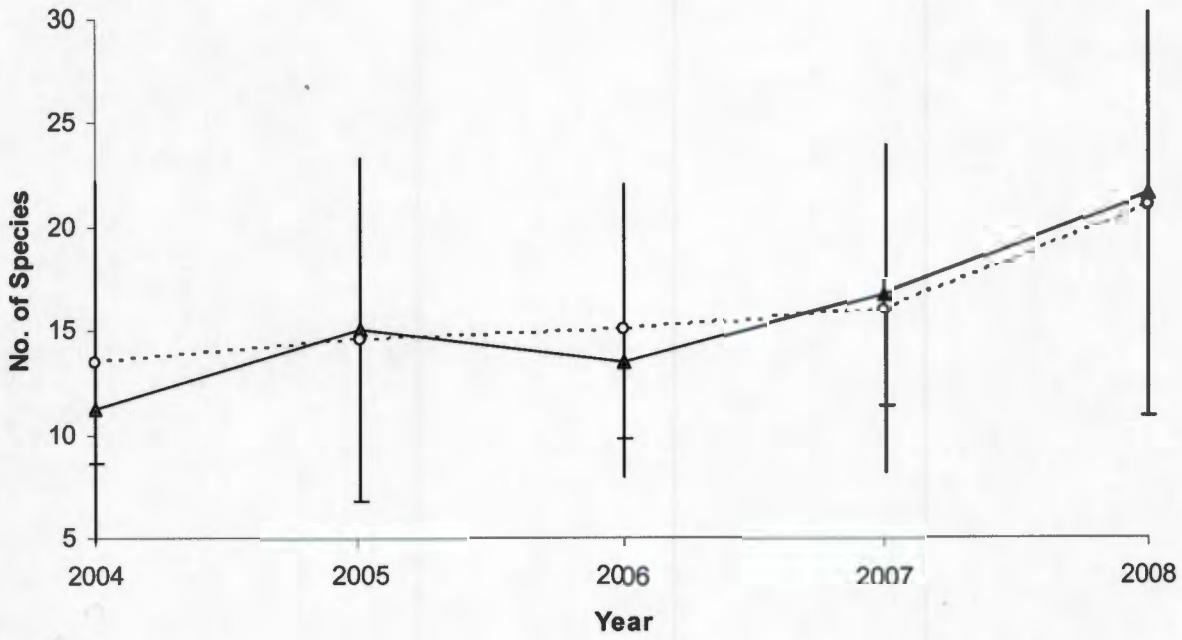

Figure 4: Changes in species richness (2004-2008) in fenced and open sites in four vegetation types in Sanbona. Species richness did not change between treatments. Open circles with dashed lines represent the open plots and the solid triangles with solid lines represent the fenced plots. Symbols and bars represent means and ±SD.

Fig. 5 a

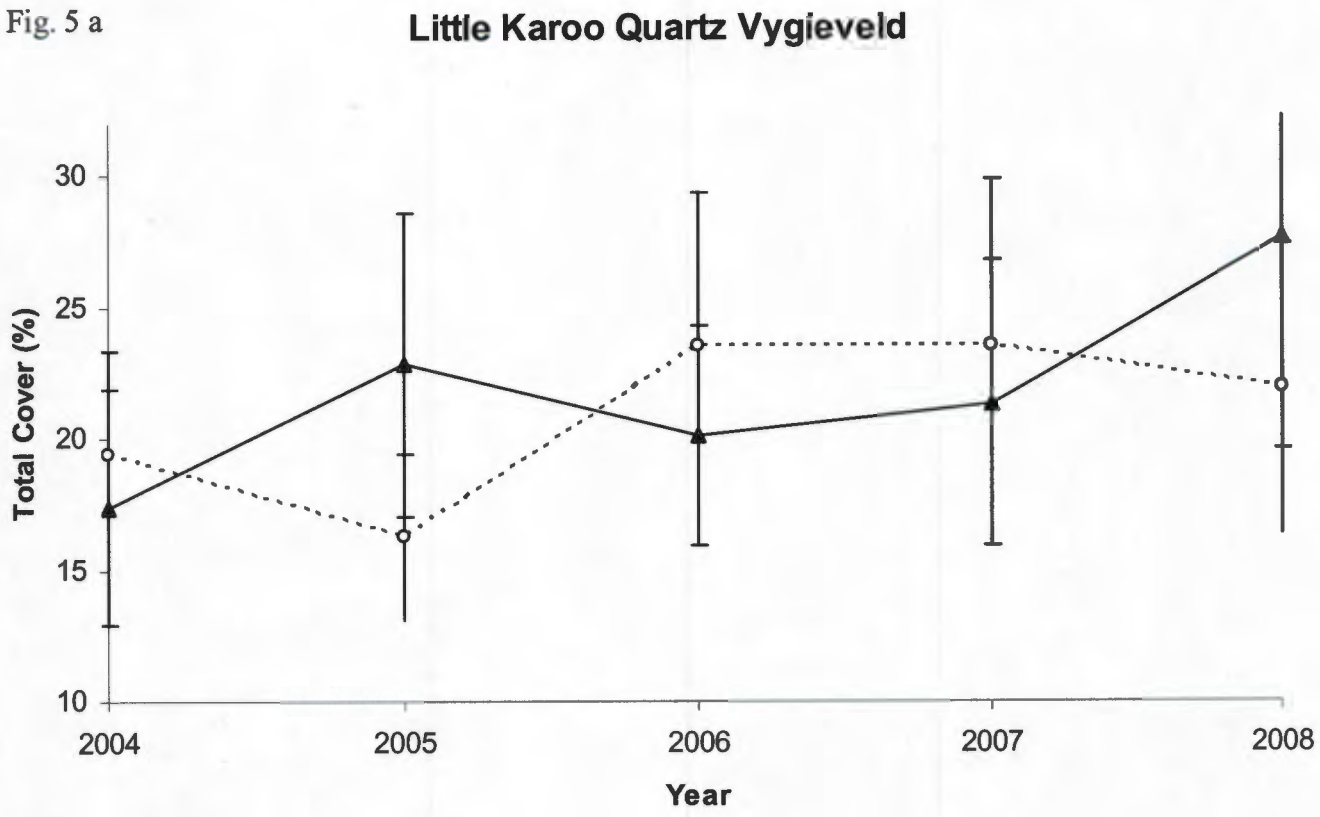
Little Karoo Quartz Vygieveld
Total Cover (%)
30
25
20
15
10
2004
2005
2006
2007
2008
Year

Fig. 5 b

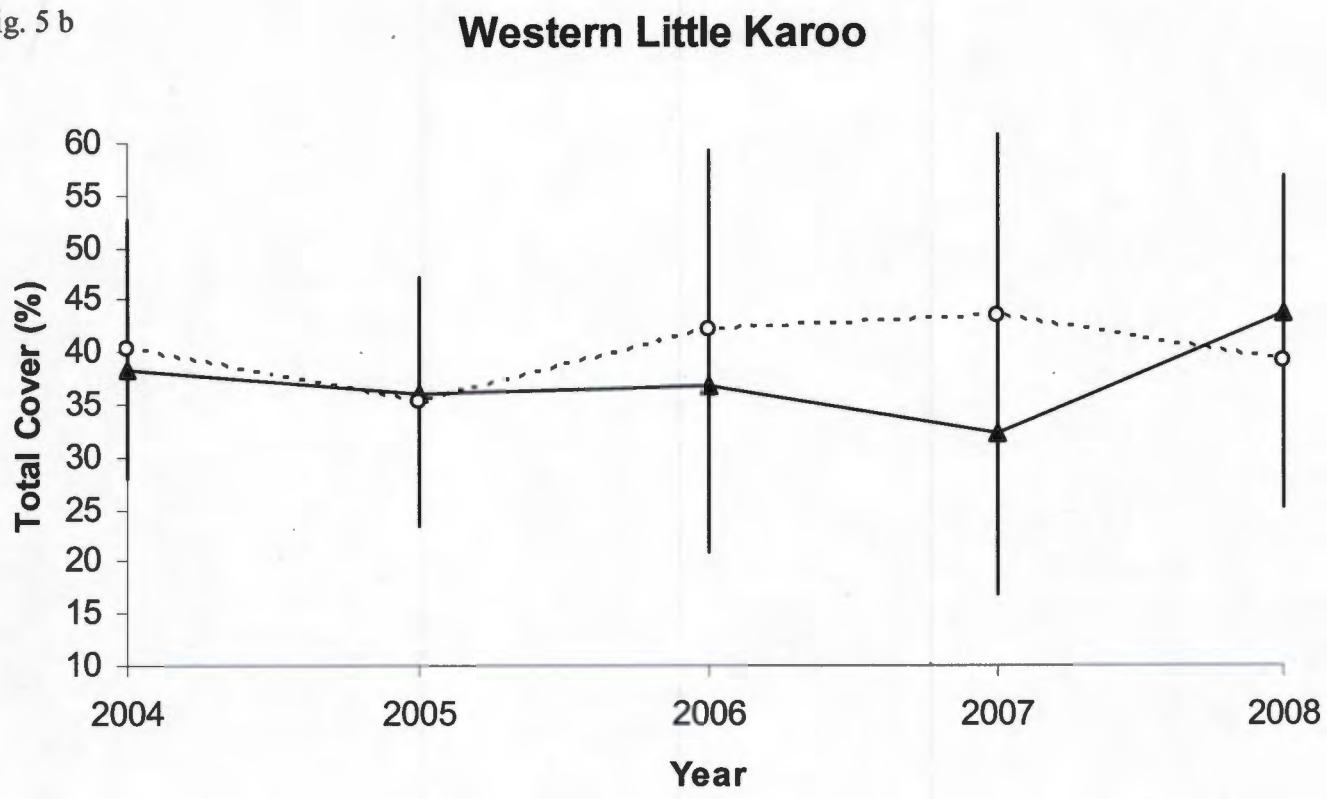
Western Little Karoo
Total Cover (%)
60
55
50
45
40
35
30
25
20
15
10
2004
2005
2006
2007
2008
Year

Fig. 5 c

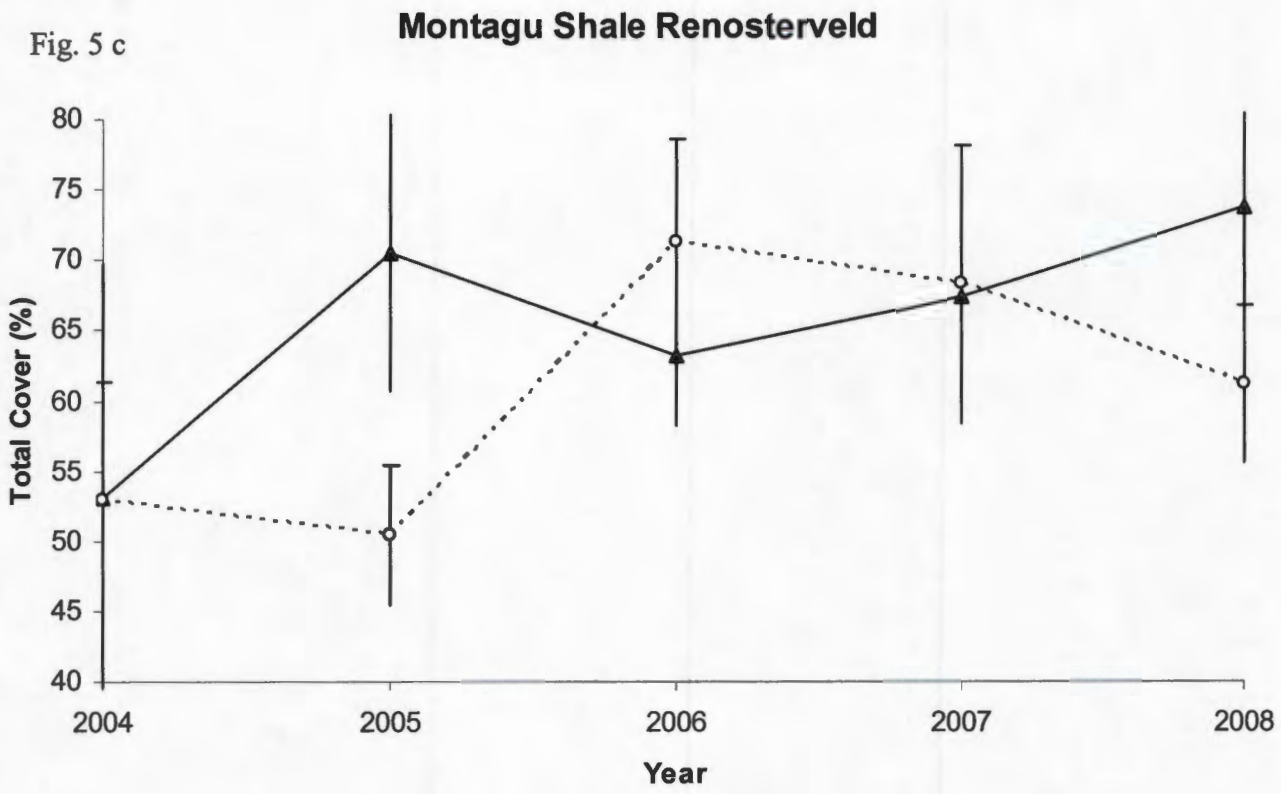

Fig. 5 d

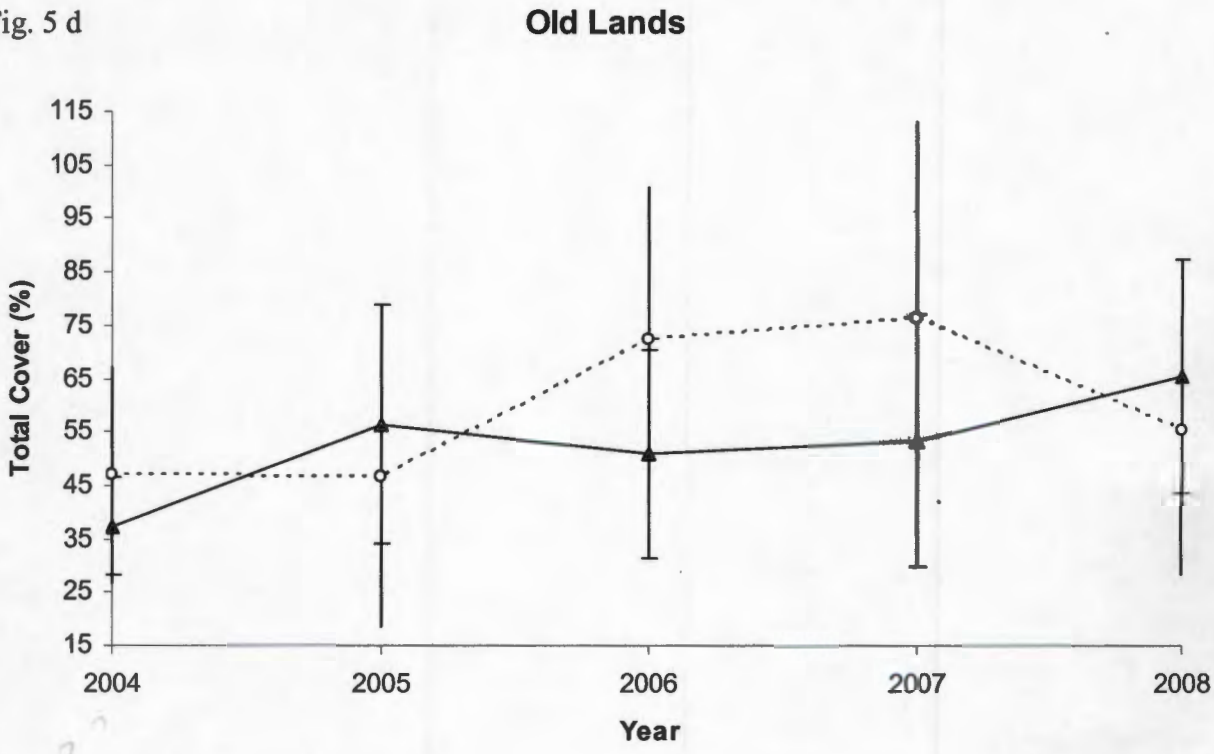

Figure 5: Changes in total plant cover (2004- 2008) in fenced and open sites in the four vegetation types studied in Sanbona. Open circles with dashed lines represent the open plots and the solid triangles with solid lines represent the fenced plots. Symbols and bars represent means and ±SD. There were no significant differences between treatments, however all vegetation types had significant differences in total plant cover between years.

Fig. 6 a

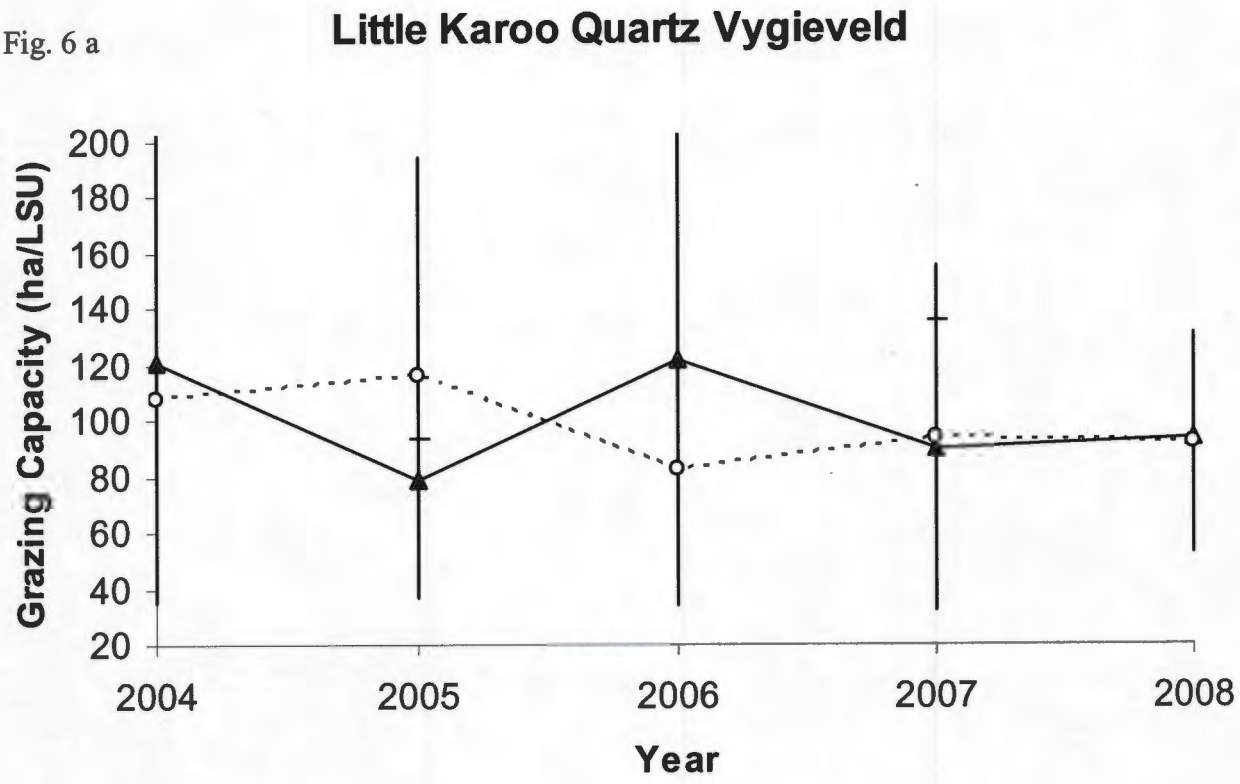
Little Karoo Quartz Vygieveld
Grazing Capacity (ha/LSU)
200
180
160
140
120
100
80
60
40
20
2004
2005
2006
2007
2008
Year

Fig. 6 b

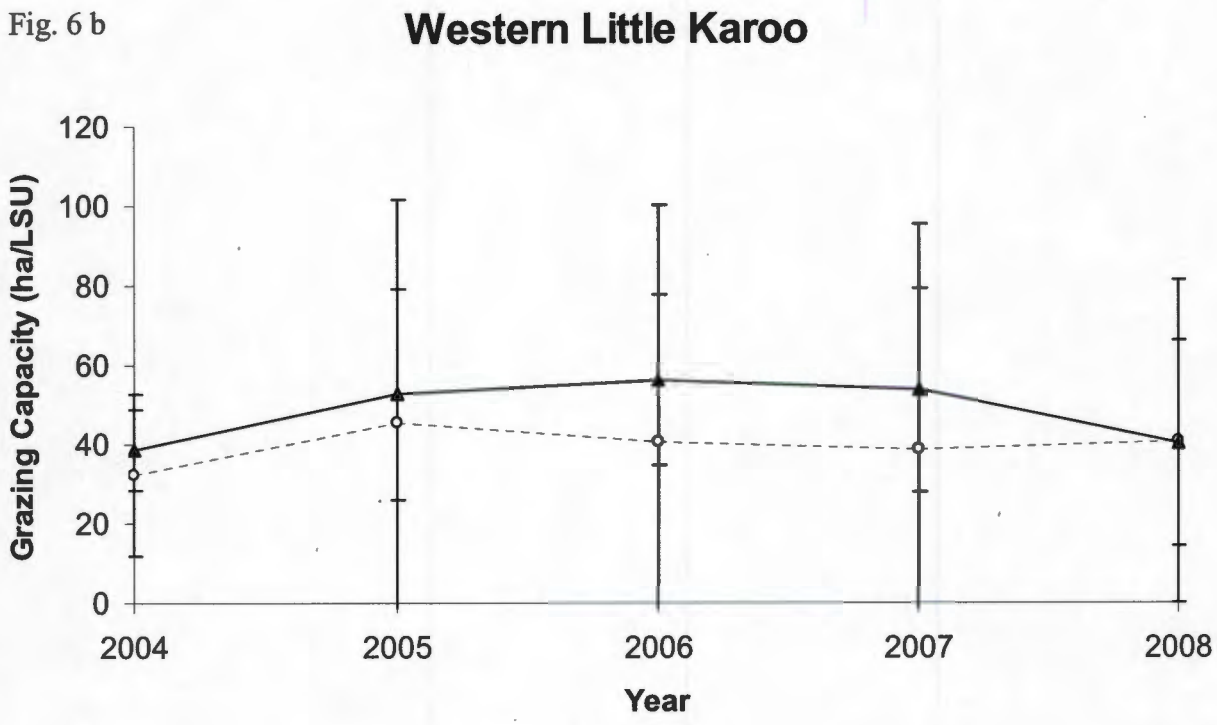
Western Little Karoo
Grazing Capacity (ha/LSU)
120
100
80
60
40
20
0
2004
2005
2006
2007
2008
Year

Fig. 6 c

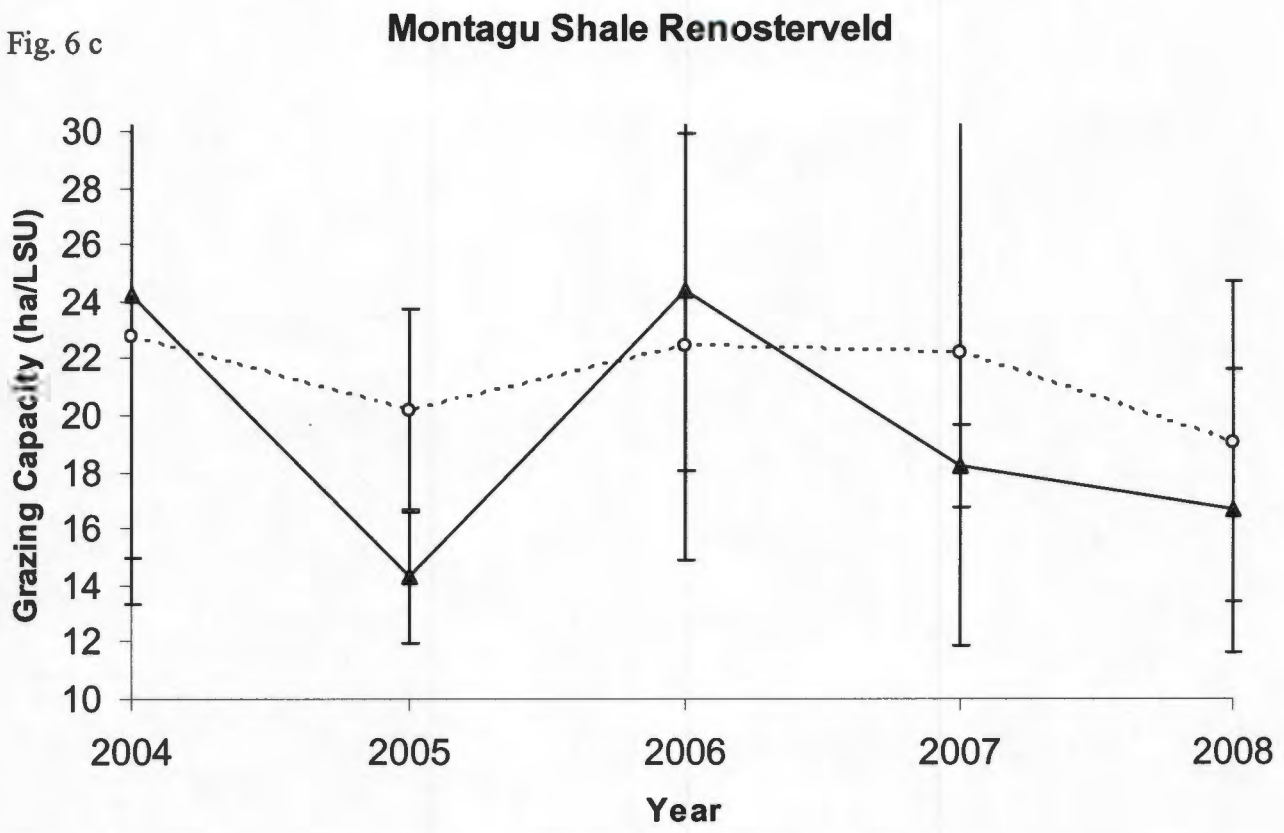

Fig. 6 d

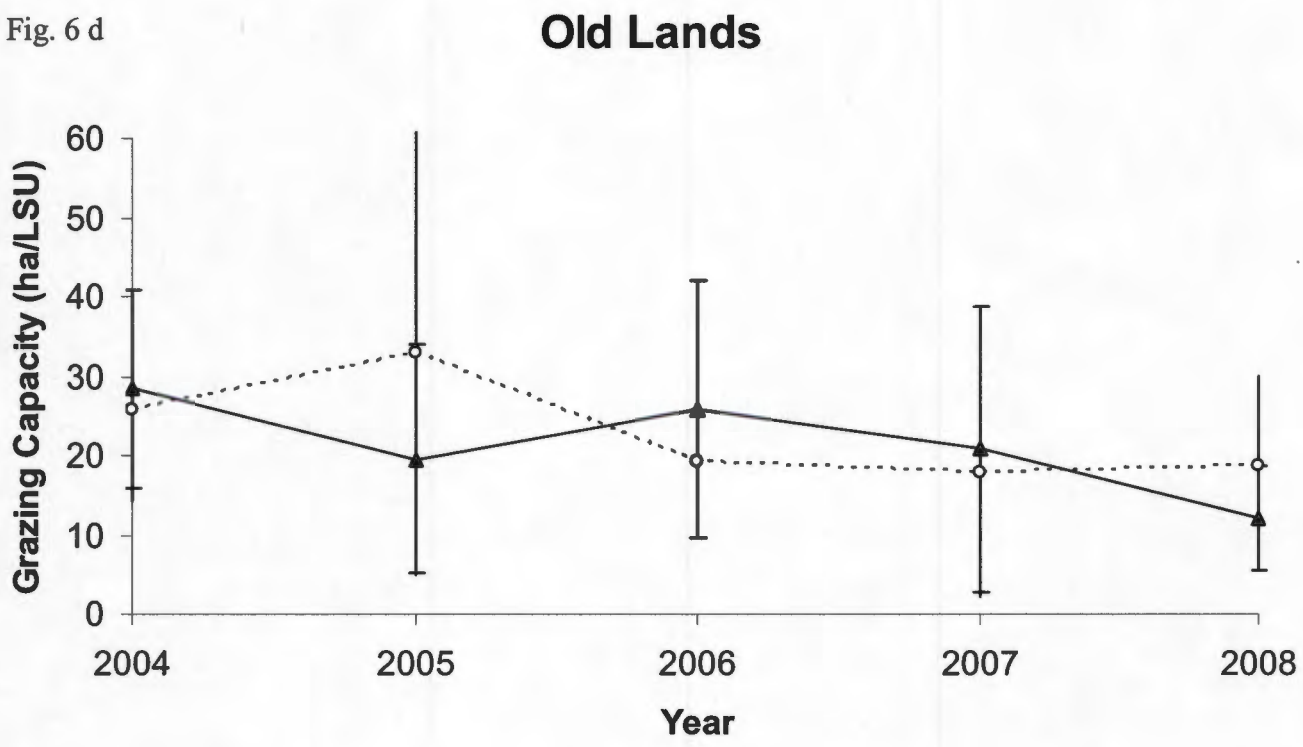

Figure 6: Changes in grazing capacity (2004 -2008) in fenced and open sites. There was no significant difference in grazing capacity between treatments. Only Western Little Karoo and Old Lands had significant differences between years.

Tables

Table 1: Meta-analysis of four Southern African Case studies concerning long-term vegetation change in semi-arid regions.

Author	Study Area	Time scale (years)	Herbivory assemblage	Mean Annual Rainfall (mm)	Methods	Statistical Approach	Findings
Kraaij & Milton (2006)	Karoo National Park South Africa	10	Wild ungulates	239	Exclosure Open	Box and whisker Plots Regression	rangeland condition increased species richness increased changes more rapid in exclosures than open areas
Burke (1997)	Naukluft Mountains Namibia	18 and 19	Large herbivores	50-100	Exclosure Open	Detrended Canonical Correspondence Analysis ordination TWINSPAN 2-way ANOVA Students t-test	Clear difference in floristic composition between non-grazed and grazed
Rahlao *et al.* (2008)	Succulent Karoo South Africa	67	Livestock	269	On termitaria Off termitaria	Non-metric multidimensional scaling (MNS) ordination Bray-Curtis Paired Wilcoxon Singed Rank test	Changes in plant cover and species composition are greater on termitaria Consistent directional change in vegetation composition
Anderson & Hoffman (2007)	Namaqualand South Africa	200	Livestock	140-320	Private land Communal lands	MNS ordination Regression Wilcoxon matched pairs test	Composition changed with a decrease in large woody species and succulent shrubs No impact on species richness

Table 2: Description of the four vegetation communities. Details and vegetation type codes are from Mucina and Rutherford (2006). Percentage values indicate the amount of land currently considered threatened.

Vegetation Type	Geology	Landscape features	Dominant genera & families	Conservation status
Little Karoo Quartz Vygieveld (SKv10)	Loamy-sandy, shallow to moderate deep, slightly alkaline soils. Soil surface is densely covered with quartz pebbles.	Flat and slightly undulating plains covered by open, low vegetation.	*Crassulaceae*, *Euphorbiaceae Gibbaeum*, accompanied with non-suculent asteraceous shrubs.	Target is 16%, with only 2-7% formally conserved. Main threats: rangeland farming of domestic ungulates, erosion (84%-12%).
Western Little Karoo (SKv8)	Sandstone and shale supporting deep, loamy-sandy soils.	Flat or slightly undulating landscape.	*Chrysocoma*, *Crassula*, *Euphorbia*, *Pentzia*, *Pteronia*, *Rhigozum*, *Ruschia*, *Tripteris*, *Tylecodon*.	Least threatened. About 3% transformed by cultivation. Main threats: alien invasives (*A. cyclops*, *A. saligna*) overgrazing and erosion (54%-15%).
Montagu Shale Renosterveld (FRs7)	Clays derived from Bokkeveld and Witteberg Groups. Some extensive quatz pebble fields.	Undulating hills with broad valleys supporting open, tall shrubland with short, divaricated shrubs.	*Elytropappus rhinocerotis*	Least threatened. Approx. 6% formally conserved. Main threats are alien invasives (*Acacia cyclops*, *A. saligna*) and erosion. Cultivation transformed 15%.
Old lands on Montagu Shale Renosterveld	As for Montagu Shale Renosterveld	As for Montagu Shale Renosterveld	*Drosanthemum*, *Galenia*, *Penztia* *Pteronia*,	Previsouly transformed by livestock and agricultural farmers. Currently being rehabilitated.

Table 3: Regression analysis relating to the number of pellets to mass (g). N= number of data points used in the regression analysis. NA= not applicable, only two pellets from elephants were found and their weight measured without regression.

Species	n	Slope	Intercept	r^2
Steenbok	8	0.0782	0.023	1
Springbok	10	0.1855	0.0192	1
Haartebeest	7	0.2978	0.1424	0.999
Gemsbok	8	0.5654	0.07	0.999
Eland	8	1.1682	0.9897	0.998
Zebra	3	8.2265	2.154	0.997
Elephant	1	NA	NA	NA

Table 4. Significance results of ANOVA (with repeated measures) for species richness, total cover, cover of different growth forms and grazing capacity at Sanbona Wildlife Reserve for the period 2004-2008. Vegetation type nomenclature follows Mucina and Rutherford (2006) and abbreviations and number of paired plots for each vegetation types are as follows: LKQV = Little Karoo Quartz Veld (n=6), WLK = Western Little Karoo (n=20); MRS = Montagu Shale Renosterveld (n=4), OL = Old Lands (n=4). NS = not significant; * = $p<0.05$; ** = $p<0.01$; *** = $p<0.001$

Variable and vegetation type	**Fenced/Open**	**Year**	**Interaction**
Species richness			
LKQV	NS	***	NS
WLK	NS	***	NS
MSR	NS	***	NS
OL	NS	***	NS
Total plant cover			
LKQV	NS	***	***
WLK	NS	*	***
MSR	NS	**	*
OL	NS	***	**
Annual cover			
LKQV	NS	NS	NS
WLK	NS	***	NS
MSR	NS	***	NS
OL	NS	**	NS
Geophyte Cover			
LKQV	Insufficient data	Insufficient data	Insufficient data
WLK	NS	NS	NS
MSR	Insufficient data	Insufficient data	Insufficient data
OL	NS	NS	NS
Grass Cover			
LKQV	Insufficient data	Insufficient data	Insufficient data
WLK	NS	**	NS
MSR	NS	NS	NS
OL	NS	**	NS
Leaf Succulent Shrubs Cover			
LKQV	NS	NS	NS
WLK	NS	***	***
MSR	NS	NS	NS
OL	NS	NS	*

Non-Succulent Shrub Cover			
LKQV	NS	**	***
WLK	NS	NS	NS
MSR	NS	NS	NS
OL	NS	***	NS
Stem-Succulent Shrub Cover			
LKQV	NS	NS	NS
WLK	NS	***	**
MSR	Insufficient data	Insufficient data	Insufficient data
OL	NS	NS	NS
Tree Cover			
LKQV	NS	NS	NS
WLK	NS	NS	NS
MSR	NS	**	NS
OL	NS	**	NS
Grazing Capacity			
LKQV	NS	NS	NS
WLK	NS	***	***
MSR	NS	NS	NS
OL	NS	*	NS

Tables 5: Mean (±SD) % cover of growth forms in the vegetation types.

Little Karoo Quartz Vygieveld

	Fenced					Open				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
ANN	0 ± 0	0 ± 0	0 ± 1	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1 ± 3	0 ± 1	0 ± 1
GEO	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GR	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
LS	8 ± 1	10 ± 2	8 ± 3	12 ± 9	12 ± 3	9 ± 1	8 ± 2	11 ± 4	9 ± 3	9 ± 1
NS	8 ± 5	13 ± 5	12 ± 3	12 ± 4	15 ± 6	9 ± 5	8 ± 3	10 ± 4	13 ± 6	12 ± 5
SS	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
TREE	0 ± 0	0 ± 0	0 ± 0	1 ± 1	0 ± 0	1 ± 1	0 ± 1	1 ± 1	0 ± 0	0 ± 1
TOTAL	16.8	22.8	20.1	24.4	27.6	18.0	16.2	23.5	22.6	22.1

Western Little Karoo

	Fenced					Open				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
ANN	0 ± 0	1 ± 1	3 ± 8	0 ± 1	0 ± 0	0 ± 0	0.5 ± 1	5 ± 9	0 ± 1	0 ± 0
GEO	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GR	0 ± 1	1 ± 2	0.3 ± 1	1 ± 1	1 ± 2	0 ± 0	0.3 ± 1	0 ± 0	0.3 ± 1	0.4 ± 1
LS	21 ± 12	17 ± 10	15 ± 11	14 ± 9	19 ± 11	23 ± 12	17 ± 10	18 ± 12	19 ± 13	18 ± 11
NS	14 ± 7	15 ± 6	15 ± 6	15 ± 6	18 ± 8	13 ± 7	15 ± 6	17 ± 7	19 ± 9	17 ± 7
SS	2 ± 3	1 ± 2	1 ± 1	1 ± 2	2 ± 3	1 ± 3	1 ± 2	1 ± 1	1 ± 2	1 ± 2
TREE	1 ± 2	2 ± 3	2 ± 3	2 ± 3	2 ± 3	2 ± 3	2 ± 3	2 ± 2	4 ± 9	3 ± 3
TOTAL	38.3	36.1	36.9	32.3	43.5	40.3	35.1	42.1	43.4	39.0

Montagu Shale Renosterveld

	Fenced					Open				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
ANN	0 ± 0	1 ± 1	3 ± 8	0 ± 1	0 ± 0	0 ± 0	0 ± 1	5 ± 9	0 ± 1	0 ± 0
GEO	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GR	0 ± 1	1 ± 2	0 ± 1	1 ± 1	1 ± 2	0 ± 0	0 ± 1	0 ± 0	0 ± 1	0 ± 1
LS	21 ± 12	17 ± 10	15 ± 11	14 ± 9	19 ± 11	23 ± 12	17 ± 10	18 ± 12	19 ± 13	18 ± 11
NS	14 ± 7	15 ± 6	15 ± 6	15 ± 6	18 ± 8	13 ± 7	15 ± 6	17 ± 7	19 ± 9	17 ± 7
SS	2 ± 3	1 ± 2	1 ± 1	1 ± 2	2 ± 3	1 ± 3	1 ± 2	1 ± 1	1 ± 2	1 ± 2
TREE	1 ± 2	2 ± 3	2 ± 3	2 ± 3	2 ± 3	2 ± 3	2 ± 3	2 ± 2	4 ± 9	3 ± 3
TOTAL	38.3	36.1	36.9	32.3	43.5	40.3	35.1	42.1	43.4	39.0

Old Lands

	Fenced					Open				
	2004	2005	2006	2007	2008	2004	2005	2006	2007	2008
ANN	0 ± 0	0 ± 0	5 ± 8	3 ± 6	0 ± 0	0 ± 0	0 ± 0	8 ± 10	3 ± 3	0 ± 1
GEO	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0
GR	0 ± 0	0 ± 0	0 ± 0	1 ± 1	1 ± 1	0 ±. 0	0 ± 0	1 ± 1	1 ± 1	1 ± 1
LS	15 ± 13	23 ± 19	19 ± 21	12 ± 8	21 ± 9	25 ± 21	23 ± 27	29 ± 20	28 ± 24	21 ± 17
NS	22 ± 9	33 ± 10	27 ± 10	37 ± 17	42 ± 17	21 ± 8	23 ± 6	33 ± 10	44 ± 17	32 ± 14
SS	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 1	0 ± 1	1 ± 1	0 ± 1	0 ± 1
TREE	0 ±	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	0 ± 0	1 ± 1	1 ± 0	1 ± 1
TOTAL	37.45	56.4	50.75	53.3	65.3	46.85	46.5	72.3	75.95	55.2

Table 6: Mean (±SD) biomass of dung from seven indigenous herbivores recorded in the four vegetation type in Sanbona Wildlife Reserve 2008.

	LKQV	WLK	MSR	OL
Steenbok				
Plots visited (%)	17	50	25	25
Biomass	5 ±	3.01 ± 0.82	9	0.3 ± 0
Springbok				
Plots visited (%)	100	100	100	100
Biomass	103 ± 108	11.88 ± 1	37 ± 26	41 ± 35
Haartebeest				
Plots visited (%)		5		
Biomass		29 ± 29		
Gemsbok				
Plots visited (%)		40	75	75
Biomass		41 ± 3	75 ± 63	69 ± 28
Eland				
Plots visited (%)	50	85	100	100
Biomass	22 ± 5	159	120 ± 126	49 ± 37
Zebra				
Plots visited (%)		40	100	100
Biomass		231 ± 3	45 ± 41	491 ± 560
Elephant				
Plots visited (%)		10		25
Biomass		128 ± 0		85 ± 0

Appendix A

A) Springbok disturbance in the Little Karoo Quartz Vygieveld Patches. B) Disturbance by Karoo bush rats (*Otomys unisulcatus*) was more frequent and more noticeable in the fenced plots in the Old Lands and Montagu Shale Renosterveld. C) Baboons uproot *Gibbeaum pubescence* while foraging for insects. In the Little Karoo Quartz Vygieveld.