THE EFFECTS OF SHEEP GRAZING ON THE RECOVERY OF SUCCULENT KAROO VEGETATION

BY

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ABSTRACT

Vegetation monitoring, recording the recovery or change in plant cover over time, for several Karoo shrubs was undertaken to evaluate the Savory Grazing System on a farm in the Succulent Karoo. This evaluation was quantified by establishing if the proposed 120-day rest period between grazing events was sufficiently long enough for complete recovery of the vegetation. Complete recovery was described as sufficient regrowth after a grazing event so that continual cover loss would not result over time. Optimum resting periods would ensure that cover loss, due to grazing, could be recovered so that plant size and reproductive potential was not detrimentally affected.

The ellipse intercept method was used to sample piospheres (or zones of attenuating animal impact) around water points in two vegetation types. From these results, 320 line transects for vegetation monitoring were located between 140 and 180m from the water points. One and a half year old piospheres of one farm were compared to seventeen year old piospheres on another farm with similar vegetation composition. The piospheres on the younger farm were expanding at an approximate linear rate of 80m per year, however, this rate slows considerably, as was found on the farm with older piospheres. Stability or equilibrium appears to be reached at approximately 320m from the water point in the older system.

The line transects were used to record the change in cover of palatable and unpalatable Karoo shrubs on a monthly basis over an 18 month period. In all instances it was concluded that the proposed 120-day rest period was not sufficiently long enough for complete recovery of the vegetation. The highly palatable species, especially *Osteospermum sinuatum* and *Tetragonia* spp., were the most heavily utilized and detrimentally affected. Larger individuals of the palatable shrubs *O. sinuatum* and *Tetragonia* spp. were more severely grazed than smaller individuals as a result of smaller individuals utilising spiny nurse plants under which to establish. If the present rest period is continued the result could be overgrazing and local extinction of these important fodder species.

The responses of two highly palatable species, *O. sinuatum* and *Tetragonia* spp., were monitored closely in relation to rainfall and grazing events. Grazed and ungrazed (protected) individuals were monitored over one year to substantiate the results obtained

from the line transects. The rest period was again found to be too short for full recovery and was also found to be reducing the reproductive output of *O. sinuatum* and *Tetragonia* spp..

The recruitment of *O. sinuatum* and *Tetragonia* spp. was also measured by comparing seedling establishment in grazed, ungrazed (vegetation protected from sheep grazing) and cleared vegetation. In an attempt to rehabilitate these rangelands, *Pteronia pallens*, a dominant unpalatable shrub, was cleared and the resultant seedling recruitment of *O. sinuatum* and *Tetragonia* spp. monitored and compared to grazed and ungrazed vegetation. Juvenile recruitment of these species was found to be significantly lower in the grazed than in the ungrazed vegetation. Recruitment of *Tetragonia* spp. was found to be significantly higher in the cleared strip compared to the grazed and ungrazed vegetation.

The results obtained in this study suggest that the present grazing regime is having a detrimental effect on the vegetation and that revised management procedures are needed to ensure the conservation of these rangelands. The rest periods between grazing events need to be lengthened as well as a reduction in stock numbers. Certain camps need to be skipped on a seasonal basis during the flowering season in order to increase the reproductive output of highly palatable species.

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DISCLAIMER

I hereby declare that the work presented in this thesis is my own. Where applicable, the work of others is acknowledged. I also declare that this thesis has not been submitted to any other university.

Ross

J.A.G. Ross September 1995

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CHAPTER 1

GENERAL INTRODUCTION

1.1 THE KAROO

The Karoo biome occupies approximately 35% of the land area of South Africa and comprises arid and semi-arid rangelands (Hoffman and Cowling 1987). The rangelands of the Karoo are used almost exclusively for pastoralism and supports a small stock industry, which produces 36% of the wool, 48% of the mutton, 60% of the mohair and 60% of the goat meat in South Africa per annum (Cowling 1986). The vegetation of the Karoo therefore, is extremely important as the small stock industry is solely dependant on this primary source of fodder (Roux *et al.* 1981).

The Karoo biome varies greatly in vegetation, climate, soils and landforms (Cowling 1986) and has subsequently been divided into three broad categories; the Desert, Nama Karoo and Succulent Karoo Biomes (Fig. 1.1) (Rutherford and Westfall 1986). The work undertaken in this thesis was done in the Succulent Karoo Biome.

The Succulent Karoo, which occupies 4.3% of South Africa (Esler 1993), experiences variability in both the amount and timing of rainfall. This region usually receives winter rainfall of between 50 and 200mm per annum (Acocks 1988; Lovegrove 1993). Extremes in temperature (i.e., extremely high and extremely low temperatures) are also characteristic of this low elevation vegetation type (Acocks 1988).

The vegetation of the Succulent Karoo is dominated by the presence of dwarf shrubs (chaemophytes), most of which are succulent (i.e., bearing succulent leaves, branches or stems (Lovegrove 1993). However, vegetation change has occurred over the last three centuries due to over-exploitation coupled with climatic change (Hoffman and Cowling 1987; Acocks 1988). Vegetation change has resulted in the replacement of the grass component by woody shrubs and weedy Mesembryanthemaceae (Yeaton and Esler 1990).

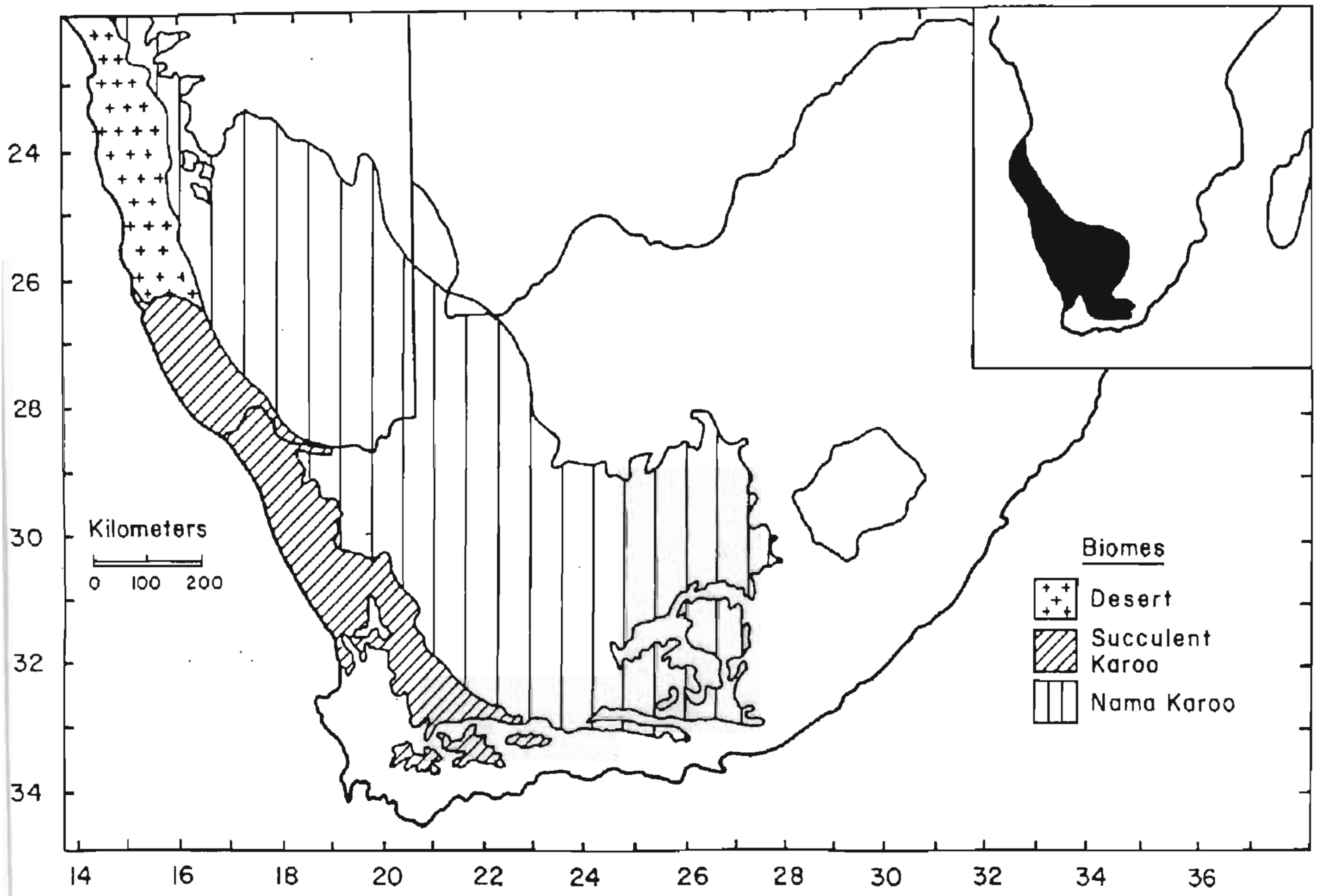

Figure 1.1: The Karoo-Namib region (insert) and the three Karoo Biomes of southern Africa (Cowling 1986).

1.2 RATIONALE

Grazing strategies need to be employed to conserve the rangelands that are used so widely by the small stock industry because vegetation deterioration has occurred in the past (Roux and Vorster 1983; Acocks 1988; Yeaton and Esler 1990). The National Grazing Strategy (NGS) was conceived to preserve the grazing lands of South Africa. The objectives of the NGS were to "utilise, develop and manage natural and cultivated pastures that they may yield the greatest sustainable benefit to the present generation while maintaining the potential to meet the needs and aspirations of future generations" (Hayward 1985 cited by King and Bembridge 1988).

Many grazing strategies have been tested in the past in accordance with the NGS. These strategies have been developed through field experiments (Acocks 1966; Roux 1968a; Skinner 1976) but overlook the responses of individual species to environmental variability (Hoffman and Cowling 1987). Four main grazing systems exist; continuous grazing (Bedford and Roberts 1975), non-selective grazing (Acocks 1966; Roux 1968b), the group camp system (Roux 1968a) and the short-duration grazing system (Savory and Parsons 1980). However, much controversy exists as to the merits of these systems and many farmers have personal views on these matters and implement their grazing schemes accordingly.

The work conducted in this study was done in collaboration with a small stock farmer who had converted his previously long-term rotationally grazed farm to a short-duration or Savory Grazing System. The primary objective was to investigate the effects of pastoralism on the recovery of the vegetation following a change in grazing strategy. Investigation into the validity of a proposed 120-day recovery period was monitored as no data is presently available for Karoo species with respect to this grazing system

(Hoffman 1988). What is reported in this thesis is only the start of what needs to be investigated further. Data on grazing systems in the arid rangelands of South Africa needs to be gathered and analysed if this resource is to be utilized sustainably.

1.3 THE SAVORY SYSTEM - AN OVERVIEW

The Savory or short-duration grazing system has been adapted from the non-selective grazing strategy (Savory 1971). Stock are rotated from one camp to another, usually based around a central water point. The stock are grazed for very short periods of time in each camp and the camps are then rested for a relatively short period. The concentrated effect of large numbers of livestock on the rangelands curtails land degradation, reversing this process towards recovery of the vegetation (Savory 1971). Land degradation may be halted as a result of urine and dung deposition as well as trampling, which enhances the soil hydrological properties and nutrient status, thus promoting vegetation growth (Savory and Parsons 1980). The trampling effects of livestock create suitable sites for the germination of seeds, and the increase in nutrient status of the soil due to urine and dung deposition is conducive to the survival of the resultant seedlings (Savory and Parsons 1980). The short periods of repeated defoliation, during the active growing season, maximises annual production (Savory and Parsons 1980). It is for these reasons that this grazing strategy appears to be attractive. To evaluate this grazing system it is important that studies on grazing strategies are continued.

1.4 STUDY SITE

The study was conducted on the farm Tierberg, roughly 25km east of Prince Albert, Cape Province, South Africa (33°6'S,22°15'E) (Fig. 1.2). Tierberg has an elevation of 869m above sea level and receives an average rainfall of 157.7±58.9mm per annum (recorded at Zacharaisfontein approximately 4km NNW of the study site) (n = 42 years) (CCWR 1993). This rainfall falls mainly in March (Venter *et al.* 1986). The mean annual temperature is 23.6±5.8°C (maximum) and 9.0±7.3°C (minimum), also recorded at Zacharaisfontein (1955 - 1976) (CCWR 1993). The colluvial soils are sandy and weakly structured and are derived from sediments of the Ecca series (Ellis and Lambrecht 1986; Milton *et al.* 1992), which is highly visible as numerous shale bands in the region.

Tierberg has a history of being rotationally grazed by Merino sheep (*Ovis aries*) for the past 60 years at a moderate 6 ha SAU^{-1} (SAU = small animal unit, equivalent to one adult sheep) (Milton 1992). Tierberg was converted to the Savory or short-duration grazing system in June 1991.

Tierberg is roughly 12 000 hectares in extent and supports two vegetation types characterised by the dominance of two different species. Approximately two-thirds of the farm is dominated by the Asteraceous shrub, *Pteronia pallens* L.F., (Plate 1.1a) and one-third by the succulent shrub, *Ruschia spinosa* Hartm. and Stüber, (Plate 1.1b).

Four study sites were chosen for the study. One water point in the *R. spinosa*-dominated vegetation, known as the Bob Murray Cell Centre, and three water points in the *P. pallens*-dominated vegetation, known as Happy Valley, Tierberg Biome and Sand River Cell Centres, were selected (Fig. 1.3). A cell centre is defined as a central water point which may serve a number of grazing camps.

Rainfall data for the study period were collected from farm records for the first three months of the study until rain gauges were set up in July 1993. One rain gauge was placed at each site *i.e.* Bob Murray, Happy Valley, Tierberg Biome and Sand River Cell Centres. These rain gauges were monitored monthly for the presence of rainfall.

1.5 PLANT SPECIES

A number of species were selected for the purposes of this study. It was decided that in order to monitor the effects of sheep grazing on the vegetation, a range of palatable species needed to be focused on. Six species were selected (Table 1.1) on the basis of palatability (Louw *et al.* 1967; Botha 1981). These species ranged from highly unpalatable, to species that were considered to be highly palatable (Botha 1981). Five of these species were found to be common to both vegetation types. However, two additional species were included; one found to be abundant in the *Ruschia spinosa*-dominated vegetation and the other found to be abundant in *Pteronia pallens*-dominated vegetation.

Table 1.1: Species list of plants selected for the study (Plates 1.2-1.5). Veg. = vegetation type; Both = occurring in both vegetation types; Rs = occurring in the *Ruschia spinosa*-dominated vegetation only; and Pp = occurring in the *Pteronia pallens*-dominated vegetation only.

Species	Family	Veg.	Palatability	Reference
Chrysocoma ciliata L.	Asteraceae	Both	unpalatable	Roux 1968c
Lycium cinereum Thunb. (*Sensu. lat.*)	Solanaceae	Rs	unpalatable	Acocks 1988
Pteronia pallens (L.f.)	Asteraceae	Pp	unpalatable	Prozesky *et al.* 1987
Ruschia spinosa Hartm. and Stüber	Aizoaceae	Both	intermediately palatable	Roux 1968d, Shearing 1994
Eriocephalus ericoides (L.f.) Druce	Asteraceae	Both	palatable	Roux 1968c
**Tetragonia* spp. L.	Aizoaceae	Both	highly palatable	Shearing 1994
Osteospermum sinuatum (D.C.) T.Norl.	Asteraceae	Both	highly palatable	Milton 1992

*Two species of *Tetragonia* occurred on the farm Tierberg, however, the abundance of these two species was low. For the purpose of this study, the two species; *T. fruticosa* L. and *T. spicata* L.f. var. *spicata* were grouped together as both are considered to be highly palatable. These two species will hereafter be referred to as *Tetragonia* spp..

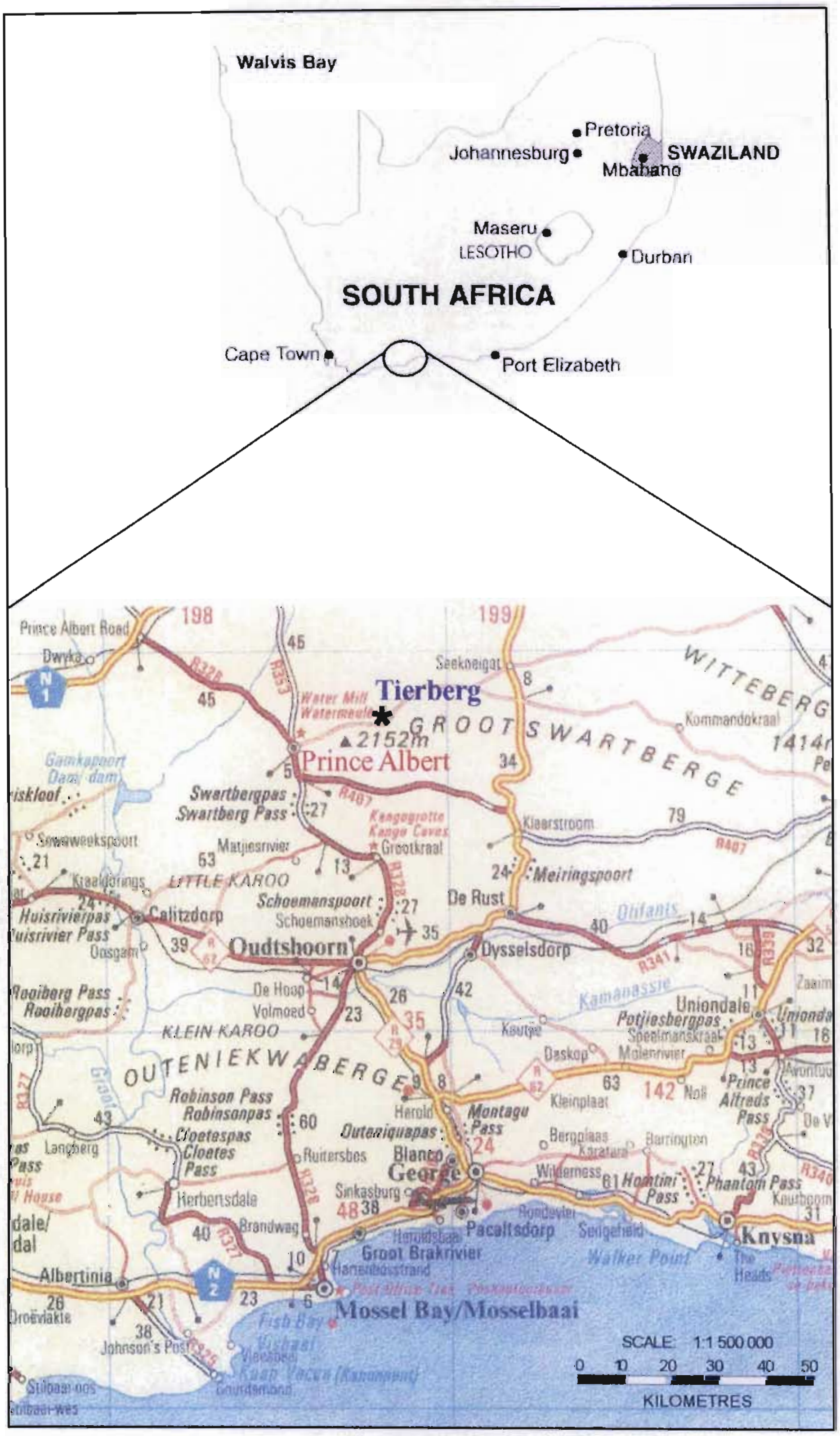

Figure 1.2: Location of the farm Tierberg in the Great Karoo, Cape Province in relation to major roads, towns and the coast (adapted from Shell Road Atlas of Southern Africa, Map Studio, Cape Town).

Plate 1.1: The two vegetation types at Tierberg (Photographed in September 1994);
a *Pteronia pallens*-dominated vegetation
b *Ruschia spinosa*-dominated vegetation.

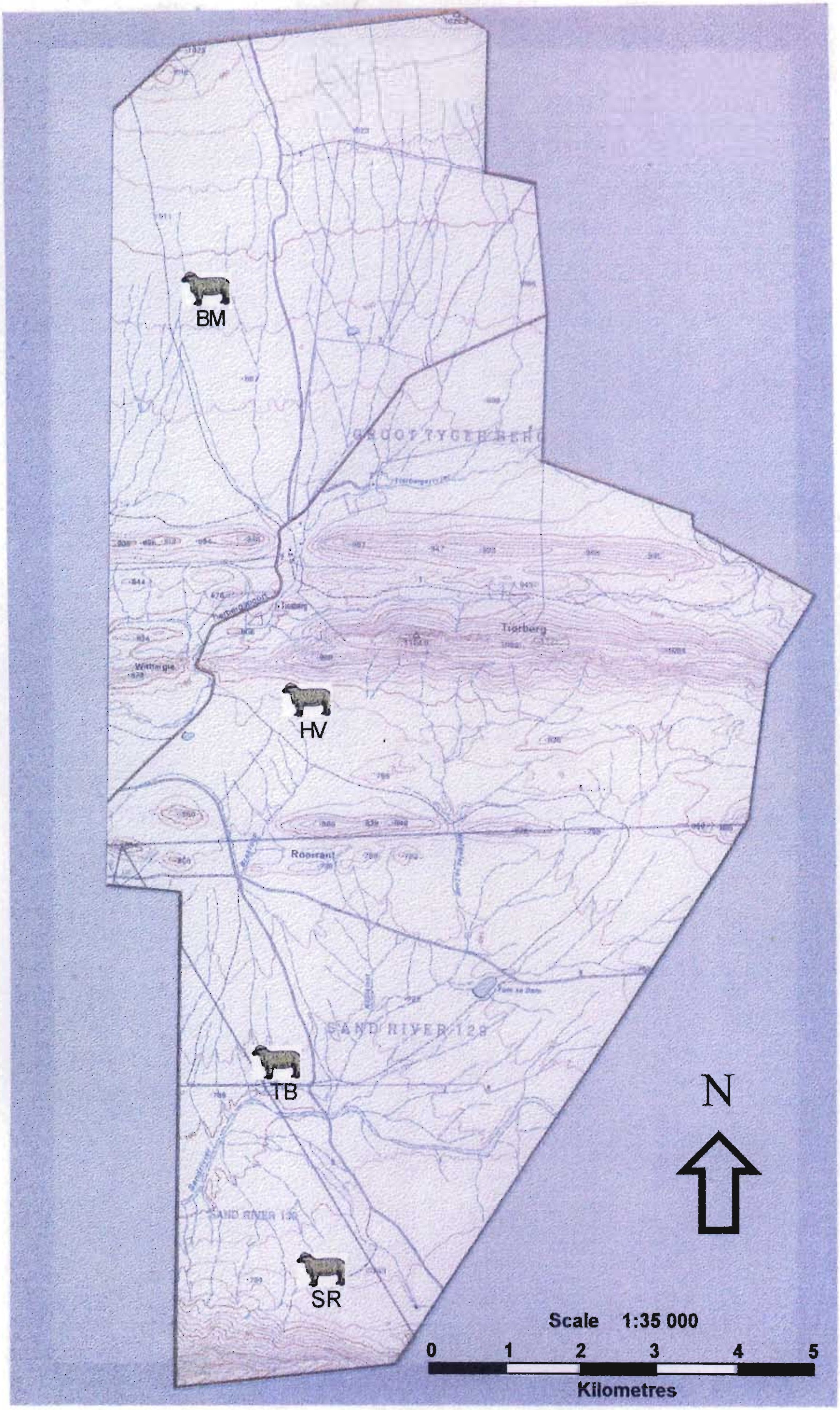

Figure 1.3: Topographical map showing the boundary of Tierberg as well as the four study sites. BM = Bob Murray, HV = Happy Valley, TB = Tierberg Biome and SR = Sand River Cell Centres (adapted from 1:50 000 topographical map, 3322AB BOTTERKRAAL,

Plate 1.2: Plant species used in this study (Photographed in September 1994);
a *Pteronia pallens* and
b *Lycium cinereum.*

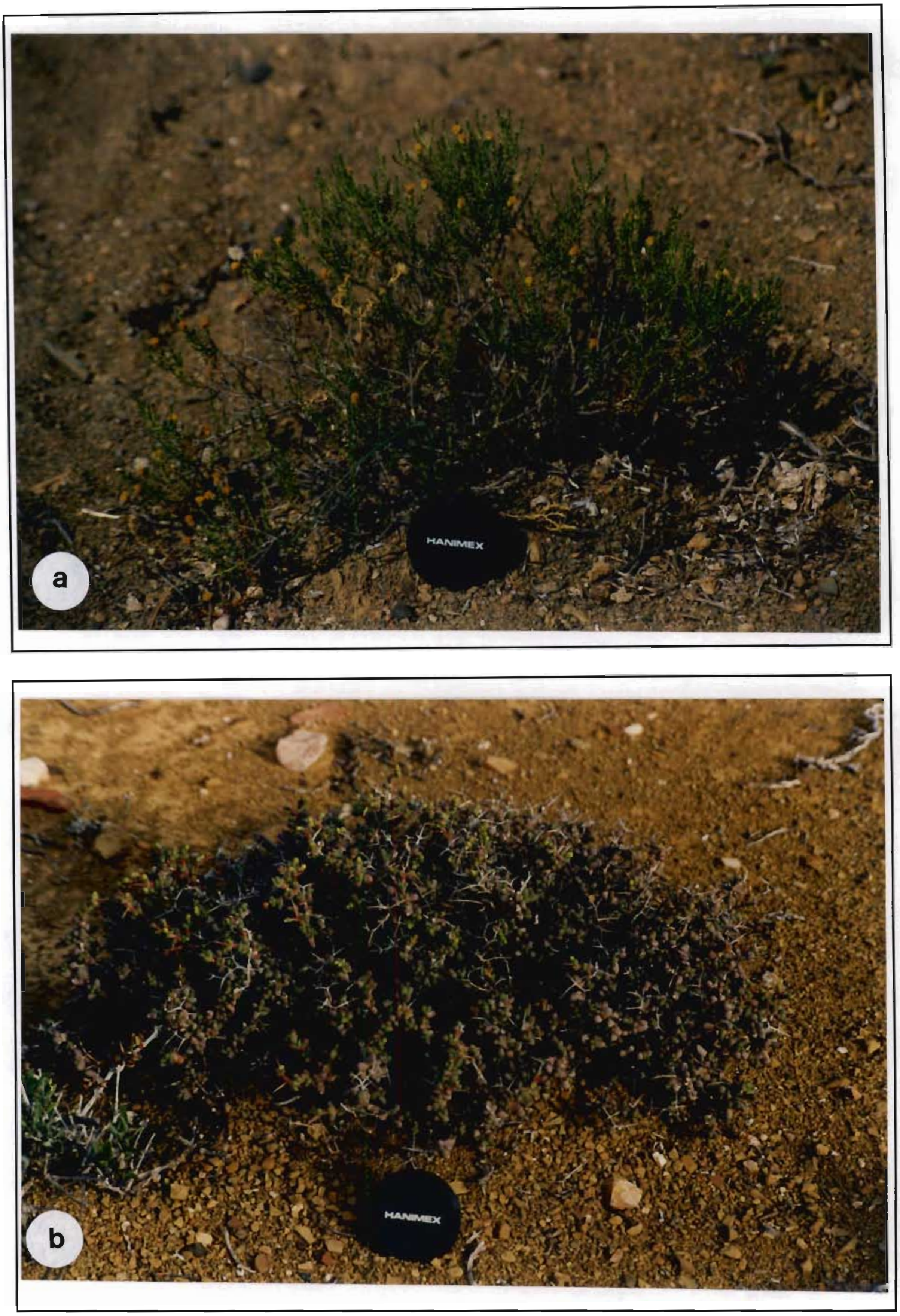

Plate 1.3: Plant species used in this study (Photographed in September 1994);
a *Chrysocoma ciliata* and
b *Ruschia spinosa*.

Plate 1.4: Plant species used in this study (Photographed in September 1994);
a *Eriocephalus ericoides* and
b *Tetragonia* spp.

Plate 1.5: Plant species used in this study (Photographed in September 1994); *Osteospermum sinuatum.*

1.6 THESIS STRUCTURE

Five main chapters constitute this thesis. Chapter 2 deals with grazing intensity gradients or piospheres around a central water point. The aim of the work undertaken in this chapter was to determine where vegetation monitoring would take place for the study period. Piospheres were determined for the variables, plant percentage cover and plant density and these are compared with a farm that has been grazed on the Savory System for the past 17 years.

The main objective of this thesis is discussed in Chapter 3. This chapter deals with 18 months of vegetation monitoring. The recovery of vegetation with reference to rainfall and grazing events is presented with the objective of determining the effect of the change in the grazing strategy on the vegetation of the farm.

Chapter 4 deals specifically with the recovery of two palatable shrubs, *Osteospermum sinuatum* and *Tetragonia* spp., after defoliation due to sheep grazing. Individual plants were monitored with reference to grazing and rainfall to determine their responses to these variables.

Chapter 5 deals with a possible method of rehabilitating the rangelands dominated by *Pteronia pallens*. Results of seedling establishment and flowering potentials of *O. sinuatum* and *Tetragonia* spp. are discussed with reference to grazed, ungrazed and cleared study sites.

The final chapter of this thesis, Chapter 6, discusses the results of the study and conclusions are drawn. Possible management implications for the farm are also discussed.

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CHAPTER 2

VEGETATIONAL PIOSPHERES

AROUND CENTRAL WATERING

POINTS IN THE SUCCULENT KAROO

2.1 INTRODUCTION

Water is a large constraint on the survival of livestock in arid rangelands (Andrew and Lange 1986a). The lack of water results in the concentration of livestock around watering points, especially in the dry season (Andrew and Lange 1986a,b; Tolsma *et al.* 1987; Andrew 1988). The concentrating effect of stock around central watering points creates zones of attenuating animal impact on the vegetation, which radiate out from the central watering point. These zones are known as piospheres and are known as either positive or negative piospheres (Andrew and Lange 1986a,b; Andrew 1988). Positive piospheres occur when the ecological variable being studied increases with increasing distance from the water point whereas negative piospheres occur when the variable being studied decreases with increasing distance from the water point (Andrew and Lange 1986a,b). Piospheres have been recorded for ecological variables such as dung deposition, sheep track density, soil lichen cover, soil compaction and dustfall (Andrew and Lange 1986a,b). Changes to the vegetation include shrub mortality, changes in forage biomass, shrub defoliation and changes in the density of certain species (Andrew and Lange 1986a,b).

The aim of this work was to determine if vegetational piospheres exist around water points in the *Ruschia spinosa* and *Pteronia pallens*-dominated vegetation on the farm Tierberg. A comparison of piospheres around a water point on the farm Trakaskuilen, of similar vegetation composition to the *R. spinosa*-dominated vegetation at Tierberg, which has been grazed on the Savory System for the past 17 years, was also made with those at Tierberg to look at the rate of development of the piospheres. The ecological variables used in this study were plant percentage cover and plant density and this work served to establish if these two variables increased or decreased with increasing distance from a water point. Any changes to the vegetation as a result of attenuating animal impact should be expressed as piospheres (Andrew and Lange 1986a,b), however, the location of these piospheres in relation to the water point is important as determinants of vegetation degradation. The stability and equilibrium of the piospheres over time is important in establishing if continued vegetation degradation occurs with the increasing age of the short duration grazing system.

2.2 STUDY SITES

The studies were conducted at two primary study areas in the Prince Albert/Beaufort West regions, the farm Tierberg, 25km east of Prince Albert (33°06'S; 22°15'E) and the farm Trakaskuilen, 70km northeast of Prince Albert and 70km south of Beaufort West (33°04'S; 22°31'E). Tierberg has an elevation of 869m above sea level and receives an average rainfall of 157.7±58.9mm per annum (recorded at Zacharaisfontein approximately 4km NNW of the study site) (n = 42 years) (CCWR 1993). The highest rainfall occurs in March (Venter *et al.* 1986). The mean annual temperature is 23.6±5.8°C (maximum) and 9.0±7.3°C (minimum) also recorded at Zacharaisfontein (1955 - 1976) (CCWR 1993). Trakaskuilen, which is situated approximately 50km north east of Tierberg, has an elevation of 1003m above sea level and receives approximately 197±73.8mm of rainfall annually (Farm records, 1955-1993). Temperatures at Beaufort West (33°19'S; 22°38'E) were for annual maximum, 25.3°C, and for annual minimum 10.6°C (1936 - 1950, Weather Bureau 1954). Trakaskuilen also receives its highest rainfall in March (Venter *et al.* 1986). The vegetation at Trakaskuilen was similar to that at Tierberg, although relatively fewer Mesembryanthemaceae occurred at Trakaskuilen than at Tierberg. This, however, did not pose a problem as only one Mesembryanthemaceae species was included in the study (*Ruschia spinosa*) and this species was present at both farms. The soil surface at Trakaskuilen was found to be more rocky than at Tierberg. However, considering the minor differences between study sites, and the steep geological, climatological and associated ecological gradients present in the Great Karoo Basin, the comparison of the two farms was undertaken as no other farm in close proximity to Tierberg could be found utilizing the Savory Grazing System.

2.3 METHODS

Five camps were sampled in each of the *R. spinosa*-dominated and *P. pallens*-dominated vegetation at Tierberg, and five camps were sampled in the *R. spinosa*-dominated vegetation at Trakaskuilen. In the *R. spinosa*-dominated vegetation at Tierberg and at Trakaskuilen, the five camps sampled were located around one central water point. Due to the mountainous topography of the area, sampling in the *P. pallens*-dominated vegetation was undertaken around three separate water points to obtain the sample of five camps. The camps selected were relatively level for distances of up to 500m from the water point and areas with distinct vegetation and soil differences were avoided.

Six species were chosen for this study and covered a range of palatabilities from unpalatable species to palatable species (Refer to Table 1.1 in Chapter 1). However, as *Tetragonia* spp. were not abundant at Trakaskuilen, possibly due to the rocky soil surface which excludes this species (pers. obs.), *Tetragonia* spp. were therefore replaced by the palatable shrub, *Pentzia incana* (Thumb) Kuntze for the purposes of this study. The species studied were: *Chrysocoma ciliata* (unpalatable), *Lycium cinereum* (unpalatable), *Ruschia spinosa* (intermediately palatable), *Eriocephalus ericoides* (palatable), *Tetragonia* spp. (palatable) at Tierberg only, *Osteospermum sinuatum* (palatable), and *Pentzia incana* (palatable) at Trakaskuilen only.

The vegetation on both farms was surveyed using the ellipse intercept method (Stokes and Yeaton 1994). Vegetation was sampled using ten, 10-metre long line transects at 20, 40, 80, 160, 320 and 640m from the central water point for each of the five camps. The two perpendicular axes; longest (L) and shortest (B) of the canopy and the species identity were recorded for each individual of the six species intercepted by the line (Stokes and Yeaton 1994).

The percentage cover and density of each species at each distance for every camp was calculated at all study sites (Stokes and Yeaton 1994). The percentage cover data were subjected to an arcsin transformation due to these data being calculated as percentages. The percentage cover and density data were subjected to an Analysis of Variance (ANOVA) and subsequent Tukey Multiple Range Tests to establish where significant changes of these two variables occurred as distance from the water point increased (Steel and Torrie 1981). The data for percentage cover and density were plotted against distance from the water point to illustrate trends.

2.4 RESULTS

2.4.1 Tierberg - *Ruschia spinosa*-dominated Vegetation

Decreasing animal impact away from the water point manifested itself in the formation of piospheres measured as percentage cover and density for all six species (Tables 2.1, 2.2). Percentage cover and density of the unpalatable shrub, *L. cinereum*, decreased with increasing distance from the water point, indicating a negative piosphere (Tables 2.1, 2.2; Figs. 2.1a,b). The individuals of *L. cinereum* were found to be tall and large relative to the other species studied. Percentage cover for *L. cinereum* was high close to the water point, but this cover decreased outwards as distance from the water point increased (Tables

2.1,2.2; Figs. 2.1a,b). While the density of *L. cinereum* decreased with increasing distance from the water point, the density was found to be low compared to the other species studied indicating the lower abundance of this species in this vegetation type.

Table 2.1: The mean percentage cover (±SD) for six Karoo shrubs at increasing distances from a water point in the *Ruschia spinosa*-dominated vegetation at Tierberg. Lc = *Lycium cinereum*, Cc = *Chrysocoma ciliata*, Rs = *Ruschia spinosa*, Ee = *Eriocephalus ericoides*, T = *Tetragonia* spp. and Os = *Osteospermum sinuatum*. Superscripts represent significant differences between distances from the water point ($P<0.05$).

Distance (m)	Lc	Cc	Rs	Ee	T	Os
20	2.36 ± 2.86^{a}	0.32 ± 0.77^{ab}	1.47 ± 1.31^{a}	0.48 ± 1.01^{a}	0^{a}	0^{a}
40	1.80 ± 2.98^{ab}	0.23 ± 0.67^{a}	1.57 ± 1.65^{a}	0.52 ± 0.97^{a}	0.01 ± 0.06^{ab}	0.03 ± 0.14^{ab}
80	1.73 ± 2.99^{abc}	0.73 ± 1.17^{ab}	1.91 ± 1.41^{ab}	0.99 ± 1.88^{ab}	0.10 ± 0.54^{ab}	0.13 ± 0.49^{ab}
160	0.78 ± 2.14^{bcd}	0.83 ± 1.10^{b}	1.76 ± 1.39^{ab}	1.85 ± 2.10^{bc}	0.36 ± 0.82^{abc}	0.46 ± 1.05^{b}
320	0.40 ± 1.82^{cd}	0.81 ± 1.13^{b}	2.27 ± 1.30^{b}	2.33 ± 2.13^{c}	0.39 ± 0.85^{bc}	0.34 ± 1.01^{ab}
640	0.34 ± 1.67^{d}	0.48 ± 1.13^{ab}	1.73 ± 1.34^{ab}	2.05 ± 1.99^{c}	0.52 ± 1.05^{c}	0.87 ± 1.25^{c}

The density and percentage cover of *L. cinereum* tended to be lower at 640m from the water point in comparison to the previous distances.

In contrast, percentage cover and density of *C. ciliata*, another very unpalatable species, increased as distance from the water point increased (Tables 2.1, 2.2; Figs. 2.1a,b). This represents a positive piosphere with its boundary situated between 80 and 160m from the water point where the most marked change in percentage cover and density of the vegetation occurs. A drop in percentage cover and density occurred at 640m from the water point, as was found for *L. cinereum*.

Table 2.2: The mean density ($\pm$SD) for six Karoo shrubs at increasing distances from a water point in the *Ruschia spinosa*-dominated vegetation at Tierberg. Lc = *Lycium cinereum*, Cc = *Chrysocoma ciliata*, Rs = *Ruschia spinosa*, Ee = *Eriocephalus ericoides*, T = *Tetragonia* spp. and Os = *Osteospermum sinuatum*. Superscripts represent significant differences between distances from the water point ($P<0.05$).

Distance (m)	Lc	Cc	Rs	Ee	T	Os
20	0.07 ± 0.09^{a}	0.07 ± 0.15^{ab}	0.23 ± 0.20^{a}	0.11 ± 0.27^{ab}	0^{a}	0^{a}
40	0.05 ± 0.09^{ab}	0.14 ± 0.37^{ab}	0.25 ± 0.25^{a}	0.10 ± 0.19^{ab}	0.07 ± 0.36^{ab}	0.04 ± 0.21^{a}
80	0.04 ± 0.07^{abc}	0.11 ± 0.20^{ab}	0.28 ± 0.25^{a}	0.07 ± 0.13^{a}	0.07 ± 0.07^{ab}	0.04 ± 0.16^{a}
160	0.02 ± 0.06^{bc}	0.23 ± 0.39^{b}	0.25 ± 0.22^{a}	0.16 ± 0.19^{ab}	0.07 ± 0.16^{ab}	0.06 ± 0.14^{a}
320	0.01 ± 0.05^{c}	0.21 ± 0.37^{ab}	0.32 ± 0.22^{a}	0.18 ± 0.19^{b}	0.07 ± 0.15^{ab}	0.05 ± 0.12^{a}
640	0.004 ± 0.02^{c}	0.05 ± 0.11^{a}	0.25 ± 0.21^{a}	0.14 ± 0.16^{ab}	0.12 ± 0.24^{b}	0.20 ± 0.30^{b}

Percentage cover of the intermediately palatable shrub, *R. spinosa*, indicates that this species is affected by increased sheep activity close to the water point (Tables 2.1, 2.2; Figs. 2.1a,b). The density of *R. spinosa* remained constant, whereas the percentage cover increased with increasing distance from the water point. Therefore, the piosphere for plant density of this species was difficult to interpret. However, the piosphere for percentage cover is situated between 160 and 320m from the water point. A decrease in percentage cover and density was observed at 640m from the water point.

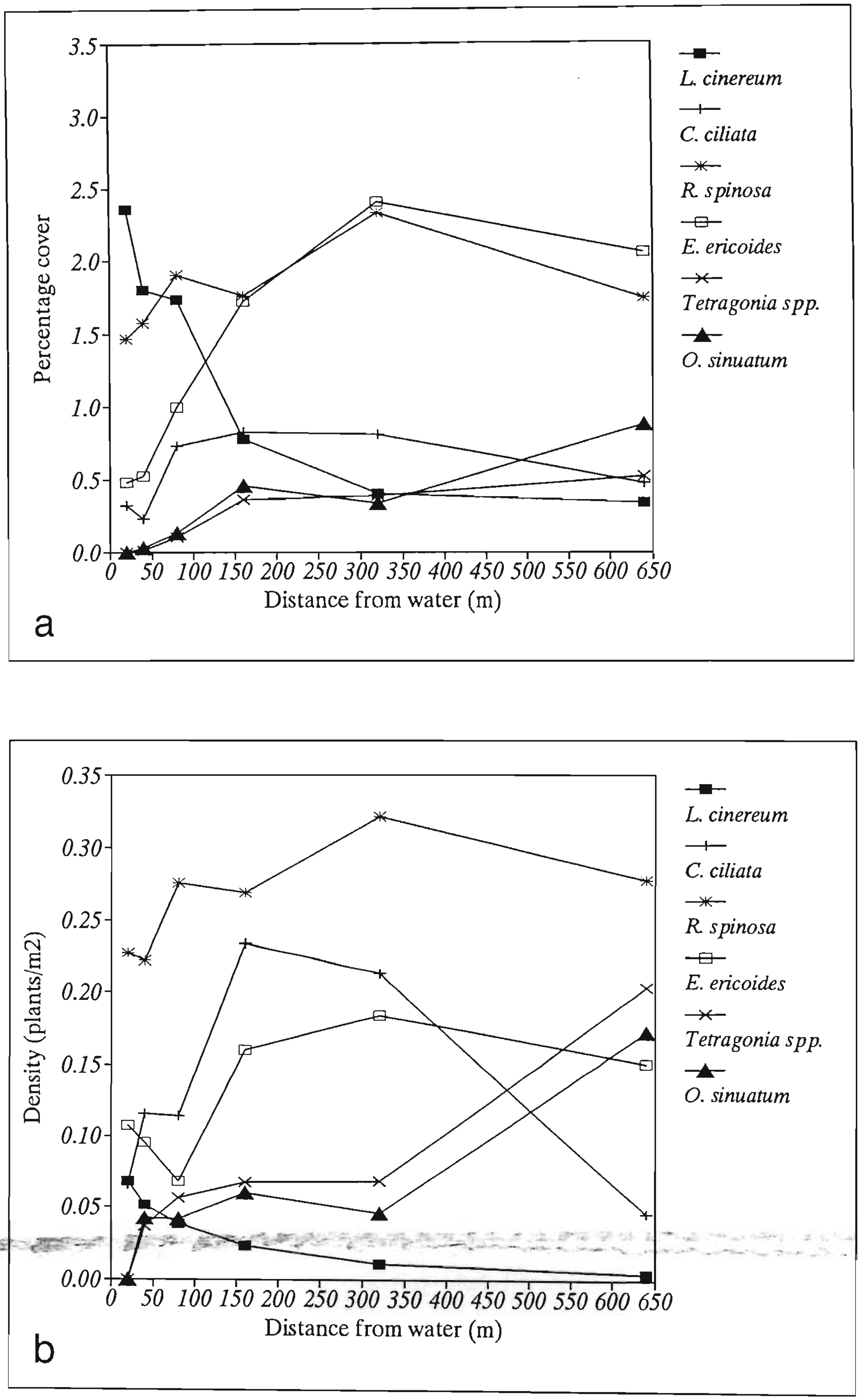


Figure 2.1: The mean percentage cover (a) and density (b) for the five camps sampled over increasing distances from a water point for six Succulent Karoo species sampled in the *Ruschia spinosa*-dominated vegetation at Tierberg.

Percentage cover of *E. ericoides*, a palatable species, increased sharply with increasing distance from the water point (Tables 2.1, 2.2; Figs. 2.1a,b). However, the density did not change significantly. The piosphere representing percentage cover was situated between 80 and 160m from the water point. However, no distinct piosphere was found to occur for plant density. The percentage cover and density were found to decrease slightly at 640m from the water point.

The highly palatable shrubs, *Tetragonia* spp. and *O. sinuatum*, showed remarkably similar trends, which probably reflect similar grazing pressures by sheep. Both species had zero cover and density close to the water point (Tables 2.1, 2.2; Figs. 2.1a,b). Percentage cover and density of both species increased with increasing distance from the water point as a consequence of decreasing grazing pressure. The piosphere representing percentage cover of *Tetragonia* spp. and *O. sinuatum* was found to exist at approximately 160m from the water point. This area was marked by a significant increase in percentage cover. However, the piospheres for plant density were not very distinct for either *O. sinuatum* or *Tetragonia* spp.

2.4.2 Tierberg - *Pteronia pallens*-dominated Vegetation

Piospheres were also found to be present for percentage cover and density for the species studied in the *P. pallens*-dominated vegetation. All species exhibited an increase in percentage cover and density with increasing distance from the water point, indicating positive piospheres (Tables 2.3, 2.4; Figs. 2.2a,b).

Table 2.3: The mean percentage cover (±SD) for six Karoo shrubs at increasing distances from a water point in the *Pteronia pallens*-dominated vegetation at Tierberg. Pp = *P. pallens*, Cc = *Chrysocoma ciliata*, Rs = *Ruschia spinosa*, Ee = *Eriocephalus ericoides*, T = *Tetragonia* spp. and Os = *Osteospermum sinuatum*. Superscripts represent significant differences between distances from the water point ($P<0.05$).

Distance (m)	Pp	Cc	Rs	Ee	T	Os
20	1.63 ± 1.95^{ab}	0^{a}	0.07 ± 0.48^{a}	0.07 ± 0.34^{a}	0^{a}	0^{a}
40	1.61 ± 2.09^{a}	0.15 ± 0.39^{a}	0.19 ± 0.59^{a}	0.43 ± 0.88^{b}	0.06 ± 0.32^{ab}	0^{a}
80	3.06 ± 2.93^{ab}	0.09 ± 0.39^{a}	0.46 ± 0.89^{a}	0.03 ± 0.13^{a}	0.07 ± 0.37^{ab}	0.20 ± 0.69^{ab}
160	2.86 ± 2.60^{ab}	0.17 ± 0.54^{a}	1.13 ± 1.19^{b}	0.06 ± 0.26^{a}	0.03 ± 0.24^{ab}	0.33 ± 0.68^{bc}
320	3.01 ± 2.41^{b}	0.02 ± 0.13^{a}	1.35 ± 1.38^{b}	0.18 ± 0.70^{ab}	0.15 ± 0.53^{ab}	0.39 ± 0.71^{bc}
640	3.16 ± 2.56^{ab}	0.25 ± 0.10^{a}	1.29 ± 1.32^{b}	0.13 ± 0.48^{ab}	0.23 ± 0.67^{b}	0.55 ± 1.01^{d}

Table 2.4: The mean density (±SD) for six Karoo shrubs at increasing distances from a water point in the *Pteronia pallens*-dominated vegetation at Tierberg. Pp = *P. pallens*, Cc = *Chrysocoma ciliata*, Rs = *Ruschia spinosa*, Ee = *Eriocephalus ericoides*, T = *Tetragonia* spp. and Os = *Osteospermum sinuatum*. Superscripts represent significant differences between distances from the water point ($P<0.05$).

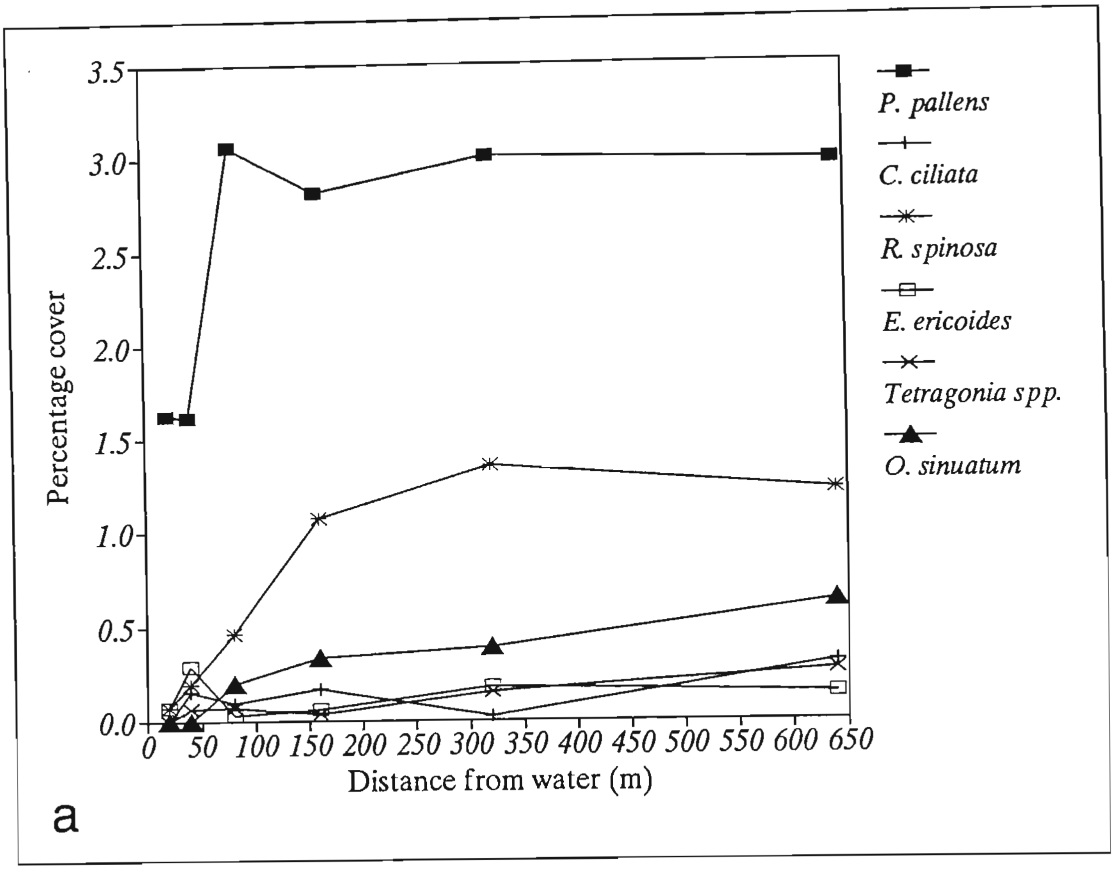
Distance (m)	Pp	Cc	Rs	Ee	T	Os
20	0.13 ± 0.17^{a}	0^{a}	0.01 ± 0.03^{a}	0.02 ± 0.09^{a}	0^{a}	0^{a}
40	0.13 ± 0.21^{a}	0.12 ± 0.31^{b}	0.10 ± 0.37^{ab}	0.07 ± 0.16^{a}	0.02 ± 0.10^{a}	0^{a}
80	0.14 ± 0.21^{a}	0.02 ± 0.08^{ab}	0.12 ± 0.22^{ab}	0.05 ± 0.25^{a}	0.02 ± 0.10^{a}	0.03 ± 0.09^{ab}
160	0.16 ± 0.18^{a}	0.06 ± 0.21^{ab}	0.21 ± 0.22^{b}	0.06 ± 0.27^{a}	0.01 ± 0.07^{a}	0.14 ± 0.29^{bc}
320	0.15 ± 0.12^{a}	0.02 ± 0.12^{ab}	0.22 ± 0.27^{b}	0.04 ± 0.14^{a}	0.07 ± 0.24^{a}	0.16 ± 0.28^{c}
640	0.18 ± 0.26^{a}	0.04 ± 0.19^{ab}	0.23 ± 0.25^{b}	0.03 ± 0.10^{a}	0.05 ± 0.13^{a}	0.11 ± 0.22^{abc}

The unpalatable shrub, *P. pallens*, was found to have the highest cover of all species studied in this vegetation type (Table 2.3, Fig. 2.2a). The percentage cover and density increased slightly away from the water point, although not significantly so (Tables 2.3, 2.4; Figs. 2.2a,b). A piosphere was only evident for percentage cover and this was situated between 160 and 320m from the water point.

The low abundance of *C. ciliata* resulted in no distinct piospheres occurring for percentage cover or density. *Chrysocoma ciliata* was not found close to the water point in this vegetation type and the percentage cover and density was not found to vary with increasing distance from the water point (Tables 2.3, 2.4; Figs. 2.2a,b). This species is a minor element in the *P. pallens*-dominated vegetation.

The percentage cover and density of *R. spinosa* increased with increasing distance from the water point (Tables 2.3, 2.4; Figs. 2.2a,b). This species followed the same trends found in the *R. spinosa*-dominated vegetation. However, the piospheres for percentage cover and density were found between 80 and 160m from the water point, rather than between 160 and 320m, as was the case in the *R. spinosa*-dominated vegetation (Tables 2.3, 2.4; Figs. 2.2a,b).

Eriocephalus ericoides also is a minor element of this vegetation type. The percentage cover and density was very low in this vegetation type in comparison to the *R. spinosa*-dominated vegetation (Tables 2.3, 2.4; Figs. 2.2a,b). Therefore, little variation in percentage cover and density occurred with increasing distance from the water point and no distinct piospheres were apparent.



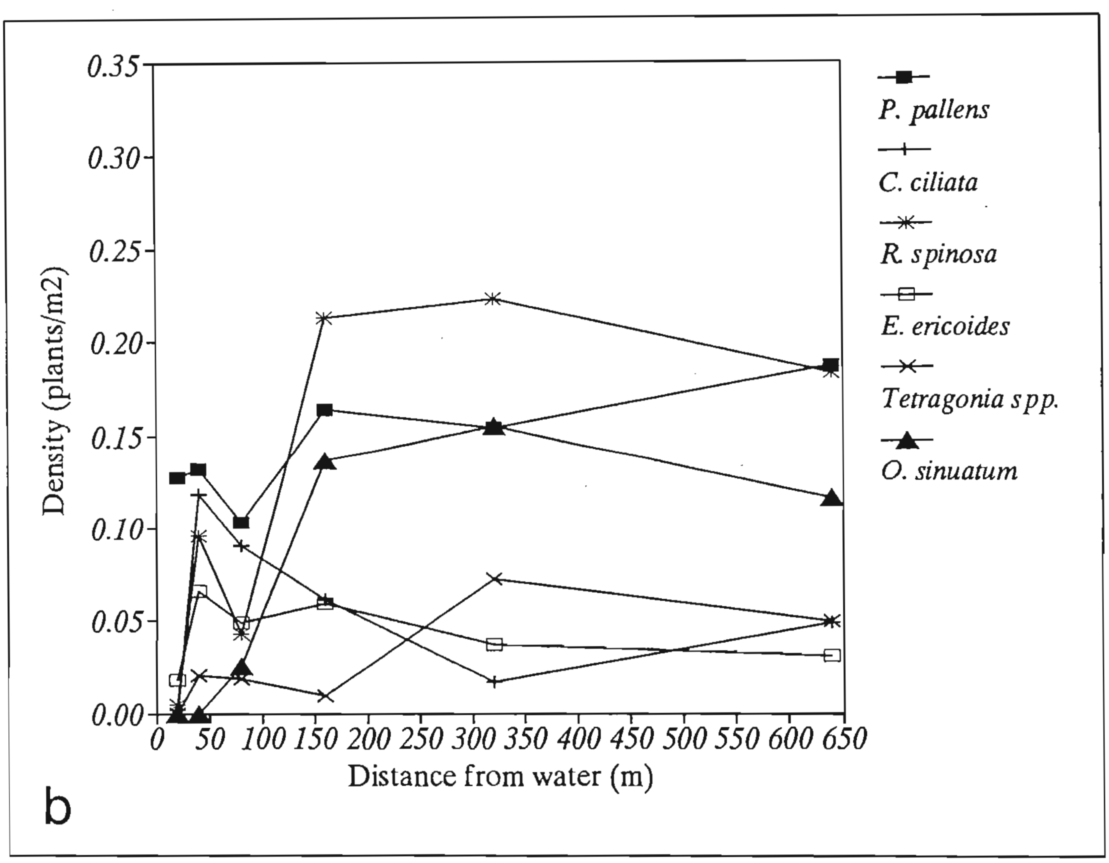


Figure 2.2: The mean percentage cover (a) and density (b) for the five camps sampled over increasing distances from a water point for six Succulent Karoo species sampled in the *Pteronia pallens*-dominated vegetation at Tierberg.

Tetragonia spp. also were in very low abundance throughout this vegetation type (Tables 2.3, 2.4; Figs. 2.2a,b). No distinct differences in percentage cover or density were found to occur with increasing distance from the water point and therefore no distinct piospheres could be detected.

The percentage cover and density of *O. sinuatum* was very low close to the water point (Tables 2.3, 2.4; Figs. 2.2a,b). Individuals of *O. sinuatum* were only first encountered at 80m from the water point and percentage cover and density increased from this distance away from the water point. A piosphere was only recorded for percentage cover and this was situated at approximately 320m from the water point.

2.4.3 Trakaskuilen - *Ruschia spinosa*-dominated Vegetation

The existence of piospheres were also found for the percentage cover and density of the six study species in the vegetation at Trakaskuilen (Tables 2.5, 2.6; Figs. 2.3a,b). Five out of the six species studied exhibited positive piospheres, whereas only one, *L. cinereum*, exhibited negative piospheres (Tables 2.5, 2.6; Figs. 2.3a,b). The percentage cover and density of *L. cinereum* decreased sharply as distance from the water point increased. A significant change in plant density occurred between 80 and 160m from the water point indicating that the piosphere for this unpalatable species was situated relatively close to the water point. However, no distinct piosphere was found with respect to percentage cover.

Table 2.5: The mean percentage cover (±SD) for six Karoo shrubs at increasing distances from a water point at Trakaskuilen. Lc = *Lycium cinereum*, Cc = *Chrysocoma ciliata*, Rs = *Ruschia spinosa*, Ee = *Eriocephalus ericoides*, Pi = *Pentzia incana* and Os = *Osteospermum sinuatum*. Superscripts represent significant differences between distances for a species ($P<0.05$).

Distance (m)	Lc	Cc	Rs	Ee	Pi	Os
20	3.07 ± 2.97^{a}	0.16 ± 0.54^{a}	0^{a}	0.20 ± 0.82^{a}	0.92 ± 1.10^{a}	0.15 ± 0.10^{a}
40	2.02 ± 2.42^{a}	0.50 ± 1.03^{a}	0.08 ± 0.39^{a}	0.57 ± 1.13^{a}	1.16 ± 1.05^{a}	0.02 ± 0.15^{a}
80	1.89 ± 2.85^{a}	0.50 ± 0.90^{a}	0.11 ± 0.46^{a}	0.61 ± 1.30^{a}	1.59 ± 1.22^{ab}	0^{a}
160	2.26 ± 3.06^{a}	0.69 ± 1.06^{ab}	0.05 ± 0.37^{a}	0.94 ± 1.50^{ab}	1.90 ± 0.95^{b}	0.09 ± 0.43^{ab}
320	1.87 ± 2.96^{a}	1.20 ± 1.24^{bc}	1.07 ± 1.47^{b}	1.50 ± 1.83^{bc}	1.32 ± 1.28^{ab}	0^{a}
640	1.96 ± 2.99^{a}	1.34 ± 1.12^{d}	1.13 ± 1.55^{b}	1.67 ± 1.53^{c}	1.66 ± 1.63^{ab}	0.20 ± 0.58^{b}

Table 2.6: The mean density (±SD) for six Karoo shrubs at increasing distances from a water point at Trakaskuilen. Lc = *Lycium cinereum*, Cc = *Chrysocoma ciliata*, Rs = *Ruschia spinosa*, Ee = *Eriocephalus ericoides*, Pi = *Pentzia incana* and Os = *Osteospermum sinuatum*. Superscripts represent significant differences between distances for a species ($P<0.05$).

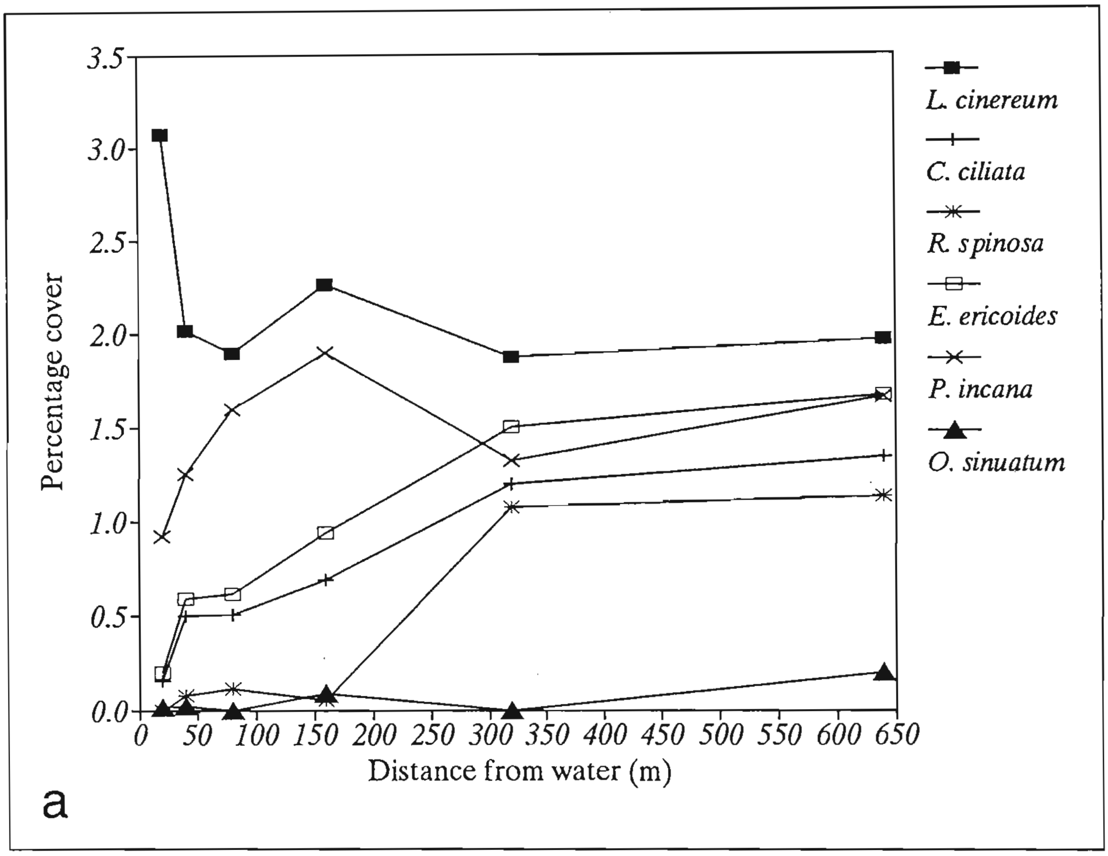
Distance (m)	Lc	Cc	Rs	Ee	Pi	Os
20	0.15 ± 0.14^{a}	0.03 ± 0.11^{ab}	0^{a}	0.01 ± 0.06^{a}	0.25 ± 0.30^{a}	0.02 ± 0.15^{ab}
40	0.13 ± 0.17^{ab}	0.01 ± 0.09^{a}	0.02 ± 0.09^{a}	0.09 ± 0.17^{ab}	0.25 ± 0.20^{a}	0.01 ± 0.10^{ab}
80	0.08 ± 0.13^{abc}	0.14 ± 0.32^{bc}	0.03 ± 0.12^{a}	0.06 ± 0.12^{a}	0.31 ± 0.23^{a}	0^{a}
160	0.07 ± 0.10^{bc}	0.13 ± 0.19^{abc}	0.01 ± 0.04^{a}	0.11 ± 0.20^{abc}	0.34 ± 0.17^{a}	0.01 ± 0.07^{ab}
320	0.06 ± 0.10^{c}	0.20 ± 0.21^{c}	0.16 ± 0.22^{b}	0.19 ± 0.29^{bc}	0.22 ± 0.22^{a}	0^{a}
640	0.05 ± 0.08^{c}	0.24 ± 0.21^{c}	0.17 ± 0.23^{b}	0.20 ± 0.22^{c}	0.22 ± 0.20^{a}	0.07 ± 0.21^{b}

Percentage cover and density of *C. ciliata* increased with increasing distance from the water point. Significant changes in percentage cover occurred at 160 and 320m from the water point, indicating the location of the piosphere (Tables 2.5, 2.6; Figs. 2.3a,b). The piosphere for density was found to be closer to the water point occurring between 40 and 80m.

The percentage cover and density of *R. spinosa* was low, but did increase with increasing distance from the water point (Tables 2.7, 2.6; Figs. 2.3a,b). Significant changes in the percentage cover and density of *R. spinosa* occurred between 160 and 320m from the water point, indicating the edge of the piosphere.

The percentage cover and density of *E. ericoides* increased with increasing distance from the water point. This species had lower cover but higher densities than that found in the *R. spinosa*-dominated vegetation at Tierberg. Significant changes in percentage cover and density were found to occur between 160 and 320m, indicating that the piospheres for this species had moved out to approximately 320m (Tables 2.5, 2.6; Figs. 2.3a,b).

A piosphere was only found to be present for the percentage cover of the palatable shrub *P. incana*, and occurred between 80 and 160m from the water point (Tables 2.5, 2.6; Figs. 2.3a,b). The percentage cover and density of this species was found to fluctuate considerably with increasing distance from the water point and this could be linked to a negative association with *R. spinosa* (Gibson pers. comm.).



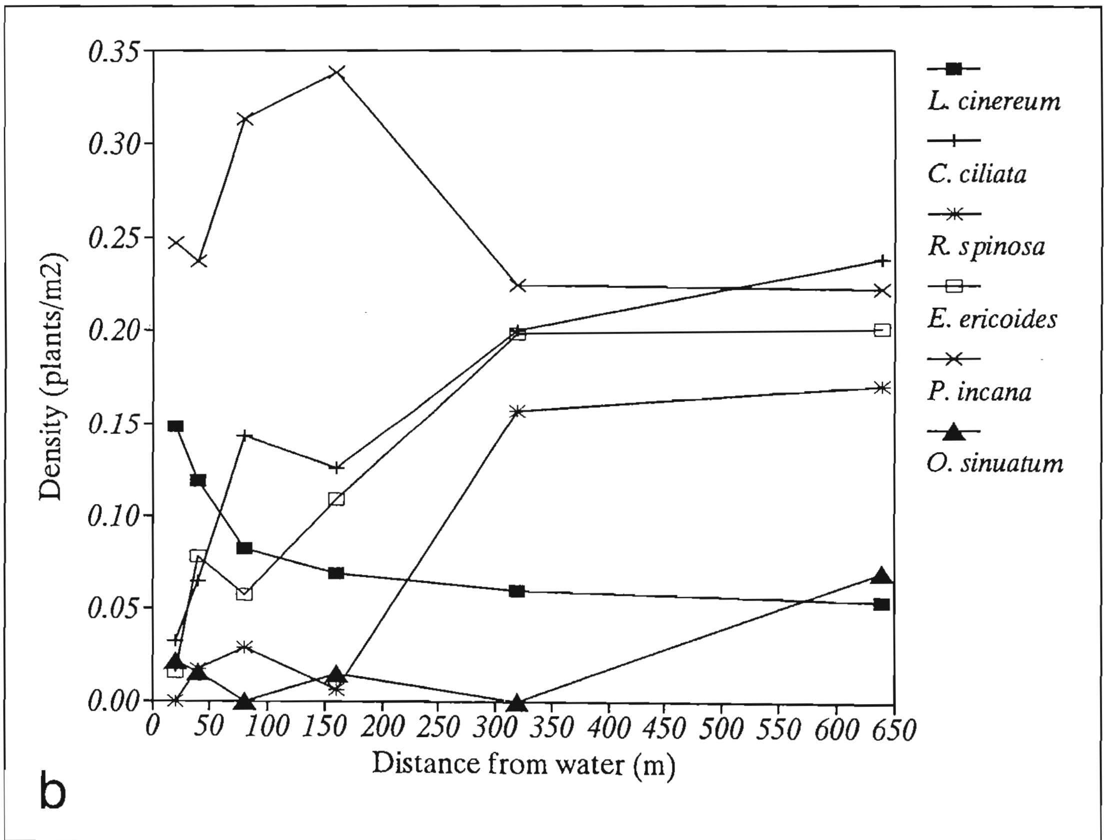


Figure 2.3: The mean percentage cover (a) and density (b) for the five camps sampled over increasing distances from a water point for six Succulent Karoo species sampled at Trakaskuilen.

The percentage cover and density of the palatable shrub, *O. sinuatum*, was found to fluctuate with increasing distance from the water point. This species was found in low abundance and did not occur consistently throughout the study site. The low abundance resulted in significant changes in percentage cover and density occurring between 320 and 640m from the water point (Tables 2.5, 2.6; Figs. 2.3a,b). The piosphere would, therefore, be located at a maximum distance of 640m from the water point.

2.5 DISCUSSION

2.5.1 Tierberg - *Ruschia spinosa*-dominated Vegetation

Lycium cinereum was found to exhibit a negative piosphere for both percentage cover and density in this vegetation type. This negative piosphere could be due to the unpalatability of this genus and its consequential avoidance by sheep (Botha 1981; Roux and Vorster 1983). These factors could be compounded because *L. cinereum* is a tall, thorny, woody shrub. Such a growth form is not conducive to the preferred foraging behaviour of sheep, which is grazing (Davies *et al.* 1986). The lack of grazing would allow the canopy cover of *L. cinereum* to grow large and remain unaffected by grazing. However, the density of *L. cinereum* decreases with increasing distance from the water point and the density is relatively low compared to the other species studied. Many large individuals of *L. cinereum*, represented by a large percentage cover, occurred close to the water point due to the higher disturbance effect of sheep activity, which causes increased coppicing in this species (Gibson pers. comm.). As distance increases from the water point, so the percentage cover and density decreases, due to the decrease in animal activity. Only those species, which are trampling and grazing resistant will survive (Barker and Lange 1969; Andrew and Lange 1986a,b; Tolsma *et al.* 1987, Andrew 1988).

Chrysocoma ciliata is known to be unpalatable to stock (Roux 1968a; Botha 1981; Roux and Vorster 1983). As this species is small leaved and shallow rooted (Riley 1963), it is vulnerable to trampling by livestock and is unable to regenerate through coppicing (Gibson pers. comm.). According to Acocks (1988), *C. ciliata* is an invasive shrub and occurs extensively in open microsites (Gibson pers. comm.). This species thus can be assumed to be an early successional disturbance species. While it may follow that *C. ciliata* would invade and colonise areas close to water points due to the continual disturbance effect by sheep, there also would be a severe decrease in the number of individuals establishing there due to this species being vulnerable to trampling by sheep.

The piosphere for *R. spinosa* was found to be indistinct, possibly because the effect of sheep grazing is minimal due to the intermediate palatability of this species. The spinescent morphology of this species makes it less preferred by sheep as it is difficult to graze compared to the spineless palatable species (Roux 1968b; Botha 1981; Roux and Vorster 1983; Vorster *et al.* 1983). Therefore *Ruschia spinosa* would not be heavily grazed by sheep but may be affected by the trampling activities of these livestock. *Ruschia spinosa* establishes in the open (Gibson pers. comm., pers. obs.) and would be vulnerable to trampling as seedlings. This may explain why the piosphere is situated between 160 and 320m from the water point. The density of this species was the highest of all species recorded in the *R. spinosa*-dominated vegetation during the study. Yeaton and Esler (1990) found a high abundance of *R. spinosa* approximately eight kilometres south of the present study site and linked a possible nurse plant function of *R. spinosa* to the establishment of palatable woody shrubs.

The piosphere for percentage cover of the palatable shrub, *E. ericoides*, was observed to be situated between 80 and 160m from the water point. However, no distinct piosphere was found to occur for plant density. This species is a low-lying, woody shrub, which is grazed and trampled by sheep. *Eriocephalus ericoides* attains the highest density for a palatable species because it is not highly palatable and escapes severe grazing pressure by sheep.

The piospheres for percentage cover of *Tetragonia* spp. and *O. sinuatum* were found to exist at approximately 160m from the water point in this vegetation type. Both these species are considered to be highly palatable and are thus severely grazed by stock. These species will therefore be the most vulnerable to the grazing and trampling activities of livestock resulting in low cover and abundance. The piospheres for plant density were not distinct for either species as the low abundance in this vegetation type, coupled with the heavy grazing pressures, results in low recruitment of seedlings.

Significant changes in percentage cover were generally found to occur between 20 and 160m from the water point for most species surveyed in this study site, indicating a change in plant cover over this distance range. The piospheres, therefore, have moved approximately 160m outwards from the water point since the establishment of the grazing system. However, this trend was not found to occur for the densities of all six species studied indicating that abrupt changes in plant densities did not occur with increasing distance from the water point. The lack of a distinct change in plant density could be the result of the age of the piosphere. Due to the grazing cell centre only being one and a half years old, the impact by sheep may have been too short to cause larger changes in plant densities at greater distances from the water point. However, large changes have been found to be present for percentage cover. Thus the impact of sheep grazing has a greater detrimental effect on plant cover than on plant density at this stage in the life of these camps.

The decreases in percentage cover and density for most species at 640m from the water point may be as a result of a moisture gradient effect. Most water points are located in depressions and as distance from the water point increases, the gradient of the topography rises. The topography would result in a moisture gradient occurring from the wetter depression up to the drier ridges, which would result in lower percentage cover and density being recorded. Plants growing on the ridges would be exposed to reduced soil moisture levels while depressions would experience an increase in moisture due to rainfall collecting at their centres (Gibson pers. comm.).

2.5.2 Tierberg - *Pteronia pallens*-dominated Vegetation

All species in the *P. pallens*-dominated vegetation were found to exhibit positive piospheres. The unpalatable shrub, *P. pallens* (Prozesky *et al.* 1986), was found to have the highest cover of all species. The percentage cover, along with the density, increased away from the water point. *Pteronia pallens* is totally excluded from the grazing pressures of sheep and would only be absent close to the water point as a result of sheep trampling effects. A piosphere was only evident for percentage cover and was found to be situated between 160 and 320m from the water point.

Chrysocoma ciliata is vulnerable to trampling due to its dwarf growth form and thin stems and therefore this shrub was not found close to the water point. The lower percentage cover and density found in the *P. pallens*-dominated vegetation compared to the *R. spinosa*-dominated vegetation could be the result of vegetation composition differences. The lack of piospheres for *C. ciliata* in this vegetation type is probably a result of the low abundance found in this vegetation type compared to the *R. spinosa*-dominated vegetation. The low abundance of certain plant species may require prolonged disturbance before distinct piospheres can be recognised.

Ruschia spinosa is considered an intermediately palatable species and thus would be more prevalent to exclusion, like *P. pallens*, from areas close to the water point by trampling. The piospheres for percentage cover and density for *R. spinosa* in this vegetation type were found to be closer to the water point compared to that found in the *R. spinosa*-dominated vegetation. The location of the piospheres could, however, be as a result of vegetation compositional differences, as lower densities of this species were recorded, which may require longer disturbance effects before piospheres are visible.

The trend found thus far for species in low abundance may explain the lack of piospheres for *E. ericoides*. No distinct piospheres were found to be present for percentage cover or density for this palatable species.

Low abundance was also recorded for the palatable shrubs, *Tetragonia* spp., in this vegetation type. The low abundance resulted in indistinct piospheres being recorded. The individuals that were present, however, were heavily utilised and this low abundance may be the result of overgrazing.

Osteospermum sinuatum had the lowest abundance of all species studied. The lack of individuals in the first 80m from the water point, therefore, resulted in the piospheres being located at 160m from the water point. The low abundance would also have resulted in high grazing pressures being exerted on individuals of *O. sinuatum* and these effects may cause the piospheres to move further out with time.

Significant changes in percentage cover were less obvious in the *P. pallens*-dominated vegetation, in comparison to the *R. spinosa*-dominated vegetation, but again it appeared as if the piosphere had moved out approximately 160m from the water point. This trend was less obvious for plant density, where it appeared as if little change was occurring. This could be a result of the vegetation composition differences between the *R. spinosa* and *P. pallens*-dominated vegetation.

2.5.3 Trakaskuilen - *Ruschia spinosa*-dominated Vegetation

The percentage cover and density of *L. cinereum* was found to be higher at Trakaskuilen than at Tierberg, which may be a result of prolonged disturbance by sheep. This species increases in abundance by coppicing due to disturbance (Gibson pers. comm.). A significant piosphere based on plant density was recognised for *L. cinereum* at Trakaskuilen and this piosphere was situated relatively close to the water point. In contrast to what was found at Tierberg, the prolonged disturbance activities of sheep have resulted in increased densities of *L. cinereum* being recorded due to the stimulation of coppicing from root stock when the plant above the soil surface is disturbed (Gibson pers. comm.).

Only a slight increase in *C. ciliata* density was found to occur at Trakaskuilen whereas the cover was approximately the same, compared to the *R. spinosa*-dominated vegetation at Tierberg. The piosphere for percentage cover was located at approximately 320m from the water point, having moved further away compared to that at Tierberg. However, the piosphere for density was found to be closer to the water point, occurring between 40 and 80m. The closer piosphere for plant density indicates that seedling recruitment may be occurring in the open sites close to the water point as a result of prolonged disturbance by sheep. These seedlings, although vulnerable to trampling, would have a higher survival rate at Trakaskuilen due to the higher rainfall.

The percentage cover and density of *R. spinosa* was found to be vastly different from that recorded in the *R. spinosa*-dominated vegetation at Tierberg. Gibson (pers.

comm.) has shown that *R. spinosa* and *P. incana* are negatively associated. Where the density and cover of *R. spinosa* is high, that of *P. incana* is low, and vice-versa, implying high interspecific competitive effects occurring between *R. spinosa* and *P. incana* (Gibson pers. comm.). However, the piospheres for percentage cover and density for *R. spinosa* occurred at 320m from the water point, further out than at Tierberg.

Eriocephalus ericoides occurred with a lower cover but higher density when compared to both the *R. spinosa*-dominated and *P. pallens*-dominated vegetation at Tierberg. These differences indicate a higher abundance of smaller shrubs at Trakaskuilen compared to a low abundance of larger shrubs at Tierberg. The prolonged exposure of these plants to the grazing system at Trakaskuilen has resulted in uniform cropping and therefore a population of individuals approximately measuring the same size. The boundaries of the piospheres also were found to be further away from the water point at Trakaskuilen (320m) compared to that at Tierberg (160m).

The percentage cover and density of *O. sinuatum* was extremely low, which is probably a consequence of overgrazing. *Osteospermum sinuatum* individuals were only found under the protection of nurse plants, especially *L. cinereum*, and were not found in the open (pers. obs.). This resulted in the piosphere being located at 640m from the water point and is the opposite to that found at Tierberg, where a higher abundance of *O. sinuatum* individuals were found to be present. The demise of the *O. sinuatum* population at Trakaskuilen could be as a result of overgrazing related to the Savory Grazing System and the rest period between grazing events, and further details of this are discussed in Chapter 3.

The piospheres for most species studied at Trakaskuilen appear to be situated at approximately 320m from the water point. This result differs from what was found at

Tierberg where the piospheres were located at approximately 160m from the water point. Species responded to the effects of sheep differently and the location of their piospheres differed accordingly. The piospheres of palatable shrubs move further away from the water points at a quicker rate than the more unpalatable species, as the former species not only are affected by trampling but also by grazing. In both vegetation types at Tierberg, the piospheres appeared to have migrated to approximately 160m from the water point whereas at Trakaskuilen, the piospheres had migrated 320m from the water point. These distances are important when comparing the age of the grazing systems. At Tierberg, the camps surveyed had been grazed on the Savory System for one and a half years. In this period, the piospheres had moved out 160m from the water point. If one assumes that both farmers apply the same grazing pressures at both farms and the piospheres do not stabilise, then the piospheres will move at an approximate rate of 106m per annum, if calculated using a linear model. If this holds true, then one would expect the piospheres at Trakaskuilen to be situated at 1802m from the water point after 17 years. However, the piospheres were found at approximately 320m from the water point. Therefore, it appears as if the piospheres have stabilised and reached equilibrium at Trakaskuilen, even though the camps are smaller than at Tierberg. One may therefore assume that the piospheres at Tierberg are still in the process of moving and being formed.

Andrew and Lange (1986b) recorded the development of a grass biomass piosphere on pristine rangelands in only three months after the construction of a central water point. However, in the same study, piospheres were not evident after eight years for the densities of some forbs. Therefore, one may assume that different vegetation types differ with respect to the time required to develop piospheres. However, it does appear as if the piospheres reach an equilibrium whereafter they do not move.

2.6 CONCLUSION

The piosphere phenomenon is not unique to the Succulent Karoo Biome and occurs where livestock are focused around a water point. However, in arid rangelands the effects of livestock on vegetation is greatly enhanced due to limited rainfall and slow plant population turnover. Indeed, piospheres have been noted around rabbit warrens, termitaria, prairie dog towns and even around reefs that shelter tropical fish (Andrew 1988).

The piospheres that were found to be present for the majority of species studied at Tierberg and Trakaskuilen reflect the vegetation degradation as a result of the Savory Grazing System. However, the location of the piospheres differed between Tierberg and Trakaskuilen, those at Tierberg being found closer to the water point whereas those at Trakaskuilen being located further away from the water point. The difference in the location of the piospheres could be related to the age of the piospheres in question. Nevertheless, it appears as if the movement of the piospheres reaches an equilibrium, as was found at Trakaskuilen, whereafter they do not move further away from the water point. No studies on the stability of piospheres over time appear to have been conducted. However, it appears from work conducted in the arid rangelands of Australia that piospheres will continue to be developed over many years of subsequent use (Andrew 1988). Piosphere stability is a new concept to studies on piospheres. The results obtained in this study suggest that stability may occur. It may follow then that piospheres will develop up to a point, whereafter, stability of the piospheres may well occur if the stocking density is kept constant. If the stocking density is increased, the effects of the increased livestock activity may cause the piospheres to migrate further away from the water point than prior to the increase in stocking density. This would terminate the stability status of the piosphere, which may occur further away from the water point if the stocking density is kept constant thereafter.

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CHAPTER 3

SUCCULENT KAROO VEGETATION MONITORING

USING LINE TRANSECTS

3.1 INTRODUCTION

Herbage production and its utilization is important to the small stock industry in the Karoo regions of South Africa. Grazing management systems, therefore, have evolved in an attempt to optimise this utilisation while simultaneously conserving these rangelands. To determine herbage utilization, a number of techniques have been developed and tested. These techniques include the destructive plant-based method (Hobson 1988), the descending-point method (Hobson and Baarnhoorn 1988), the ocular technique (Hobson 1989) and the objective point sampling techniques (Hobson and Baarnhoorn 1989).

The destructive plant-based method measures the dry organic matter of edible and inedible fractions of burnt specimens that have been clipped at ground level (Hobson 1988). This method has been found to be laborious and expensive, although the data has been found to be useful.

The descending-point method measures vegetation by recording every plant intercepted using a 5000 point survey technique and measures basal cover, canopy cover, canopy spread and the height of strikes (Hobson and Baarnhoorn 1988). This method proves effective in measuring meaningful canopy cover changes over a grazing period, however, data collection is very time consuming.

The ocular technique (Hobson 1989) is a subjective approach where plant utilization is calculated as the arithmetic average of given utilization estimates of a number of shrubs. This method classes the utilization of Karoo bushes from unutilized to extremely heavily utilized, based on a visual estimate. This method is open to operator bias and does not consider grazing by natural herbivores, such as antelope and hares.

Three, objective, point-sampling techniques; percentage-cover technique, percentage-edible-strikes, and percentage-twigs-grazed, are all utilized to measure plant utilization (Hobson and Baarnhoorn 1989). However, the percentage-cover technique was found to be the least sensitive of the three techniques in determining minimal utilization, which limits its usefulness.

Plant canopy cover is a reliable measure of shrub utilization between grazing periods (Hobson and Baarnhoorn 1988). Therefore, the monitoring of the recovery of the vegetation on Tierberg was determined by the change in canopy cover.

The aim of this part of the study was to monitor the change in canopy cover of a number of species over time with respect to grazing and rainfall events in the *Ruschia spinosa*-dominated and *Pteronia pallens*-dominated vegetation. The work was done in an attempt to establish whether the proposed 120-day recovery period envisaged by the farmer was sufficient for full recovery of the vegetation. In addition, the effects of sheep grazing on the vegetation with and without accompanying rainfall was determined, as was the vegetation condition following rainfall but without the effects of sheep grazing. The effects of sheep grazing during winter and summer were also determined for each vegetation type.

The effect of sheep grazing on the recovery of small and large plant individuals was also determined in an attempt to establish which size class of plants is more heavily utilized by grazing livestock.

3.2 STUDY SITES

The study was conducted in both the *Pteronia pallens*-dominated vegetation and the *Ruschia spinosa*-dominated vegetation at Tierberg, 25km east of Prince Albert (33°06'S; 22°15'E). Both these vegetation types have been grazed on the Savory system (Chapter 1) since June 1991. Details of the study sites used have been previously described in

Chapter 1.

The stocking densities for the camps studied were between 10.2 and 25.6 stock days per hectare for the *Ruschia spinosa*-dominated vegetation and between 6.0 and 28.8 stock days per hectare for the *Pteronia pallens*-dominated vegetation. Stock spent a minimum of 3 days and a maximum of 13 days in any one camp before being rotated to the next camp. The rotation frequency of stock was determined by the farmer who took vegetation condition into account when determining the length of time his stock would spend in any particular camp.

3.3 METHODS

The method used to monitor the vegetation was a slight modification of the ellipse intercept method of Stokes and Yeaton (1994). The ellipse intercept method was used as it is a quick and efficient method of determining plant cover (Stokes and Yeaton 1994). Ten, permanent, 20-metre-long line transects were positioned in each of 16 camps and were used to monitor the change in canopy cover of a number of Karoo shrubs. The canopy dimensions of each species intercepted by the line were recorded. To measure the canopies accurately each month, the axes of the plants that were intercepted by the length of the transect line were recorded as the length (L) measurement. The perpendicular axes of the plants (and to the transect line) were recorded as the breadth (B) measurement and the cover for each species was calculated by a length multiplied by breadth (LXB) function.

Due to the wedge-shape of the camps that were to be monitored, the placement of these transects was important as grazing impact is enhanced by the funnelling effect of the wedge-shaped camps. An indication of grazing pressure had to be determined in order for representative data to be collected. These transects had to be placed in areas that were not overgrazed, such as those close to the water point, and not under-utilized, such as those areas far from the water points. This meant that a "critical zone" had to be determined, which would yield data representing the worst scenario of grazing pressure. The vegetation extending from the "critical zone" outwards away from the water point would not be as severely grazed as this zone. This would suggest that any recommendations derived from the "critical zone" would apply to the rest of the camp, and thus leave a substantial margin for error in stocking density calculations.

The "critical zone" was determined from the data collected and analysed in Chapter 2 for these study sites. The locations of the piospheres around the water points in the *R. spinosa* and *P. pallens*-dominated vegetation were used as the criteria for the determination of the "critical zone". The distance of 160m away from the water point was determined to be where the piospheres for the majority of species occurred, as this area was found to be the region where the highest change in plant cover and density occurred. Thus, the line transects were placed in this area. To sample this area with the 20 metre-long transects, a staggered arrangement was used. Five transects were set up covering the distance between 140 and 160m and the other five were located between 160 and 180m from the water point. This placement of transects was done to sample 40m extending from 140 to 180m from the water point.

The line transects were set up in March 1993 at Tierberg. These transects were located in eight camps around the water point in the *R. spinosa*-dominated vegetation and in eight camps around three water points in the *P. pallens*-dominated vegetation. Three separate water points were selected in the *P. pallens*-dominated vegetation as the water points in this vegetation type were still not divided up into numerous camps served by a single water point. As a result, certain of these water points had a maximum of only four camps around them. The vegetation intersected by the transects was measured on a monthly basis starting in May 1993, after the first spring rains, and continued until August 1994.

Rainfall data for the first three months of the study were obtained from farm records, after which, rain gauges were set up at each of the water points. Rainfall was recorded on a monthly basis when data for the transects were collected. A hailstorm occurred in March 1994, which caused damage to a number of study plants in certain camps. The hailstones measured approximately 4.5cm in diameter and the significance thereof will be discussed when looking at the camps that were affected.

The species selected for the vegetation monitoring were determined on a palatability scale as discussed in Chapter 1. The key species that were monitored were *Pteronia pallens* (*P. pallens*-dominated vegetation only), *Chrysocoma ciliata*, *Ruschia spinosa*, *Eriocephalus ericoides*, *Tetragonia* spp. and *Osteospermum sinuatum*. Any of the above mentioned species with an abundance of three or more individuals occurring in more than four out of the eight camps in each vegetation type were included in the analysis.

The total cover of each species was calculated for all ten transects for each month. The combined difference in cover of all the individuals of all species for each vegetation type at the start and end of the study were compared using a Wilcoxon Signed Ranks Test (Siegal and Castellan 1988). The difference in cover between the individuals in each camp for each species between successive months was also compared using this test for the two vegetation types (Siegal and Castellan 1988). The differences in canopy cover were related to grazing charts obtained from farm records and rainfall data collected in the field. The total cover for a species after a grazing event (when the camp was exposed to a flock of sheep) was compared to that before a subsequent grazing event to determine the degree of recovery. Full recovery would be represented by a cover value measured before the second grazing event, approximately equalling that measured before the first grazing event.

The Wilcoxon Signed Ranks Test was also used to establish significance between selected comparisons in selected camps (Siegal and Castellan 1988). These camps were not inclusive of all the data sampled and were only used to determine changes in cover of individual groups of plants before and after specific events. These events were between successive data recording periods and included; a grazing event and rainfall, a grazing event without rainfall, no grazing event with rainfall, the overall change in cover over the study period (*i.e.*, the start compared to the end) and the effects of summer and winter grazing.

To establish if small individuals of the plant species recorded in this study reacted to grazing in the same way as large individuals, each group of species in each vegetation type had to be divided into two according to plant size. The median of plant sizes was calculated for each species in each vegetation type and all plants that were less than or equal to the median value were regarded as small individuals and the remaining plants as large individuals. Frequency histograms were also used to determine the division of plants into small and large individuals. The plant size divisions were adhered to throughout the analysis of the data.

The first analysis undertaken was to establish if small and large plants reacted differently to grazing over the entire study period. In this instance, the cover of all small and large individuals of each species in both vegetation types was compared to the cover values at the end of the study period. These cover values were tested using the Wilcoxon Signed Ranks Test to establish if there was a significant increase or decrease in cover over the study period.

The second analysis of these data was used to establish the response of small and large individuals to summer and winter grazing events. Monthly data were grouped according to seasons, *i.e.* summer or winter, and during these months a grazing event had to have taken place. The cover values of both small and large individuals were compared before and after the grazing event using a Wilcoxon Signed Ranks Test, and the resulting difference in cover of small and large individuals was compared using a Students-*t*-Test to establish which size class of plants was affected most.

3.4 RESULTS

3.4.1 The Effect of Sheep Grazing on All Plant Individuals in the *Ruschia spinosa*-dominated Vegetation

Five species were included in the analysis of vegetation recovery in the *R. spinosa*-dominated vegetation. These were; *C. ciliata*, *R. spinosa*, *E. ericoides*, *Tetragonia* spp. and *O. sinuatum*. The cover data is presented in tabular form for each species (Tables 3.2 - 3.6). Table 3.1 represents the pooled data for all individuals of the five species in all eight camps at the start and at the end of the study. A number of trends were found to be common for many of these species. The general trends for each species will be discussed individually and then summarised generally.

Table 3.1: Pooled mean cover ($cm^2 x 10^{-2}$) $\pm$SD of all individuals of five species recorded at the start and end of the study period in the *Ruschia spinosa*-dominated vegetation. N = the combined number of individuals measured in all eight camps, *P* = probability, ns = not significant.

Species	N	Start	End	*P*
C. ciliata	124	9.27±6.78	9.71±7.14	ns
R. spinosa	401	10.8±9.65	11.0±9.95	$P < 0.05$
E. ericoides	82	34.7±35.0	33.7±32.9	ns
Tetragonia spp.	27	7.19±5.35	5.08±3.53	$P < 0.001$
O. sinuatum	29	10.6±8.88	9.23±8.64	$P < 0.05$

3.4.1.1 *Chrysocoma ciliata*

The unpalatable shrub, *C. ciliata*, was found in abundance in all eight camps. The cover of this species did not change significantly over the study period (March 1993 to August 1994) (Table 3.1).

The cover of *C. ciliata* was observed to decrease during the hot, dry summer months between September 1993 and January 1994 (Tables 3.2b). *Chrysocoma ciliata* cover, however, was found to increase in the cooler, wetter winter months especially after rainfall events (Tables 3.2a,b). Cover loss due to branch and foliage damage after the hailstorm in March 1994 was found to occur. However, recovery following this event was slow (Tables 3.2b).

In the selected camps, where grazing and rainfall occurred between measuring periods, the cover of *C. ciliata* did not decrease. However, the cover decreased significantly by 6.7% ($P<0.01$) where there was a grazing event but no rain fell (Table 3.7). The cover of *C. ciliata* increased significantly by 11.8% ($P<0.001$) after a rainfall event when grazing was absent (Table 3.7). Although a net gain in cover of 5.2% was attained by this species over the study period in the selected camps, this increase was not significant (Table 3.7).

le 3.2a: Mean cover (cm^2x10^{-3}) ±SD of *Chrysocoma ciliata* from eight camps measured from March 1993 to November 1993 in the *Ruschia spinosa*-dominated vegetation. N = the number ndividuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
1	40	0.67±0.56	0.64±0.55	0.68±0.59*	0.67±0.59 G	0.69±0.60	0.66±0.58	0.66±0.57	0.66±0.58
2	5	1.29±0.68	1.27±0.72	1.36±0.73	1.46±0.79* G	1.45±0.82	1.38±0.75	1.38±0.76	1.36±0.77
3	12	1.59±1.05	1.52±1.02	1.71±1.09**	1.69±1.13 G	1.67±1.04	1.64±1.02	1.68±1.06 G	1.61±1.05*
4	12	1.28±0.56	1.23±0.57	1.36±0.64*	1.30±0.59 G	1.31±0.62	1.26±0.58	1.31±0.60* G	1.23±0.60
5	23	0.78±0.51	0.78±0.54	0.81±0.56 G	0.83±0.56	0.83±0.57	0.84±0.58	0.85±0.58 G	0.81±0.52
6	5	1.18±0.62	1.19±0.58	1.40±0.71* G	1.43±0.64	1.45±0.69	1.48±0.73 G	1.39±0.58	1.37±0.57
7	6	1.03±0.68	1.06±0.62	1.24±0.68* G	1.27±0.79	1.25±0.74	1.24±0.71 G	1.23±0.73	1.29±0.69
8	21	0.82±0.38	0.85±0.41 G	0.90±0.45*	0.90±0.43	0.92±0.43	0.91±0.41 G	0.89±0.41	0.87±0.41*
Rain		30mm	9mm	8mm	0mm	17mm	26mm	0mm	13mm

le 3.2b. Mean cover (cm^2x10^{-3}) ±SD of *Chrysocoma ciliata* from eight camps measured from December 1993 to August 1994 in the *Ruschia spinosa*-dominated vegetation. N = the number ndividuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
1	40	0.68±0.61 G	0.65±0.58**	0.66±0.58	0.71±0.61*** G	0.69±0.58	0.65±0.56*	0.64±0.55	0.64±0.55	0.66±0.56**
2	5	1.34±0.76 G	1.37±0.82	1.31±0.25	1.54±0.96* G	1.52±1.01	1.46±0.91	1.46±0.91	1.47±0.92 G	1.48±0.91
3	12	1.54±1.01	1.52±0.99	1.49±0.96	1.64±1.02** G	1.57±0.98	1.59±1.00	1.59±1.00	1.59±1.00 G	1.68±1.01**
4	12	1.24±0.62	1.24±0.62	1.25±0.62	1.38±0.63* G	1.17±0.60*	1.17±0.61	1.17±0.61	1.19±0.60 G	1.25±0.60**
5	23	0.82±0.53	0.80±0.53	0.81±0.54 G	0.90±0.58**	0.85±0.55**	0.84±0.55	0.84±0.55	0.82±0.54	0.85±0.56**
6	5	1.37±0.60	1.35±0.60 G	1.37±0.60	1.47±0.66*	1.28±0.64	1.28±0.64	1.28±0.64 G	1.27±0.62	1.40±0.62*
7	6	1.34±0.80	1.29±0.77 G	1.29±0.77	1.32±0.78	1.28±0.73	1.27±0.66	1.27±0.66 G	1.26±0.65	1.34±0.66
8	21	0.88±0.41	0.85±0.41 G	0.85±0.42	0.87±0.42*	0.82±0.39	0.82±0.40	0.79±0.39** G	0.76±0.37**	0.82±0.40**
Rain		32mm	40mm	0mm	31mm	5mm	8mm	20mm	5mm	-

No loss in cover was found to occur after a grazing event that occurred during summer in the selected camps (Table 3.8). A slight (1.0%) loss in cover ($P<0.05$) however, did occur after a grazing event that occurred in winter (Table 3.8).

3.4.1.2 *Ruschia spinosa*

All eight camps were found to contain *R. spinosa*, and this species occurred in high abundance. It is due to the high abundance of this species that this vegetation type has been classified as *R. spinosa*-dominated vegetation in this study.

The cover of *R. spinosa* increased significantly over the study period ($P<0.05$) (Table 3.1). This species generally did not decrease in cover after grazing events and therefore was assumed not to be grazed (Tables 3.3a,b).

The growth of *R. spinosa* exhibits definite seasonal effects. Active growth occurs during the cooler, wetter winter months and declines during the hot, dry summer months (Tables 3.3a,b).

In the selected camps where grazing and rainfall occurred between measuring periods, the cover of *R. spinosa* did not decrease, whereas the cover decreased significantly ($P<0.001$) where there was a grazing event but no rain fell (Table 3.7). The cover of *R. spinosa* increased significantly ($P<0.001$) following a rainfall event when grazing did not occur (Table 3.7). No net gain in cover was attained for the species in the selected camps over the study period (Table 3.7).

The cover of *R. spinosa* did not decrease due to grazing in the selected camps during summer (Table 3.8). Only a small loss in cover (0.8%) was found to occur after the grazing event in winter ($P<0.001$) (Table 3.8).

ble 3.3a: Mean cover (cm^2x10^{-3}) ±SD of *Ruschia spinosa* from eight camps measured from March 1993 to November 1993 in the *Ruschia spinosa*-dominated vegetation. N = the number individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
1	55	1.01±0.80	0.99±0.77	1.04±0.76***	1.07±0.81 G	1.10±0.81*	1.10±0.82	1.11±0.84	1.09±0.82*
2	75	1.24±0.86	1.21±0.94*	0.28±1.00	1.31±1.06 G	1.28±1.04*	1.29±1.02	1.29±1.02	1.27±1.00**
3	74	0.84±0.68	0.82±0.62	0.86±0.63	0.87±0.65 G	0.87±0.66	0.92±0.66**	0.92±0.67 G	0.89±0.66***
4	67	1.07±0.96	1.01±0.89	1.19±0.99***	1.18±0.98 G	1.17±0.97	1.19±0.99	1.19±0.99 G	1.16±0.94***
5	56	1.04±0.69	1.08±0.74	1.21±0.81*** G	1.19±0.79	1.20±0.79	1.22±0.80	1.22±0.80 G	1.20±0.80
6	16	1.43±0.82	1.46±0.84	1.59±0.88* G	1.58±0.90	1.68±0.93*	1.60±0.85* G	1.56±0.92	1.53±0.87
7	34	1.17±1.45	1.18±1.45	1.27±1.50*** G	1.28±1.46	1.31±1.49	1.32±1.46 G	1.28±1.45**	1.26±1.42
8	24	1.28±1.70	1.28±1.62 G	1.35±1.76	1.40±1.86	1.41±1.80	1.39±1.78 G	1.41±1.76	1.36±1.74
Rain		30mm	9mm	8mm	0mm	17mm	26mm	0mm	13mm

ble 3.3b. Mean cover (cm^2x10^{-3}) ±SD of *Ruschia spinosa* from eight camps measured from December 1993 to August 1994 in the *Ruschia spinosa*-dominated vegetation. N = the number individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
1	55	1.05±0.80** G	1.03±0.77**	1.04±0.78	1.06±0.79** G	1.04±0.79**	1.04±0.80	1.04±0.80	1.05±0.81*	1.07±0.81***
2	75	1.27±1.02 G	1.26±1.01*	1.26±1.00	1.27±1.01* G	1.23±1.04**	1.23±1.05	1.21±1.05	1.24±1.05 G	1.25±1.06***
3	74	0.87±0.65	0.85±0.63***	0.85±0.63	0.87±0.64*** G	0.84±0.64***	0.84±0.64	0.84±0.64	0.84±0.64 G	0.86±0.66**
4	67	1.14±0.94	1.12±0.91	1.13±0.92	1.13±0.92 G	1.03±0.81***	1.02±0.78	1.02±0.78	1.00±0.79 G	1.00±0.84
5	56	1.20±0.79	1.18±0.79	1.18±0.80 G	1.19±0.81	1.12±0.78***	1.12±0.78	1.12±0.78	1.11±0.76	1.10±0.81
6	16	1.52±0.89	1.49±0.89 G	1.50±0.90*	1.52±0.91*	1.44±0.84*	1.43±0.84	1.44±0.84 G	1.43±0.84	1.49±0.84**
7	34	1.24±1.41	1.22±1.39* G	1.24±1.43	1.26±1.45	1.21±1.42*	1.21±1.42	1.21±1.42 G	1.20±1.42	1.25±1.50**
8	24	1.36±1.74	1.32±1.68 G	1.31±1.67	1.33±1.69	1.29±1.61	1.30±1.61	1.30±1.61 G	1.27±1.59	1.29±1.61
Rain		32mm	40mm	0mm	31mm	5mm	8mm	20mm	5mm	-

3.4.1.3 *Eriocephalus ericoides*

Eriocephalus ericoides was also common, occurring in all eight camps. The cover of *E. ericoides* decreased from March 1993 to August 1994 by 4.14%, although this was not significant (Table 3.1). Cover was significantly lower ($P<0.01$) after a camp had been grazed (6.8% reduction in cover) than before the grazing event (Tables 3.4a,b). This was found to occur mainly between late winter and early spring. The recovery period between grazing events appears to be too short as the plants appear to be decreasing in cover over time. This suggests that the plants do not recover fully. The cover was found to be lower before a second successive grazing event when compared to the cover before the first event (Tables 3.4a,b).

Eriocephalus ericoides also exhibits seasonal growth and grows actively during winter, whereas growth appears to cease during the summer months (Tables 3.4a,b).

In the selected camps, where grazing and rainfall occurred between measuring periods, the cover of *E. ericoides* decreased significantly ($P<0.001$) and a loss of 4.3% in cover was recorded (Table 3.7). An even greater decline in cover (9.9%) occurred after there was a grazing event but no rain fell ($P<0.001$) (Table 3.7). The cover of *E. ericoides* increased slightly (1.2%) following a rainfall event when grazing did not occur ($P<0.001$) (Table 3.7). No net gain in cover was attained for the species in the selected camps over the study period (Table 3.7).

A significantly higher ($P<0.001$) loss in cover occurred after a grazing event in winter (5.4%), than after a grazing event in summer where no significant increase occurred (Table 3.8).

ble 3.4a: Mean cover (cm^2x10^{-3}) ±SD of *Eriocephalus ericoides* from eight camps measured from March 1993 to November 1993 in the *Ruschia spinosa*-dominated vegetation. N = the mber of individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
1	6	1.64±1.27	1.58±1.23	1.64±1.17	1.89±1.49 G	1.78±1.38	1.71±1.23	1.76±1.28	1.75±1.28
2	15	2.05±1.78	1.94±0.57	2.09±1.68*	2.11±1.68 G	1.89±1.62**	1.88±1.54	1.84±1.51	1.87±1.57
3	7	2.52±2.58	2.17±2.36*	2.21±2.33	2.25±2.39 G	2.26±2.49	2.42±2.52	2.36±2.47 G	2.04±2.17*
4	11	4.96±4.37	5.07±4.34	5.23±3.90	5.58±4.30* G	5.40±3.99	5.39±4.05	5.31±4.03 G	5.04±3.79
5	12	2.58±1.60	2.44±1.69	3.07±2.16* G	2.83±1.92	2.96±1.98	2.93±1.92	2.85±1.90 G	2.68±1.90**
6	14	4.35±3.33	4.65±4.00	5.37±4.50*** G	5.47±4.62	5.33±4.50	5.31±4.35 G	4.98±4.14	4.85±4.19*
7	10	5.41±5.17	5.31±5.05	5.86±5.97 G	5.85±5.67	5.69±5.06	5.94±5.59 G	5.69±5.53**	5.87±6.07
8	7	3.54±3.56	3.52±3.38 G	3.48±3.48	3.26±3.02	3.55±3.48	3.55±3.47 G	3.24±3.38*	3.28±3.39
Rain		30mm	9mm	8mm	0mm	17mm	26mm	0mm	13mm

le 3.4b. Mean cover (cm^2x10^{-3}) ±SD of *Eriocephalus ericoides* from eight camps measured from December 1993 to August 1994 in the *Ruschia spinosa*-dominated vegetation. N = the nber of individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
1	6	1.56±1.16* G	1.49±1.06	1.50±1.08*	1.72±1.24* G	1.61±1.20	1.54±1.22	1.54±1.21	1.49±1.18*	1.59±1.18*
2	15	1.92±1.60 G	1.89±1.57	1.92±1.58	2.04±1.64*** G	1.83±1.49*	1.81±1.47	1.81±1.47	1.84±1.49* G	1.80±1.46*
3	7	2.02±2.22	2.08±2.36	2.14±2.45*	2.29±2.52* G	2.08±2.33*	2.14±2.43	2.14±2.43	2.15±2.42 G	2.13±2.41
4	11	4.97±3.73	4.89±3.69**	5.15±3.98*	5.31±4.13** G	4.70±3.24*	4.78±3.42	4.76±3.44*	4.81±3.45* G	4.89±3.51
5	12	2.74±1.95	2.62±1.82	2.82±1.97**	2.92±2.01** G	2.69±1.93**	2.73±1.91	2.73±1.91 G	2.61±1.86**	2.80±1.92**
6	14	4.86±4.14	4.80±4.07 G	4.62±3.91*	4.85±4.01**	4.47±3.66**	4.73±3.80**	4.73±3.80 G	4.38±3.63**	4.60±3.76**
7	10	5.68±5.74	5.70±5.79 G	5.69±5.79	5.72±5.75	4.86±4.45*	4.91±4.41*	4.90±4.42 G	4.77±4.43*	5.00±4.48**
8	7	3.34±3.42	3.35±3.44 G	3.42±3.59	3.48±3.60*	3.11±3.07	3.19±3.19	3.27±3.34 G	3.07±3.23*	3.17±3.21
Rain		32mm	40mm	0mm	31mm	5mm	8mm	20mm	5mm	-

3.4.1.4 *Tetragonia* spp.

Six of the eight camps contained the palatable shrubs *Tetragonia* spp., but in low numbers.

The cover of *Tetragonia* spp. decreased significantly ($P<0.001$) over the study period (37.7%) (Table 3.1). These fodder plants were severely grazed during each grazing event (removing 21% of the cover). This indicates how vulnerable *Tetragonia* spp. are to selective grazing.

Prolific growth occurred during winter, especially after a couple of months following rainfall events (Tables 3.5a,b). In the selected camps, a 20.5% decline ($P<0.01$) in cover occurred after a grazing event in winter, whereas after a summer grazing event, cover declined by only 4.8% ($P<0.05$) (Table 3.8).

Tetragonia spp. were also found to be susceptible to hail damage but recovered quickly regaining 20.7% in 30 days following this event (Tables 3.5b).

The vegetation recovery period is too short as cover loss was found to occur over the study period. The individuals of *Tetragonia* spp. did not have sufficient time to regain biomass lost due to grazing. This trend has already been established for *E. ericoides*.

In the selected camps, a 39.7% loss in cover ($P<0.001$) was recorded over the study period (Table 3.7). Cover loss was found to occur after each grazing event, (22.2-26.9%), whether rain had fallen or not ($P<0.001$) (Table 3.7). However, the cover of *Tetragonia* spp. increased by 23.8% ($P<0.001$) after rainfall, when the plants were not exposed to grazing.

le 3.5a: Mean cover (cm^{2}x10^{-2}) ±SD of *Tetragonia* spp. from six camps measured from March 1993 to November 1993 in the *Ruschia spinosa*-dominated vegetation. N = the number of ividuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
1	5	5.33±1.08	4.89±1.45	5.05±1.29	4.85±1.18 G	4.06±1.34*	4.13±1.35	4.23±1.44	3.99±1.41
2	6	9.06±6.50	9.18±6.51	9.99±7.02*	10.2±6.85 G	7.09±5.06*	7.23±5.10	6.85±4.82	6.36±4.28
3	4	10.5±3.86	6.21±3.17	7.60±3.15*	7.76±3.46 G	6.64±3.41*	6.13±3.26	6.34±3.04 G	4.62±1.85*
4	3	5.03±4.06	4.27±3.65	4.46±3.71	4.85±3.87 G	3.75±3.26	4.24±3.80	4.14±3.85* G	2.53±2.73*
7	3	8.40±0.92	5.38±1.17	6.52±2.52 G	5.71±1.49	6.83±1.13	6.61±1.88 G	4.96±1.49	5.02±1.57
8	6	5.17±2.55	6.01±3.66* G	4.81±3.01*	5.01±3.16	5.56±3.39	5.74±3.38 G	4.56±2.98*	4.45±2.74
Rain		30mm	9mm	8mm	0mm	17mm	26mm	0mm	13mm

le 3.5b. Mean cover (cm^{2}x10^{-2}) ±SD of *Tetragonia* spp. from six camps measured from December 1993 to August 1994 in the *Ruschia spinosa*-dominated vegetation. N = the number ndividuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
1	5	3.49±1.33* G	3.31±1.32*	3.37±1.20	3.93±1.10* G	3.07±1.05*	3.49±1.08	3.34±0.97	3.46±0.97	3.95±1.46
2	6	6.03±4.38* G	5.96±4.46	6.06±4.41*	7.53±5.44* G	6.01±4.59*	6.88±5.19	6.94±4.99	6.96±4.87 G	6.43±4.67*
3	4	4.80±1.64	4.74±1.74	5.09±1.61*	6.36±2.49* G	5.23±2.15*	6.17±2.89**	6.00±2.96*	6.50±3.78* G	5.91±3.62
4	3	2.43±2.48	2.34±2.35	2.58±2.69*	3.38±3.16 G	1.15±0.74*	1.74±0.75*	1.61±0.79	1.89±0.84	1.75±0.95*
7	3	5.12±1.49	5.27±1.79 G	4.92±1.83	5.17±2.02	4.22±1.65	5.44±1.93	5.58±1.97 G	4.27±1.75	5.70±1.70
8	6	4.61±3.09*	4.29±2.79 G	4.20±2.81	4.77±3.04*	4.04±2.58	4.95±3.45*	4.81±3.47 G	4.03±2.80*	5.49±3.58*
Rain		32mm	40mm	0mm	31mm	5mm	8mm	20mm	5mm	-

3.4.1.5 *Osteospermum sinuatum*

Osteospermum sinuatum was present in only four camps and occurred in low abundance. Two of the four camps exhibited an increase in cover (9.8%) over the study period whereas the remaining two showed a decrease (19.4%) (Tables 3.6a,b). However, the cover in all camps declined by 9% overall over the study period ($P<0.05$) (Table 3.1). *Osteospermum sinuatum* was heavily utilized during each grazing event, resulting in a loss of cover each time (Tables 3.6a,b).

Osteospermum sinuatum was also found to exhibit seasonal growth. Growth appears to cease during summer but becomes more vigorous during winter (pers. obs.). In the selected camps, no significant loss in cover occurred due to grazing during summer, whereas 27.1% ($P<0.05$) was lost during winter (Table 3.8).

It is evident from the data that the rest period between grazing events is not long enough for the full recovery of these plants before they are grazed again. Individuals of *O. sinuatum* exhibited a 12.96% lower cover value before a second grazing event, compared to that before the first grazing event (Tables 3.6a,b).

In the selected camps, a decrease of 15.2% ($P<0.001$) in cover was found to occur over the study period (Table 3.7). It appears as if individuals that are grazed and receive rain recover better (26.0%) ($P<0.001$) than those that are not grazed and receive rainfall (23.8%) ($P<0.001$) (Table 3.7). Individuals that are grazed but received no rainfall do not recover as well as the aforementioned two treatments (20.5%) ($P<0.001$) (Table 3.7).

ble 3.6a: Mean cover (cm^{2}x10^{-3}) ±SD of *Osteospermum sinuatum* from four camps measured from March 1993 to November 1993 in the *Ruschia spinosa*-dominated vegetation. N = the nber of individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
2	13	1.41±1.07	1.59±1.44	1.69±1.32	1.69±1.42 G	1.25±1.16*	1.29±1.21	1.32±1.20	1.31±1.20
3	6	0.65±0.66	0.72±0.69	1.01±1.26	1.00±1.22 G	0.73±0.88*	0.70±0.82	0.73±0.85	0.58±0.64*
4	4	0.94±0.29	0.79±0.45	1.11±0.46	1.13±0.46 G	0.94±0.29*	0.98±0.45	1.11±0.46	1.13±0.46*
5	6	0.77±0.56	1.05±0.65*	1.19±0.68* G	0.78±0.54*	0.83±0.34	0.87±0.49	0.82±0.48* G	0.70±0.47*
Rain		30mm	9mm	8mm	0mm	17mm	26mm	0mm	13mm

le 3.6b. Mean cover (cm^{2}x10^{-3}) ±SD of *Osteospermum sinuatum* from four camps measured from December 1993 to August 1994 in the *Ruschia spinosa*-dominated vegetation. N = the nber of individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
2	13	1.14±1.09* G	1.14±1.07	1.14±1.07	1.48±1.31** G	1.15±1.13***	1.24±1.09*	1.24±1.10	1.21±1.11	1.14±1.07*
3	6	0.55±0.58	0.53±0.60	0.53±0.58	0.69±0.73* G	0.61±0.70*	0.70±0.75*	0.72±0.78	0.71±0.79	0.66±0.74*
4	4	0.59±0.33	0.56±0.32	0.56±0.32	0.63±0.32 G	0.49±0.32*	0.57±0.35*	0.58±0.36	0.58±0.35	0.60±0.36
5	6	0.66±0.48*	0.64±0.47	0.66±0.48	0.79±0.54* G	0.57±0.45*	0.64±0.42*	0.64±0.42 G	0.62±0.44	0.90±0.54*
Rain		32mm	40mm	0mm	31mm	5mm	8mm	20mm	5mm	-

Table 3.7: Mean cover ($\pm$SD) and percentage cover loss/gain of five Karoo shrubs in the selected camps at the beginning of the study (Start), after a grazing event with no rainfall (G+NR), after a grazing event with rainfall (G+R), after no grazing and rainfall (NG+R) and at the end of the study (Final) in the *Ruschia spinosa*-dominated vegetation at Tierberg. Cc = *Chrysocoma ciliata* (cm^2x10^{-3}), Rs = *Ruschia spinosa* (cm^2x10^{-3}), Ee = *Eriocephalus ericoides* (cm^2x10^{-2}), T = *Tetragonia* spp. (cm^2x10^{-2}) and Os = *Osteospermum sinuatum* (cm^2x10^{-2}). * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, ^{ns} = not significant.

Species	Start	G+NR	Loss	G+R	Loss	NG+R	Gain	Final	Net Gain
Cc	1.21 ± 0.39	$1.24\pm0.41^{**}$	6.7%	1.29 ± 0.42^{ns}	0%	$1.32\pm0.42^{***}$	11.8%	1.27 ± 0.45^{ns}	+5.2%
Rs	1.04 ± 0.17	$1.03\pm0.17^{***}$	4.7%	1.11 ± 0.17^{ns}	0%	$1.08\pm0.17^{***}$	1.2%	1.04 ± 0.17^{ns}	0%
Ee	2.80 ± 1.49	$2.56\pm1.44^{***}$	9.9%	$2.83\pm1.72^{***}$	4.3%	$2.84\pm1.67^{***}$	5.7%	2.60 ± 1.54^{ns}	-7.3%
T	7.48 ± 2.71	$3.87\pm2.19^{***}$	26.9%	$5.39\pm1.72^{***}$	22.2%	$5.30\pm1.97^{***}$	23.8%	$4.51\pm2.13^{***}$	-39.7%
Os	1.01 ± 0.38	$0.79\pm0.31^{***}$	20.5%	$0.94\pm0.27^{***}$	26.0%	$0.99\pm0.43^{***}$	23.8%	$0.85\pm0.25^{***}$	-15.2%

Table 3.8: Mean cover ($\pm$SD) and percentage cover loss of five Karoo shrubs before and after a summer and winter grazing event in the *Ruschia spinosa*-dominated vegetation at Tierberg. Cc = *Chrysocoma ciliata* (cm^2x10^{-3}), Rs = *Ruschia spinosa* (cm^2x10^{-3}), Ee = *Eriocephalus ericoides* (cm^2x10^{-2}), T = *Tetragonia* spp. (cm^2x10^{-2}) and Os = *Osteospermum sinuatum* (cm^2x10^{-2}). * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, ^{ns} = not significant.

Species	Summer Before	Summer After	Loss	Winter Before	Winter After	Loss
Cc	1.17 ± 0.25	1.17 ± 0.28^{ns}	0%	1.04 ± 0.27	$1.03\pm0.27^{*}$	1.0%
Rs	1.35 ± 0.14	1.35 ± 0.13^{ns}	0%	1.27 ± 0.14	$1.26\pm0.14^{***}$	0.8%
Ee	4.62 ± 1.18	$4.57\pm1.13^{*}$	1.1%	3.91 ± 1.07	$3.70\pm1.03^{***}$	5.4%
T	4.79 ± 0.69	$4.56\pm0.50^{*}$	4.8%	5.20 ± 0.54	$4.15\pm0.17^{**}$	20.1%
Os	0.57 ± 0.82	0.56 ± 0.80^{ns}	1.8%	1.29 ± 0.36	$0.94\pm0.27^{*}$	27.1%

3.4.2 The Effect of Sheep Grazing on All Plant Individuals in the *Pteronia pallens*-dominated Vegetation

Four species were included in the analysis of vegetation recovery in the *Pteronia pallens*-dominated vegetation. These were; *P. pallens*, *R. spinosa*, *Tetragonia* spp. and *O. sinuatum*. Cover data are presented in tabular form for each species (Tables 3.10 - 3.13). Table 3.9 represents the pooled data for all individuals of the four species in all eight camps at the start and end of the study. A number of trends were found to be common for many of these species. The general trends for each species will be discussed individually.

Table 3.9: Pooled mean cover ($cm^2 x 10^{-2}$) $\pm$SD of all individuals of four species recorded at the start and end of the study period in the *Pteronia pallens*-dominated vegetation. N = the combined number of individuals measured in all eight camps, P = probability, ns = not significant.

Species	N	Start	End	*P*
P. pallens	293	38.1±36.2	40.7±39.2	$P<0.001$
R. spinosa	304	11.0±10.5	11.2±10.8	ns
Tetragonia spp.	22	4.23±29.5	5.00±3.76	$P<0.05$
O. sinuatum	50	6.68±6.70	7.72±7.31	$P<0.01$

3.4.2.1 *Pteronia pallens*

Pteronia pallens is an unpalatable shrub that was found in all eight camps and dominated the vegetation in both cover and density.

The cover of *P. pallens* increased significantly ($P<0.001$) over the study period by 9.09% (Table 3.9). This species was also not found to be grazed (Tables 3.10a,b).

The cover of *P. pallens* increased after rainfall events, especially after the dry summer months, but plants were severely damaged during the hailstorm of March 1994 (See camps 6 and 7 in Tables 3.10b). However, *P. pallens* recovered quickly after this storm, utilizing the high rainfall that accompanied the hail and regaining 9.4% in cover.

In the selected camps, the cover of *P. pallens* increased significantly ($P<0.001$) by 14.94% over the study period (Table 3.14). Very little cover change (0.7-1.9%) occurred after the grazing events, whether or not they were accompanied by rainfall (Table 3.14).

No significant loss in cover occurred for the individuals in the selected camps after the grazing event in summer, whereas, a significant increase ($P<0.001$) in cover occurred after the grazing event during winter (2.2%) (Table 3.15).

ble 3.10a: Mean cover (cm^{2}x10^{-3}) ±SD of *Pteronia pallens* from eight camps measured from March 1993 to November 1993 in the *Pteronia pallens*-dominated vegetation. N = the number individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
1	33	5.09±5.84	5.39±6.26***	5.41±5.94	5.63±6.29 G	5.48±6.06	5.55±6.27	5.70±6.56	5.43±6.34**
2	47	3.83±4.00	4.00±4.28	4.15±4.30**	4.18±4.25 G	4.16±4.25	4.14±4.23	4.21±4.32	4.07±4.33***
3	36	2.09±1.71	2.25±1.86*	2.42±1.89***	2.43±1.99 G	2.36±1.91*	2.42±1.88*	2.37±1.84	2.36±1.90 G
4	35	3.39±2.08	3.49±2.07*	3.63±2.13	3.67±2.11 G	3.73±2.24	3.78±2.19	3.77±2.20	3.70±2.15 G
Rain		30mm	9mm	8mm	0mm	15mm	22mm	0mm	17mm
5	13	3.00±1.84	3.22±1.88	3.20±1.88	3.20±1.83 G	3.29±1.89 G	3.33±1.95	3.29±2.02**	3.18±2.06
Rain		30mm	9mm	8mm	0mm	13mm	19mm	0mm	15mm
6	49	4.25±3.18 G	4.35±3.18*	4.55±3.09**	4.52±3.02	4.53±3.18 G	4.50±3.04	4.59±3.15	4.58±3.24*
7	56	3.78±2.91	3.69±2.63 G	3.77±2.73	3.66±2.66	3.73±2.75	3.78±2.83	3.80±2.86	3.72±2.86
8	27	4.46±4.37	4.54±4.82 G	4.72±4.94*	4.47±4.53**	4.56±4.69	4.62±4.77	4.62±4.81	4.65±5.00
Rain		30mm	9mm	8mm	0mm	18mm	30mm	0mm	13mm

ble 3.10b. Mean cover (cm^{2}x10^{-3}) ±SD of *Pteronia pallens* from eight camps measured from December 1993 to August 1994 in the *Pteronia pallens*-dominated vegetation. N = the number individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
1	33	5.47±6.33	5.43±6.23*	5.52±6.21** G	5.52±6.17	5.67±6.23***	5.68±6.23	5.69±6.23	5.67±6.17	5.78±6.24***
2	47	4.16±4.34*	4.12±4.34	4.12±4.34	4.22±4.60** G	4.27±4.62***	4.27±4.62	4.28±4.62	4.28±4.62	4.33±4.68***
3	36	2.29±1.79	2.24±1.74*	2.24±1.75	2.29±1.74*** G	2.32±1.73*	2.32±1.72	2.33±1.72	2.34±1.74*	2.41±1.75***
4	35	3.70±2.16	3.63±2.11	3.66±2.15	3.72±2.17*** G	3.73±2.16	3.75±2.17	3.77±2.18*	3.78±2.19*	3.84±2.20***
Rain		32mm	52mm	0mm	33mm	3mm	7mm	22mm	6mm	-
5	13	3.32±2.06*	3.28±2.05	3.26±1.94	3.32±1.94*	3.30±1.95 G	3.27±1.95	3.28±1.99	3.27±1.96	3.33±1.950*
Rain		30mm	48mm	0mm	25mm	5mm	11mm	26mm	4mm	-
6	49	4.58±3.23	4.49±3.20**	4.53±3.22**	4.54±3.24	3.69±2.75***	4.04±2.89*** G	4.04±2.89	4.09±2.92***	4.18±2.96***
7	56	3.72±2.88	3.68±2.85	3.69±2.85	3.74±2.88***	3.07±2.46***	3.33±2.60***	3.36±2.61* G	3.49±2.72***	3.62±2.81***
8	27	4.56±4.93	4.48±4.79	4.57±4.84*	4.66±4.90***	4.26±4.50***	4.64±5.00***	4.65±5.00* G	4.71±5.04**	4.92±5.28***
Rain		32mm	36mm	0mm	55mm	4mm	9mm	24mm	6mm	-

3.4.2.2 *Ruschia spinosa*

Ruschia spinosa was present in seven of the eight camps in varying abundance (Table 3.11a).

The cover of *R. spinosa* did not increase significantly over the study period (Tables 3.9). Cover decline due to grazing was low and no significant decreases in cover occurred after the summer grazing event (Table 3.15). However, a significant ($P<0.001$) increase in cover (1.0%) was recorded after the grazing event in winter (Table 3.15)

The seasonal growth of this species that was observed in the *R. spinosa*-dominated vegetation was also observed in the *P. pallens*-dominated vegetation as well. An active winter growing period and a dormant summer period was observed for this species (Tables 3.11a,b).

Ruschia spinosa grew actively after rainfall, especially when it fell in spring. In the selected camps, the cover of *R. spinosa* increased slightly (2.9%) after rainfall when there was no grazing, although this was not found to be significant (Table 3.14). *Ruschia spinosa* was severely damaged by the hail that fell in March 1994 (See camps 6,7,8 in Tables 3.11b). However, in contrast to the other species, recovery after this hailstorm was slow (Table 3.11b). The cover of *R. spinosa* in the selected camps was found to increase significantly ($P<0.001$) over the study period (Table 3.14).

ble 3.11a: Mean cover (cm^2x10^{-3}) ±SD of *Ruschia spinosa* from seven camps measured from March 1993 to November 1993 in the *Pteronia pallens*-dominated vegetation. N = the number individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
1	9	1.86±1.76	1.99±1.84	2.02±1.82	1.94±1.71 G	1.90±1.63	1.89±1.64	1.87±1.64 G	1.83±1.58
2	7	0.91±0.91	1.01±0.98*	1.19±0.94	1.25±1.02 G	1.41±1.23	1.29±1.07	1.33±1.18 G	1.29±1.08
3	4	0.36±0.32	0.42±0.35	0.42±0.35	0.45±0.39 G	0.47±0.41	0.48±0.43	0.45±0.37	0.45±0.35 G
Rain		30mm	9mm	8mm	0mm	15mm	22mm	0mm	17mm
5	23	1.10±1.01	1.07±1.05	1.13±1.10	1.18±1.17** G	1.24±1.28 G	1.23±1.27	1.25±1.32	1.22±1.29
Rain		30mm	9mm	8mm	0mm	13mm	19mm	0mm	15mm
6	63	1.08±0.89 G	1.07±0.91	1.12±0.88***	1.12±0.86	1.11±0.88 G	1.16±0.91**	1.14±0.90*	1.12±0.90
7	100	0.87±0.77	0.89±0.78* G	0.94±0.81***	0.90±0.79***	0.93±0.80**	0.95±0.82	0.94±0.82	0.92±0.79***
8	98	1.34±1.24	1.35±1.25* G	1.38±1.29***	1.32±1.23*	1.33±1.25	1.35±1.25	1.36±1.27	1.35±1.27
Rain		30mm	9mm	8mm	0mm	18mm	30mm	0mm	13mm

ble 3.11b. Mean cover (cm^2x10^{-3}) ±SD of *Ruschia spinosa* from seven measured from December 1993 to August 1994 in the *Pteronia pallens*-dominated vegetation. N = the number of ividuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
1	9	1.86±1.61*	1.86±1.64	1.88±1.66 G	1.85±1.65	1.89±1.67*	1.91±1.68*	1.92±1.68	1.94±1.70	2.00±1.74*
2	7	1.31±1.06	1.25±1.01*	1.26±1.01	1.27±1.02 G	1.29±1.02	1.32±1.04*	1.33±1.03	1.35±1.04	1.42±1.07*
3	4	0.46±0.37	0.45±0.36	0.46±0.38	0.49±0.41 G	0.51±0.38	0.47±0.35*	0.47±0.35	0.48±0.35	0.53±0.39*
Rain		32mm	52mm	0mm	33mm	3mm	7mm	22mm	6mm	-
5	23	1.21±1.26	1.22±1.31	1.22±1.30	1.24±1.31**	1.26±1.32* G	1.25±1.35	1.25±1.35	1.26±1.35*	1.32±1.36***
Rain		30mm	48mm	0mm	25mm	5mm	11mm	26mm	4mm	-
6	63	1.11±0.88*	1.08±0.89***	1.09±0.90**	1.10±0.90	0.97±0.82***	0.96±0.83 G	0.96±0.83	0.96±0.84	1.00±0.85***
7	100	0.91±0.79	0.90±0.80*	0.90±0.79	0.91±0.80	0.80±0.73***	0.79±0.73*	0.79±0.74 G	0.80±0.75*	0.85±0.78***
8	98	1.35±1.27	1.33±1.26*	1.31±1.23	1.34±1.27***	1.25±1.19***	1.26±1.20**	1.26±1.18 G	1.27±1.19*	1.33±1.22***
Rain		32mm	36mm	0mm	55mm	4mm	9mm	24mm	6mm	-

3.4.2.3 *Tetragonia* spp.

Although *Tetragonia* spp. occurred in five out of eight camps, few individuals were encountered in these camps (Table 3.12a). Nonetheless, the cover of these species increased significantly ($P<0.05$) by 17.5% over the study period (Table 3.9). In the selected camps, an increase of 7.37% ($P<0.05$) was found to occur over the study period (Table 3.14). *Tetragonia* spp. were severely grazed (cover decreasing by 17% after each grazing event) especially during the winter months (Tables 3.12a,b). In the selected camps, 4.9% ($P<0.01$) cover was lost after the grazing event in summer, whereas 14.9% ($P<0.001$) was lost after the winter grazing event (Table 3.15). *Tetragonia* spp. are, however, able to recover quickly after a rainfall event (Tables 3.12a,b). This recovery was found to be greater than that recorded in the *R. spinosa*-dominated vegetation. The overall cover increased during the study.

The hailstorm during March 1994 severely damaged individuals of *Tetragonia* spp., where cover decreased by 15.6% (See Camp 5,6 in Tables 3.12b). Although these plants were subjected to grazing soon thereafter, they still managed to recover quickly, gaining 19.2% cover in 30 days.

Larger cover losses (14.9%) were recorded for the selected camps, where grazing and rainfall occurred between measuring periods ($P<0.001$), than all the camps combined (Table 3.14). Individuals that were grazed, but no rain had fallen lost, 7.2% in cover ($P<0.01$) whereas those individuals that were not grazed, but rain had fallen, gained 12.2% in cover ($P<0.001$) (Table 3.14). A net gain in cover for the individuals of *Tetragonia* spp. over the study period was recorded to be 7.37% in the selected camps ($P<0.05$) (Table 3.14).

ble 3.12a: Mean cover (cm²x10⁻²) ±SD of *Tetragonia* spp. from five camps measured from March 1993 to November 1993 in the *Pteronia pallens*-dominated vegetation. N = the number individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
2	3	6.20±2.83	6.42±2.40	6.02±1.79	6.45±2.20 G	6.01±2.91	5.81±2.82	5.83±2.99	5.16±3.06
3	6	4.92±2.13	6.03±2.94*	6.25±2.87*	6.88±3.15* G	4.92±2.30*	4.71±2.38	4.01±1.82* G	3.84±1.55
4	6	3.16±2.69	4.50±4.59*	5.79±6.77	5.97±6.67* G	3.67±3.94*	3.40±3.79	3.44±3.73	3.18±3.65* G
Rain		30mm	9mm	8mm	0mm	15mm	22mm	0mm	17mm
5	4	5.76±2.80	6.39±3.68	6.81±3.97	6.59±3.69 G	6.31±2.98 G	6.06±2.94	5.97±2.80	5.50±2.72
Rain		30mm	9mm	8mm	0mm	13mm	19mm	0mm	15mm
6	3	1.01±1.10	1.39±1.29	1.41±1.18	1.69±1.37	1.74±1.44 G	0.74±0.67	0.88±0.86*	0.80±0.82
Rain		30mm	9mm	8mm	0mm	18mm	30mm	0mm	13mm

le 3.12b. Mean cover (cm²x10⁻²) ±SD of *Tetragonia* spp. from five measured from December 1993 to August 1994 in the *Pteronia pallens*-dominated vegetation. N = the number of viduals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
2	3	4.94±3.22	4.97±3.03	5.06±3.01*	5.82±3.57 G	5.59±3.14	5.88±3.64	5.66±3.13	5.82±3.12*	6.60±3.53
3	6	3.63±1.70	3.75±1.81	3.93±1.80	4.82±2.12* G	4.16±1.93*	3.92±1.60	4.19±1.82*	5.06±2.21*	6.47±2.77*
4	6	2.84±3.70*	3.25±3.96	3.21±3.96*	3.65±4.40* G	2.72±3.37*	5.21±3.19	5.34±3.32	5.67±3.54	6.42±3.27*
Rain		32mm	52mm	0mm	33mm	3mm	7mm	22mm	6mm	-
5	4	5.40±2.81	4.82±2.55	4.92±2.73	5.56±3.07*	5.04±2.91 G	5.21±3.19	5.34±3.32	5.67±3.54	6.42±3.27*
Rain		30mm	48mm	0mm	25mm	5mm	11mm	26mm	4mm	-
6	3	0.82±0.90	0.62±0.58	0.68±0.61	0.98±0.79	0.50±0.39	1.35±1.21 G	0.54±0.19	0.61±0.22	1.11±0.46
Rain		32mm	36mm	0mm	55mm	4mm	9mm	24mm	6mm	-

3.4.2.4 *Osteospermum sinuatum*

The abundance of *O. sinuatum* in the five camps was higher than that of *Tetragonia* spp., however it was still found to be low compared to the other species studied (Table 3.13a).

The cover of *O. sinuatum* was found to increase significantly ($P<0.01$) over the study period by 14.6% (Table 3.9). In the selected camps, an increase in cover of 28% ($P<0.05$) was recorded over the study period (Table 3.14).

If one looks at the individual recovery periods between grazing events, full recovery is not taking place. The decrease in cover after each grazing event was 10.5%, which is 8% lower than for the same species in the *R. spinosa*-dominated vegetation.

The hailstorm in March 1994 only caused damage to the individuals in Camp 5, causing an approximate 4% loss in cover, after which they were subjected to a grazing event (Table 3.13b). However, these individuals recovered quickly and within 120 days were 2.98% larger than they were directly after the hailstorm.

Osteospermum sinuatum was found to be grazed more heavily in winter than in summer. In the selected camps, 8.4% cover ($P<0.001$) was lost to grazing during summer whereas 15.5% ($P<0.001$) was lost during winter (Table 3.15). In these same camps, an increase in cover of 28% was recorded over the study period (Table 3.14). *Osteospermum sinuatum* increased in cover after rainfall events by up to 22.5%, whereas between 4.84% and 15.5% was lost during grazing events ($P<0.001$) (Table 3.14).

le 3.13a: Mean cover (cm^{2}x10^{-2}) ±SD of *Osteospermum sinuatum* from five camps measured from March 1993 to November 1993 in the *Pteronia pallens*-dominated vegetation. N = the nber of individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Mar 93	May 93	June 93	July 93	Aug 93	Sept 93	Oct 93	Nov 93
1	4	5.24±2.71	6.90±3.59*	6.56±2.76	5.62±2.11 G	5.88±2.74	5.45±2.04	5.26±2.39 G	4.85±2.24
2	3	3.99±2.08	6.59±4.45	6.64±4.22	7.27±4.81 G	6.29±4.97	5.70±4.39	6.23±5.00 G	5.69±4.89
3	17	5.15±6.01	7.15±7.93**	7.77±8.90	7.96±9.15 G	5.68±7.51***	5.45±7.51*	5.23±7.55*	5.04±7.53* G
4	14	8.55±9.16	9.24±9.19*	9.31±8.67*	9.71±9.90 G	9.19±9.13***	8.47±8.70	8.17±7.86	7.22±7.37** G
Rain		30mm	9mm	8mm	0mm	15mm	22mm	0mm	17mm
5	12	6.71±7.19	7.26±7.22	7.31±6.81	7.62±7.78 G	7.22±7.17 G	6.65±6.83*	6.42±6.17	5.67±5.78**
Rain		30mm	9mm	8mm	0mm	13mm	19mm	0mm	15mm

le 3.13b. Mean cover (cm^{2}x10^{-2}) ±SD of *Osteospermum sinuatum* from five camps measured from December 1993 to August 1994 in the *Pteronia pallens*-dominated vegetation. N = the nber of individuals measured in each camp. * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, G = Grazing event.

Camp	N	Dec 93	Jan 94	Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
1	4	4.85±2.24	4.87±2.26	5.16±2.54 G	4.96±2.31	5.27±2.09	5.14±2.05	5.34±2.25*	5.56±2.34	7.13±2.47*
2	3	4.74±3.66	4.88±3.77	4.90±3.77	5.36±3.64 G	5.68±4.35	5.68±4.35	5.68±4.35	5.68±4.35	6.85±5.02
3	17	4.69±7.34**	5.19±7.73**	5.39±7.88*	7.28±8.88*** G	5.45±7.50***	5.28±7.57	5.39±7.80	5.65±7.85**	7.15±8.65***
4	14	6.98±7.10	7.54±7.50**	7.83±7.72	8.91±8.57*** G	8.55±8.52**	7.20±7.77	7.41±7.94	7.58±7.93**	8.81±8.86***
Rain		32mm	52mm	0mm	33mm	3mm	7mm	22mm	6mm	-
5	12	5.48±5.58	5.92±5.98*	6.15±6.07*	7.00±6.73**	6.72±6.69** G	5.65±6.11**	5.82±6.24*	5.95±6.23	6.92±6.96**
Rain		30mm	48mm	0mm	25mm	5mm	11mm	26mm	4mm	-

Table 3.14: Mean cover (±SD) and percentage cover loss/gain of four Karoo shrubs in the selected camps at the beginning of the study (Start), after a grazing event with no rainfall (G+NR), after a grazing event with rainfall (G+R), after no grazing and rainfall (NG+R) and at the end of the study (Final) in the *Pteronia pallens*-dominated vegetation at Tierberg. Cc = *Chrysocoma ciliata* (cm^2x10^{-3}), Rs = *Ruschia spinosa* (cm^2x10^{-3}), Ee = *Eriocephalus ericoides* (cm^2x10^{-2}), T = *Tetragonia* spp. (cm^2x10^{-2}) and Os = *Osteospermum sinuatum* (cm^2x10^{-2}). * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, ^{ns} = not significant.

Species	Start	G+NR	Loss	G+R	Loss	NG+R	Gain	Final	Net Gain
Pp	3.07±0.10	3.44 ± 0.98^{ns}	+0.7%	3.43 ± 0.97^{ns}	1.1%	$3.41\pm0.99^{***}$	1.9%	$3.53\pm0.98^{***}$	14.94%
Rs	0.64±0.39	0.90 ± 0.55^{ns}	+1.4%	0.94 ± 0.66^{ns}	+10.5%	0.89 ± 0.55^{ns}	2.9%	$0.98\pm0.62^{***}$	54.0%
T	4.32±1.64	$4.46\pm1.53^{**}$	7.2%	$4.80\pm1.17^{***}$	14.9%	$4.80\pm1.10^{***}$	12.2%	$5.22\pm1.44^{*}$	7.37%
Os	5.68±2.01	$5.74\pm0.33^{***}$	15.5%	$6.25\pm0.65^{***}$	4.84%	$6.80\pm1.26^{***}$	22.5%	$7.27\pm0.50^{*}$	28.0%

Table 3.15: Mean cover (±SD) and percentage cover loss of five Karoo shrubs before and after a summer and winter grazing event in the *Pteronia pallens*-dominated vegetation at Tierberg. Cc = *Chrysocoma ciliata* (cm^2x10^{-3}), Rs = *Ruschia spinosa* (cm^2x10^{-3}), Ee = *Eriocephalus ericoides* (cm^2x10^{-2}), T = *Tetragonia* spp. (cm^2x10^{-2}) and Os = *Osteospermum sinuatum* (cm^2x10^{-2}). * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$, ^{ns} = not significant.

Species	Summer Before	Summer After	Loss	Winter Before	Winter After	Loss
Pp	3.04±0.94	2.99 ± 0.99^{ns}	1.6%	4.01±0.90	$4.10\pm0.87^{***}$	+2.2%
Rs	1.52±0.24	1.48 ± 0.24^{ns}	2.6%	1.03±0.33	$1.04\pm0.33^{***}$	+1.0%
T	3.85±0.93	$3.66\pm1.16^{**}$	4.9%	5.64±1.02	$4.80\pm1.17^{***}$	14.9%
Os	5.62±0.82	$5.15\pm0.66^{***}$	8.4%	6.57±1.83	$5.55\pm0.80^{***}$	15.5%

3.4.3 The Effect of Sheep Grazing on Small and Large Plant Individuals in the *Ruschia spinosa*-dominated Vegetation

The cover of large and small individuals of *C. ciliata* did not change significantly over the study period (Table 3.16). This conforms to the results obtained for the combination of small and large individuals found in Table 3.1. Plant size, therefore, was not found to be a factor in the recovery of *C. ciliata* over the study period.

Table 3.16: Mean cover ($cm^2 X10^{-2}$) $\pm$SD of all large and small individuals at the start and end of the study period in the *Ruschia spinosa*-dominated vegetation. N = number of small and large of individuals in all eight camps, *P* = probability, ns = not significant.

Species	Small Plants (N)	Start	End	*P*	Large Plants (N)	Start	End	*P*
C. ciliata	62	3.23±1.98	3.63±2.41	ns	62	11.3±4.47	11.6±5.0	ns
R. spinosa	202	3.19±1.65	3.75±2.50	$P < 0.001$	199	13.9±7.42	13.7±8.15	ns
E. ericoides	41	8.21±5.79	7.79±5.39	ns	41	46.1±27.3	44.9±24.5	ns
Tetragonia spp.	14	3.09±0.93	2.51±1.14	ns	13	8.40±4.59	5.58±3.11	$P < 0.05$
O. sinuatum	15	3.49±2.25	2.92±2.30	ns	14	13.4±6.63	11.9±6.94	ns

Smaller individuals of *R. spinosa* increased in cover significantly ($P<0.001$) over the study period, whereas that of the larger individuals did not change significantly over the same period (Table 3.16). The combined data for the small and large individuals over the study period also yielded a significant increase in cover (Table 3.1).

No significant change in cover occurred for small and large individuals of *E. ericoides* over the study period (Table 3.16); this result also being found for the combined small and large individual data (Table 3.1).

The larger individuals of *Tetragonia* spp. decreased significantly ($P<0.05$) over the study period whereas that of the smaller individuals did not change significantly (Table 3.16). A significant decrease in cover ($P<0.001$) was found to occur for all the individuals recorded in the study over the study period (Table 3.1).

The cover of large and small individuals of *O. sinuatum* did not change significantly over the study period (Table 3.16) although a significant decrease in cover ($P<0.05$) was found to occur for all the plant individuals combined (Table 3.1).

3.4.4 The Effect of Sheep Grazing on Small and Large Plant Individuals in the *Pteronia pallens*-dominated Vegetation

The cover of small and large individuals of *P. pallens* was found to increase significantly over the study period (small $P<0.001$ and large $P<0.01$) (Table 3.17). This trend was also found for the combination of both small and large individuals ($P<0.001$) (Table 3.17).

Table 3.17: Mean cover (cm^{2}X10^{-2}) ±SD of all large and small individuals at the start and end of the study period in the *Pteronia pallens*-dominated vegetation. N = number of small and large individuals in all eight camps, P = probability, ns = not significant.

Species	Small Plants (N)	Start	End	P	Large Plants (N)	Start	End	P
P. pallens	147	10.4±6.14	12.7±8.59	$P < 0.001$	146	49.5±28.6	51.4±32.8	$P < 0.01$
R. spinosa	152	2.95±1.78	3.34±2.24	$P < 0.001$	152	14.4±8.22	14.2±8.93	ns
Tetragonia spp.	11	1.52±0.95	1.58±0.99	ns	11	5.12±1.82	6.27±2.32	$P < 0.05$
O. sinuatum	26	1.76±0.89	2.55±1.41	$P < 0.01$	24	9.02±5.42	9.87±6.21	ns

Smaller individuals of *R. spinosa* were found to increase significantly ($P<0.001$) over the study period, whereas that of the large individuals did not change significantly (Table 3.17). However, when the plant sizes were combined, no significant increase or decrease was found to occur (Table 3.9).

The cover of the small individuals of *Tetragonia* spp. was not found to change significantly over the study period whereas that of the larger individuals increased significantly ($P<0.05$) (Table 3.17). The cover of the combined individuals did, however, increase significantly ($P<0.05$) over the study period (Table 3.9).

In contrast, the smaller individuals of *O. sinuatum* increased in cover significantly ($P<0.05$) over the study period whereas the cover of the larger individuals did not vary significantly (Table 3.17). The cover of both the small and large individuals of *O. sinuatum* did, however, increase significantly ($P<0.01$) over the study period (Table 3.17).

3.4.5 The Effect of Seasonal Grazing on Small and Large Plant Individuals in the *Ruschia spinosa*-dominated Vegetation

3.4.5.1 Summer Grazing

The cover of small individuals of *C. ciliata* did not change significantly after a summer grazing event, whereas that of the large individuals was found to decrease significantly ($P<0.05$) (Table 3.18). The larger individuals of *C. ciliata* were more greatly affected during the grazing event than the smaller individuals ($t=-2.914$, $P<0.01$).

Both small ($P<0.01$) and large ($P<0.001$) individuals of *R. spinosa* decreased in cover over the summer grazing period (Table 3.18), however, the larger individuals were affected more heavily than the smaller ones ($t=-4.250$, $P<0.001$).

Table 3.18: Mean cover (cm^2X10^{-2}) ±SD of all large and small individuals before and after a summer and winter grazing event in all eight camps in the *Ruschia spinosa*-dominated vegetation. * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ^{ns} = not significant.

Species	Plant Size	Summer Before	Summer After	Winter Before	Winter After
C. ciliata	Small	3.25±1.86	3.22±1.88^{ns}	3.23±1.91	3.56±2.12**
C. ciliata	Large	12.1±4.75	11.5±4.73*	12.2±4.81	12.3±4.84^{ns}
R. spinosa	Small	3.39±1.68	3.24±1.70**	3.34±1.64	3.41±1.66**
R. spinosa	Large	14.4±7.49	13.8±7.52***	14.4±7.83	14.5±8.02^{ns}
E. ericoides	Small	7.73±5.06	7.33±4.97**	8.39±5.40	8.18±5.48^{ns}
E. ericoides	Large	49.2±29.2	44.1±23.1***	50.9±30.9	49.4±28.6^{ns}
Tetragonia spp.	Small	2.73±0.95	2.24±1.06***	3.21±0.99	2.71±1.02^{ns}
Tetragonia spp.	Large	8.09±2.72	6.22±2.80*	8.21±3.88	6.73±2.85**
O. sinuatum	Small	3.18±2.08	2.41±1.93**	2.97±2.00	2.11±1.47*
O. sinuatum	Large	15.0±8.76	12.3±7.62**	14.7±9.37	11.1±7.41***

The cover of small and large individuals of *E. ericoides* decreased significantly after the grazing in summer ($P<0.01$ for the small individuals and $P<0.001$ for the large individuals) (Table 3.18). Again the larger individuals of *E. ericoides* were affected more heavily than the smaller individuals (t=-3.756, $P<0.001$).

Both the small ($P<0.05$) and large ($P<0.001$) individuals of *Tetragonia* spp. lost cover after the grazing event in summer (Table 3.18). However, the larger individuals of *Tetragonia* spp. lost proportionally more cover and were therefore found to be more severely affected by the grazing event during summer (t=-4.717, $P<0.001$).

The cover of both small and large individuals of *O. sinuatum* decreased significantly ($P<0.01$) over the summer grazing period (Table 3.18). The larger individuals of *O. sinuatum* were also found to be affected by the grazing more than the smaller ones (t=-3.931, $P<0.001$).

3.4.5.2 Winter Grazing

The cover of the small individuals of *C. ciliata* increased significantly over the winter grazing period ($P<0.01$), whereas that of the large individuals did not change significantly (Table 3.18). Nevertheless, no significant difference was found to occur when the cover differences of the small individuals were compared to that of the large individuals (t=-1.440, ns). Therefore no conclusion can be drawn as to which plant size class is affected more during a winter grazing event.

A significant increase in cover ($P<0.01$) occurred for the small individuals of *R. spinosa*, whereas no significant difference occurred for the cover of the larger individuals (Table 3.18). Again, no significant difference (t=0.274, ns) was found to occur between the small and large individuals, therefore no distinction between size classes can be made.

No significant difference occurred for the cover of both small and large individuals of *E. ericoides* after the grazing event in winter (Table 3.18). Thus, no significant difference occurred between the small and large individuals of *E. ericoides* (t=-1.209, ns). No conclusions could be drawn, therefore, as to which size class was being affected more by the grazing effects of sheep.

The cover of large individuals of *Tetragonia* spp. decreased significantly ($P<0.01$) after the grazing event in winter, whereas that of the small individuals did not change significantly (Table 3.18). The larger individuals of *Tetragonia* spp. were grazed more severely than those of the smaller ones (t=-2.114, $P<0.05$).

The cover of both the small ($P<0.05$) and the large ($P<0.001$) individuals of *O. sinuatum* decreased significantly after the grazing event during winter (Table 3.18). Again, the larger individuals of *O. sinuatum* were more severely grazed (t=-3.323, $P<0.01$), although both showed a decrease in cover.

3.4.6 The Effect of Seasonal Grazing on Small and Large Plant Individuals in the *Pteronia pallens*-dominated Vegetation

3.4.6.1 Summer Grazing

The cover of both small ($P<0.001$) and large ($P<0.05$) individuals of *P. pallens* increased significantly after the grazing event in summer, emphasising the fact that this species is not grazed (Table 3.19). No distinct difference between the smaller and the larger individuals could therefore be determined ($t=0.967$, ns).

No significant difference in the cover of *R. spinosa* occurred for either the small or large individuals (Table 3.19). Likewise, no distinction could be made between the small and large individuals after the grazing event ($t=1.524$,ns).

Table 3.19: Mean cover (cm^2X10^{-2}) $\pm$SD of all large and small individuals before and after a summer and winter grazing event in six camps in the *Pteronia pallens*-dominated vegetation. * = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ^{ns} = not significant.

Species	Plant Size	Summer Before	Summer After	Winter Before	Winter After
P. pallens	Small	10.1 ± 5.58	$10.5\pm5.78^{***}$	10.6 ± 5.52	10.6 ± 5.71^{ns}
P. pallens	Large	51.1 ± 35.4	$51.7\pm35.5^{*}$	49.4 ± 31.4	49.3 ± 30.9^{ns}
R. spinosa	Small	2.59 ± 1.38	2.56 ± 1.32^{ns}	2.63 ± 1.62	2.68 ± 1.65^{ns}
R. spinosa	Large	17.1 ± 10.5	17.3 ± 10.8^{ns}	14.4 ± 7.97	$14.9\pm8.09^{**}$
Tetragonia spp.	Small	1.36 ± 0.80	$1.13\pm0.66^{*}$	1.08 ± 0.74	$0.74\pm0.62^{*}$
Tetragonia spp.	Large	5.32 ± 2.37	4.94 ± 2.24^{ns}	5.88 ± 3.37	$4.27\pm2.42^{**}$
O. sinuatum	Small	1.79 ± 0.85	$1.46\pm0.79^{*}$	1.83 ± 0.85	$1.41\pm0.74^{***}$
O. sinuatum	Large	8.76 ± 5.93	$7.11\pm5.45^{***}$	9.37 ± 6.35	$7.26\pm5.62^{***}$

No significant difference occurred between the smaller and larger individuals of *Tetragonia* spp., however, a significant decrease in cover was found to occur after the grazing event for the small individuals ($P<0.05$) (Table 3.19).

The cover of both small ($P<0.05$) and large ($P<0.001$) individuals of *O. sinuatum* decreased significantly after the grazing event during summer (Table 3.19). However, the larger individuals were more severely grazed (t=-4.892, P<0.001) than the smaller individuals.

2.3.2 Winter Grazing

No significant difference occurred after the grazing event in winter for either the small or large individuals of *P. pallens* (Table 3.19). Likewise, no distinction could be drawn between the small and large individuals (t=-0.283, ns).

The cover of the large individuals of *R. spinosa* increased significantly (P<0.01) after the grazing event in winter, whereas that of the small individuals did not change significantly (Table 3.19). However, the larger individuals of *R. spinosa* showed a larger increase in cover than that of the smaller individuals (t=2.265, P<0.05).

Both the cover of the small (P<0.05) and large (P<0.001) individuals of *Tetragonia* spp. decreased significantly over the winter grazing period (Table 3.19). However, no distinction between the effects of sheep grazing could be inferred between the smaller and larger individuals of *Tetragonia* spp. (t=-1.848, ns).

A significant decrease in cover for both the small and large individuals of *O. sinuatum* occurred (P<0.001) (Table 3.19). Once again the larger individuals of *O. sinuatum* were more severely affected by the grazing action of sheep over the winter grazing period (t=-3.980, P<0.001).

3.5 DISCUSSION

3.5.1 The Effect of Sheep Grazing on All Plant Individuals in the *Ruschia spinosa*-dominated Vegetation

3.5.1.1 *Chrysocoma ciliata*

Chrysocoma ciliata is known to be an invasive species (Roux 1968a; 1976a, Acocks 1988, Shearing 1994) and thus may be an indicator of overgrazing or vegetation degradation. The cover of this species was found to increase over the study period, which may be as a result of this species being unpalatable, as no grazing would have taken place (Roux 1968a). This was confirmed by very small losses occurring over grazing events.

It was important to include the unpalatable species in the monitoring program as reductions in the cover of palatable species could be directly linked to grazing if the cover of the unpalatable species remained unchanged after a grazing event.

Chrysocoma ciliata exhibited seasonal growth as described by Shearing (1994). Cover decreased during the hot, dry summer months between September and January. This species is known to be drought sensitive, losing leaves during hot dry periods (Roux 1968a). This would explain the decrease in cover over the summer months. However, the cover was found to increase in the cooler, wetter winter months, especially after rainfall events, as was found by Shearing (1994).

The approximate 120-day rest period employed by the farmer does not affect the cover of *C. ciliata*, as this species does not have grazing pressure exerted on it. Therefore, although important for use as a comparative with palatable species, the growth exhibited in this study should be ignored when determining the optimum resting period for this vegetation type.

3.5.1.2 *Ruschia spinosa*

Ruschia spinosa is a succulent shrub whose palatability varies according to seasons and soil type (Shearing 1994). This species is considered unpalatable by many authors due to its high tannin content (Lovegrove 1993), its spiny morphology (Roux 1968b) and its relatively low ether extract (Louw *et al.* 1967). This species may be grazed after rainfall events when there is new shoot growth (Shearing 1994). Some farmers rely on this species during severe droughts when it is grazed by sheep due to its succulence (W.H.L. Wright. 1993. pers. comm.).

The cover of *R. spinosa* increased slightly over the study period and it was assumed that this was either due to it being unpalatable or due to the surrounding vegetation providing enough fodder so that stock were not forced to utilize it. However, a slight decrease was observed in some camps in mid-summer, this decrease coinciding with a dry period and the species could have been grazed. However, this was not found to occur in the summer grazed selected camps, therefore this drop could be as a result of seasonal growth. Most Aizoaceae exhibit seasonal growth whereby they grow actively in winter but growth ceases in summer (Milton 1990), as was found to be the case for *R. spinosa*. This seasonal effect was evident in the selected camps where significant growth occurred after rainfall events in winter.

The decreases in cover which occurred in the selected camps after grazing events could be due to a trampling effect. Where grazing and rainfall occurred between measuring periods, cover did not decrease whereas when there was a grazing event but no rain fell between measuring periods, cover decline occurred. The cover loss or trampling effects were found to be very slight and any cover lost over these periods was regained only if there was rainfall. When there was no grazing but rain did occur, a slight increase in cover was the result. The importance of rainfall in maintaining the cover of this species is therefore evident, even though grazing does not appear to be causal in cover loss.

Again, the recovery period does not seem to be important in the maintenance of *R. spinosa* cover. However, trampling may be an important disturbance effect for this species, and due to the possible fodder value mentioned earlier, could play a role in determining rest periods.

3.5.1.3 *Eriocephalus ericoides*

The value of *E. ericoides* as a fodder plant was also found to be controversial. Roux (1976b) states that this species is not very acceptable to stock and Louw *et al.* (1967) recorded this species as only moderately palatable due to its relatively high ether extract. This species has also been described as "not very palatable" by Shearing (1994) but no reason for this was given. Roux (1968a) states that *E. ericoides* is seasonally palatable, only being grazed in late winter and early spring, whereas it is not grazed at all in summer and autumn.

In this study, a loss in cover occurred over the entire study period, indicating that this species is probably grazed. Cover loss was recorded after a grazing event, confirming that this species is grazed. The seasonal palatability mentioned by Roux (1968a), which was observed as cover loss was approximately five times greater after a grazing event in winter than in summer.

Eriocephalus ericoides was noted to exhibit seasonal growth, as do many of the Asteraceae (Milton 1990), growing actively in winter and remaining dormant in summer. The active growth during winter probably reflects the seasonal palatability as new growth is probably utilized by stock (pers. obs.).

Recovery of *E. ericoides* was found to be 50% greater in the selected camps if rainfall occurred after a grazing event compared to camps that had lacked rainfall following grazing. *Eriocephalus ericoides* responded well to rain when not grazed, gaining approximately what was lost during a previous grazing event.

The recovery period between grazing events was found to be too short as cover regrowth was not attaining what was lost to grazing. *Eriocephalus ericoides* appears to be an important fodder species on Tierberg and therefore needs to be conserved. Hobson and Sykes (1980) found that *E. ericoides* produces more above-ground biomass with less frequent defoliation and therefore the rest period needs to be lengthened.

3.5.1.4 *Tetragonia* spp.

The genus *Tetragonia* is known to contain palatable species (Shearing 1994). These species are considered important fodder plants in the Karoo (W.H.L. Wright. 1993. pers. comm.) as they are grazed readily by stock. Low ether extracts (Louw *et al.* 1967) probably account for their high palatability status.

The cover of *Tetragonia* spp. was found to decrease dramatically over the study period. Large decreases in cover were recorded after grazing, indicating the high pressure exerted on these species.

The seasonal growth exhibited by these species has been noted for other Aizoaceae (*e.g.*, *R. spinosa*) (Milton 1990). Prolific growth occurs during winter compared to summer and this resulted in cover loss being four times greater during winter grazing compared to summer grazing. Recovery after defoliation events was found to be rapid, however, the rest periods again appear to be too short for full recovery. In order to conserve these species, the rest periods between defoliation events need to be lengthened in order for lost cover to be regenerated resulting in no net loss of cover over time (almost 40% was lost in the selected camps).

Tetragonia spp. are consumed by the Cape Hare, *Lepus capensis* L. (Kerley 1990). This mammal therefore competes directly with sheep for fodder and this would increase the pressure on these species. The need, therefore, to conserve *Tetragonia* spp. becomes increasingly important.

3.5.1.5 *Osteospermum sinuatum*

Osteospermum sinuatum is considered to be highly palatable (Louw *et al.* 1967, Milton 1992, Shearing 1994). This species also needs to be conserved as extreme grazing pressures are exerted on it.

As was found with the other palatable species in this vegetation type, the cover of *O. sinuatum* decreased over the study period. *Osteospermum sinuatum* is grazed heavily at each grazing event and this results in large cover losses. Grazing appears to stimulate growth in some instances. In the selected camps where rain had fallen, grazed individuals recovered better than those not grazed. However, this may be as a result of differences in the amount of rainfall. Van der Heyden (1992) states that *O. sinuatum* is able to recover rapidly after a grazing event. However, under the present grazing system, *O. sinuatum* appeared to be unable to recover fully, which resulted in a continual loss in cover.

Osteospermum sinuatum does have the ability to grow rapidly after rainfall in the absence of grazing, and in the selected camps, the cover of these individuals increased by almost 25%.

Osteospermum sinuatum also exhibited seasonal growth, conforming to Milton

(1990). This species is known to be drought deciduous, losing its leaves during summer. Therefore, it would be expected to be heavily exploited during winter. In the selected camps, grazing during winter was found to remove 13 times more cover than in summer. This heavy utilization also was found to be the case with *Tetragonia* spp..

It appears once again that the recovery period is not sufficiently long enough for full recovery of *O. sinuatum* before they are grazed again. If this species is to be conserved, the rest periods between these defoliation events will have to be lengthened as the scenario presented from these data will result in overgrazing of this species.

3.5.2 The Effect of Sheep Grazing on All Plant Individuals in the *Pteronia pallens*-dominated Vegetation

3.5.2.1 *Pteronia pallens*

Pteronia pallens is an hepatotoxic species that causes stock losses if grazed heavily (Prozesky *et al.* 1986). The toxicity therefore would exclude *P. pallens* from the grazing pressures of sheep. It is for this reason that cover was found to increase over the study period. Cover loss, however, does occur during summer as this species is not drought tolerant and large leaves are shed under moisture stress (Milton 1990). Cover loss also occurred as a result of the hailstorm, but recovery was found to be very quick. Cover loss during summer was also noted in the selected camps, but this loss was very small. A gain in cover was recorded during the winter months due to increased moisture during these months.

As was found to be the case with *C. ciliata* in the *R. spinosa*-dominated vegetation, the rest period is of no importance when one looks at *P. pallens*. This species has no fodder value and merely served as a comparison against which, grazing of palatable species could be compared.

3.5.2.2 *Ruschia spinosa*

As stated previously, the palatability of *R. spinosa* is variable (*e.g.*, Roux 1968b, Louw *et al.* 1967). This resulted in the cover increasing over the study period with results similar to that found in the *R. spinosa*-dominated vegetation. A loss in cover, however, was found to occur after the summer grazing in the selected camps. This could again be attributed to the trampling activities of sheep and the seasonal decline in growth of this species over summer. An increase in cover was found to occur over the winter grazing period as the trampling effects would be lost due to the active growth of this species during this season.

Ruschia spinosa is able to recover well after the summer dormant period following rainfall. This would result in the regain of any loss in cover due to die-back that occurred during the hot summer. The regain in cover could be as a result of re-hydration of the succulent leaves, as growth of new shoots following defoliation was found to be very slow, as occurred after the hailstorm.

The rest period does not influence the cover status of *R. spinosa* in this vegetation type, as was found to be the case in the *R. spinosa*-dominated vegetation. *Ruschia spinosa* responded similarly in both vegetation types, indicating that this species is not vulnerable to grazing.

3.5.2.3 *Tetragonia* spp.

The response of *Tetragonia* spp. in the *P. pallens*-dominated vegetation was found to be very different to that found in the *R. spinosa*-dominated vegetation. The cover of *Tetragonia* spp. was found to increase over the study period. Taking into account the dormant growth period during summer and the effects of natural herbivores, it is encouraging to see an increase in cover being recorded. However, although an overall increase in cover occurred, the rest period between defoliation events again appears to be too short. Full recovery was not being obtained after grazing events even though these species were able to recover quickly.

The seasonal growth exhibited in the *R. spinosa*-dominated vegetation was also found to occur in the *P. pallens*-dominated vegetation. Again, these species were grazed more severely during winter in comparison to summer. When these species are not grazed but receive rainfall, recovery is quick (± 30 days) to gain between 10% and 20% cover.

3.5.2.4 *Osteospermum sinuatum*

The response of *O. sinuatum* in the *P. pallens*-dominated vegetation was found to differ from that in the *R. spinosa*-dominated vegetation. As was found to occur with *Tetragonia* spp., an increase in cover was recorded over the study period.

Grazing by livestock causes large decreases in cover, especially during winter when approximately twice as much foliage is removed compared to the summer grazed plants. However, as was the case with *Tetragonia* spp., the rest periods are not long enough for full recovery between grazing events.

A larger loss in cover was found to occur for plants that were grazed without rainfall as opposed to plants that were grazed with rainfall. This is probably as a result of the rapid response of *O. sinuatum* to rainfall, which enabled growth to be initiated and new foliage to be produced. Plants that were not grazed but were exposed to rainfall increased in cover by almost 25%, indicating the ability of *O. sinuatum* to utilize moisture efficiently.

3.5.3 The Effect of Sheep Grazing on Small and Large Plant Individuals in the *Ruschia spinosa*-dominated Vegetation

Over the entire study period, only small *R. spinosa* and large *Tetragonia* spp. individuals exhibited a significant change in cover. The small individuals of *R. spinosa* exhibited a significant increase in cover whereas large individuals of *Tetragonia* spp. were found to lose a significant amount of foliage cover. The remainder of the species studied, both small and large individuals, exhibited no significant change in cover over the study period.

The increase in cover of small individuals of *R. spinosa* may indicate that this species is not heavily grazed in the *R. spinosa*-dominated vegetation. The smaller individuals of *R. spinosa* would be more susceptible to grazing due to their lack of numerous spines and secondary compounds relative to the larger, more older individuals. However, the increase in cover over the study period suggests that this species may not be grazed at all.

On the other hand, the significant decrease in cover of the large individuals of *Tetragonia* spp. illustrate that this size class was severely grazed over the study period. A possible reason for the small individuals of *Tetragonia* spp. not losing a significant amount of foliage cover could be due to the fact that the majority of small *Tetragonia* spp. individuals occur in or under the protection of nurse plants (pers. obs). These nurse plants, predominantly *R. spinosa*, would protect the smaller individuals from the grazing action of sheep, while the larger individuals would not benefit from the protection of nurse plants (Yeaton and Esler 1990).

As was found to be the case for all plant individuals combined, the results from the data for the entire study period do not highlight concisely how the vegetation reacts and therefore, the seasonal effects of grazing sheep, in the next section, serve to highlight more specifically how plant size relates to grazing pressure.

3.5.4 The Effect of Sheep Grazing on All Plant Individuals in the *Pteronia pallens*-dominated Vegetation

In comparison to the results obtained in the *R. spinosa*-dominated vegetation, more significant changes in cover were found to occur in the *Pteronia pallens*-dominated vegetation.

Both the small and large individuals of *P. pallens* exhibited a significant increase in cover over the study period, again highlighting that this species is not affected by grazing due to it not being palatable (Prozesky *et al.*1986).

As was found to be the case in the *R. spinosa*-dominated vegetation, the smaller individuals of *R. spinosa* increased significantly in foliage cover over the study period, whereas the cover of larger individuals did not change. Again, as was found to be the case in the *R. spinosa*-dominated vegetation, this small size class of plants may not be grazed, even with their lower tannin content and minimal spine numbers. The constant cover of *R. spinosa* also may be due to the surrounding vegetation providing enough fodder to allow sheep to avoid grazing *R. spinosa*.

As was found to be the result using all individuals combined, both the cover of *Tetragonia* spp. and *O. sinuatum* showed significant increases. These results, however, could be masked by the fact that the study was concluded towards the end of winter, after relatively high winter rainfall compared to the start of the study which was during the dry mid-summer. Again, the seasonal grazing results illustrate more conclusively the response of the vegetation to the grazing activities of sheep.

3.5.5 The Effect of Seasonal Grazing on Small and Large Plant Individuals in the *Ruschia spinosa*-dominated Vegetation

3.5.5.1 Summer Grazing

The loss in cover observed for *C. ciliata* is as a consequence of leaf loss due to this species being drought sensitive (Roux 1968a). However, the larger individuals of *C. ciliata* were found to lose a significant amount of cover whereas the smaller individuals did not. Although both the larger and smaller individuals would be sensitive to drought, the larger individuals may lose more foliage as a consequence of sheep trampling (pers. obs). As a result, the larger individuals of *C. ciliata* are affected more than the smaller ones, not through the grazing of sheep, but through the effect of sheep trampling.

Both small and large individuals of *R. spinosa* lost significant cover during the summer grazing period. However, the larger individuals again were more severely damaged during this period. As mentioned earlier, however, cover loss could be as a consequence of trampling and not grazing, as the smaller individuals, which contain less secondary compounds and spines, would theoretically be more vulnerable to grazing. This does not, therefore, exclude sheep grazing on *R. spinosa* altogether and the loss in cover could be a combination of both sheep grazing, mainly restricted to the smaller individuals, and trampling.

The larger individuals of *E. ericoides* were affected more severely than the smaller individuals during the summer grazing period. Again, the larger individuals could be losing cover as a consequence of trampling by sheep as the smaller individuals usually utilized nurse plants under which to establish. Therefore, although both small and large individuals lost significant amounts of cover, the larger individuals were more severely affected.

The trend of larger individuals of plant species being affected to a greater extent than smaller individuals is again manifested in the cover loss of *Tetragonia* spp. and *O. sinuatum*. These species are the most important fodder plants in this study and utilize nurse plants under which to establish (pers. obs, Yeaton and Esler 1990). This would again explain why the larger individuals would be more severely grazed and trampled than the protected smaller ones.

3.5.5.2 Winter Grazing

During the wetter, winter grazing period, plant species are able to recover after a grazing event at a faster rate than during the drier summer months. For this reason, the cover of *C. ciliata* increased for both the small and large individuals over this period. Foliage loss would not be occurring due to desiccation and the lack of grazing would result in both small and large individuals increasing in cover. No difference was detected between the response of small and large individuals of *C. ciliata*.

Likewise, the cover of both small and large individuals of *R. spinosa* increased during the winter grazing period. This could be as a result of a total lack of grazing as the surrounding vegetation could support enough palatable fodder to avoid grazing pressure on *R. spinosa*. The trampling effects of sheep would be reduced as the leaves of this succulent would not be dry and brittle and could withstand trampling better than during summer. Again, no distinction between the response of small and large individuals could be determined.

No distinction between the response of small and large individuals of *E. ericoides* could be determined. In both size classes, no significant change in cover was found to occur, which could be as a consequence of rapid growth due to the increase in rainfall as well as the surrounding vegetation providing enough more highly palatable fodder to reduce the grazing pressure on *E. ericoides*.

The trend of larger individuals being grazed more heavily during summer for *Tetragonia* spp. and *O. sinuatum* was again found to be the case during the winter months. The location of the small and large individuals of these species is also important. The smaller individuals utilizing nurse plants in which to establish is again highlighted and stresses the importance of nurse plants to the survival of fodder species in the system.

3.5.6 The Effect of Seasonal Grazing on Small and Large Plant Individuals in the *Pteronia pallens*-dominated Vegetation

3.5.6.1 Summer Grazing

No distinction between the response of small and large individuals of *P. pallens* could be detected during the summer grazing period, both size classes increasing in cover significantly. This is as a result of this species not being grazed and therefore no cover loss resulting (Prozesky *et al.* 1986).

Again, the response of small and large individuals of *R. spinosa* did not differ significantly. Although the small individuals decreased in cover and the larger ones increased in cover, these differences were not significant. The decrease in cover of the small individuals could be as a result of light grazing during this dry period, where the surrounding vegetation is relatively dry and not supporting a large quantity of palatable fodder.

The smaller individuals of *Tetragonia* spp. lost a significant amount of foliage whereas the larger ones did not. No distinct difference could be determined with respect to the response of these species over the summer grazing period.

The larger individuals of *O. sinuatum* were found to be more severely grazed by sheep during the summer months than the smaller individuals. Both small and large individuals lost a significant amount of cover and again the location of the smaller individuals under nurse plants may explain the higher grazing pressure exerted on the larger individuals.

3.5.6.2 Winter Grazing

As was found to be the case during the summer grazing period, no distinct difference in the response of small and large individuals of *P. pallens* could be determined. The cover of small and large individuals of *P. pallens* did not change significantly due to this species not being grazed (Prozesky *et al.*1986).

The larger individuals of *R. spinosa* were found to respond to the rainfall more significantly than the smaller ones, increasing in cover significantly during this period. The increased rainfall, therefore, ensured an increase in cover as a result of a lack of grazing due to the surrounding vegetation supporting more palatable fodder, as was found in the *R. spinosa*-dominated vegetation.

Both small and large individuals of *Tetragonia* spp. lost significant amounts of cover over the winter grazing period. However, no difference between their responses could be detected. This may be as a result of both small and large individuals responding to rainfall in similar ways, although the larger individuals lost proportionally more cover than the smaller ones.

The larger individuals of *O. sinuatum* were found to be more severely affected by grazing than the smaller individuals during the winter grazing period. Both size classes lost significant amounts of cover, but again the location of the plants is important. The smaller ones were protected by nurse plants and the larger ones were more exposed and more readily grazed by sheep.

3.6 CONCLUSIONS

It appears that although the two vegetation types are being grazed on the same grazing system, the *R. spinosa*-dominated vegetation is being grazed more heavily than the *P. pallens*-dominated vegetation. This difference is pronounced in the response of the palatable species studied, which increased in cover in the *P. pallens*-dominated vegetation and decreased in cover in the *R. spinosa*-dominated vegetation over the study period. However, in all instances, the individual recovery periods between grazing events appeared to be too short, although not all camps conformed to the proposed 120-day recovery period. The average resting period for the eight camps in the *R. spinosa*-dominated vegetation was 129$\pm$5 days, whereas that of the *P. pallens*-dominated vegetation was 141$\pm$54 days. This would suggest that the vegetation in the *P. pallens* was allowed a longer time to recover between grazing events than the vegetation in the *R. spinosa*-dominated vegetation.

It is evident from these results that the longer the resting period between grazing events, the greater the benefit to the recovery of the vegetation. This is proposed in the work of Hobson and Sykes (1980) who suggest that the less frequent a defoliation event is, the more above-ground biomass will be produced and the healthier the root system will be. A healthy root system is important for the recovery of these plants after a dry season, as labile carbohydrates in root reserves (Van der Heyden 1992) and residual leaves (Hobson and Sykes 1980) are important in initiating regrowth after these periods. If the root system of a plant is not healthy, due to overgrazing, then these plants will not recover after dry seasons or grazing events as cessation of root growth will occur (Hobson and Sykes 1980).

Larger palatable species in both vegetation types are more heavily utilized than smaller ones, regardless of in which season the grazing takes place. This is as a consequence of the locations of the plant individuals in the two size classes. The smaller individuals are found under the protection of nurse plants, usually the spiny shrub *R. spinosa*, and the larger individuals are usually exposed and not protected by nurse plants. This would result in the larger ones exposing more palatable stems available for grazing than those of the smaller individuals. Smaller individuals of the succulent shrub, *R. spinosa*, may be utilized during the dry summer months when the more palatable species are dry and desiccated. The larger individuals of *R. spinosa* are usually not grazed and this may also explain why the smaller palatable species are not grazed when growing in or under the protection of *R. spinosa* nurse plants.

The importance of nurse plants in the system is therefore highlighted in the survival of palatable species. The overgrazing of larger individuals in the system, however, could decrease the reproductive output of these species (see following chapters). If overgrazing was to occur, no juvenile recruitment would take place even though grazing pressure on these individuals is relatively low compared to the larger individuals. Therefore, one can conclude from these results, that grazing pressure increases with increasing size of a palatable shrub. However, this only being the case if nurse plants are present in the system to afford protection to the small individuals.

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CHAPTER 4

THE RECOVERY OF *Osteospermum sinuatum* AND *Tetragonia* spp. IN RELATION TO GRAZING AND RAINFALL EVENTS IN KAROO RANGELANDS

4.1 INTRODUCTION

Defoliation is known to adversely affect vegetative growth and reproductive output of Karoo shrubs (Milton 1992, Van der Heyden 1992). The frequency of these defoliation events will also influence herbage production (Hobson and Sykes 1980). Thus these two factors directly affect domestic livestock production by reducing available fodder (Vorster *et al.* 1983).

The various grazing strategies used by Karoo farmers attempt to address this problem so that maximum fodder production is attained without detrimentally affecting the standing vegetation (King and Bembridge 1988). However, this may not always be the case, as increased demand for mutton and wool may directly affect the vegetation because of farmers increasing their stocking rates. Strict control over stocking rates and defoliation frequencies need to be employed if the semi-arid and arid rangelands of the Karoo are to be used sustainably. Evidence of over-grazing by past management schemes, albeit with relatively moderate stocking densities, are evident (Milton 1992, Stokes 1994, this study).

In this chapter, the recovery of the most important fodder species on Tierberg, *Osteospermum sinuatum* and *Tetragonia* spp. (*T. fruticosa* and *T. spicata*) were monitored for a year. The change in cover relative to grazing and rainfall was monitored to determine if the proposed 120-day resting period employed by the farmer was sufficiently long enough for full recovery of these species. Full recovery in this study was considered to be a cover value measured before a second grazing event approximately equalling that measured before the first grazing event (*i.e.*, 100%).

4.2 STUDY SITES

This study was conducted in three camps, two in the *P. pallens*-dominated vegetation (one at the Happy Valley and one at the Tierberg Biome Cell Centres) and one from the *R. spinosa*-dominated vegetation (from the Bob Murray Cell Centre) at Tierberg, 25km east of Prince Albert (33°06'S; 22°15'E). Attributes of these sites have been described in Chapter 1.

4.3 METHODS

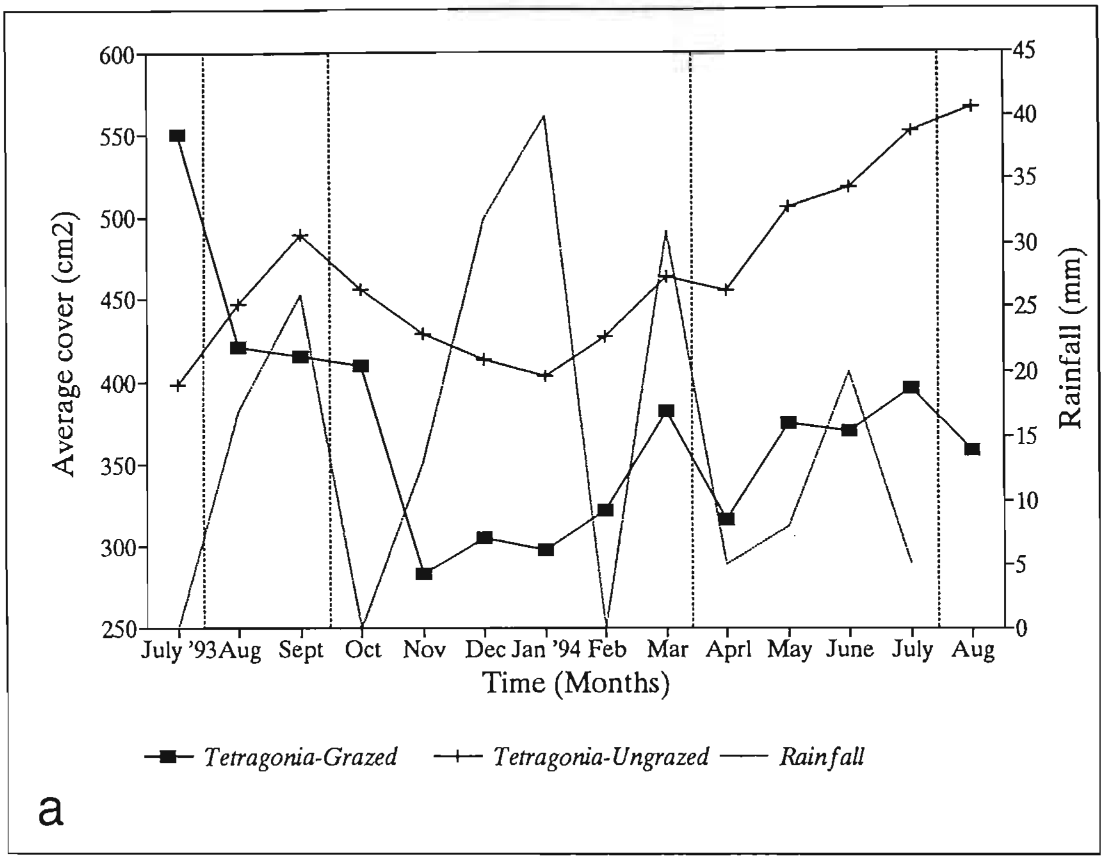
Twenty individuals each of *O. sinuatum* and *Tetragonia* spp. were randomly selected in each camp. Ten individuals of each species at each site were covered using bird-wire, 1.5cm diameter mesh, to exclude grazing animals. These "caged" plants served as controls. The remaining ten individuals of each species at each site were exposed to grazing. Cover was recorded as the two perpendicular axes; longest (L) and shortest (B) and calculated according to the formula, $\pi/4$ LB (Stokes and Yeaton 1994). Difference in cover between two months was compared using a Wilcoxon Signed Ranks Test (Siegal and Castellan 1988). The same test also was used to test for significance between the grazed and ungrazed treatments. The recovery periods mentioned in this study differ from that of Chapter 3 as this study was undertaken over one year. The recovery periods therefore were calculated over a 12 month period and not for the 18 months as was the case for Chapter 3.

4.4 RESULTS

4.4.1 Bob Murray Camp

The detrimental effects of grazing on *O. sinuatum* and *Tetragonia* spp. are evident in Figures 4.1a,b. Both grazed treatments have significantly ($P<0.01$) lower total cover at the end of the study period compared to a significant ($P<0.05$) increase in cover of the protected individuals.

The cover of grazed *Tetragonia* spp. and *O. sinuatum* decreased significantly ($P<0.05$) following the three grazing events, by 20.3% and 21.3% respectively (Tables 4.1a,b). The ungrazed individuals of *O. sinuatum* increased in cover during these periods by 6.8% ($P<0.01$), whereas no significant increase in the cover of *Tetragonia* spp. occurred. As was the case with the line transects (Chapter 3), the rest period for these camps, in this case 115±33 days, between grazing events appears to be too short, especially during the summer months (Tables 4.1a,b). However, during winter, the cover of *Tetragonia* spp. and *O. sinuatum* increased by 23.0% ($P<0.05$) and 19.0% ($P<0.01$) respectively before the grazing events of March and July 1994 (Tables 4.1a,b). This could be as a result of the high rainfall (205mm) which fell during the study period.



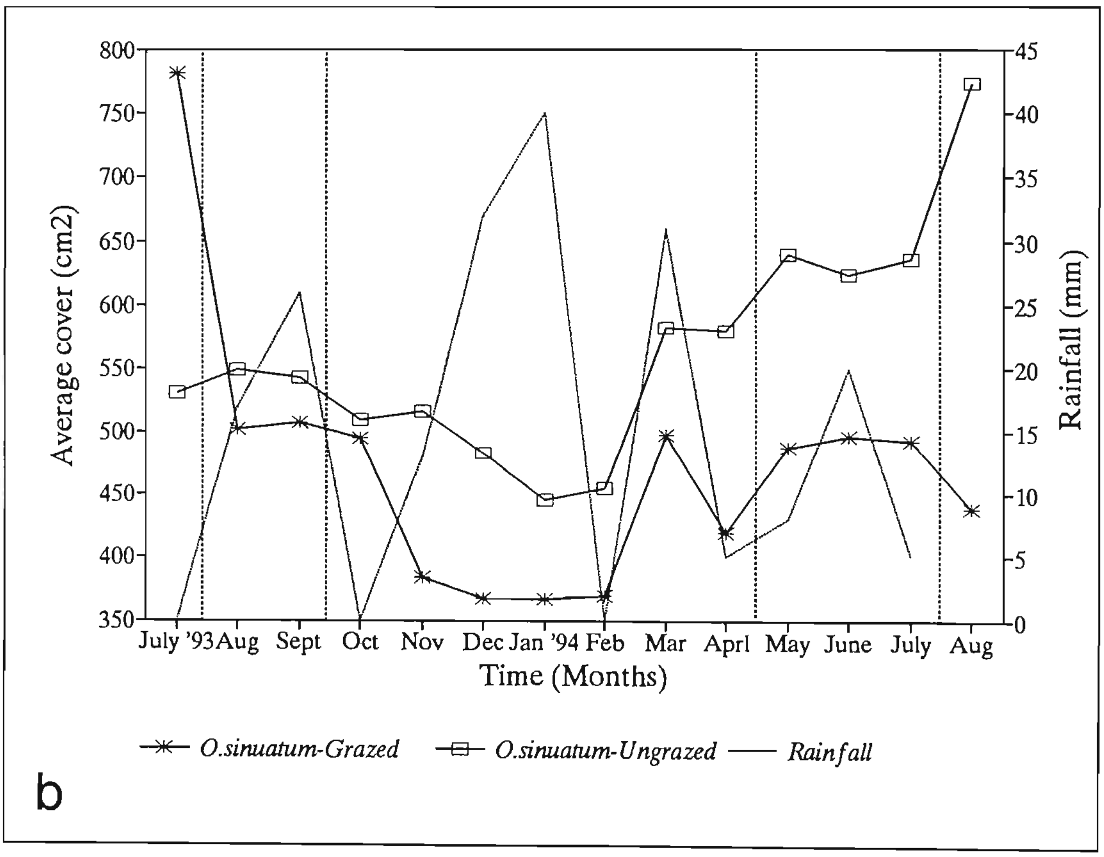


Figure 4.1: Change in total cover of grazed and ungrazed (a) *Tetragonia* spp. and (b) *Osteospermum sinuatum* over a year relative to grazing and rainfall events in a camp from Bob Murray Cell Centre. Horizontal dotted line = grazing events.

Table 4.1a: Mean cover ($cm^2 x 10^{-2}$) ±SD of grazed and ungrazed *Tetragonia* spp. and *Osteospermum sinuatum* individuals measured from July 1993 to January 1994 in Camp 3 of Bob Murray Cell Centre. N = 10. T = *Tetragonia* spp., O = *O. sinuatum*, Gr = Grazed plants and Un = Ungrazed plants. * = $P<0.05$, ** = $P<0.01$, G = Grazing event.

		Jul 93	Aug 93	Sept 93	Oct 93	Nov 93	Dec 93	Jan 94
T	Gr	5.50±2.86 G	4.21±2.48**	4.15±2.43	4.09±2.32 G	2.83±1.72**	3.05±1.79*	2.98±1.74
T	Un	3.99±2.47 G	4.47±2.61*	4.89±3.23*	4.56±2.68 G	4.28±2.36	4.13±2.30*	4.03±2.09
O	Gr	7.81±7.65 G	5.02±5.44**	5.07±5.02	4.94±5.32 G	3.84±3.98*	3.67±3.58	3.67±3.69
O	Un	5.30±2.40 G	5.49±2.23	5.42±2.09	5.09±2.04 G	5.16±2.04	4.83±2.11**	4.46±1.80*
Rain		0mm	17mm	26mm	0mm	13mm	32mm	40mm

Table 4.1b: Mean cover ($cm^2 x 10^{-2}$) ±SD of grazed and ungrazed *Tetragonia* spp. and *Osteospermum sinuatum* individuals measured from February 1994 to August 1994 in Camp 3 of Bob Murray Cell Centre. N = 10. T = *Tetragonia* spp., O = *O. sinuatum*, Gr = Grazed plants and Un = Ungrazed plants. * = $P<0.05$, ** = $P<0.01$, G = Grazing event.

		Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
T	Gr	3.22±1.80*	3.81±2.29**G	3.16±2.15**	3.75±2.49**	3.70±2.43	3.96±2.81 G	3.58±2.60**
T	Un	4.27±2.12*	4.63±2.37*G	4.55±2.42	5.05±2.97*	5.17±3.14	5.51±3.47 G	5.66±3.87
O	Gr	3.70±3.58	4.98±4.49**G	4.19±4.32**	4.88±4.59**	4.97±4.78	4.93±4.85 G	4.38±4.60**
O	Un	4.54±1.73*	5.82±2.00**G	5.79±2.24	6.40±2.62*	6.25±2.59	6.36±2.57 G	7.74±2.54**
Rain		0mm	31mm	5mm	8mm	20mm	5mm	-

The seasonal growth exhibited in Chapter 3 for these species was again found to occur, with cover decreasing over the summer months and increasing in winter (Figs. 4.1a,b).

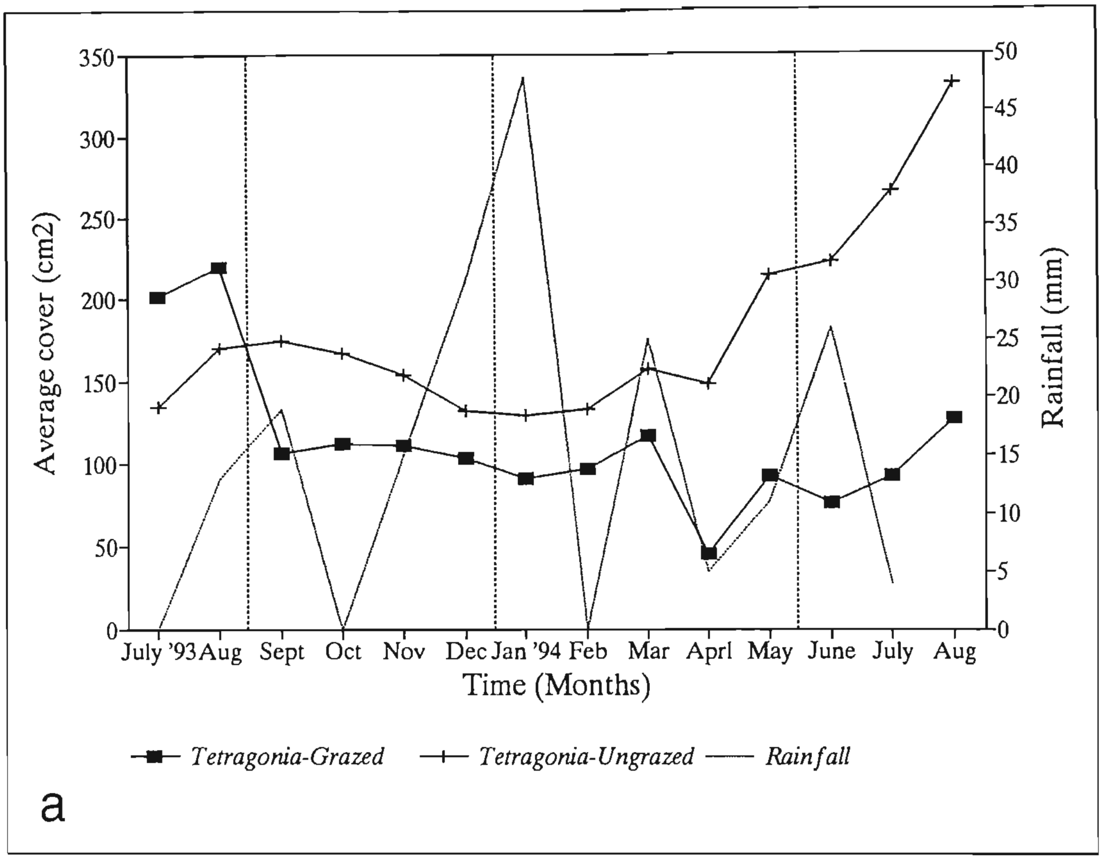
Significant differences were found to occur between the grazed and ungrazed treatments for *O. sinuatum* and *Tetragonia* spp. after all grazing events ($P<0.05$) (Figs. 4.1a,b). Both treatments of both species exhibited growth after a rainfall event and therefore no significant differences were found to occur between grazed and ungrazed individuals after such an event.

4.4.2 Happy Valley Camp

The cover of the grazed *O. sinuatum* did not decrease significantly, whereas that of *Tetragonia* spp. decreased significantly ($P<0.05$) over the study period. However, the cover of the ungrazed individuals of both species increased significantly ($P<0.01$) over the study period (Figs. 4.2a,b). The decrease in cover of the grazed treatment was not as pronounced as in the Bob Murray camp. This is possibly due to the hail event which occurred between March and April 1994, which damaged the exposed plants by removing foliage.

The cover of grazed *O. sinuatum* and *Tetragonia* spp. treatments decreased significantly ($P<0.05$) after the three grazing events, by 26.7% and 14.0% respectively (Tables 4.2a,b). Significant decreases ($P<0.05$) in cover of both species also resulted from the hail, which fell between March and April 1994. However, *Tetragonia* spp. exhibited an overall significant ($P<0.05$) negative recovery in cover (*i.e.*, the cover decreased between the grazing events). *Osteospermum sinuatum* also showed an overall significant ($P<0.01$) negative recovery after the grazing events.

The hail damage makes it difficult to determine if the rest period for the recovery of these species was long enough for this camp. However, it still appears that the rest period of approximately 133 days is not enough for full recovery of these species. The seasonal growth of these species should be taken into account as recovery was found to be slower during summer compared to winter (Tables 4.2a,b).



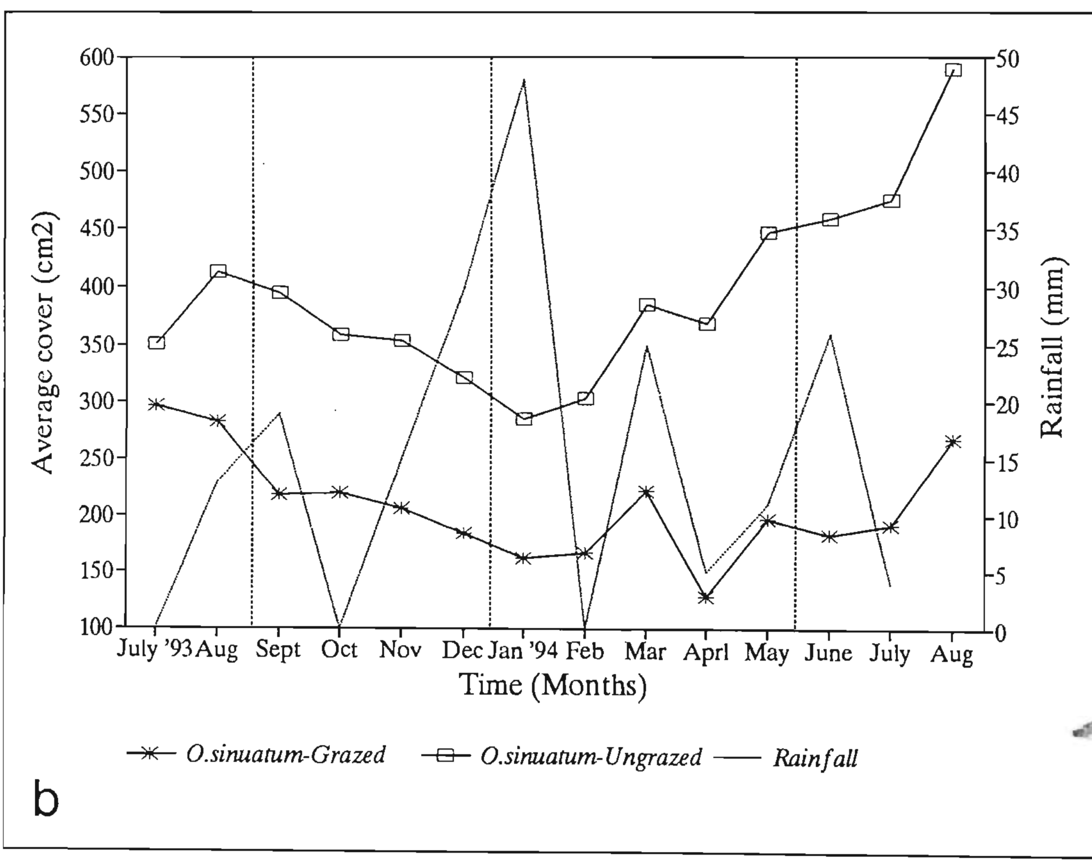


Figure 4.2: Change in total cover of grazed and ungrazed (a) *Tetragonia* spp. and (b) *Osteospermum sinuatum* over a year relative to grazing and rainfall events in a camp from Happy Valley Cell Centre. Horizontal dotted line = grazing events.

Table 4.2a: Mean cover (cm^2x10^{-2}) $\pm$SD of grazed and ungrazed *Tetragonia* spp. and *Osteospermum sinuatum* individuals measured from July 1993 to January 1994 in Camp 6 of Happy Valley Cell Centre. N = 10. T = *Tetragonia* spp., O = *O. sinuatum*, Gr = Grazed plants and Un = Ungrazed plants. * = $P<0.05$, ** = $P<0.01$, G = Grazing event.

		Jul 93	Aug 93	Sept 93	Oct 93	Nov 93	Dec 93	Jan 94
T	Gr	2.01 ± 1.25	$2.20\pm1.43^{*}$G	$1.06\pm1.04^{**}$	1.12 ± 1.22	1.11 ± 1.22	1.02 ± 1.10G	$0.91\pm0.96^{*}$
T	Un	1.34 ± 0.83	$1.70\pm0.91^{**}$G	1.74 ± 0.89	1.66 ± 0.79	$1.54\pm0.77^{*}$	$1.31\pm0.68^{*}$G	1.29 ± 0.68
O	Gr	2.97 ± 2.36	2.83 ± 2.35G	$2.18\pm2.26^{**}$	2.19 ± 2.21	$2.06\pm2.14^{**}$	$1.84\pm1.85^{*}$G	1.62 ± 1.43
O	Un	3.51 ± 2.05	$4.13\pm1.98^{*}$G	3.95 ± 1.83	$3.60\pm1.59^{*}$	3.54 ± 1.70	$3.21\pm1.48^{**}$G	$2.85\pm1.67^{*}$
Rain		0mm	13mm	19mm	0mm	15mm	30mm	48mm

Table 4.2b: Mean cover (cm^2x10^{-2}) $\pm$SD of grazed and ungrazed *Tetragonia* spp. and *Osteospermum sinuatum* individuals measured from February 1994 to August 1994 in Camp 6 of Happy Valley Cell Centre. N = 10. T = *Tetragonia* spp., O = *O. sinuatum*, Gr = Grazed plants and Un = Ungrazed plants. * = $P<0.05$, ** = $P<0.01$, G = Grazing event.

		Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
T	Gr	$0.96\pm1.03^{*}$	$1.16\pm1.25^{**}$	$0.45\pm0.45^{**}$	$0.92\pm0.82^{**}$G	$0.76\pm0.69^{*}$	$0.92\pm0.71^{**}$	$1.27\pm0.99^{**}$
T	Un	1.32 ± 0.75	$1.57\pm0.90^{**}$	1.48 ± 0.77	$2.15\pm1.21^{**}$G	2.23 ± 1.37	$2.66\pm1.53^{**}$	$3.32\pm1.70^{**}$
O	Gr	1.67 ± 1.38	$2.22\pm1.81^{**}$	$1.27\pm1.42^{**}$	$1.97\pm1.99^{*}$G	$1.83\pm1.93^{*}$	1.92 ± 2.03	$2.68\pm2.44^{**}$
O	Un	$3.02\pm1.74^{*}$	$3.85\pm2.10^{**}$	3.69 ± 2.07	$4.47\pm2.14^{**}$G	4.59 ± 2.45	4.75 ± 2.33	$5.89\pm2.35^{**}$
Rain		0mm	25mm	5mm	11mm	26mm	4mm	-

Significant differences occurred between the grazed and ungrazed treatments of *O. sinuatum* and *Tetragonia* spp. after the grazing event between August and September 1993 ($P<0.05$) (Figs. 4.2a,b). The grazing event between December 1993 and January 1994 gave no significant results (Figs. 4.2a,b). However, no significant decreases occurred after the grazing event between May and June 1994, which could be due to extensive growth of *O. sinuatum* and *Tetragonia* spp. following the rain, which accompanied the hailstorm.

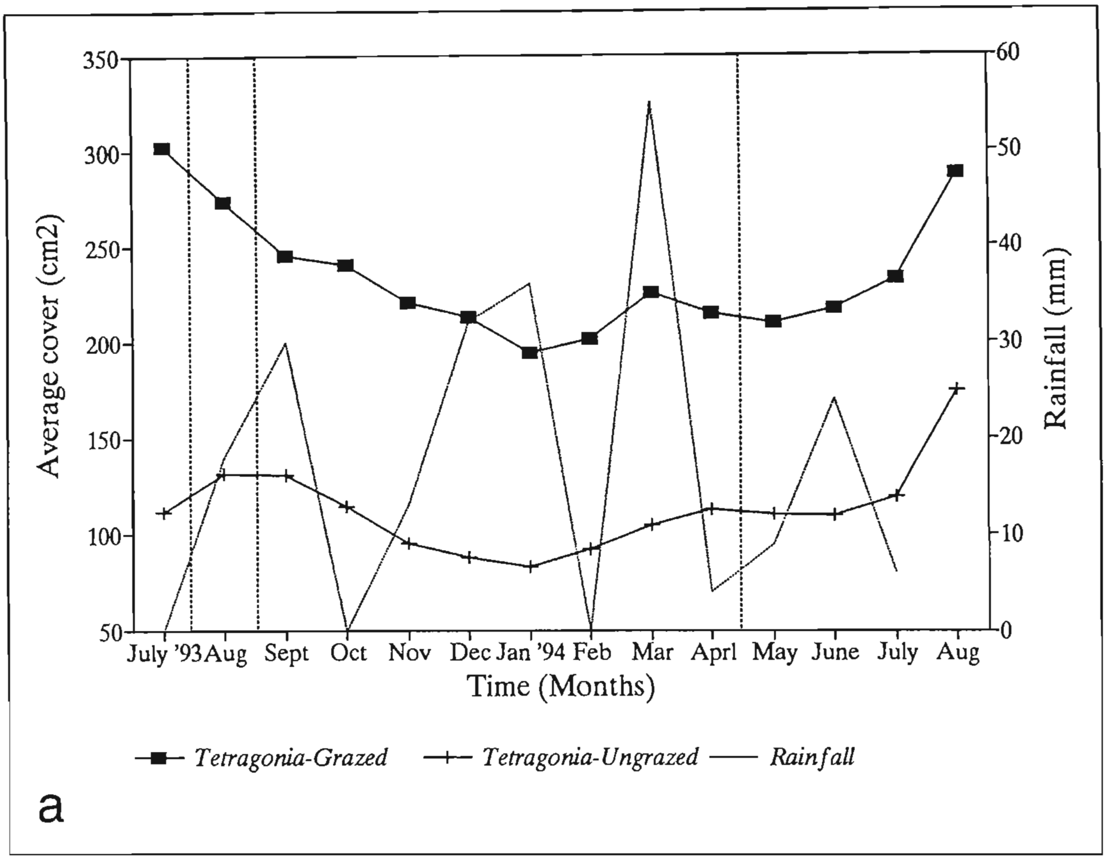
Significant increases ($P<0.05$) were found to occur for the ungrazed *O. sinuatum* and *Tetragonia* spp. compared to the grazed treatment between March and April 1994, which coincided with the hailstorm over the same period (Figs. 4.2a,b).

4.4.3 Tierberg Biome Camp

The results obtained from the Tierberg Biome camp were different from those obtained for the other two camps. The cover of the grazed *Tetragonia* spp. and *O. sinuatum* did not decrease significantly over the study period (Figs. 4.3a,b). However, a significant increase in cover of the ungrazed *Tetragonia* spp. ($P<0.05$) and *O. sinuatum* ($P<0.01$) was found to occur, by 35.6% and 39.0% respectively.

The seasonal growth curve observed in this camp was not as pronounced as that of the other two camps and this could again be due to the difference in the amount of rainfall (Figs. 4.3a,b). However, there was still a slight decrease in cover of *O. sinuatum* and *Tetragonia* spp. over the summer months with an increase in cover during winter. No grazing events occurred during summer and the grazed and ungrazed treatments of *O. sinuatum* and *Tetragonia* spp. followed remarkably similar growth patterns (Figs. 4.3a,b). The grazing pressure exerted on *Tetragonia* spp. and *O. sinuatum* did not decrease the cover significantly.

Significant differences ($P<0.05$) between the grazed and ungrazed treatments of *O. sinuatum* and *Tetragonia* spp. occurred after the grazing events. The growth initiated after a rainfall event was not found to be significant as *O. sinuatum* and *Tetragonia* spp., in both treatments, increased in cover (Figs. 4.3a,b).



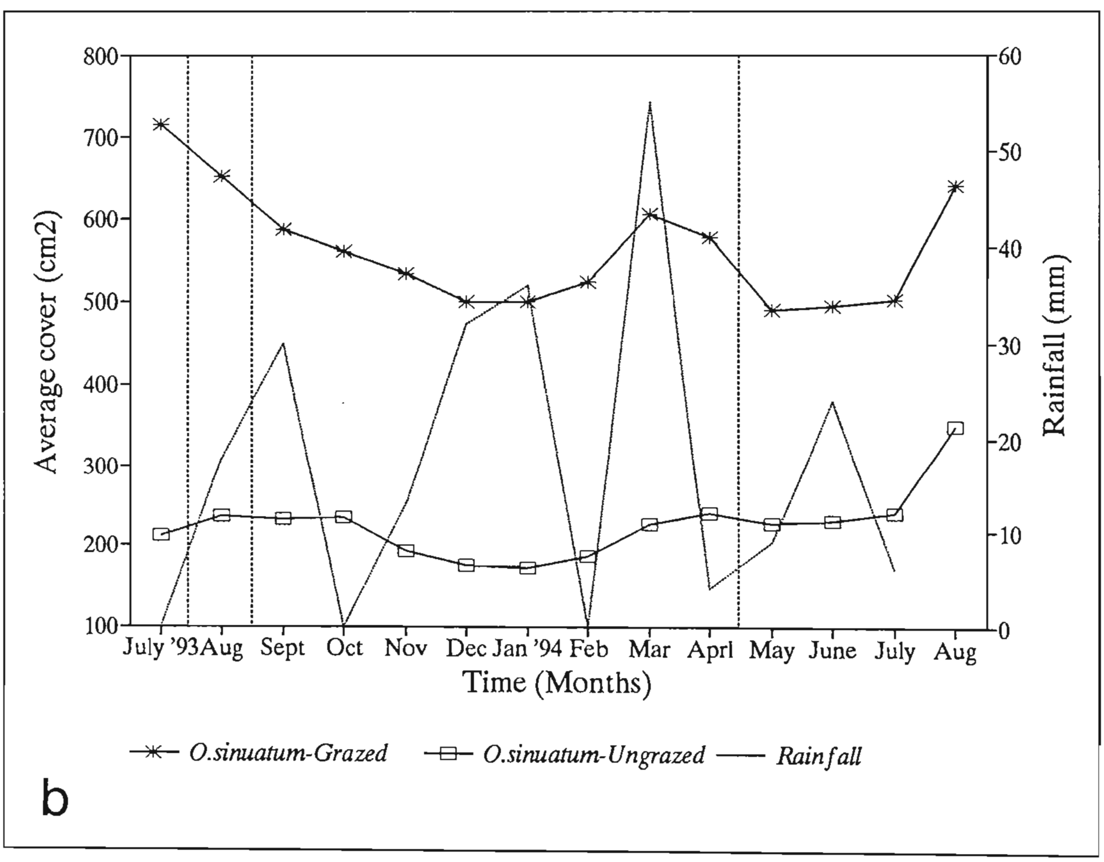


Figure 4.3: Change in total cover of grazed and ungrazed (a) *Tetragonia* spp. and (b) *Osteospermum sinuatum* over a year relative to grazing and rainfall events in a camp from Tierberg Biome Cell Centre. Horizontal dotted line = grazing events.

Table 4.3a: Mean cover (cm^2x10^{-2}) ±SD of grazed and ungrazed *Tetragonia* spp. and *Osteospermum sinuatum* individuals measured from July 1993 to January 1994 in Camp 5 of Tierberg Biome Cell Centre. N = 10. T = *Tetragonia* spp., O = *O. sinuatum*, Gr = Grazed plants and Un = Ungrazed plants. * = $P<0.05$, ** = $P<0.01$, G = Grazing event.

		Jul 93	Aug 93	Sept 93	Oct 93	Nov 93	Dec 93	Jan 94
T	Gr	3.02±2.60G	2.73±2.42*G	2.45±2.43	2.40±2.37	2.21±2.22*	2.13±2.24*	1.94±2.00*
T	Un	1.12±0.43G	1.31±0.50**G	1.31±0.54	1.14±0.52**	0.95±0.51**	0.88±0.51*	0.83±0.50*
O	Gr	7.15±8.24G	6.53±7.47*G	5.88±6.99	5.61±6.17	5.34±6.00**	5.00±5.78**	5.01±5.87
O	Un	2.13±1.23G	2.37±1.45*G	2.33±1.41	2.35±1.46	1.94±1.09**	1.75±1.04**	1.73±1.01
Rain		0mm	18mm	30mm	0mm	13mm	32mm	36mm

Table 4.3b: Mean cover (cm^2x10^{-2}) ±SD of grazed and ungrazed *Tetragonia* spp. and *Osteospermum sinuatum* individuals measured from February 1994 to August 1994 in Camp 5 of Tierberg Biome Cell Centre. N = 10. T = *Tetragonia* spp., O = *O. sinuatum*, Gr = Grazed plants and Un = Ungrazed plants. * = $P<0.05$, ** = $P<0.01$, G = Grazing event.

		Feb 94	Mar 94	Apr 94	May 94	June 94	July 94	Aug 94
T	Gr	2.01±2.06	2.25±2.33**	2.14±2.12G	2.10±2.31	2.17±2.38*	2.32±2.51**	2.87±2.46**
T	Un	0.92±0.48*	1.05±0.53**	1.13±0.58*G	1.10±0.60	1.10±0.57	1.19±0.60*	1.74±0.92**
O	Gr	5.25±6.05*	6.05±6.81**	5.77±6.66G	4.91±6.26**	4.96±6.39	5.04±6.35	6.40±7.11**
O	Un	1.87±1.07**	2.28±1.24**	2.40±1.33G	2.29±1.25	2.31±1.25	2.42±1.29*	3.49±1.76**
Rain		0mm	55mm	4mm	9mm	24mm	6mm	-

4.5 DISCUSSION

It is evident from these results that sheep grazing has a large impact on the growth and recovery of the two palatable shrubs, *Tetragonia* spp. and *O. sinuatum* (Chapter 3). If these species are protected from grazing animals, growth increases throughout the season. However, if these species are exposed to grazing, large decreases in cover occur and this cover is often slow to regrow (Chapter 3). This regrowth is dependant on rainfall and seasons, both *Tetragonia* spp. and *O. sinuatum* exhibiting active growth periods during winter and dormant periods during summer.

The timing of rainfall is also important for the growth of *Tetragonia* spp. and *O. sinuatum*. Although high rainfall was recorded in all camps during summer, the growth of these species was slow and cover did not increase. This was probably as a result of the rainfall not being effective, falling in short duration thunderstorms, which resulted in rapid run-off and little subsurface penetration.

The recovery period between grazing events also has a large influence on the cover status of *Tetragonia* spp. and *O. sinuatum*. In only one camp, the Tierberg Biome camp, was the cover of grazed *Tetragonia* spp. and *O. sinuatum* not found to have decreased significantly over the study period in comparison to the other camps. At the Bob Murray camp and the Happy Valley camp, the cover of grazed *Tetragonia* spp. and *O. sinuatum* decreased significantly over the study period. These differences could be due to two reasons. Firstly, the length of time between the grazing events in the Tierberg Biome camp was longer (237 days) than that of the Bob Murray (115 days) and the Happy Valley camps (133 days). This extended recovery period coupled with the increased rainfall recorded at the Tierberg Biome camp (235mm *c.f.*, an average of 204 ± 0.71mm for the other two camps) may have resulted in a better recovery of *Tetragonia* spp. and *O. sinuatum* individuals.

4.6 CONCLUSION

The vulnerability of species like *O. sinuatum* and *Tetragonia* spp. to overgrazing is evident. As this species has high fodder value in these rangelands, they need to be conserved or the result may be overgrazing and local extinction. Under the present grazing regime these valuable species could become overgrazed unless an adjustment to the rest period is made. Although Milton (1992) states that *O. sinuatum* is able to recover rapidly after a grazing event, a rest period of between 84 and 112 days after effective rainfall is suggested. Van der Heyden (1992) suggests a rest period of no less than 182 days for recovery of *O. sinuatum* in this vegetation type following a defoliation event. In this study, the average rest period was 126 days, which may be long enough during cold wet winter months but not long enough during the hotter, drier summer months. This rest period therefore needs to be extended to incorporate both seasons. However, as was evident in the Tierberg Biome camp, a longer recovery period (in this case 237 days) could yield better results. The data collected in this study, together with that discussed in Chapter 3, suggest that the rest periods employed by the farmer should be lengthened.

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CHAPTER 5

SEEDLING ESTABLISHMENT OF TWO PALATABLE KAROO SHRUBS IN GRAZED, UNGRAZED AND CLEARED KAROO RANGELAND - A CONSEQUENCE OF FLOWERING MORPHOLOGY?

5.1 INTRODUCTION

For semi-arid plant communities, seedling establishment may be the most crucial stage in their life-cycles (Esler 1993). This is as a result of seedling vulnerability to water stress, which is a direct consequence of low and variable rainfall. Post germination rainfall appears to be the determining factor in seedling survival (Milton 1994). Therefore, the timing of flowering, seed set, seed dispersal and germination is important for the survival and continuance of the species in the system (Esler 1993).

The climatic factors governing reproductive output may also be extenuated by predation, both from natural herbivores and domestic livestock. Large proportions of seed that are produced are plundered by small mammals (Kerley 1992) and insects (Dean and Yeaton 1992, 1993; Milton and Dean 1992), which results in reduced seed input into the system.

The suggestion that grazing livestock may reduce seed set in Karoo rangelands is well documented (Acocks 1955, Milton and Dean 1990, Milton 1992). This may lead to changes in vegetation composition (Roux and Vorster 1983, Acocks 1988) and result in certain areas being invaded by unpalatable woody shrubs (Yeaton and Esler 1990).

The shrub, *Pteronia pallens*, is known to cause stock losses due to its hepatotoxicity (Prozesky, *et al.* 1986). This unpalatable shrub has become dominant in certain areas of the Karoo and is therefore considered undesirable. The increasing abundance of this species has led to the overgrazing of important fodder plants, including *Osteospermum sinuatum* and *Tetragonia* species. The concentration of grazing activity on these particular fodder plants has the potential to cause local extinction of these palatable species as reproductive potential is reduced. If measures to conserve these important species are not devised, further species compositional changes will occur, which is already evident with the increasing abundance of *P. pallens*.

In an experiment conducted in January 1993 by Yeaton (R.I. Yeaton, 1993, pers. comm.), plots of *P. pallens*-dominated vegetation were cleared of all individuals of *P. pallens*. An increase in seedling abundance was observed in comparison to uncleared control plots in December of the same year. Following these results the owner of the farm decided to clear *P. pallens* on a larger scale.

The study addressed the following two questions. These were:

1: Is there a difference in the seedling emergence of *O. sinuatum* and *Tetragonia* spp. between the grazed, ungrazed and cleared study sites?

2: Does sheep grazing reduce the flowering potential of *O. sinuatum* and *Tetragonia* spp.?

5.2 STUDY SITES

This study was conducted in the Tierberg Karoo Research Centre, which has not been grazed by sheep since June 1987, and in one camp at the Happy Valley Cell Centre at Tierberg, 25km east of Prince Albert (33°06'S; 22°15'E). Attributes of the study sites have been described in Chapter 1.

5.3 METHODS

A strip of *P. pallens*-dominated vegetation measuring 2000m X 10m was cleared in March 1994 in one camp at the Happy Valley Cell Centre. All individuals of *P. pallens* were chopped at ground level using axes and the remaining canopy skeleton was left over the stump.

Three sampling sites were selected to test for seedling emergence. One thousand square meters of a portion of the cleared strip, adjacent grazed vegetation and similar homogenous vegetation, not grazed by sheep since June 1987, were sampled in July 1994. The presence and location of *O. sinuatum* and *Tetragonia* spp. seedlings were noted. Seedlings were defined as individuals shorter than 6cm in height with unlignified and unbranched main stems. The location was defined as either in the open, under the canopy of a member of the Mesembryanthemaceae, under the canopy of a woody shrub or under the skeleton of *P. pallens*. The number of seedlings at each site was compared using a Chi-Square for a 2 X 2 contingency table (Steel and Torrie 1981).

To test the effect of sheep grazing on the flowering potential of *O. sinuatum* and *Tetragonia* spp., 10 individuals of each species were fenced off using birdwire, with a mesh size of approximately 1.5cm (ungrazed or protected), and 10 were marked as controls (grazed or unprotected). These plants were monitored monthly for the production of flowers. Plants were scored as either flowering or non-flowering and the proportion of flowering to non-flowering individuals was calculated. The grazed and ungrazed plants were compared using an ANOVA and Tukey Multiple Range Tests. These tests were conducted within and not between months (Steel and Torrie 1981).

5.4 RESULTS

5.4.1 Seedling Establishment

The total number of seedlings of both species found in the ungrazed vegetation was significantly higher than that of the grazed vegetation ($P<0.001$) and the cleared strip ($P<0.001$) (Table 5.1). Significantly more seedlings of *Tetragonia* spp. occurred in the cleared strip compared to the adjacent grazed vegetation ($P<0.001$) and ungrazed vegetation ($P<0.001$) (Table 5.1). In the ungrazed vegetation, 93.1% of the seedlings were *O. sinuatum* whereas 96.8% of the seedlings in the cleared strip were *Tetragonia* spp. (Table 5.1).

Very low numbers of seedlings were found in the open in all sites. Both species were found predominantly under mesembs (73.2% of *O. sinuatum* and 85.7% of *Tetragonia* spp.) in the ungrazed vegetation (Table 5.2). In the cleared strip 63.0% of the *Tetragonia* spp. seedlings were located under mesembs and 30.4% under the skeletons of *P. pallens* (Table 5.2).

Table 5.1: Number of *Osteospermum sinuatum* and *Tetragonia* spp. seedlings found in $1000m^2$ at the three study sites.

Species	Ungrazed	Grazed	Cut Strip
Tetragonia spp.	14	5	92
O. sinuatum	190	2	3

Table 5.2: The number and location of *Osteospermum sinuatum* and *Tetragonia* spp. seedlings found in $1000m^2$ at the three study sites. mesemb = seedlings located under a member of the Mesembryanthemaceae, woody shrub = seedlings found under the canopy of a woody shrub, open = seedlings found in the interstices between vegetation, *P. pallens* skeleton = seedlings found under the dead skeleton of cleared *P. pallens*.

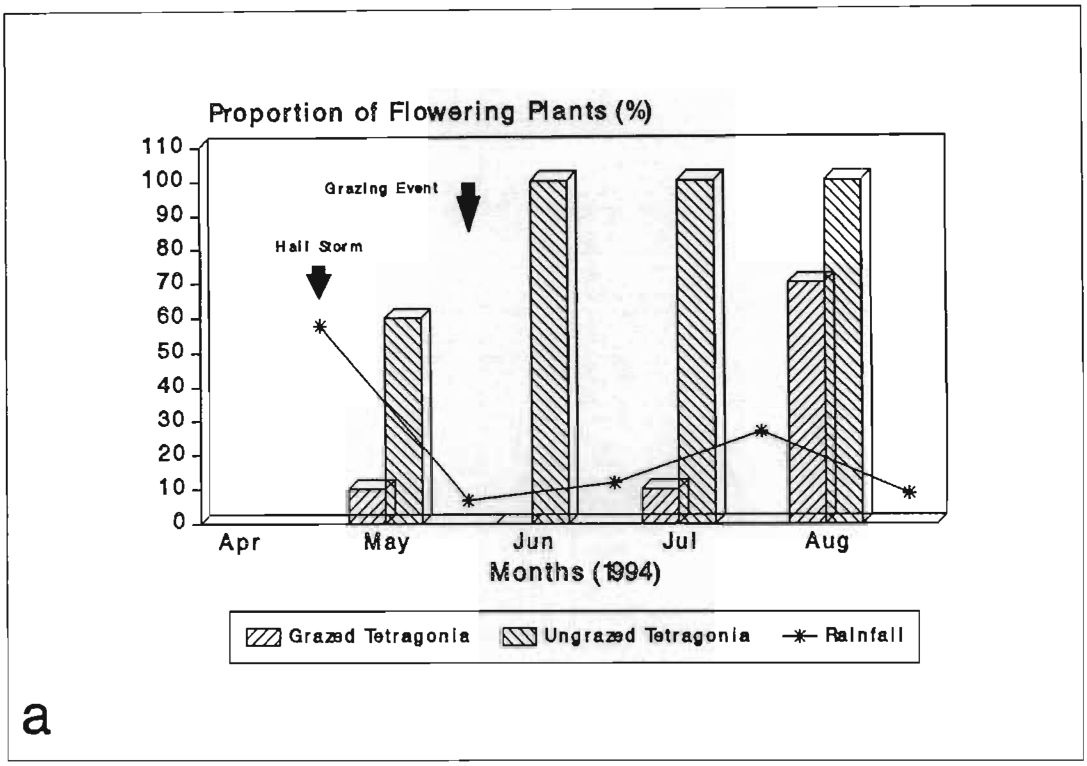
Study site	Location	*O. sinuatum*	*Tetragonia* spp.
Ungrazed	mesemb	139	12
	woody shrub	49	2
	open	2	0
Grazed	mesemb	2	5
	woody shrub	0	0
	open	0	0
Cut strip	mesemb	2	58
	woody shrub	0	3
	open	0	3
	P. pallens skeleton	1	28

5.4.2 Flowering Potential

Between April and May 1994, 55mm of rain fell during a hailstorm, with the hailstones measuring approximately 4.5mm in diameter. This rainfall initiated extensive growth and flowering of the caged *Tetragonia* spp. (60%) and *O. sinuatum* (50%) individuals ($P<0.05$) (Figs. 5.1a,b). The unprotected *Tetragonia* spp. individuals also flowered (10%), but there were significantly fewer ($P<0.05$) flowering individuals than the protected individuals (Fig. 5.1a). No unprotected *O. sinuatum* flowered after this rainfall event (Fig. 5.1b). The low flowering of the unprotected individuals after the rain may be explained due to the damaging effect of the hail. This caused the plants to be broken so reserves would be used in repairing the damage and producing new shoots before reproductive processes could take place. The protected plants were, however, sheltered from the hail by the wire cages and therefore were not subjected to this set-back.

Although little rain fell between May and June there was a significant increase ($P<0.05$) in flowering individuals of both ungrazed species (100% of *Tetragonia* spp. and 60% of *O. sinuatum*) compared to the grazed individuals. However, during this period there was a grazing event. This grazing event caused retardation of flowering in *Tetragonia* spp. and slowed the recovery of *O. sinuatum*. Between June and July, 9mm of rain fell, which caused 10% of the grazed *Tetragonia* spp. to flower, but still no flowering was observed on the grazed *O. sinuatum* individuals.

The flowering of the ungrazed *Tetragonia* spp. remained at 100% and that of *O. sinuatum* decreased to 20%, possibly due to the end of that flowering event as seed set had occurred. The 24mm of rain that fell between July and August, the usual spring rains, caused extensive flowering of both the ungrazed (both species at 100%) and grazed individuals of both species. There was no significant difference between the flowering proportions of the ungrazed and grazed individuals of both species.



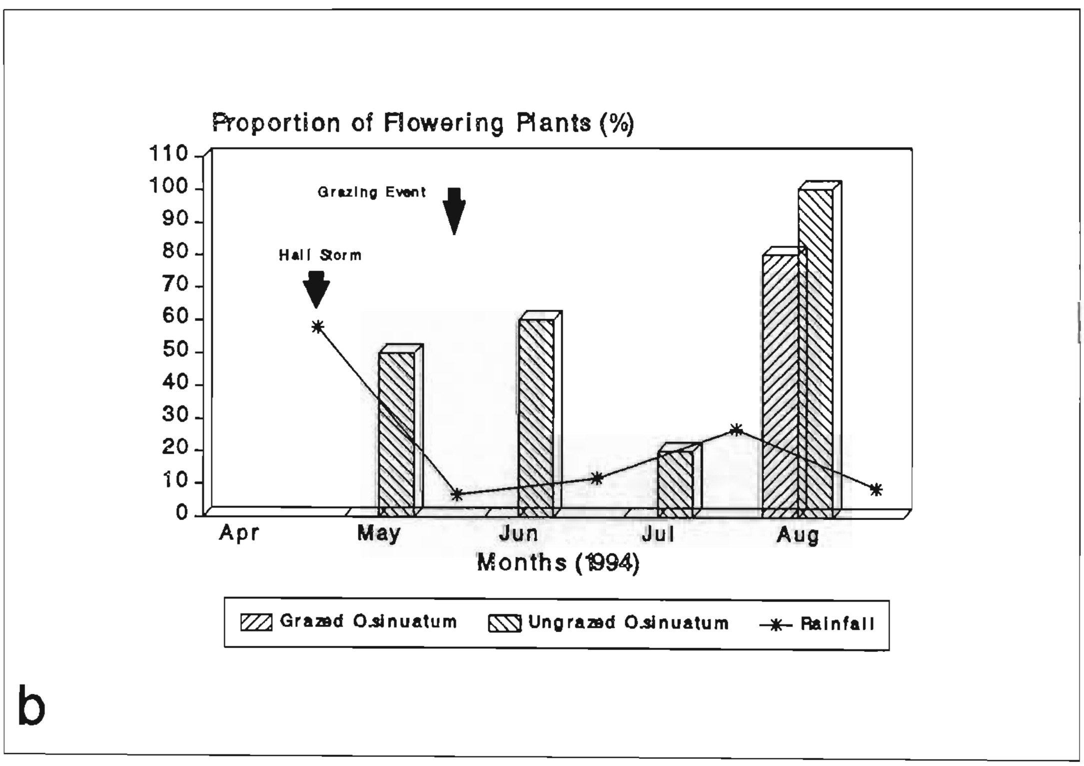


Figure 5.1: Proportion of flowering individuals of grazed and ungrazed a) *Tetragonia* spp. and b) *Osteospermum sinuatum* plants on Tierberg.

5.5 DISCUSSION

To explain the results that have been obtained in this study, the flowering morphologies of *Tetragonia* spp. and *O. sinuatum* must first be discussed. *Tetragonia* species are dwarf shrubs with erect stems. The flowers of these species are borne laterally against the stems of the plant between the stem and the leaf axis. The flowers are protected to a certain extent by the surrounding stems and flowering is not reliant on the development of new shoots. *Osteospermum sinuatum* is also a dwarf shrub but with extensive lateral branching. The flowers are borne terminally on new shoots and therefore these shoots, and the potential flowers that they may bear, are highly vulnerable to grazing by sheep.

The reasons for the low numbers of seedlings of both *Tetragonia* spp. and *O. sinuatum* found to occur in the grazed vegetation was thought to be due to reduced seed numbers in the soil seed bank, as a result of sheep grazing. Milton (1992) found that sheep grazing reduced seed production of *O. sinuatum* by up to 90%, which would result in low seed input into the system.

A high abundance of *O. sinuatum* seedlings was found to occur in the ungrazed vegetation possibly due to the high numbers of seed being produced. The low seedling abundance in the grazed vegetation therefore may be due to low numbers of seeds being produced as a result of sheep grazing.

There was, however, a low *Tetragonia* spp. seedling abundance in both the grazed and ungrazed vegetation. One could therefore assume that the soil seed bank was deficient in these seeds at both sites. No work similar to Milton (1992) has been done on *Tetragonia* species, but one can infer from the flowering morphology that sheep grazing would not reduce seed production as significantly as it does with *O. sinuatum*. Therefore, the seed bank should not be deficient in these seeds. Why then, was there low seedling establishment in both the grazed and ungrazed vegetation? It is known that the seed dormancy mechanisms of *Tetragonia* spp. may be complex and that the seeds may require a long after-ripening period before germination (Henrici 1935, 1939). The high numbers of seedlings found in the cleared strip may be due to a number of reasons. Firstly, the disturbance effects of manually clearing *P. pallens* would bring ripened seeds to the soil surface where good rains would cause germination. Secondly, the reduction in competition from the *P. pallens* could also result in better seedling survival.

It is evident from the work on flowering potential that sheep grazing does suppress the flowering of *O. sinuatum* and to a lesser extent, *Tetragonia* spp.. However, it was observed that the latter species can recover more quickly after grazing and therefore flower at a faster rate after significant rainfall, when compared to *O. sinuatum*. The different flowering morphologies may also explain the different speeds at which these two species flower after a grazing event. *Osteospermum sinuatum* must first produce new shoots and only after some time will a flower develop at the end of these shoots. *Tetragonia* spp., on the other hand, can produce flowers on the stems and energy does not have to be invested in new shoot production before flowering can occur. This may explain why the seed bank is deficient in seeds of *O. sinuatum* as seed production is being suppressed due to frequent grazing events, whereas, the seed bank of *Tetragonia* spp. may still be sufficiently large to maintain the population, as seeds are still being introduced into the system.

5.6 CONCLUSIONS

It can be concluded from this study that the removal of *P. pallens* may have a beneficial effect on the seedling recruitment of *Tetragonia* spp., but not of *O. sinuatum*. The removal of plants, however, needs to be approached with some caution as soil loss could result from run-off (Milton 1995). It may be assumed from these data that the soil seed bank in this area is deficient in seeds of *O. sinuatum* (Milton 1994) and to a lesser extent *Tetragonia* spp.. If rehabilitation is to occur, the clearing of *P. pallens* will not solely be sufficient to rehabilitate these rangelands. To build up the soil seed bank of desirable fodder plants, stocking rates are going to have to be decreased and rest periods between grazing events increased. Camps are also going to have to be skipped during the flowering season and rested for at least 12-16 weeks after high rainfall (Milton 1992) so that seeds can be re-introduced into the soil. By reducing stocking density and increasing the length of the rest periods, the damage to the growing shoots of *O. sinuatum* will be reduced and a quicker flowering response to rainfall events will be obtained, as was observed with *Tetragonia* spp.. In clearing *P. pallens*, competition with adult fodder plants and seedlings will be reduced. Milton (1992) found that the removal of neighbours from around *O. sinuatum* individuals caused more prolific flowering of this species. The disturbance effects of *P. pallens* removal, which can be likened to Aardvark (*Orycteropus afer* (Pallas)) diggings (Dean and Yeaton 1992), ant activity (Dean and Yeaton 1992, 1993) and rodent activity (Lovegrove 1993) also may bring seeds of *Tetragonia* spp. to the surface in order to germinate.

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CHAPTER 6

CONCLUSIONS

6.1 CONCLUSIONS AND IMPLICATIONS

Vegetation change by grazing by domestic livestock is well documented (Henrici 1935, Acocks 1955; 1988, Roux and Vorster 1983, Milton *et al.* 1992). Consequently, vegetation degradation by livestock has been recorded and grazing strategies implemented to conserve these rangelands (See Chapter 3). Stocking rates on semi-arid and arid rangelands have decreased by approximately 44% from 1911-1981 (Dean and Macdonald 1994). This linked to the development of improved range management should ensure the conservation of this resource.

The aim of this study was to determine if one of these grazing management strategies; namely the Savory or short duration grazing system, is a viable option for the Karoo rangelands of South Africa. As no data exists for this strategy in the arid regions of this country (Hoffman 1988), this work attempted to quantify some of the changes that the vegetation of this biome undergoes when subjected to this grazing system.

The effects of grazing domestic livestock on the degradation of Karoo rangelands are apparent with piospheres being set up as a consequence of stock frequenting centralised water points. Vegetation changes with respect to shrub density and percentage cover as distance from the water point increases. It was found that these piospheres may in fact stabilise with increasing age, but that this may be relative to unchanging or constant stocking densities. Although a significant proportion of the ground surface of each camp around the central water point may be obliterated by animal tracks (Andrew 1988), the vegetation of the Succulent Karoo appears to stabilise relatively close to the water point (160m for a relatively young grazing camp system and 320m for a relatively old grazing camp system).

The long term effects of sheep grazing on the individual plant populations of the Succulent Karoo were recorded by measuring the response of palatable as well as unpalatable Karoo shrubs over time. In so doing, a data base of changing plant cover was obtained for 18 months. These data were used to establish whether the proposed 120-day recovery period (or sheep rotation time) employed by the farmer was sufficiently long enough to maintain and utilize this fodder resource sustainably. From the data collected, the 120-day time period was found to be inadequate to ensure the sustainable use of these rangelands. The data also highlights that if the current rest period is maintained with the present stocking densities, overgrazing of important palatable shrubs may be the result. The importance of nurse plants for the persistence of palatable shrubs in the system is also highlighted, as sheep tend to graze more heavily on larger individuals. These larger individuals are usually not found under the protection of nurse plants whereas the smaller individuals are. This alleviates some grazing pressure from the smaller individuals and thus allows them time to grow large and fully establish in the system. However, if overgrazing occurs on the larger individuals, reproductive output may be detrimentally affected and the recruitment of the species may be reduced. If this grazing impact continues as at present, local extinction of the palatable shrubs may occur in the system.

The possible management strategies that could be employed if this grazing strategy is to be continued could be three fold. Firstly, the stocking density needs to be reduced if the rest period of 120-days is to be maintained. This would ensure that excessive defoliation would not occur and result in palatable species being able to regenerate lost foliage at a quicker rate. The second proposal would be to increase the rest periods between grazing events to allow more time for the vegetation to recover from heavy defoliation events. This may be dependant on rainfall, as during times of drought the large stocking rates could be detrimental to the fodder resource in cropping vegetation too heavily so that there would not be enough root stock to recover in the absence of moisture. The third, and possibly the most conservative approach, could be to combine the two proposals. In reducing stocking rates as well as increasing the length of time between defoliation events, the vegetation of these rangelands could be sustained, even during times of drought. However, this may not be economically viable as reduced stock numbers may not be profitable to the small stock farmer. However, if the current scenario is continued, major degradation of fodder resources could result which may threaten the livelihood of the small stock farmer in the long run. Although the data set collected covers a relatively short period of time (18 months), the results show conclusively that adjustments need to be implemented if this grazing strategy is to prove viable.

Nevertheless, what is evident is that this grazing system is a "hands-on" one and requires constant supervision, planning and foresight by the farmer if it is to succeed (W.H.L. Wright, 1993, pers. comm.). With this thought in mind, it is becoming increasingly important for science and farming to mix and ideas and thoughts to be addressed by both disciplines. This is especially true for semi-arid and arid regions, which are increasingly more vulnerable to degradation than are the more wetter agricultural regions of the country.

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