

# Patch Grazing at Kroomie

Justin Christopher Okes du Toit

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School of Applied Environmental Sciences,

Faculty of Science and Agriculture,

University of Natal,

Pietermaritzburg.

Supervisors:

Jock E. Danckwerts

Peter J.K. Zacharias

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## **DEDICATION**

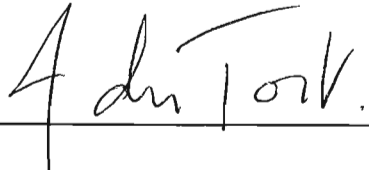
*For Jock*

*Supervisor, Mentor, Confidant, and Friend*

## DECLARATION

The experimental work described in this research was carried out in the Adelaide District of the Eastern Cape under the auspices of the School of Applied Environmental Sciences, University of Natal, Pietermaritzburg. The work was supervised by Dr JE Danckwerts and Prof PJK Zacharias from January 1995 to February 2002.

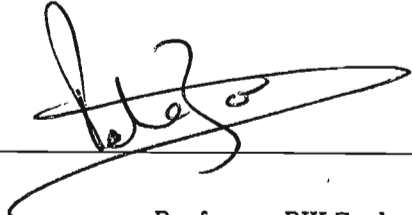
The studies presented are the results of my own investigations, except where the work of others is acknowledged, and have not been submitted in any form to another institute.



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Justin Christopher Okes du Toit

I declare the above statement to be true.



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Professor PJK Zacharias

(SUPERVISOR)

November 2003

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## ABSTRACT

The patch structure of the grass sward at Kroomie (26°25'38"E 33°48'30"S) in a semi-arid savanna in the Eastern Cape, South Africa, was investigated. The study was conducted on long term grazing trials on five treatments varying in stocking rate (SR; recommended (low) and 1.5 x recommended (high)), grazing system (continuous and rotational), and animal type (cattle and sheep). The treatments studied were CR (cattle, rotational stocking, low SR), CC (cattle, continuous stocking, low SR), CH (cattle, rotational stocking, high SR), SC (sheep, continuous stocking, low SR), and SR (sheep, rotational stocking, low SR).

Rainfall during the two years of the study (1997/98 and 1998/99) was slightly below the mean average rainfall of the area (66 and 84% of the mean of 519 mm, respectively).

Analysis of sward height data using Maximum Likelihood Estimation reflected a bimodal height structure in all treatments. Due to a high overlap of the two distributions in some cases, however, the height at which to separate patches (short grass) from non-patches (tall grass) could not be determined.

Canonical Correspondence Analysis (CCA) was used to relate species composition to sward height. It emerged that there are two distinct grass communities at Kroomie, and these are associated with sward height (i.e. patches and non-patches). The interface (in cm) between these two communities, as determined using Two Way Indicator Species Analysis (TWINSPAN) was 6 cm, and this value was subsequently used to discriminate between patches and non-patches.

Sward structure was affected by treatments. Animals (cattle and sheep) stocked rotationally at low SR's grazed less than a third of the total area, and this grazing was concentrated primarily in small patches (< 6 m; length is used as a linear indicator of patch size). Animals stocked continuously at low SR's grazed approximately half the area, in small and large (up to 40 m) patches. Animals in the CH treatment grazed approximately two-thirds of the area, in both small and large patches. There was an inverse relation between the size of patches and the size of non-patches, as expected.

Nine common grass species were related to sward height. *Digitaria eriantha*, *Eragrostis racemosa*, *Eustachys paspaloides*, and *Microchloa caffra* were associated with short swards, while *Cymbopogon plurinodis*, *Eragrostis chloromelas*, and *Sporobolus fimbriatus* were associated with tall swards. *Themeda triandra* (themeda), the most abundant grass

at Kroomie, was principally associated with tall swards, but was present at all sward heights.

Applying CCA demonstrated a considerable difference between the species composition of patches and of non-patches. There was also a difference in composition between treatments, although these were not as pronounced. Patches reflected a higher species diversity than non-patches.

There was a significant ( $P < 0.05$ ) effect of treatment, and of an interaction of treatment by sward structure (i.e. patches and non-patches), on the density of themeda plants. The density of themeda plants was positively correlated with patch size, which suggested that themeda plants that have been grazed may suffer fatal competition from ungrazed neighbours.

Anecdotal evidence suggested that patches are stable over the medium term, and that non-patches that are grazed during a drought return to a non-patch structure after rainfall.

There was no evidence to support the contention that rotational stocking reduced patch-selective grazing, nor that the species composition of rotationally stocked treatments was better than continuously stocked treatments.

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# 1. OVERVIEW

## 1.1 INTRODUCTION

A perusal of agricultural and ecological literature reveals that the term 'patch' has been widely, but non-uniformly, used to describe areas of vegetation which differ in some way from the surrounding vegetation, resulting often in a mosaic comprising two or more 'patch' types.

Kotliar & Wiens (1990) note that: "the term 'patch' typically implies a discrete and internally homogenous entity, yet such patches are rarely observed in nature". They further suggest that the definition of what constitutes a patch is often rather subjective or, more importantly, the boundaries between patches and surrounding vegetation are seldom objectively defined. Therefore, in the following review, while various patch types will be described and commented upon, the term 'patch' holds no single precise definition. However, the general definition of a 'patch' by Kotliar & Wiens (1990) as "a surface area differing from its surroundings" usually holds. Furthermore, most patch structures reviewed have formed as a result of an animal/plant interaction, generally herbivory, on vegetation composed primarily of grasses. In such cases, a patch is shorter (usually due to prolonged or repeated grazing) than a non-patch.

## 1.2 OVERVIEW OF PATCH DYNAMICS

Patches created by animals of different species through the process of grazing have been widely observed (*inter alia* by Gammon & Roberts 1978; Bridge *et al.* 1983; McNaughton 1984; Mott 1985; Andrew 1986a; Andrew 1986b; Day & Detling 1990; Hatch & Tainton 1990; Novellie 1990; O'Connor 1991; Fuls & Bosch 1991; Fuls 1991; Barnes 1992; Fuls 1992a; Fuls 1992b; Milton *et al.* 1992; Pitman *et al.* 1994; Lütge *et al.* 1995) over a wide range of vegetation types and on different continents. In fact, I could find no example of where vegetation was consumed uniformly enough as to create a sward structure devoid of some patchiness. Patchiness as a response to herbivory appears, therefore, to be an inevitable consequence at the animal/plant interface. This is even so in situations of high stocking density on improved pastures (e.g. Ogura *et al.* 2002).

Patch formation in natural and cultivated grasslands is often viewed as being an undesirable consequence of herbivory by domestic animals, which is exacerbated by poor management (e.g. Hatch & Tainton 1990; Fuls & Bosch 1991; Fuls 1991; Barnes 1992;

Fuls 1992a; Fuls 1992b), presumably as it results in the 'inefficient' utilization of the available grass, and 'overgrazing' of selectively grazed patches. Changes in patch structure (Meltzer & Hastings 1992) and increases in patch size (Fuls & Bosch 1991) have been linked to a system change, perceived to be degradation. Consequently, various means have been proposed to reduce patchiness in vegetation, including burning, resting, and various strategies of moving animals (Mott 1985; Barnes 1992).

The formation of patches by wild herbivores has been regarded as undesirable (e.g. Mentis & Collinson 1979). However, current improvements in understanding diet selection by such animals has led to the emerging view that such selected areas are invariably a consequence of the grazing habits of some animals, or one or more species e.g. zebra and wildebeest (Novellie 1990). McNaughton (1984) considers patches to improve forage availability, thereby being an important component of grazed systems, especially in multi-species animal guilds.

The perception of the nature, role, and consequences of patches evidently differs amongst scientists, probably as one term ('patch') is used to describe small-scale sites of vegetation with greatly differing characteristics, united possibly only in their relative lack of above-ground dry matter (DM) compared to adjacent areas.

### **1.3 THE IMPACTS OF SOME LARGE HERBIVORES ON GRASSES**

#### **1.3.1 ANIMAL SELECTIVITY**

The selective feeding habits of domestic animals have been well documented. This selection by an individual animal may take place at several levels, in the following hierarchy of scale:

1. plant part selection;
2. species selection (with cultivar selection as a special case);
3. patch selection; and
4. area (vegetation type) selection.

**(Note:** This hierarchy is scale-related, and may differ from the preference exhibited by animals, which is driven by factors of, *inter alia*, plant quality and dietary need.)



The first level of selection practised by animals is for aboveground plant parts low in structural material (e.g. cellulose & hemicellulose; Danckwerts 1989b) and woodiness and hairiness (Hatch & Tainton 1993): the plant parts selected are usually glabrous leaves (Chacon & Stobbs 1976; Gammon & Roberts 1978; Andrew 1986a; Kreuter & Tainton 1988). As plants which have been grazed will produce new leaves, the traditional contention is that such plants will be selected for many times during the season, thereby reducing their vigor and rendering them less competitive in the grass sward (Tainton 1981). In practice, such plants are not necessarily regrazed extensively during the season (Gammon & Roberts 1978; O'Connor 1992).

The second level of selection is cultivar selection. New cultivars for planted pastures are continually being developed in an attempt to increase animal production by a) increasing fodder production, and b) by increasing the intake of forage by animals. Improved animal intake is due, *inter alia*, to increased acceptability of the forage to the animal grazing it. Pitman *et al.* (1994) found differences in selection between two cultivars of limpogress (*Hemarthria altissima*). One cultivar (Bigalta) was grazed in a more patchy fashion (discussed later) than the other cultivar (Florida). Bigalta cultivar had higher *in vitro* organic matter digestibility than Florida cultivar, which was reflected in the improved mass gains of steers grazing Bigalta.

Probably the most common level of selection is that of species selection, which has been extensively researched in natural grasslands (Gammon & Roberts 1978; Danckwerts *et al.* 1983; Andrew 1986b; O'Reagain & Mentis 1989; Stoltsz & Danckwerts 1990; O'Connor 1992; Hatch & Tainton 1993). A model used to explain the successional response of grasses to grazing has been devised (Foran *et al.* 1978); grasses are grouped into Increaser I, Decreaser, and Increaser II species. Increaser I species tend to increase in the absence of defoliation, Decreaser species decrease in the presence of over- or under-grazing, and Increaser II species increase in the presence of overgrazing. Decreaser species are considered to be the most desirable from an agricultural production perspective, and suggested range management practices aim at increasing or maintaining this group (e.g. Barnes 1992).

*Themeda triandra* (hereafter referred to as themeda) is a widely occurring bunchgrass in southern Africa, Asia, and Australia (Acocks 1953, Danckwerts 1993), and is generally considered the most important natural forage grass in southern Africa (Danckwerts *et al.* 1985; Danckwerts & Stuart-Hill 1987). Selection for themeda occurs across a wide range of vegetation types in southern Africa (Gammon & Roberts 1978; Danckwerts *et al.* 1983; Stoltsz & Danckwerts 1990; O'Connor 1992; Hatch & Tainton 1993), and this preference is

usually maintained throughout the growing season, and even into winter, although this is not always the case (e.g. Stoltz & Danckwerts 1990). Animals do not, however, necessarily exhibit uniform patterns of selection for species over a season. Hatch & Tainton (1993) observed preferential selection for *Hyparrhenia hirta* (generally classified as an Increaser II species) following a burn, which declined during the season. A similar trend was observed for *Tristachya leucothrix* (commonly regarded as an Increaser I species).

The formation of grazed patches has frequently been noted although, as mentioned earlier, their discreteness or homogeneity is seldom defined. Such patches may be categorised into two groups:

1. patches characterised by a relatively dense cover of grasses grazed to a low height and/or grasses with a low growth habit (McNaughton 1984; Hatch & Tainton 1990; Novellie 1990; O'Connor 1992; Hatch & Tainton 1993; Lütge *et al.* 1995); or
2. patches characterised by a loss of basal cover over time, usually with subsequent soil and nutrient losses from those patches (Mott 1985; Andrew 1986b; Fuls 1991).

A patch may be considered as a group of grasses in an area which is selectively grazed over a season, and which may be selected over subsequent seasons. In investigating patch dynamics, therefore, the fundamental component to consider is the individual grass plant. If the number of grass plants selected increases over time, so the extent of patch grazing should increase. The vast grazing lawns of the Serengeti (McNaughton 1984) may be considered patch-grazed. Patch grazing is considered in more detail in section 1.3.2.

The broadest scale of selection practised by animals is area selection (veld type selection). Area selection may be distinguished from patch selection by regarding abiotic factors such as aspect, slope, edaphic factors, and distance from water: if selection takes place where these factors are relatively homogenous, patch selection as opposed to area selection is occurring. Cattle have been found to select areas near water (Pinchak *et al.* 1991), on bottom lands (Cook 1966), on recently burnt areas (Andrew 1986b), on areas with specific vegetation structure (Novellie 1990), and in pans (Milton *et al.* 1992). In agricultural production systems advocated in South Africa, area types are usually separated with fencing to reduce area selective grazing. This is reasonably widely practiced (pers. obs.).

### 1.3.2 GRASS GROWTH HABIT IN RESPONSE TO GRAZING

As mentioned earlier, patches may be separated into a) those which form a stable, high basal cover vegetation structure (grazing lawns), and b) those which have plant die-back, resulting in bare patches. The development of grazing lawns has been attributed to the co-evolution of grasses and grazers (McNaughton 1984; Coughenour 1985); whether this is in fact the case has been the grounds of rigorous debate (e.g. Belsky 1986; McNaughton 1986). The response of grasses in such lawns to herbivory results in the miniaturization of photosynthetic structures, and an increase of plant biomass close to the ground due to the interaction of the opposing forces of competition for light, and grazing pressure (Diaz *et al.* 1992). These lawns provide a continual supply of high quality herbage, in a high plant biomass concentration, to the animals which maintain them (McNaughton 1984; Coughenour 1985; Diaz *et al.* 1992). McNaughton (1984) considers the "local grazing lawn patches found in vegetation grazed by domestic animals" to be a miniature example of the similar, though vast, patches created in natural systems, such as the Serengeti.

Grazing lawns have been observed in South Africa (e.g. Hatch & Tainton 1990), though these are usually considered to be degraded due to changes in species composition (covered in more detail later), and to initiate degradation that is more widespread (Barnes 1992). Elsewhere in South Africa patch grazing appears to have caused degradation (the loss of basal cover, with subsequent soil loss) (Fuls 1991; Fuls 1992a; Fuls 1992b) and similar findings have been reported from Australia (Mott 1985; Andrew 1986b). In Australia, Bridge *et al.* (1983) demonstrated (using simulated grazing) that patch grazing initiates further degradation. It seems that in these cases the vegetation has not been able to tolerate the degree of grazing imposed on it, and the degradation is therefore a consequence of grazing *per se*, and not specifically of patch grazing. Consequently, increases in patch size may be considered to increase the overall degree of degradation of an area. If, however, the vegetation is subjected to less grazing by discontinuing patch selection between seasons (e.g. Mott 1985) by providing nutritious herbage at sites other than perennial patches (in this case by burning), the negative effects of grazing may be minimised. It must be questioned whether such an approach (i.e. burning) is necessary for vegetation types which can form stable patches (Barnes 1992). (Here I am reflecting only upon the interaction between patch grazing and fire, and ignoring the other potentially positive effects of burning, for example removal of moribund material, and bush control.)

## 1.4 CHANGES IN SPECIES COMPOSITION

**Note:** Grazing by gregarious animals (e.g. cattle, sheep, etc.) results in the formation of patches. In many cases, grazing has resulted in a change in species composition of the affected area. Therefore, in looking at the effect of grazing on species dynamics of patches, I include in this discussion the effect of grazing on species dynamics *per se*.

Few would dispute that grazing affects the grass composition of swards over time; such responses have been recorded many times. Furthermore, such changes are generally considered to be undesirable (e.g. Tainton 1981 pp 266-268), although some grasslands appear to be maintained in a productive state due to the presence of grazing (e.g. McNaughton 1984). The literature indicates that grazing may have one of three effects on the grass sward:

1. an increase in the proportion of decumbent grasses, resulting in a substantial increase in basal cover. Such grasses usually have relatively low production, and create a 'carpet' of grass on the affected area;
2. a sward comprising relatively short, relatively dense tussocks of grass. In the agricultural sense, this is considered the most favourable sward structure for animal production; or
3. a decrease of basal cover, resulting in the formation of bare patches. Such areas are prone to erosion by rain and wind.

Decumbent grasses usually proliferate under conditions of high moisture, high nutrient status, and trampling. The common example is around watering holes or paddock gates (e.g. Mentis 1981). My personal experience, after having observed hundreds of such sites, is that a carpet of the decumbent species *Cynodon dactylon* is almost always present, especially round water holes. Decumbent growth is, however, not restricted to such areas. Novellie (1990) found that some wild ungulates appeared to maintain certain areas in a condition of high basal cover, termed 'grass lawns'. Black wildebeest, for example, favoured areas dominated by the decumbent grasses *Cynodon incompletus* and *Tragus koelerioides*, and avoided sites dominated by taller species. He concluded that high veld condition scores (due to the presence of Decreaser species) are indicative of a high value to long grass grazers, but not for short grass grazers. Considering this, one could say that an area dominated by such 'lawn' species is degraded if long grass grazers are present (e.g. zebra), though in pristine condition if wildebeest production is one's objective. Agricultural management recommendations

in South Africa are aimed at maintaining the grass sward in a Decreaser dominated stage, but the effects of grazing have often been to move it to an Increaser II dominated stage. Such veld is considered to have degraded. Bearing in mind the wildebeest/zebra example above, one can easily conceive that perhaps cattle prefer an Increaser dominated sward, even if the grasses are not as productive as the Decreaser dominated sward. O'Reagain and Mentis (1990) found that the quality of ingested forage by cattle grazing Natal Sour Sandveld (Acocks 1953) was independent of veld condition score. This lends support to the argument that too little is known about animal's requirements and preferences to be prescriptive in managing those resources that grazing animals exploit. In saying this, I bear in mind that a trend towards Increaser II dominated veld is usually concomitant with other, unfavourable, changes, such as reduced basal cover, increased water runoff, loss of species richness and soil erosion. Barnes and Denny (1991) found that although grazing had an impact on the grass species composition of veld, such changes were not correlated with animal performance. The veld condition, however, declined over the six-year period presented in the data.

In certain areas, grazing considerably reduces the basal cover of the grass sward. Fuls (1992a) found that 'long term patch overgrazing' reduced the basal cover of affected areas by up to 90% in the *Cymbopogon - Themeda* veld (Acocks 1953) of South Africa. Precipitation in the area is approximately 625 mm per year, occurring predominantly in short duration thundershowers. In a more arid environment (<400 mm per year), the Karoo of South Africa, Milton & Dean (1996) report on the effect of grazing on vegetation. In this region, a decline in grass cover is accompanied by an increase in shrubby vegetation, and the development of bare patches. In areas subjected to long-term winter grazing, grass densities are considerably higher than areas subjected to long-term summer grazing. Similar findings were made by Mott (1986) in Australia. Bare patches were formed (due to grass mortality) in the tropical savannas of Northern Australia after two years of grazing with cattle. The affected area increased each year.

It is clear that grazing affects species composition in grazed rangelands. It appears, however, that rainfall (actually, the lack thereof, namely drought) has a more pronounced effect on changes in species composition than does grazing. For example, O'Connor (1994) found species abundance to be more responsive to rainfall variability than grazing, while O'Connor and Roux (1995) found community change in the karoo to be mostly driven by rainfall. I am not going to expand the discussion on the effects of

rainfall on community changes, as it lies outside the scope of the topic under review, but its impact must be borne in mind to give appropriate context to this discussion.

## 1.5 SUMMARY AND CONCLUSION

Grass swards that are grazed by animals invariably develop a patch-grazed structure. The type of patch formed, however, varies under different circumstances: basal cover is either maintained or increased, or basal cover is reduced. In the first type, the predominant grasses may be either stoloniferous or bunch species. These patches may be considered undegraded. Patches that are characterized by a loss of basal cover, often being prone to soil loss, may be considered degraded. It is, therefore, important to consider the degradation status of patches when referring to 'patch grazing'.

Animals exhibit various forms of selection when grazing, one of which is patch selective grazing. It appears as though patch selection is of a higher priority to animals than is species selection: animals will often return to grazed patches even if palatable and desirable species may be available on adjacent non-patches. This is probably due to the relatively high concentrations of nutritious and available plant parts (food) present in patches. Because of this *favourable* response of vegetation to herbivory (i.e. high concentration of nutritious herbage on patches), it has been proposed that animals 'farm' or 'manage' patches in order to maximize grazing efficiency (e.g. rate of ingestion of digestible forage). This is demonstrated in practice in both agricultural and natural systems where animals (such as sheep and wildebeest respectively) return to and maintain patches over time. Furthermore, such patches appear stable and productive in the long term in many instances.

It seems unreasonable, in consequence, to consider 'patch grazing' in a negative light, as patches are a natural consequence of the animal/plant interaction. However, patch degradation (the degraded patches mentioned above) does certainly occur. Much vegetation has undergone degradation in the form of losses in biodiversity, species richness, plant basal cover, and soil. This is, naturally, undesirable, and an understanding of why such phenomena take place, or at least the circumstances under which such phenomena take place, would be useful, with the ultimate purpose of developing management strategies to minimize the undesirable effects.

It is the objective of this study to further our understanding of patch dynamics in the following ways:

1. defining patches and non-patches, and devising a method of objectively separating them;
2. determining the effect of animal type, number, and distribution on patch geometry;
3. investigating the species composition of swards as related to sward height;
4. determining whether patches reflect degradation; and
5. using anecdotal evidence to investigate the spatial stability of patches over time.

These objectives are expanded upon in more detail at the beginning of each of the following chapters.

## 2. DESCRIPTION OF THE EXPERIMENT

### 2.1 INTRODUCTION

This study took place on trials initiated in 1989 to investigate the effects of animal manipulation on animal performance and vegetation dynamics. The purpose of this chapter is to provide descriptions of the area in which the study was conducted and why the trials were originally initiated. Subsequent chapters will report on the details of this study, which form part of an extension of the original objectives.

### 2.2 EXPERIMENTAL SITE

#### 2.2.1 LOCATION, TOPOGRAPHY AND SOILS

This study was undertaken on the farm Waterfall (26°25'38"E 33°48'30"S), Kroomie, approximately 20 km east of Adelaide, Eastern Cape (hereafter referred to as "Kroomie"). It is situated on a gentle (<5%) slope with a northeasterly aspect.

The soils at Kroomie are primarily of the Mispah form (Soil Classification Working Group 1991), though the Oakleaf, Sterkspruit, Hutton, Swartland, and Glenrosa forms are also present.

#### 2.2.2 VEGETATION

Kroomie is situated in the False Thornveld of the Eastern Cape (Veld type 21; Acocks 1953), where the vegetation is characterised by a multi-species grass layer in an open *Acacia karroo* woody layer (Table 2.1). Themeda is the most common grass of the region (Acocks 1953, Danckwerts 1989c), and is generally perceived to be the most useful grass in the area for grazers, especially domestic livestock (Danckwerts 1993). Its high relative abundance in the region is often taken as an indicator of veld in good condition (Danckwerts 1987). Themeda, *Digiteria eriantha*, and *Eragrostis chloromelas* comprised 75% of all grass species surveyed at Kroomie in 1989.



Table 2.1 Species composition of the most abundant grasses of the False Thornveld of the Eastern Cape as classified into Increasers and Decreasers (from Danckwerts 1989c)

Species	Code	Category	Average % in sward
<i>Heteropogon contortus</i>	Heco	Decreaser	1.70
<i>Panicum stapfianum</i>	Past	Decreaser	1.20
<i>Themeda triandra</i>	Thtr	Decreaser	29.40
<i>Cymbopogon plurinodis</i>	Cypl	Increaser I a	5.07
<i>Cynodon dactylon</i>	Cyda	Increaser II c	1.53
<i>Digiteria eriantha</i>	Dier	Increaser II b	22.10
<i>Eragrostis chloromelas</i>	Erch	Increaser II b	24.28
<i>Eragrostis curvula</i>	Ercu	Increaser II b	0.80
<i>Eragrostis obtus</i>	Erob	Increaser II c	4.61
<i>Eustachys paspaloides</i>	Eupa	Increaser II a	3.45
<i>Microchloa caffra</i>	Mica	Increaser II c	4.58
<i>Sporobolus fimbriatus</i>	Spfi	Increaser II a	4.43
<i>Sporobolus nitens</i>	Spni	Increaser II c	0.40

### 2.2.3 RAINFALL

Rainfall at Kroomie is highly variable, with a range of 640 mm (from 277 to 917 mm) being recorded from 1961 to 1999 (Figure 2.1). The mean annual rainfall (519 mm) is higher than the median annual rainfall (493 mm): most years, therefore, experience rainfall less than the mean. October is usually the first month in the spring with good rainfall (Figure 2.2). Annual rainfall values recorded since the trials were initiated covers most of the range of values experienced since 1961 (Figure 2.3), though the rainfall experienced during this study was below average for both years (345 and 437 mm for 1997/98 and 1998/99 seasons respectively). Monthly rainfall from 1961 to 1999 is presented in Appendix 1.

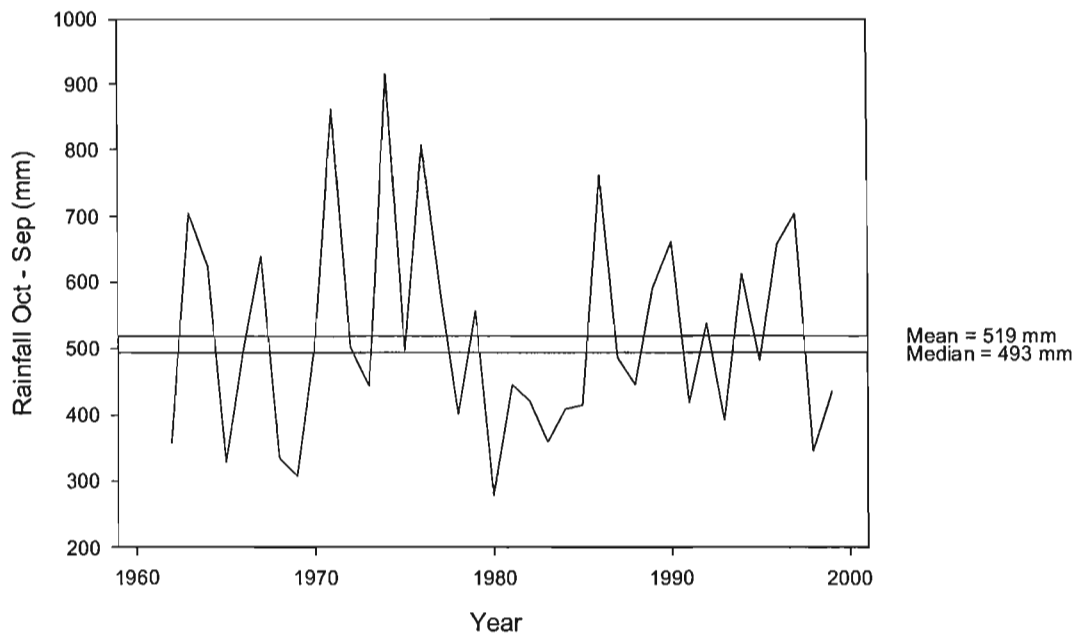


Figure 2.1. Rainfall recorded at Kroomie (1961 – 1999). The horizontal lines represent the long term mean and median values (rainfall season taken from October to September each year).

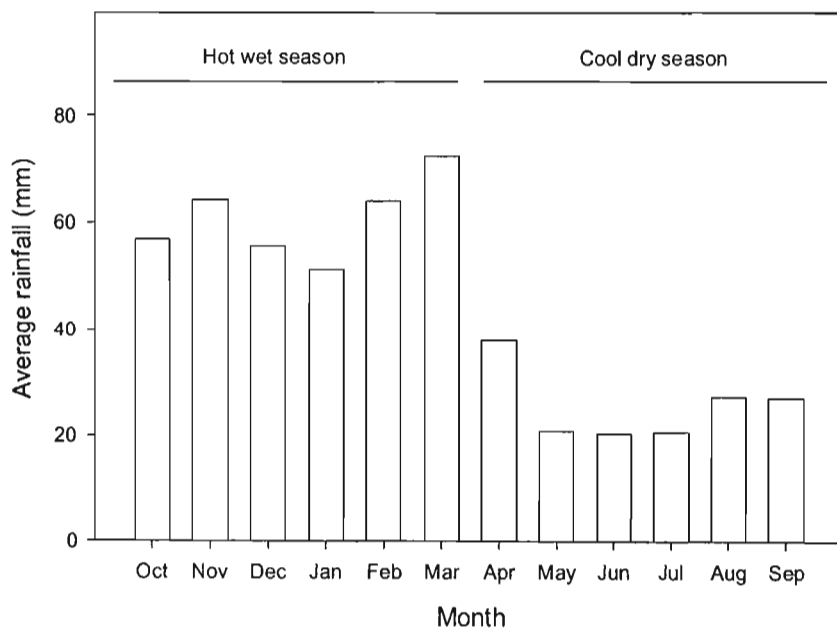


Figure 2.2. Mean monthly rainfall recorded at Kroomie (1961 – 1999).

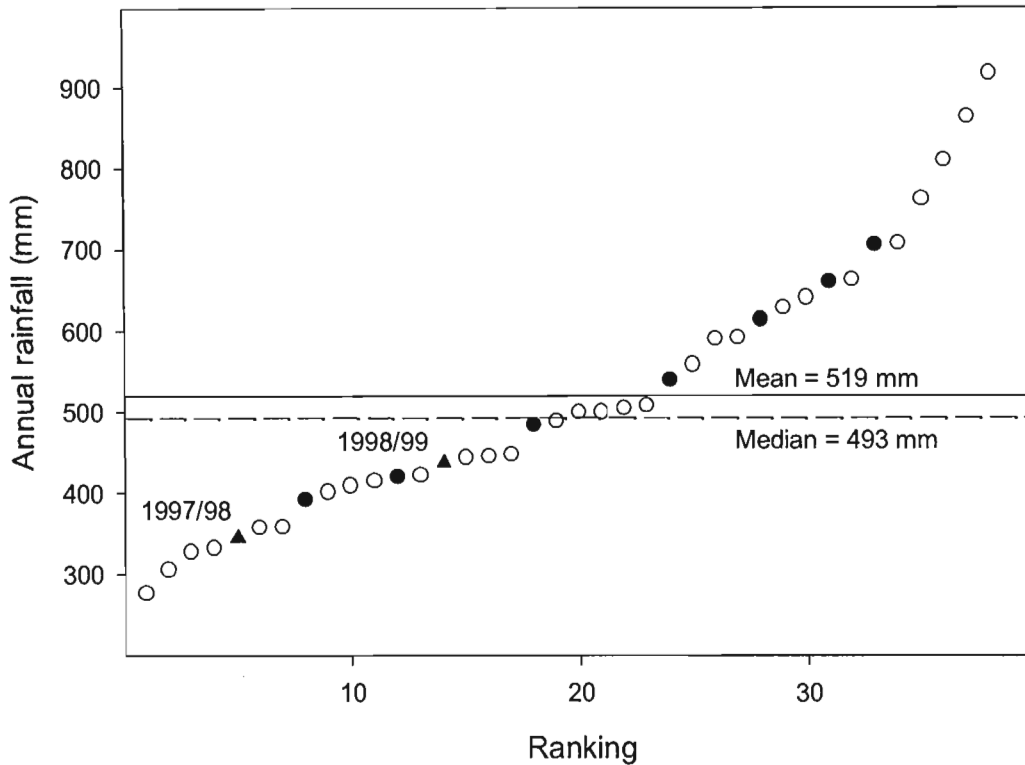


Figure 2.3 Annual rainfall values (October to September) recorded at Kroomie (1961 to 1999), ranked in ascending order. Solid markers represent values since the trials commenced, while triangles represent values experienced during this study (the year is annotated). The horizontal solid and dashed lines represent the long term mean and median rainfalls, respectively.

## 2.3 DESCRIPTION OF THE KROOMIE TRIALS

### 2.3.1 MANAGEMENT VARIABLES TESTED

The trials were initiated in 1989 (though stocked for the first time in 1991) to investigate the effect of animal manipulation on animal performance and vegetation dynamics. Stated simply, there are only three types of animal manipulation: animal numbers (stocking rate), animal distribution (grazing system, including resting schedule), and animal type (species of animal, and ratios of animals of different species). These are dealt with separately.

#### 2.3.1.1 Animal type

Sheep are generally considered to be concentrate feeders, and cattle to be bulk feeders (Mentis 1980). Consequently, it has been proposed that sheep are more detrimental to the condition of the veld, causing degradation over time, than are cattle (as revised by Barnes 1992). The effect of animal type is investigated on the trials by stocking with both cattle and sheep. The effect of animal ratio, however, is not addressed.

#### 2.3.1.2 Animal distribution

Recommendations regarding animal distribution (i.e. grazing system) historically made in South Africa, maintain that veld condition hinges on a) the need for rotational stocking and b) the need for rotational resting (e.g. Booysen 1969; Booysen & Tainton 1978; Edwards 1981 and Vorster *et al.* 1983). More recently, the lack of empirical evidence for, especially, rotational as opposed to continuous stocking, has been reviewed (Barnes 1992; O'Reagain & Turner 1992).

The effect of animal distribution is investigated on the trials by implementing:

- a) 6 paddock vs. 3 paddock vs. 1 paddock (continuous) systems; and
- b) no year-long rest vs. a full year's rest every third year.

#### 2.3.1.3 Animal number

Jones and Sandland (1974) presented a model describing the response of animal production (per hectare and per animal unit (AU)) to stocking rate (Figure 2.4). The model describes how production per AU remains constant as stocking rate increases, until a critical stocking rate is reached, after which it decreases linearly. The response curve of production per hectare to stocking rate is a negative parabola (calculated as the product of animal number by production per animal). Production per hectare is, therefore, zero both when stocking rate is zero, and when animal production per animal is zero (at a high stocking rate). On the assumption that resources are fixed, maximum production per hectare occurs where the stocking rate is half the maximum stocking rate.

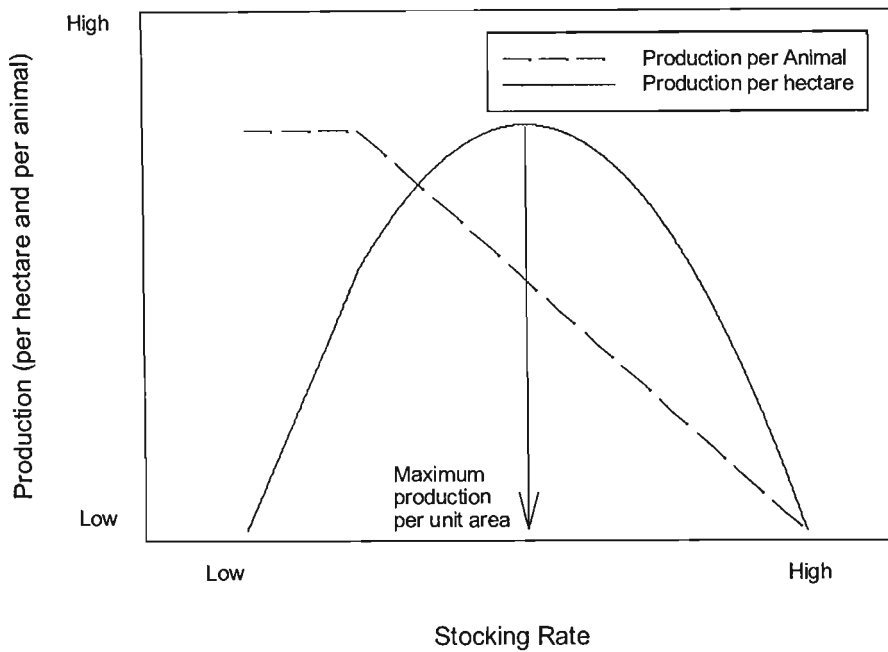


Figure 2.4 The effect of stocking rate on production of animals, per hectare and per animal (after Jones and Sandland, 1974).

Danckwerts (1987) developed a model for calculating the grazing capacity of the False Thornveld of the Eastern Cape, using the parameters of veld condition score and preceding twelve months rainfall, to optimise production per hectare. This model is used to calculate the grazing capacity of the veld in the trials, and stocking rates of animals are adjusted six monthly. Animals are replaced annually to keep the average size of animals relatively constant.

In order to test the effect of stocking rate on animal performance and vegetation dynamics, animals are stocked at recommended and heavy (recommended x 1.5) stocking rates.

### 2.3.2 DESCRIPTION OF THE TREATMENTS

All cattle treatments have remained constant over the entire experimental period, as has the sheep control treatment (Table 2.2). In 1994, one sheep treatment was

discontinued, and two new treatments initiated (Table 2.3), as it was felt that the new treatments would better reflect the impact of grazing system on vegetation than would the original treatment (Danckwerts, pers comm. 1998. Saxfold Park, Adelaide, South Africa).

Treatments are stocked with young growing steers (averaging about 250 kg) or young Merino wethers (averaging about 40 kg). A detailed description of the treatments follows:

**Control (CR):** Cattle are stocked, at the recommended stocking rate, rotationally in six paddocks, two of which are rested sequentially every year (i.e. four of the six paddocks are grazed in any one year). Animals are moved between paddocks every four to six weeks. Animals on the other 6-paddock treatments are moved at the same time as those on the control treatment.

**Heavy (CH):** As for CR, but animals are stocked at 1.5 times the recommended stocking rate.

**No rest (NR):** As for CR, but four paddocks are stocked rotationally each year, none of which is rested. However, it must be noted that the long term stocking rates of the CR and NR treatments are similar.

**3 paddock (3C):** As for CR, but there are only three paddocks, with two out of the three being grazed each year, with the third being rested.

**Cattle continuous + rest (CCR):** As for CR, but only 1 paddock is grazed for the full growing season. This paddock is rested for a full year (i.e. stock are removed from this treatment) every third year. To ensure that the long term stocking rate remains comparable, however, stocking rate is increased by 50% for the two years when it is stocked.

**Cattle continuous (CC):** As for CCR, but no resting of paddocks takes place.

**Sheep control (SR):** As for CR, but sheep rather than cattle are used.

**Sheep 3 paddock (S3C):** As for 3C, but sheep rather than cattle are used. This treatment was terminated in mid-1994.

**Sheep continuous + rest (SCR):** As for CC, but sheep rather than cattle are used. This treatment has been in existence since mid-1994.

**Sheep continuous (SC):** As for CC, but sheep rather than cattle are used. Animals have, therefore, been stocked on this treatment (without a year-long rest) for about nine years to date.

Table 2.2 Description of treatments at Kroomie that remained constant from 1991 to 1999

Treatment name	Code	Description
Control	CR	Cattle, recommended stocking rate, six paddock rotational stocking, recommended rest.
Heavy	CH	Cattle, 1.5 x recommended stocking rate, six paddock rotational stocking, recommended rest.
No Rest	NR	Cattle, recommended stocking rate, four paddock rotational stocking, no rest.
3 Paddock	3C	Cattle, recommended stocking rate, three paddock rotational stocking, recommended rest.
Cattle continuous	CC	Cattle, recommended stocking rate, 1 paddock continuous stocking, no rest.
Cattle continuous + rest	CCR	Cattle, recommended stocking rate, 1 paddock continuous stocking, recommended rest.
Sheep control	SR	Sheep, recommended stocking rate, 6 paddock continuous stocking, recommended rest.

Table 2.3 Description of the treatment at Kroomie which was converted into two alternative treatments

Treatment name	Code	Description
Sheep 3 Paddock (1991-1994)	S3K	Sheep, recommended stocking rate, 3 paddock rotational stocking, recommended rest.
Sheep continuous	SC	Sheep, recommended stocking rate, 1 paddock continuous stocking, no rest.
Sheep continuous + rest	SCR	Sheep, recommended stocking rate, 1 paddock continuous stocking, recommended rest.

## **2.4 STUDY PERIOD**

Data for this study were collected from August 1997 to September 1999, the majority being during the second half of this period. The data that are collected on an ongoing basis (species composition and animal performance) do not appear here. This study is possible as a consequence of the long-term trials, but does not report directly on the effects of animal type, stocking rate, or grazing system on rangeland dynamics or secondary production.



### 3. DEVELOPMENT OF A MODEL FOR OBJECTIVELY SEPARATING PATCHES FROM NON-PATCHES

#### 3.1 GENERAL INTRODUCTION AND AIM

In order to study patch structure, it is necessary to be able to distinguish between patches and non-patches in an objective and repeatable manner. It is easy to recognise patches and non-patches in many cases. However, there are many instances where visual separation is impossible. Species composition, patterns of defoliation, basal cover, and scale result in an almost infinite combination of sward geometry, and the interface between patches and non-patches becomes difficult to recognise. Therefore, before the patch structure of the treatments could be studied, it was important (and is the aim of this section) to develop a simple, repeatable, and objective model for distinguishing between patches and non-patches. A disc-meter was chosen as a tool to provide quick, repeatable, and objective estimates of sward height (*sensu* Bransby & Tainton 1977, Bransby *et al* 1977).

#### 3.2 TREATMENTS STUDIED

Five treatments were considered during this study, namely CR, CH, CC, SR, and SC (these abbreviations will be used from here on, and are described in Table 3.1).

Table 3.1 Treatments selected for investigation of the nature of patches at Kroomie

Treatment code	Treatment details
SC	Sheep, recommended stocking rate, continuous stocking, no rest.
SR	Sheep, recommended stocking rate, rotational stocking, recommended rest.
CH	Cattle, heavy stocking rate, rotational stocking, recommended rest.
CC	Cattle, recommended stocking rate, continuous stocking, no rest.
CR	Cattle, recommended stocking rate, rotational stocking, recommended rest.

### 3.3 STUDY 1: SEPARATION OF PATCHES AND NON-PATCHES USING MAXIMUM LIKELIHOOD ESTIMATION

#### 3.3.1 INTRODUCTION AND AIM

If a uniform sward is defoliated patchily, the formation of a bimodally structured sward (some tall grass, and some short grass) is intuitively anticipated: due to this structure, patches may be separated from non-patches at some height (Figure 3.1a). Reciprocally, if many measurements of sward height are taken, then patches can be objectively distinguished from non-patches on a frequency distribution (Figure 3.1b).

In practice, such uniform distributions rarely exist, and frequency distributions of height measurements are typically more jagged. To overcome this problem, single or double normal distributions may be fitted to frequency distributions mathematically using a procedure known as Maximum Likelihood Estimation (MLE; Gibb & Ridout 1986). See Figure 3.2 for an example.

The aim of this section was to determine the structure of the sward of the five treatments using a disc-meter, and then analyse the distributions using MLE to determine at what height patches were distinguished from non-patches. It was anticipated that the sward structure of all treatments would be bimodally distributed, and that the height of the patch/non-patch interface would be similar across all treatments.

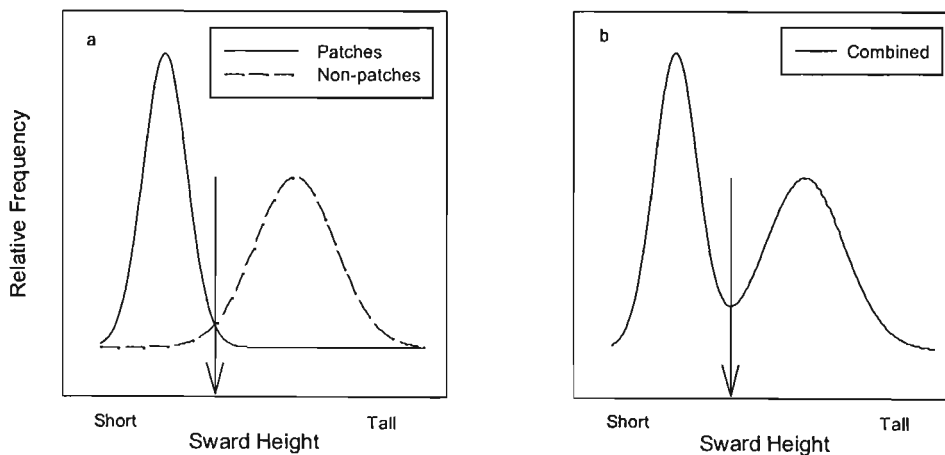


Figure 3.1 a) Hypothetical structure of a patch-grazed sward - the vertical arrow reflects the height at which patches are separated from non-patches; b) the sum of the distributions in (a) - the vertical arrow again reflects the height of separation.

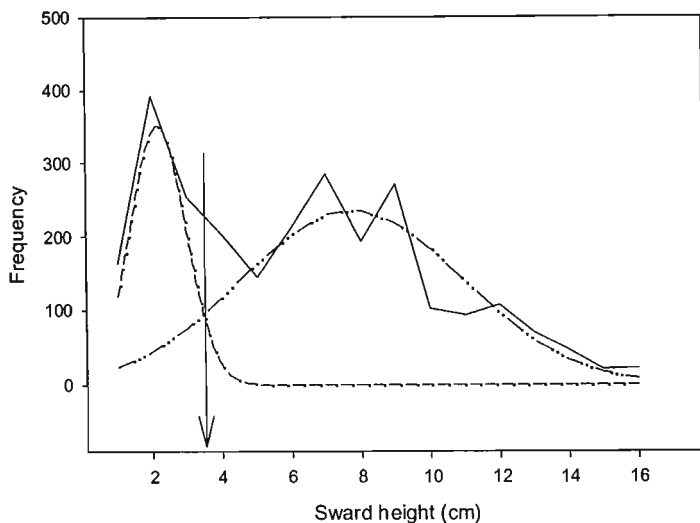


Figure 3.2 Frequency distribution of measurements of sward height for the SC treatment (solid) with two normal distributions fitted reflecting the patch (short dashed; left) and non-patch (dash-dot dot; right) components of the sward. The two structural components of the sward (i.e. patches and non-patches) have an interface at approximately 3.5 cm (vertical arrow).

### 3.3.2 METHODS

In each of the treatments studied, line transects 100 m in length were laid out parallel to one another; they were stratified uniformly across treatment in order to account for as much structural diversity as possible. The CR, CH, SC, and SR treatments each had eight transects, while the CC treatment had only seven. Derry (Pers Comm 1997. University of Natal, Pietermaritzburg) suggested taking at least 1000 readings to ensure sufficient sampling intensity for analysis using MLE. For the CR, CH, SC, and SR treatments, approximately 1600 readings were taken in each treatment (200 readings per transect), while approximately 1400 readings were taken in the CC treatment. The additional readings were taken to preclude the possibility of under-sampling. It was later demonstrated by Morris *et al.* (1999) that approximately 500 readings would probably have been sufficient. Only seven transects were laid out in the CC treatment due to time constraints at the end of the sampling period.

Metal standards mark the beginning, middle, and end of each transect. A 100 m fiberglass tape measure was laid out along the length of each transect, and contiguous disc-meter readings were made along the full length of each transect (approximately 200 per transect).

When trees, rocks and termite mounds intercepted the line of the transect and prevented a disc-meter reading, a "B" for bush, "M" for termite mound, or "R" for rock was recorded on the data sheet.

Double and single normal distributions were fitted to the data using the MLE technique, using dedicated software (Derry *et al.* 1999).

### 3.3.3 RESULTS AND DISCUSSION

Frequency distributions of sward-height data were calculated for each of the five treatments. Single and double normal distributions were fitted to the data (Figure 3.3). In all cases, data demonstrated a bimodal distribution; this was significant (using the Log Likelihood Ratio method of Buckland *et al.* (1993)) for all treatments other than the SR treatment (Table 3.2).

The results (Figure 3.3) indicate that the sward height of all treatments is bimodally distributed. However, these distributions differ across the treatments, as indicated by the heights of the short and tall components of the sward (Table 3.3). The most structured sward is evident in the SC treatment, where there is relatively little overlap (2.2 cm, or 13.8%; see Table 3.3 for explanation of overlap) between the short and tall components. The CC, CR, and CH treatments have patches and non-patches of approximately similar heights to the SC treatment (all less than 4 cm for patches, and between 6.5 and 8 cm for non-patches), and with similar degrees of overlap (between 3.49 and 4.41 cm). In contrast, the SR treatment exhibits a different structure, where the MLE technique estimates the mean height of patches to be 7.1 cm, with an overlap of 7.06 cm (44%). For the CC, CH, SC, and CR treatments, MLE predicts that the patch/non-patch interface occurs between 5 and 6 cm. In contrast, the value for the SR treatment is 8.6 cm. From this, it appears that the presence of short-grazed patches is not the most important factor in determining the structure of the grass sward, at least in the case of the SR treatment.

Consequently, it was concluded that MLE was not a satisfactory method for determining the height of the interface between patches and non-patches, and a further model was consequently investigated.

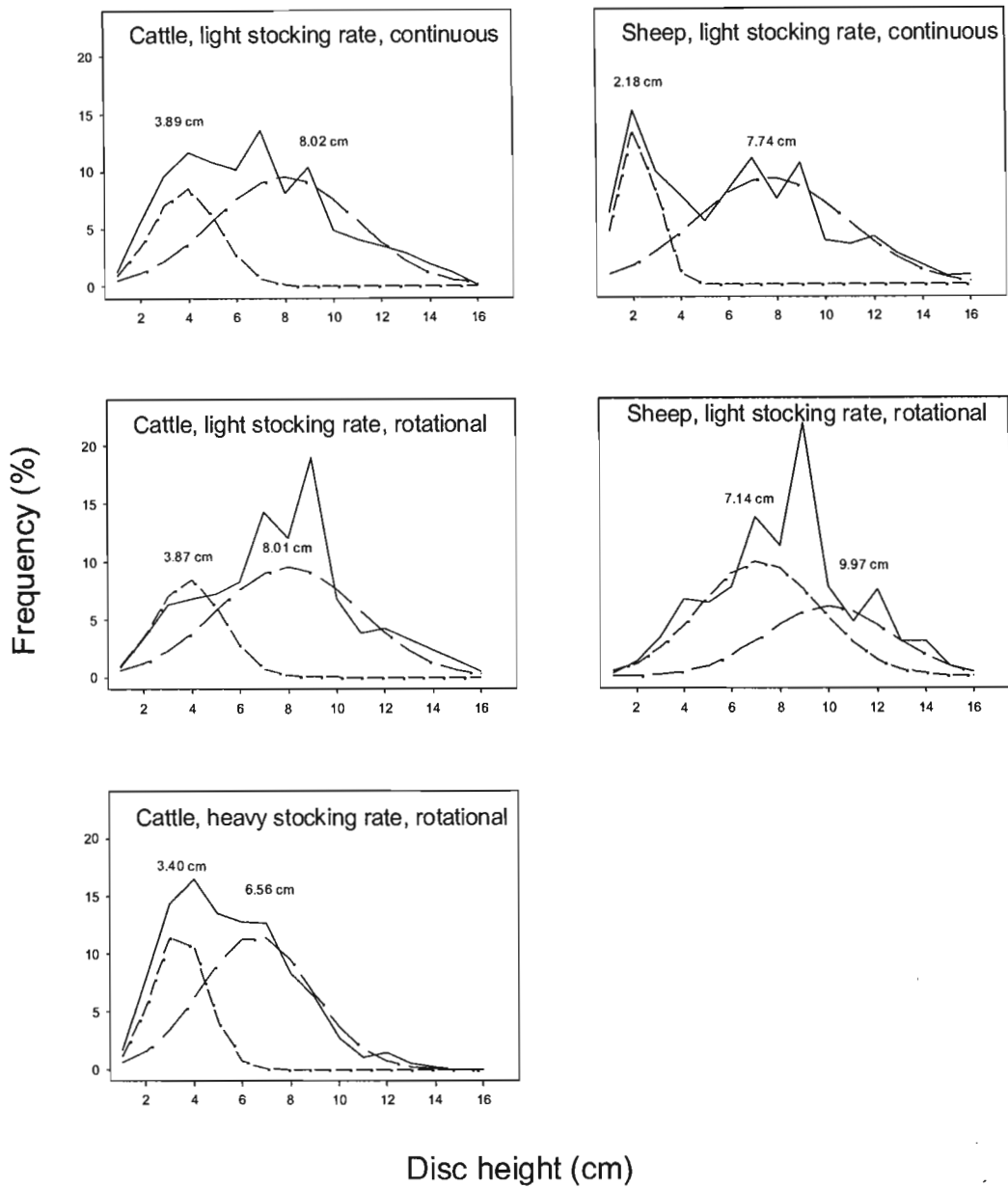


Figure 3.3 Frequency histograms of disc-meter readings from all treatments (solid line) with fitted double normal distributions (short dashed (short grass) and long dashed (long grass) lines). The values reflect the means of the fitted normal distributions.

Table 3.2 Log likelihood function values for single and double distributions for five treatments at Kroomie. P-values were determined using Chi-square analysis

Treatment	Single	Double	P-value
CC	-1839.2	-1798.1	<0.01
CH	-1915.9	-1858	<0.01
CR	-2092.8	-2089.6	<0.05
SC	-4652.4	-4336.9	<0.01
SR	-1964.7	-1963.1	>0.05 (ns)

Table 3.3 Patch and non-patch heights, as estimated using MLE, of five treatments at Kroomie. The interface value reflects the mean of patch and non-patch values

Treatment	Patch Height (cm)	Non-Patch Height (cm)	Interface (cm)	Overlap (cm) <sup>*</sup>	Overlap (%) <sup>**</sup>
CC	3.9	8.0	6.0	4.41	27.5
CH	3.4	6.5	5.0	3.49	21.8
CR	3.9	8.0	5.9	4.39	27.4
SC	2.2	7.7	5.0	2.20	13.8
SR	7.1	10.0	8.6	7.06	44.1

\* overlap (cm) = a - b, where a is the upper limit (cm) of the normal distribution comprising 95% of all patch values; b is lower limit (cm) of the normal distribution comprising 95% of all non-patch values. a and b calculated as t-value x SD (patches and non-patches), where t = 1.96 (95%)

\*\* overlap (%) = overlap (cm) / r x 100, where r = 16 (the full range of height readings, i.e. 0 to 16 cm)

### 3.4 STUDY 2: DESCRIPTION OF PATCHES BASED ON SPECIES COMPOSITION AND SWARD HEIGHT

#### 3.4.1 INTRODUCTION AND AIM

An attempt was made to determine the height of the patch/non-patch interface using MLE. However, certain problems arose, and this necessitated that another technique be investigated (see Section 3.3).

Patches are essentially defined as areas that have been grazed short, while non-patches are areas that are tall and ungrazed. Furthermore, many studies have noted that the species composition of patches and non-patches differ (e.g. Hatch & Tainton 1990, Novellie 1990, Barnes & Denny 1991, O'Connor 1991, Fuls 1992a).

The aim of this study was to correlate the species composition of the vegetation with sward height, in order to determine whether patches may be separated from non-patches at some height, based on species composition.

### 3.4.2 METHODS

The transects that were described in Section 3.3.2 were revisited, and the species composition and sward height in 1 x 1 m quadrats were estimated across each treatment (SC, n=75; SR, n=55; CC, n=49; CH, n=50; CR, n=56) in the following way.

A steel 1 x 1 m quadrat was constructed, and divided into four square sub-quadrats. This was placed on the ground at various randomly selected points along the transect. In each sub-quadrat, the height of the vegetation was measured using a disc-meter (one reading). The species composition of each sub-quadrat was then described by estimating the basal cover of each of the three most abundant species (see Appendix 2 for details). The average sward height and the species composition for the whole quadrat were then calculated. By grouping the data from the four sub-quadrats, a more accurate estimation of the species composition of the 1 x 1 m quadrat is obtained (with potentially up to nine species being accommodated).

A specific test for mean variance ratios was not conducted, but the technique used here for estimating species composition is essentially a slight modification of the Dry-Weight-Rank method of 't Mannelje & Haydock (1963), a useful technique that is often ignored (Kirkman *et al.* 1994), with herbage mass being substituted with basal cover. Barnes *et al.* (1982) recommend that at least 100 quadrats of 0.2 x 0.2 m be used. In this study, species composition was estimated in a minimum of 196 (49 x 4) quadrats that were 0.25 x 0.25 m in size.

There is variation in the number of quadrats sampled per treatment. The high number of quadrats in the SC treatment (75) was a consequence of another study that required a large number of quadrats, but which was subsequently terminated. (The study was to relate the number of *Acacia karroo* seedlings to the species composition of grass: not one seedling was found after 75 quadrats had been inspected, and the study was

abandoned.) For the other treatments, 60 quadrats were examined per treatment, but some quadrats were ignored if they had been located on top of a large rock or termite mound.

Data were ordinated using Canonical Correspondence Analysis (CCA; Ter Braak & Šmilauer 1998), and classified using Two Way Indicator Species Analysis (TWINSpan; Hill 1979).

### 3.4.3 RESULTS AND DISCUSSION

#### 3.4.3.1 Ordination

Species x sample data, with sward height as an explanatory variable, were ordinated using CCA (Figure 3.4). The results indicate a significant correlation between species and sward height ( $r = 0.848$ ;  $P = 0.05$ , using a Monte Carlo test). Axis 1 reflects a height gradient or, in other words, a transition from patches to non-patches. Axis 2 is not related to sward height.

These results indicate that species composition is related to sward height, and that certain species are associated with short swards, and others with tall swards. There is a general trend reflecting the Increaser/Decreaser model. Increaser II species (*Aristida congesta*, *Microchloa caffra*, *Tragus* species, and *Eragrostis racemosa*) are associated with heavily grazed areas, while Decreaser and Increaser I species (themedas, *Eragrostis chloromelas*, *Sporobolus fimbriatus*, and *Cymbopogon plurinodis*) are associated with taller, ungrazed areas. There is a distinct group of quadrats evident on Axis 2 that are characterised by tall grass and *Sporobolus fimbriatus*. These quadrats were located on a relatively narrow band of deep, moist soils in the CC treatment, indicating that species composition of grasses, on non-patches at any rate, is probably affected by water and nutrient status.



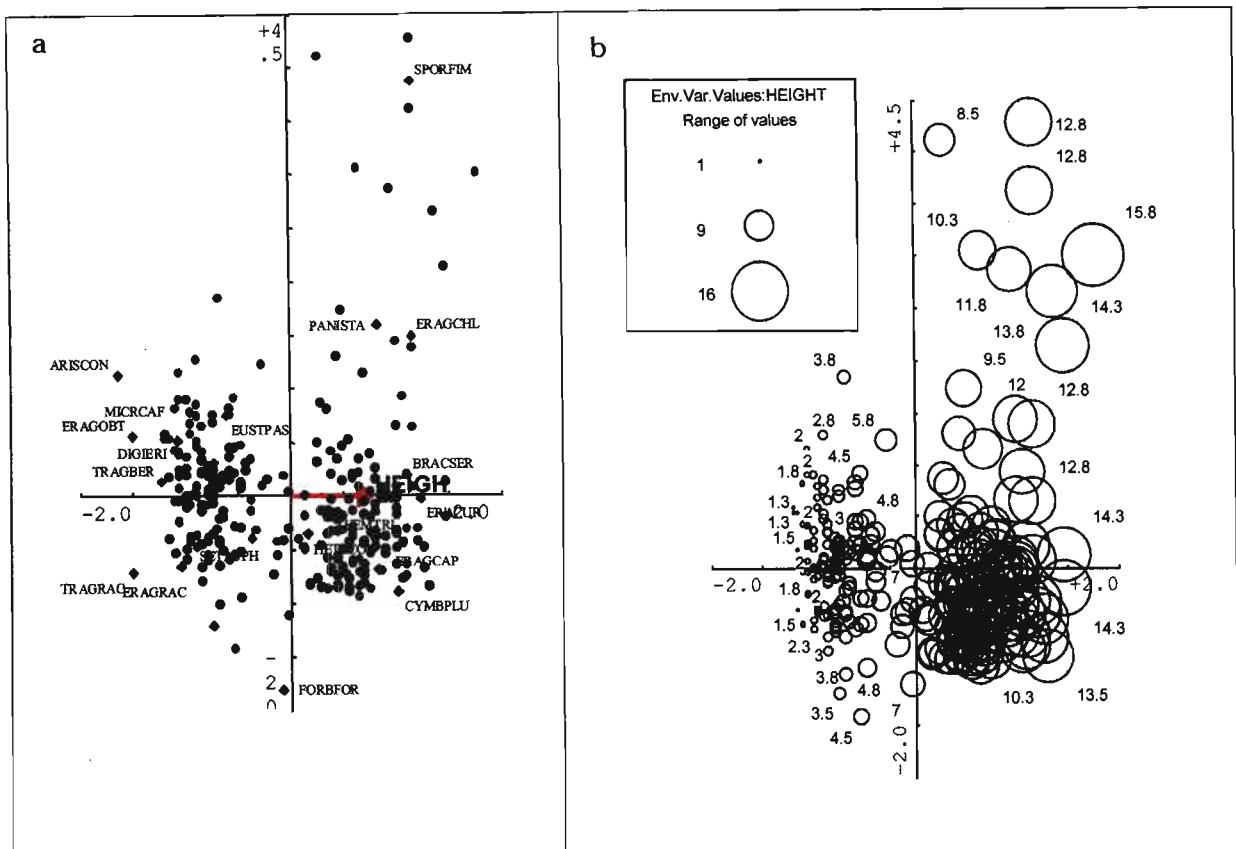


Figure 3.4 CCA results of species x sample data, with sward height as an explanatory variable, from the five treatments studied, a) with height and species overlaid; and b) reflecting sward height graphically (circle size is directly related to sward height). Eigen values are 0.360 and 0.343 for the X and Y axes respectively. (ARISCON = *Aristida congesta*; BRACSER = *Brachlaria serrata*; CYMBPLU = *Cymbopogon plurinodis*; DIGIERI = *Digiteria eriantha*; ERAGCAP = *Eragrostis capensis*; ERAGCHL = *Eragrostis chloromelas*; ERACUR = *Eragrostis curvula*; ERAGOBT = *Eragrostis obtusa*; ERAGRAC = *Eragrostis racemosa*; EUSTPAS = *Eustachys paspaloides*; FORBFOR = *Forb species*; HETECON = *Heteropogon contortus*; MICRCAF = *Microchloa caffra*; PANISTA = *Panicum stapfianum*; SETASPH = *Setaria sphacelata*; SPORFIM = *Sporobolus fimbriatus*; THEMTRI = *Themeda triandra*; TRAGBER = *Tragus berteronianus*; TRACRAC = *Tragus racemosus*.)

### 3.4.3.2 Classification

Species x quadrat data were classified using Two Way Indicator Species Analysis (TWINSPAN). Results for species groupings (Figure 3.5) were in general agreement with the results derived from the CCA ordination (Figure 3.4), indicating that Increaser II species are associated with short swards, while Decreaser and Increaser I species are associated with tall swards.

The sward height of each quadrat was plotted in the order generated by a TWINSpan (Figure 3.6), and it is evident that the association of species is dependent on sward height. This concurs with the results from the CCA (Figure 3.4), but is more useful. There is separation of quadrats at a sward height of approximately 6 cm, and this is evident for all treatments. Therefore, the height of 6 cm can be used to discriminate patches from non-patches.

The species composition of patches and non-patches is discussed in more detail in Chapter 5.

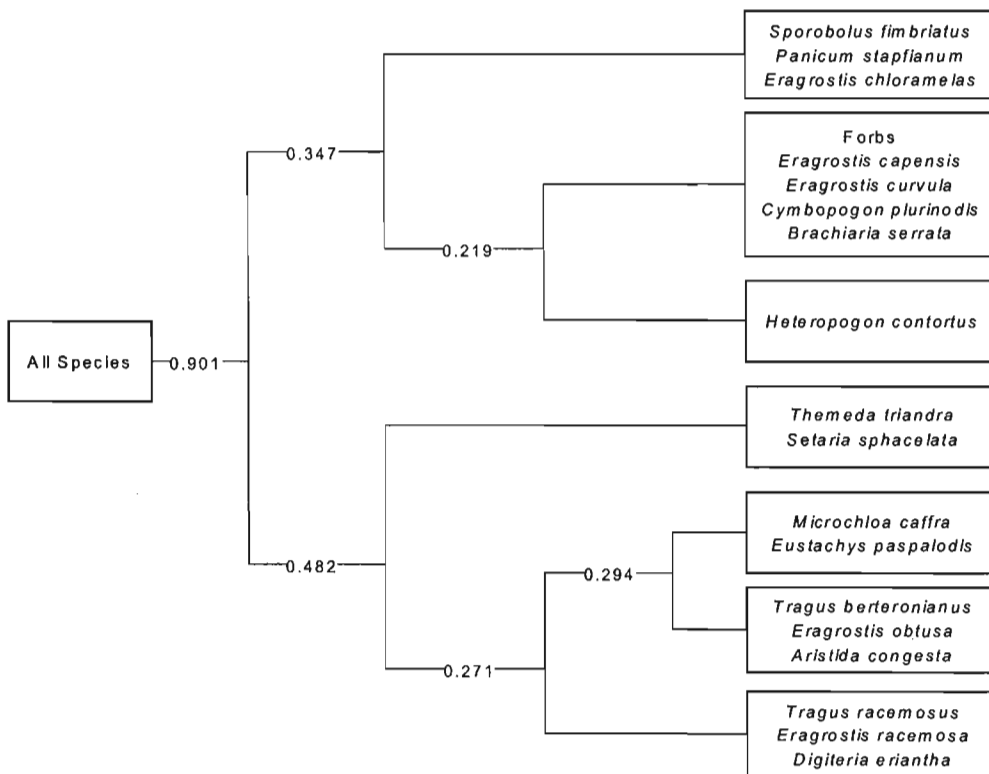


Figure 3.5 Species dendrogram, derived from TWINSpan classification, for the five treatments studied at Kroomie. Sub-division of a group was terminated if the group contained four or less species, or if the eigen value was less than 0.2.

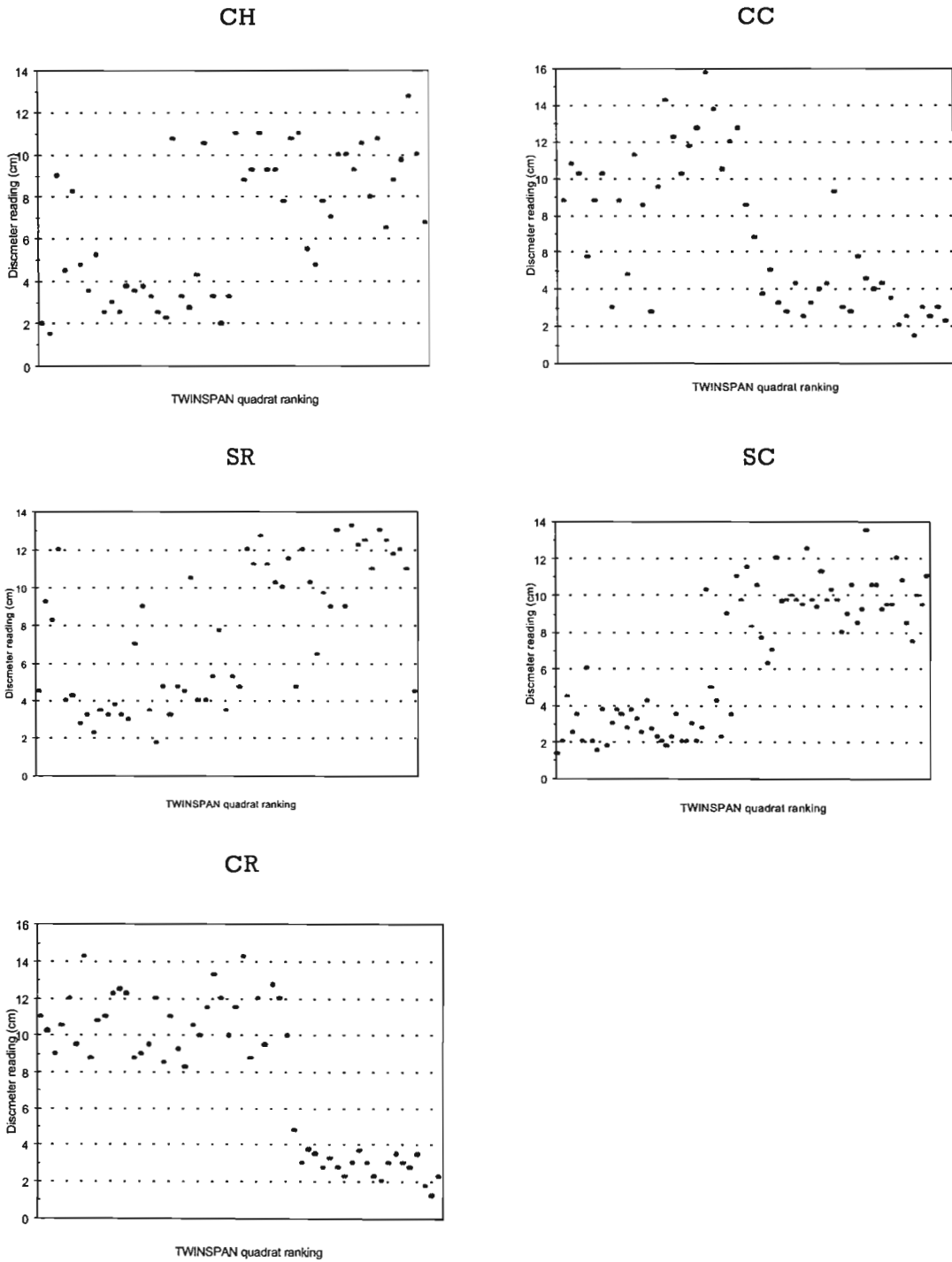


Figure 3.6 The relation between sward height (cm) as estimated using a disc-meter and the TWINSpan ranking of quadrats for the five treatments under study.

### **3.5 SUMMARY AND CONCLUSION**

Two methods were tested to develop an objective and reliable means for distinguishing between patches and non-patches.

The first technique considered only the distribution of sward height in the five treatments. It revealed that all swards reflect a bimodal structure, but the nature of this structure varies across treatments. For four of the five treatments it predicted that the patch/non-patch interface occurs at between 5 and 6 cm. However, height separation for the SR treatment was considerably higher, suggesting that the bimodal structure of the vegetation may not, in that instance, be related to patch grazing. This variation of results necessitated the development of another model.

The second technique related sward height to species composition. Both CCA and TWINSpan reflected a distinct correlation between these two variables.

The upshot of this study is that patches at Kroomie can be objectively and reliably separated from non-patches at a sward height of 6 cm.

## **4. VARIATION IN SWARD GEOMETRY ACROSS TREATMENTS**

### **4.1 INTRODUCTION AND AIM**

In Chapter 3, a model to objectively separate patches from non-patches was described. It showed that there is a clear distinction between the two regarding species composition, and that they may be objectively separated by estimating vegetation height using a disc-meter.

This chapter uses the model to describe the geometry in patch/non-patch structure across the five treatments. "Geometry" refers to the spatial extent, size, and layout of grazed patches in each treatment.

The aim of this section is to examine the following key questions.

1. How does the total area that is patch-grazed vary across treatments?
2. What is the frequency distribution of patches of different sizes across treatments?
3. What is the structural pattern of patches across treatments?

### **4.2 METHODS**

The methods used to collect the data have been described in Chapter 3. Data collected during September 1999 were used to answer the questions stated above. This was at the end of the winter season and, although some rain had fallen during July, the dry conditions over the preceding several months had resulted in relatively little growth of grass. The patch structure of the vegetation was, therefore, relatively distinct, and treatment effects were well pronounced at this time.

### **4.3 RESULTS AND DISCUSSION**

The model described in Chapter 3 was used to classify the contiguous disc-meter readings into patches (short grass) and non-patches (long grass).

#### 4.3.1 EXTENT OF PATCHES ACROSS TREATMENTS

The transects surveyed in each treatment were delineated into patches and non-patches using the model described previously. This gave an indication of the relative extents of patches and non-patches (Figure 4.1).

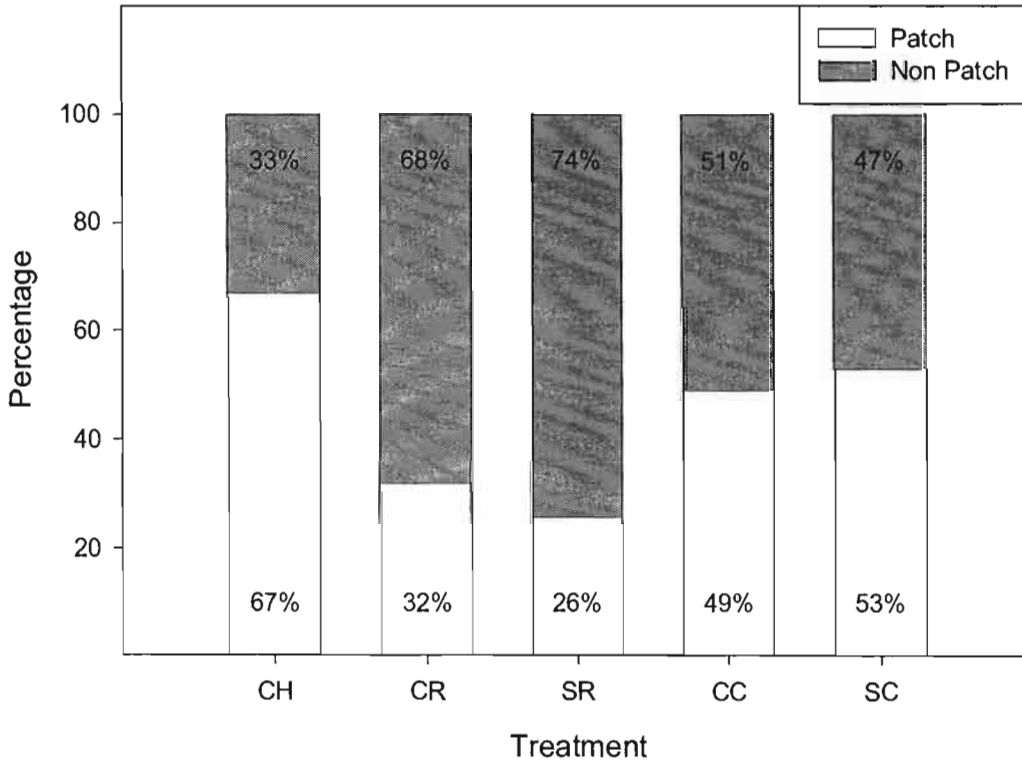


Figure 4.1 The relative areas (as a percentage of total area) comprising patches ( $\leq 6$  cm) and non-patches ( $> 6$  cm) on five treatments at Kroomie.

The extent of patch formation may be summarized as follows:

1. two-thirds of the area on the CH treatment is characterized by patches;
2. less than one third of the total area is patch-grazed in the CR and SR treatments (32 and 26% respectively); and
3. approximately half the total area is patch-grazed in the CC and SC treatments (49 and 53% respectively).

Let us consider the effect of animal type, animal distribution, and animal number on the degree of patch grazing. The CH and CR treatments provide the only direct comparison on the effect of stocking rate. Here, a 50% increase in the stocking rate results in a 109% increase in the area patch-grazed, and not a 50% increase as one may intuitively expect. Results from this study do not provide an explanation for this discrepancy. As speculation, however, it is possible that the higher reduction in vigour under heavy stocking relative to conservative stocking (Martens 1996, unpublished data) results in a greater proportion of the available area being grazed to satisfy animals' demands. What is of importance, though, is the finding that the area of veld grazed by animals (i.e. the patches) does not appear to be linearly related to the stocking rate of animals. Similar results were obtained by Morris *et al.* (1999) in a humid grassland. Cattle stocked at 'low' stocking rates ( $0.5 \text{ AU}\cdot\text{ha}^{-1}$ ) patch-grazed about 40% of the available area, while at 'medium' stocking rates ( $0.71 \text{ AU}\cdot\text{ha}^{-1}$ ) patch-grazed about 80% of the area. In other words, a 42% increase in the stocking rate resulted in a 100% increase in the area patch-grazed. These results are comparable to the results obtained at Kroomie.

Considering the CR, CC, SR, and SC treatments, animal type appears to have had a relatively small effect on the area patch-grazed. In the rotationally stocked treatments, there is a 6% difference in the total area comprising patches, while in the continuously stocked treatments this figure is 4%. Under conservative stocking rates, therefore, it appears that the total area patch-grazed is correlated with the metabolic mass of animals present, irrespective of animal species. In a humid grassland (sourveld), at 'low' stocking rates and under rotational stocking, Morris *et al.* (1999) found sheep and cattle to patch-graze 25% and 40% of the total area respectively. The effect of animal type was considerably more pronounced in the sourveld results, with cattle patch-grazing 15% more of the area than sheep. At both Kroomie and the sourveld site, sheep patch-grazed a very similar area (26 and 25% respectively). I suggest that there are two possible explanations for the differences in the area patch-grazed by cattle at the two sites.

Firstly, the patch-grazing habits of cattle may be affected to a greater extent by the type of grass sward (sweetveld vs. sourveld) than sheep.

Secondly, the Kroomie trials are stocked at a very conservative rate (approximately 20% below the already conservative Department of Agriculture recommended rate); the stocking rates in the sourveld were less conservative (bearing in mind, of course, the higher potential carrying capacity of sourveld areas). As described above, an increase

in the stocking rate results in an increase in the total area patch-grazed. If the stocking rate of sheep were increased, I would anticipate a smaller increase in the area patch-grazed.

The effect of animal distribution (grazing system) on patch formation at conservative stocking rates is pronounced. Continuous stocking resulted in 53% and 104% more patch formation than rotational stocking for cattle and sheep respectively. Hence, the data suggest that a smaller area is grazed when animals are rotated between paddocks than when they are not, and that this effect is pronounced more with cattle than with sheep. In their review, O'Reagain & Turner (1992) note that animal performance on trials stocked continuously with animals is generally better than trials stocked rotationally, and these concur with results of animal performance at Kroomie (du Toit 2000). The results from the Kroomie trials suggest why this may be the case: animals stocked continuously graze a larger area than those stocked rotationally, with the implication that more forage is ultimately consumed.

#### 4.3.2 VARIATION IN THE SIZE OF PATCHES ACROSS TREATMENTS

Using the model described earlier, the vegetation along line transects in five treatments was classified into patches and non-patches. Patches varied in length from 0.5 m to 39 m. Small patches were found to be overwhelmingly more abundant than large patches: as patch size increases, the frequency of such patches decreases exponentially (Figure 4.3). These data, however, give no indication as to the size of patch in which grazing is taking place. I expand on this concept, with an example, for clarity.

Consider, for example, an area of land with 16 patches of 1 m<sup>2</sup> in area, and one patch 16 m<sup>2</sup> in area (Figure 4.2). A frequency histogram, such as the one in Figure 4.3, would show merely a predominance of small patches. However, an equal area of grazed land occurs within each of the two patch sizes. Stated alternatively, one could say that 50% of the total area patch-grazed occurred within the patch size class of 1 m, and 50% of the total area patch-grazed occurred within the patch-size class of 4 m.

Therefore, the data indicating the frequency of patches of various sizes was converted to reflect the relative proportion of the total area patch-grazed within patches of various sizes.



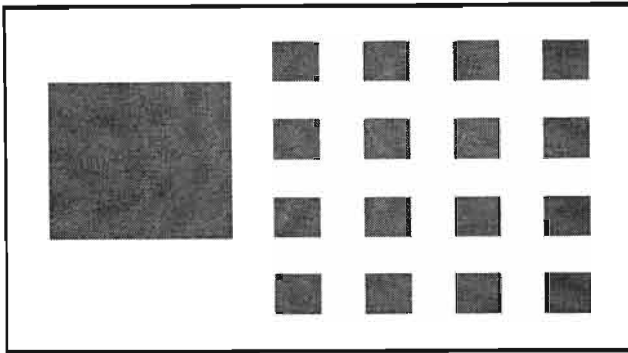


Figure 4.2 Diagrammatic representation of an area with one large patch (16 m<sup>2</sup>) and sixteen small patches (each 1 m<sup>2</sup>).

To make such a conversion, the number of patches in each size class was multiplied by the length of the patch in each size class. The result is the total 'length' of patch in each size class, which is a linear index of the total area patch-grazed (Figure 4.4). The principal behind this conversion is exactly the same as that behind estimating the total area patch-grazed using line transects: it does not assume that patches are any particular shape (e.g. circular or square), but that they can be reliably indexed using a single linear dimension.

The results show that, although there is a preponderance of small patches, a considerable proportion of the total area patch-grazed is found within large patches (Figure 4.4).

The results presented in Figure 4.3 and Figure 4.4 are for all treatments combined, and do not reflect variation in size distribution and area patch-grazed across treatments. Results were, therefore, separated on a treatment basis (Figure 4.5). Furthermore, a comparison of these distributions has been made (Table 4.1), reflecting the kurtosis and skewness of each distribution. Kurtosis reflects the relative peakedness or flatness of a distribution. Positive kurtosis indicates a relatively peaked distribution, and *vice versa*. Skewness reflects the degree of asymmetry of a distribution around its mean: a positive value indicates a distribution with an asymmetric tail extending toward values that are larger than the mean, and *vice versa*. For both kurtosis and skewness, a zero value indicates a normal distribution.

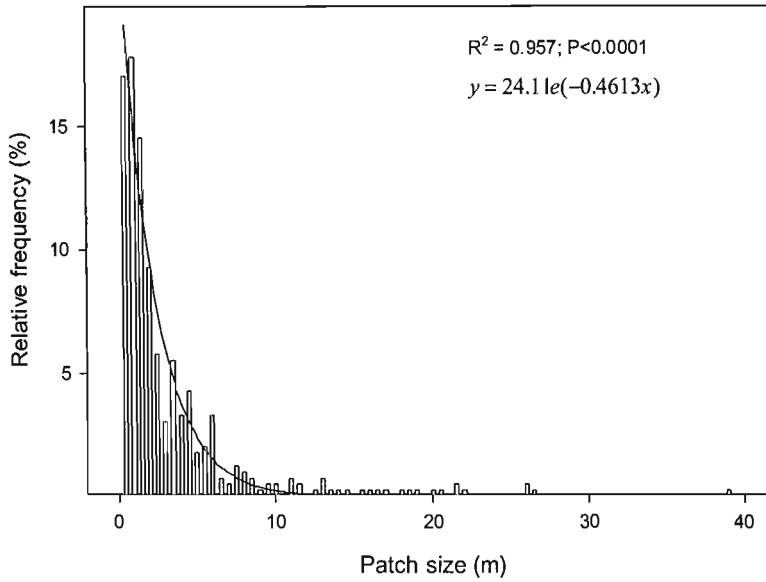


Figure 4.3 Frequency distribution of patch sizes for all treatments combined, where patch size is expressed as the length of the patch as recorded on a line transect (m).

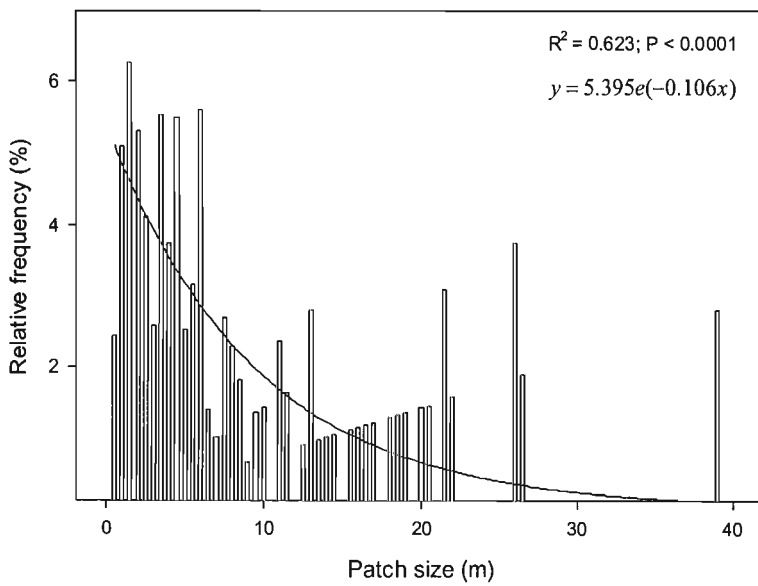


Figure 4.4 Area of 'patch' in each patch size class for all treatments combined; e.g. 2.8% of the total patch-grazed area occurred in patches 39 m in diameter.

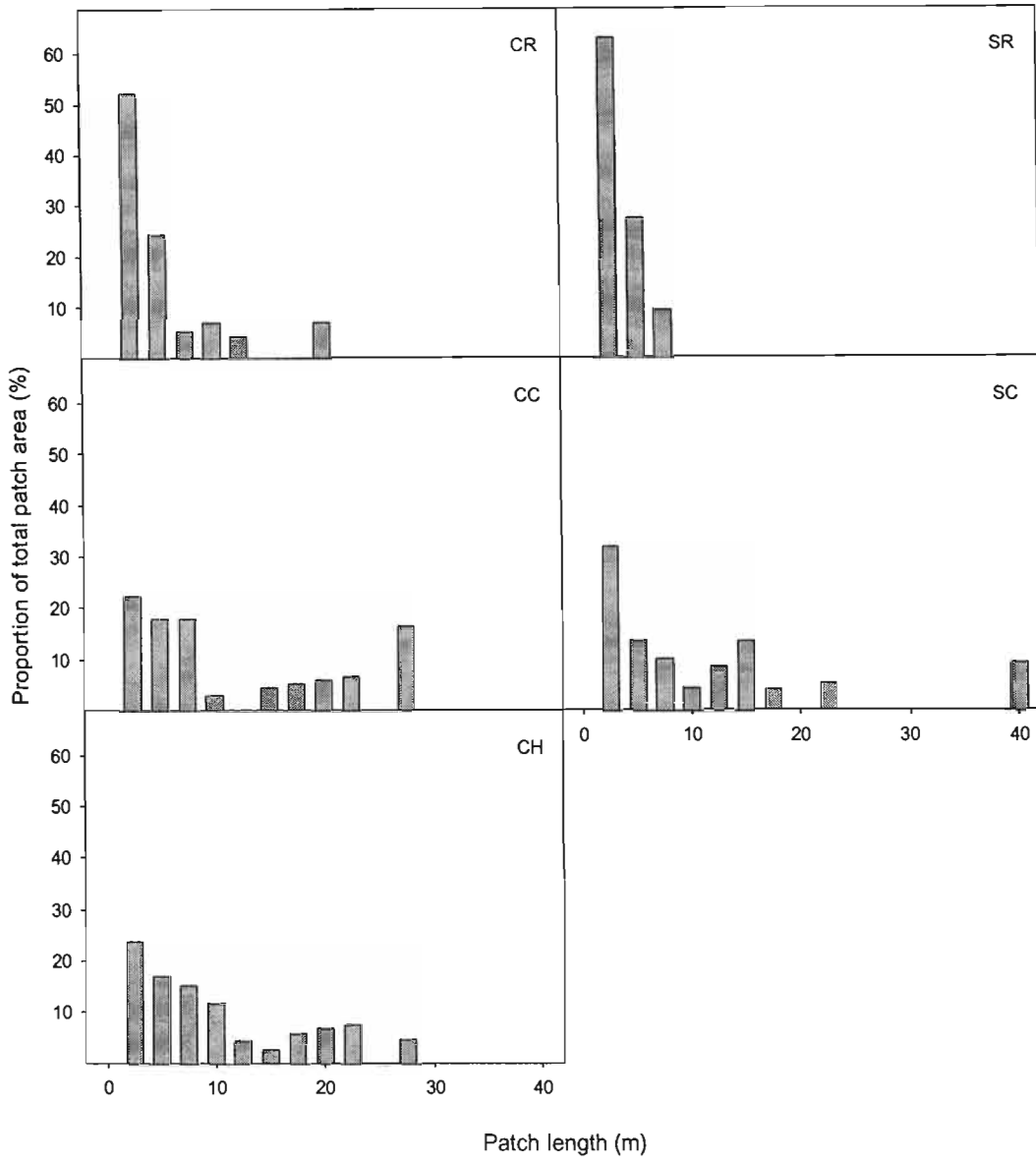


Figure 4.5 The proportion of the total area patch-grazed within various patch size classes for each treatment.

Table 4.1 Kurtosis and skewness of distributions presented in Figure 4.5

	CH	CR	SR	CC	SC
<b>Kurtosis</b>	-1.09	4.16	5.28	-0.86	-0.96
<b>Skewness</b>	0.61	2.16	2.47	0.84	0.62

Results may be summarized as follows.

1. Treatments that are stocked lightly and rotationally (CR and SR) exhibit strongly peaked distributions (positive kurtosis; 4.16 and 5.28 respectively) that are also positively skewed (positive skewness; 2.16 and 2.47 respectively).
2. Treatments that are stocked continuously or heavily (CH, CC, and SC) exhibit flattened distributions (negative kurtosis; -1.09, -0.86 and -0.96 respectively) that are slightly positively skewed (0.61, 0.84 and 0.62 respectively).
3. All treatments reflect positive skewness.
4. There is a significant positive linear relation between skewness and kurtosis ( $R^2=0.99$ ;  $F=450$ ;  $P<0.001$ ).

The results may be interpreted regarding the three basic management variables, *viz.* animal number, animal distribution, and animal type. A comparison of CH and CR treatments indicates the effect of stocking rate on patch size distribution. At higher stocking rates, there is a higher incidence of large patches and a lower incidence of small patches. This implies that at higher stocking rates, animals are selecting a greater proportion of their diet from large patches than from small patches. However, the total area patch-grazed on the CH treatment is approximately double that on the CR treatment. Therefore, the apparent formation of large patches may be a function of many small patches having coalesced.

Animal movement (grazing system) appears to have strongly influenced patch size distribution. For cattle and for sheep, treatments stocked rotationally comprise mainly small patches – this is more pronounced in the sheep treatment. Conversely, distributions of patch sizes are noticeably more normally distributed under continuous stocking. As with the CH vs. CR treatment, however, the total area patch-grazed is considerably higher under continuous than rotational stocking.

Animal type has had relatively little effect on patch size distribution. Firstly, let us consider the continuously stocked treatments (CC and SC). Their distributions are statistically similar, both exhibiting a negative kurtosis and slight positive skewness. In addition, the total area patch-grazed is similar (Figure 4.1). Secondly, consider the rotationally stocked treatments (CR and SR). Both distributions exhibit a positive kurtosis, and strong positive skewness: again, the total area patch-grazed is similar.

The positive relation between the skewness and the kurtosis of the distributions reflects that as the distribution of sward heights becomes more peaked, so it also becomes more positively skewed. Stated alternatively: as patch size increases, so the overall frequency distribution reflects more closely a normal distribution.

### 4.3.3 LAYOUT OF PATCHES AND NON-PATCHES ACROSS TREATMENTS

This section serves to:

1. describe graphically, using a map, the layout of patches and non-patches across the five treatments; and
2. describe the relation between the size of patches and non-patches in each of the five treatments.

Figure 4.6 is a map (to scale only in the horizontal dimension) of each of the transects in each of the five treatments. The variation in the extent of patch grazing, and the range and frequency of patch sizes (Section 4.3.2) is evident.

Of more interest, however, is the relation between the size of patches and non-patches across the treatments. As expected, a negative correlation is reflected (Figure 4.7), i.e. as the size of patches increases, so the size of the inter-patch areas (non-patches) decreases. The correlation between the average size of all patches and non-patches per treatment is reflected in Figure 4.8. The SR, CR, and SC treatments follow, almost exactly, the anticipated gradient of  $y = -x + c$ , while the CC and CH treatments deviate above and below this line respectively. The mean patch size for the CC and CH treatments is very similar, but the mean non-patch size is significantly different ( $P < 0.05$ ), with non-patches on the CC treatment being larger. For the CC treatment this may be explained by the several large non-patches apparent in some of the transects (Figure 4.6). For the CH treatment, the occurrence of unexpectedly small non-patches may be due to the formation of patches (or disruption of non-patches) formed when animals forage for food outside patches (the animals are stocked more heavily, and readings were taken at the end of winter).

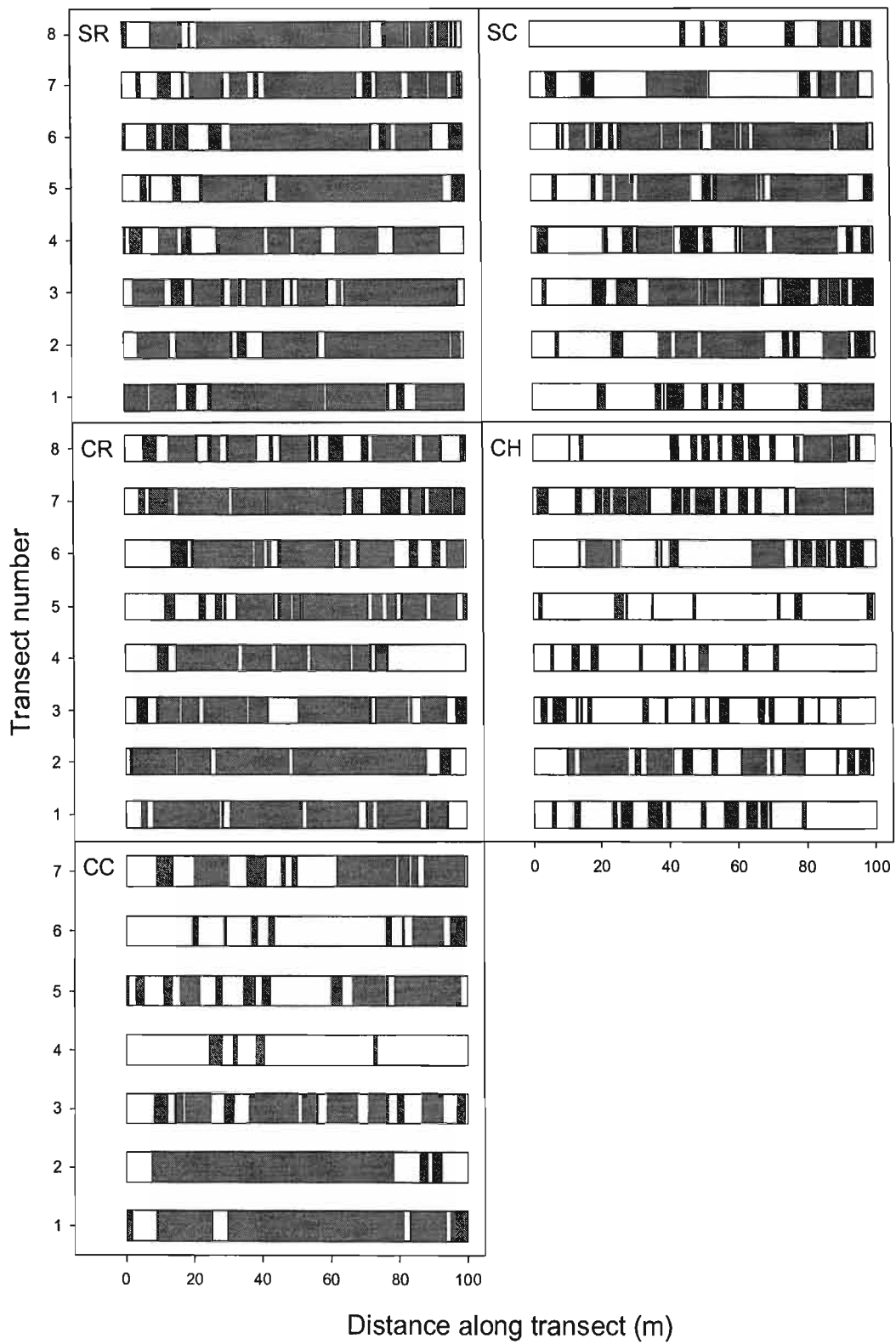


Figure 4.6 Spatial pattern of patches (white) and non-patches (grey) on five treatments at Kroomie.

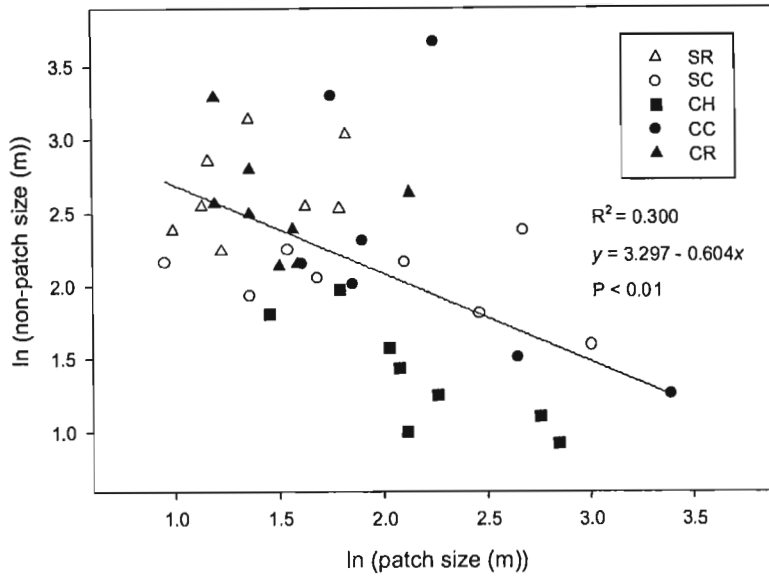


Figure 4.7 Relation between size of patches and non-patches for five treatments at Kroomie. Each point reflects the mean sizes of patches and non-patches on one transect.

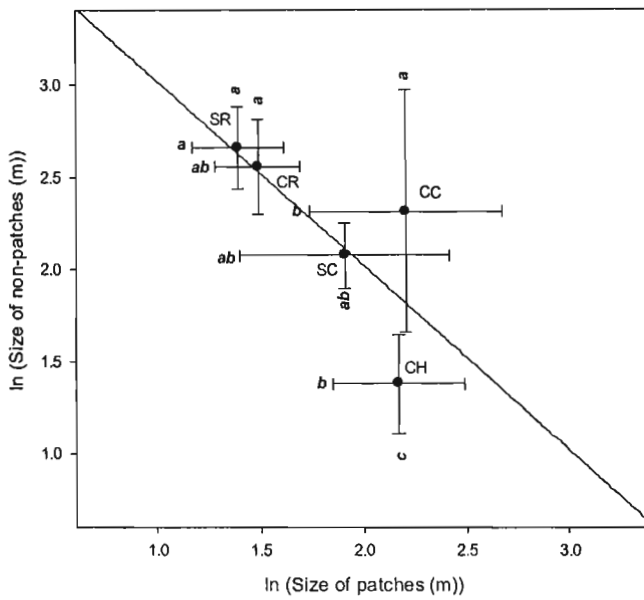


Figure 4.8 Relation between the average size of all patches and all non-patches for each treatment. Bars are 95% confidence intervals; different letters reflect significant differences ( $P < 0.05$ ). The solid line reflects the anticipated inverse relation between the size of patches and non-patches ( $y = -x + 4.02$ ).

#### 4.4 SUMMARY AND CONCLUSION

The area patch-grazed is affected by grazing system and stocking rate, where continuous or heavy stocking result in an increase in the area patch-grazed. The effect of animal type was not evident. The effect of stocking rate concurs with results from other studies, while the effect of grazing system may offer insight into why animal performance is higher under continuous rather than rotational stocking. The lack of effect of animal type may be due to the low stocking rates or stocking densities at Kroomie, but this conclusion is tentative.

All treatments demonstrated an overwhelming preponderance of small patches, and their frequency decreased exponentially, which is described with a decay curve, as patch size increased. However, the division of the total area patch-grazed amongst patches of different sizes differed among treatments. Animals stocked rotationally at conservative rates tended to graze primarily within small patches, while those stocked rotationally at heavy rates, or continuously, tended to graze within a greater range of patch sizes. Analysis of the peakedness and skewness of these distributions indicated that distributions were always positively skewed, especially in the CR and SR treatments. Similarly, the CR and SR treatments were strongly peaked, while the other treatments were slightly flattened. Further research is required to see if this trend continues as patch size increases; i.e. will the distribution become more flattened and negatively skewed? I suspect that distributions would become negatively skewed – in a heavily grazed system, one would anticipate that a relatively small proportion of the total area patch-grazed would fall within small patches, and a larger proportion within large patches.

As suspected, there was a negative relation between the size of patches and non-patches across the treatments. The CC and CH treatments did not, however, conform completely to expectation, and further research is required to provide an explanation.



## 5. THE RELATION BETWEEN SWARD STRUCTURE AND SPECIES COMPOSITION

### 5.1 INTRODUCTION AND AIM

In Chapter 3, a model was developed to objectively separate patches from non-patches, and it was found that the grass layer comprised two distinct components, differing according to height and species composition. However, the species composition of patches and non-patches was not discussed in detail.

In Chapter 4, the geometry, or structure, of the grass layer was described in some detail.

The aim of this section follows.

1. Describe how species composition varies between patches and non-patches across the five treatments by:
  - a. examining the relation between relative abundance and sward height for the most common grass species; and
  - b. examining compositional gradients using multivariate methods.
2. Determine whether patches have degraded by :
  - a. comparing the density of themeda plants on patches and non-patches across the five treatments; and
  - b. relating the density of themeda to the size of patches and non-patches across the five treatments.

### 5.2 SPECIES COMPOSITION OF PATCHES AND NON-PATCHES

#### 5.2.1 INTRODUCTION

Some of the effects of herbivory on the grass sward have been discussed (Chapter 1). In essence, swards that are leniently grazed are usually characterised by tall Decreaser

and Increaser I species, while swards that are heavily grazed are characterised by short Increaser II species. In some cases, heavy grazing leads to a loss of basal cover.

In Section 3.4 it was demonstrated that animals graze patchily, and that the sward can structurally be separated into short (grazed) patches and tall (ungrazed) non-patches. Furthermore, it was demonstrated that the species composition of these patches and non-patches differed.

## 5.2.2 METHODS

The species composition of the five treatments was estimated, as described in Section 3.4.2.

## 5.2.3 RESULTS AND DISCUSSION

### 5.2.3.1 Species' responses

Eighteen grass species were encountered in the five treatments (Table 5.1), although not all species were present in each treatment, and between four and six species accounted for 75% of the basal cover in each treatment (Figure 5.1). Themeda was the most abundant species in all treatments.

The relative abundance of a species in the grass sward was related to sward height for the ten most common species (Figure 5.2). Gaussian (Equation 5.1) and exponential increase (Equation 5.2) and decrease (Equation 5.3) regressions were fitted to each plot, and the regression with the highest significance was used (if more than one regression was significant, the line with the highest adjusted-R<sup>2</sup> value was chosen).

$$y = ae^{\left[-0.5\left(\frac{x-x_0}{b}\right)^2\right]} \dots\dots\dots \text{Equation 5.1}$$

$$y = e^{ax} \dots\dots\dots \text{Equation 5.2}$$

$$y = ae^{-bx} \dots\dots\dots \text{Equation 5.3}$$

Table 5.1 Percentage composition of species as estimated using basal cover

Species	Code	SC	SR	CR	CH	CC
<i>Aristida congesta</i> Roem & Schult. subsp. <i>congesta</i>	Arco	1.1	0.0	1.1	0.0	1.2
<i>Bracharia serrata</i> (Thunb.) Stapf	Brse	0.0	1.1	0.0	1.3	0.5
<i>Cymbopogon plurinodis</i> (Stapf) Stapf ex Burt Davy	Cypl	12.2	8.6	8.0	10.2	4.5
<i>Digitaria eriantha</i> Steud.	Dier	19.1	13.5	7.8	8.5	14.3
<i>Eragrostis capensis</i> (Thunb.) Trin.	Erca	3.8	2.7	5.9	4.9	0.7
<i>Eragrostis chloromelas</i> Steud	Erch	1.6	2.8	2	3.1	2.8
<i>Eragrostis curvula</i> (Schrad.) Nees	Ercu	0.0	0.0	1.8	0.0	1.1
<i>Eragrostis obtusa</i> Munro ex Fical. & Hiern	Erob	4.7	2.5	6.9	2.6	7.3
<i>Eragrostis racemosa</i> (Thunb.) Steud	Erra	7.6	3.2	10.8	9.4	5.3
<i>Eustachys paspaloides</i> (Vahl) Lanza & Mattei	Eupa	1.1	2.4	4.7	4.8	10.9
Forb species	Forb	0.3	1.7	0.0	0.0	0.0
<i>Heteropogon contortus</i> Pers.	Heco	0.9	3.5	0.7	2.8	1.9
<i>Microchloa caffra</i> Nees	Mica	5.0	5.4	8.4	4.2	9.1
<i>Panicum stapfianum</i> Fourc.	Past	0.0	0.6	0.2	0.7	0.6
<i>Setaria sphacelata</i> (Schumach.) Moss var. <i>sphacelata</i>	Sesp	0.9	0.0	0.0	0.0	1.9
<i>Sporobolus fimbriatus</i> (Trin.) Nees	Spfi	0.0	0.6	1.0	1.3	9.9
<i>Themeda triandra</i> Forssk.	Thtr	39.5	50.7	40.6	45.8	25.2
<i>Tragus berteronianus</i> Schult.	Trbe	0.0	0.7	0.0	0.3	0.0
<i>Tragus racemosus</i> (L.) All.	Trra	2.2	0.0	0.0	0.0	2.8

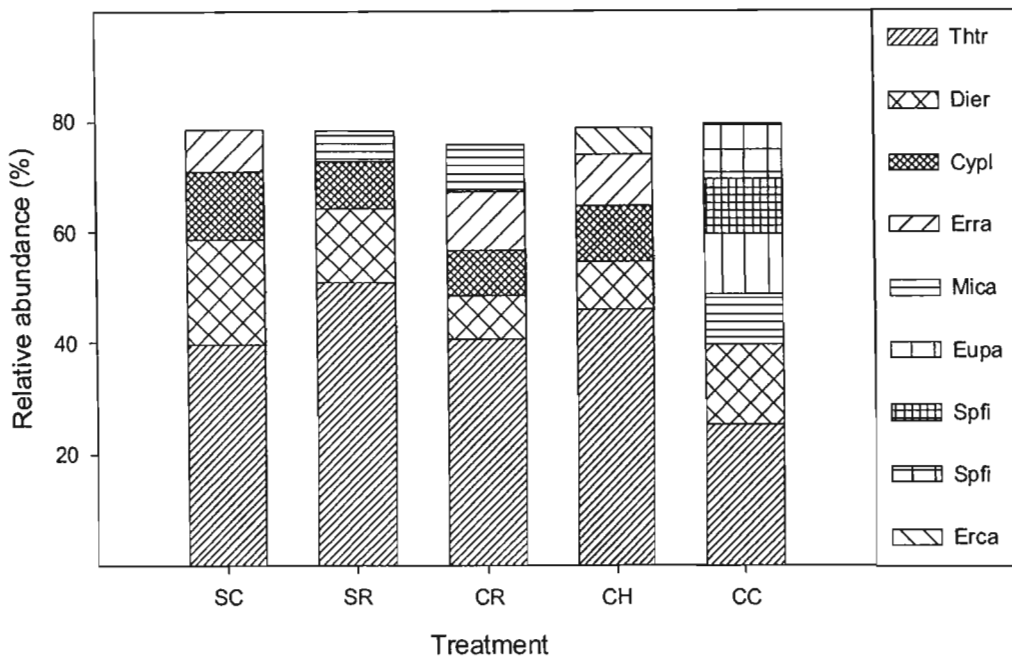


Figure 5.1 Species composition, as estimated using basal cover, for the five treatments studied. The most abundant species, comprising at least 75% of the total composition, are illustrated. See Table 5.1 for species codes.

All grasses, other than *Heteropogon contortus*, changed significantly in abundance with reference to sward height (Figure 5.2 and Table 5.2). *Digiteria eriantha*, *Eragrostis obtusa*, *Eragrostis racemosa*, *Eustachys paspaloides*, and *Microchloa caffra* were associated with short swards; *Cymbopogon plurinodis*, *Eragrostis chloromelas*, and *Sporobolus fimbriatus* were associated with tall swards. Themeda was present in tall (non-patch) and short (patch) swards, but was more abundant in the former.

Figure 5.3 summarises the relation between relative abundance and sward height, and provides an illustration of nine of the ten most abundant species at Kroomie (these being the species with significant regression lines (Figure 5.2)).

There is a general trend from Increaser II, through Decreaser, to Increaser I species (i.e. a successional gradient), indicating that species composition is affected by grazing pressure (assuming that sward height is an index of grazing pressure), following the classical model of rangeland succession (Dyksterhuis 1949). Results from humid areas of South Africa (Morris & Fynn 2003) demonstrated similar responses, although the species in that study were different, and their study included the effect of fire as a disturbance.

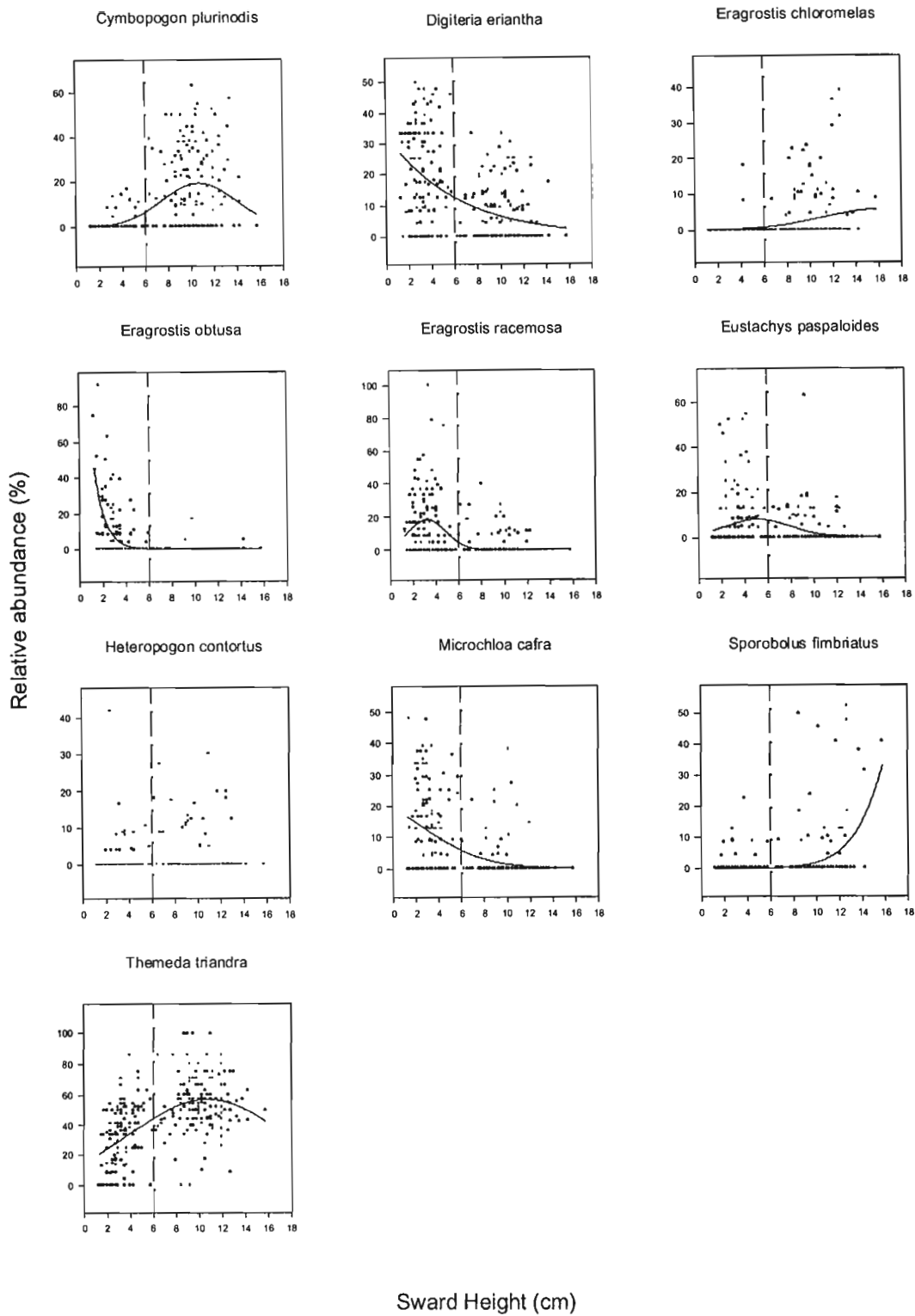


Figure 5.2 Relation between relative abundance (%) and sward height for the ten most common species at Kroomie (all treatments combined). The vertical lines in each graph define the patch/non-patch boundary occurring at a sward height of 6 cm. Fitted lines reflect regressions; see Table 5.2 for regression statistics.

Table 5.2 Formulas of regression lines, with F-values, P-values, and R<sup>2</sup> values for each of the curves fitted to the relative abundance by sward height data in Figure 5.2

Species	Equation	F-value	P-value	R <sup>2</sup>
<i>Cymbopogon plurinodis</i>	$y = 19.23e^{\left(-0.5\left(\frac{x-10.68}{3.146}\right)^2\right)}$	54.21	<0.0001**	0.278
<i>Digiteria eriantha</i>	$y = 32.95e^{(-0.161x)}$	98.47	<0.0001**	0.258
<i>Eragrostis chloromelas</i>	$y = 5.989e^{\left(-0.5\left(\frac{x-16.682}{5.555}\right)^2\right)}$	25.02	<0.0001**	0.082
<i>Eragrostis obtusa</i>	$y = 172.7e^{(-1.072x)}$	171.0	<0.0001**	0.377
<i>Eragrostis racemosa</i>	$y = 18.46e^{\left(-0.5\left(\frac{x-3.203}{1.642}\right)^2\right)}$	39.21	<0.0001**	0.217
<i>Eustachys paspilodis</i>	$y = 8.01e^{\left(-0.5\left(\frac{x-5.148}{2.830}\right)^2\right)}$	9.373	0.0001**	0.063
<i>Heteropogon contortus</i>	$y = 2.21e^{\left(-0.5\left(\frac{x-7.909}{4.9121}\right)^2\right)}$	0.807	0.447 (NS)	0.006
<i>Microchloa caffra</i>	$y = 19.230e^{\left(-0.5\left(\frac{x-10.679}{3.1459}\right)^2\right)}$	42.27	<0.0001**	0.277
<i>Sporobolus fimbriatus</i>	$y = 284.71e^{\left(-0.5\left(\frac{x-26.429}{5.156}\right)^2\right)}$	14.89	<0.0001**	0.154
<i>Themeda triandra</i>	$y = 57.11e^{\left(-0.5\left(\frac{x-10.694}{6.647}\right)^2\right)}$	72.20	<0.0001**	0.339

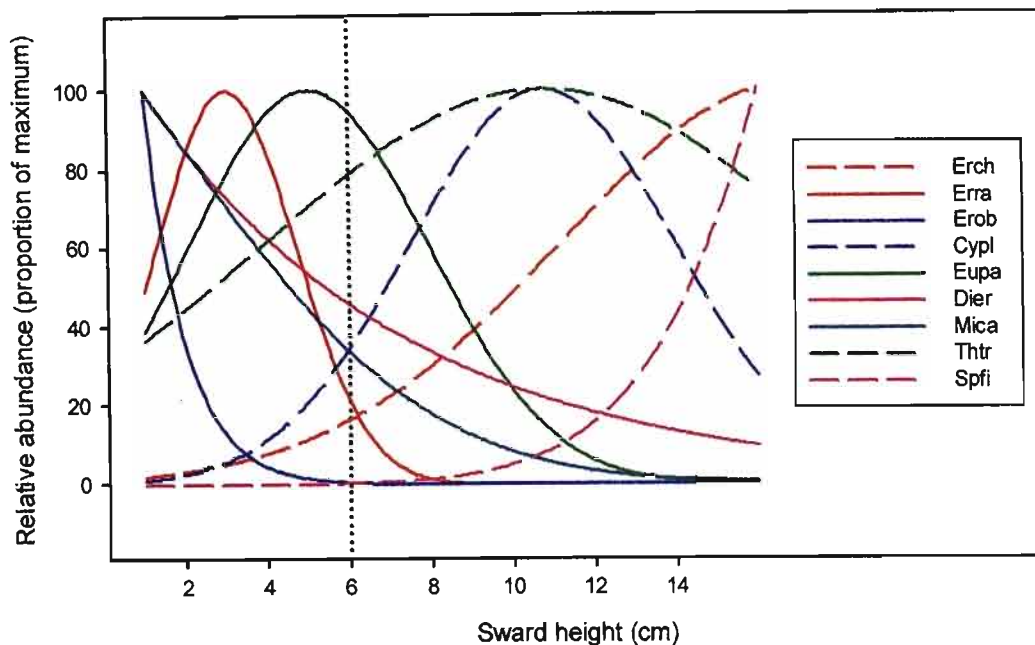


Figure 5.3 Regression lines (see Table 5.2 for equations) showing relativised response (% of maximum abundance) of nine species along a sward height gradient. The vertical dotted line reflects the separation between patches and non-patches at 6 cm. See Figure 5.2 for details of individual species' response, and Table 5.1 for species codes.

### 5.2.3.2 Compositional responses

Unfortunately, as the initial species composition in each of the treatments was estimated using a 200 point method, and this study described species composition in terms of density, the two cannot be reliably compared.

Canonical correspondence analysis (CCA) was used to assess the differences in species composition between treatments, sward structure (patches vs. non-patches), and treatment by sward structure interaction. In the analysis, *Sporobolus fimbriatus* was rendered passive, but was overlaid afterwards, as this species occurred in abundance only on moist sites in the CC treatment. A Monte Carlo test revealed that treatment, sward structure, and the interaction between treatment and sward structure were all significant ( $P < 0.005$ ).

The species composition of all treatments was generally similar (Figure 5.4), although the CC treatment was somewhat different from the other treatments, due probably to the comparatively high proportion of *Eustachys paspaloides* and low proportion of themeda (Table 5.1 and Figure 5.6). However, the greatest differences in species composition were between patches and non-patches, which were widely separated on Axis 1 (Figure 5.4); these differences were consistent across treatments. In other words, species composition differs more between patches and non-patches than between treatments.

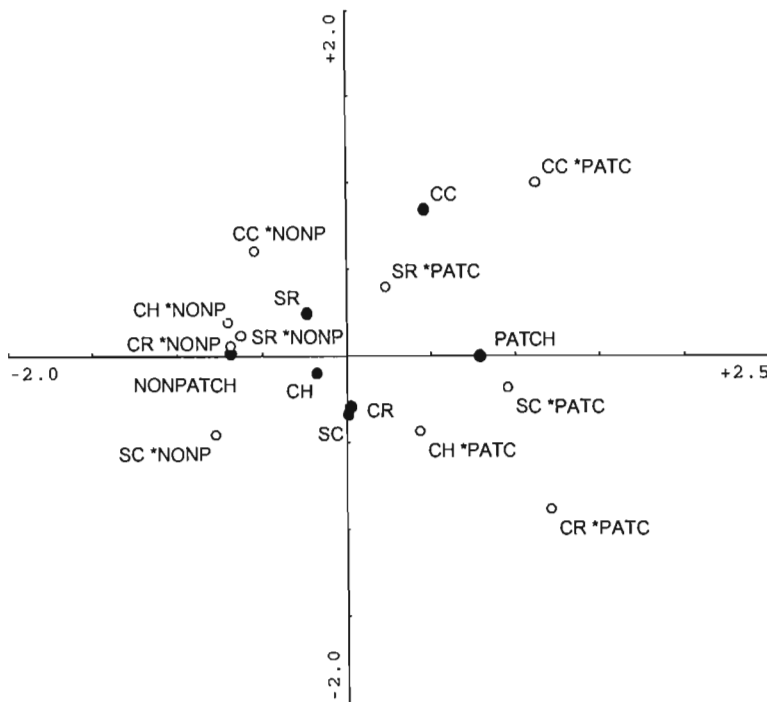


Figure 5.4 Canonical correspondence analysis of all sites at Kroomie (axes 1 and 2). Eigen values for axes 1 and 2 are 0.375 and 0.058 respectively. Circles are centroids for main effects of treatments and sward structure (filled) and the treatment by sward structure interaction (open). CC, SC, CH, CR, and SR are treatment codes as described in Table 3.1; PATC = patch, NONP = non-patch.

The CCA site plot (Figure 5.5) revealed that sites are separated primarily according to sward structure. Of particular interest is that the heterogeneity of patches is considerably higher than that of non-patches, and this is most marked in the CR treatment. This is contradictory to popular thought, where it is generally considered that heavy grazing pressure (e.g. on patch-grazed areas) leads to a loss of species richness (e.g. Fuls 1992a). The Kroomie trials demonstrate that grazing increases heterogeneity, and non-patches are likely to demonstrate lower heterogeneity than patches. Patches are characterised by *Eustachys paspaloides*, *Microchloa caffra*, *Digiteria*



*eriantha*, *Eragrostis obtusa*, and *Eragrostis racemosa*; non-patches are characterised by themeda, *Cymbopogon plurinodis*, and *Eragrostis capensis*. Themeda, however, does occur near the interface between patches and non-patches (Figure 5.6), suggesting that themeda is likely to occur on both patches and non-patches. The species response of themeda (Figure 5.2) supports this observation.

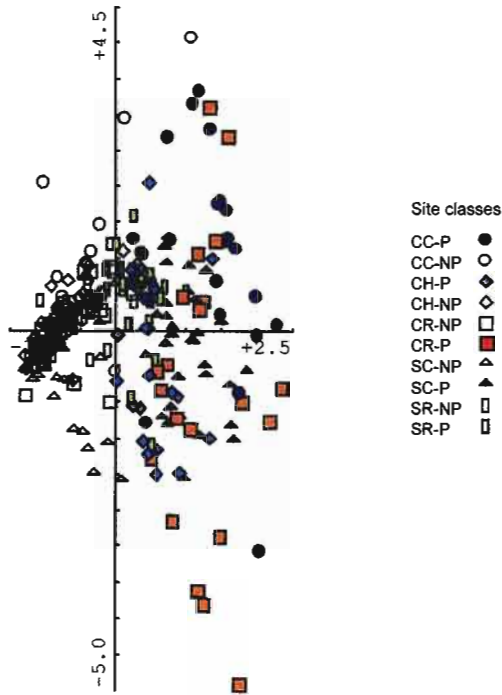


Figure 5.5 Canonical correspondence analysis site plot (axes 1 and 2) labeled by treatment\*sward-structure. Eigen values for axes 1 and 2 are 0.375 and 0.058 respectively, representing cumulatively 19.5% of the total species variance and 80.3% of the species environment relation (closed symbols reflect patches; open symbols reflect non-patches).

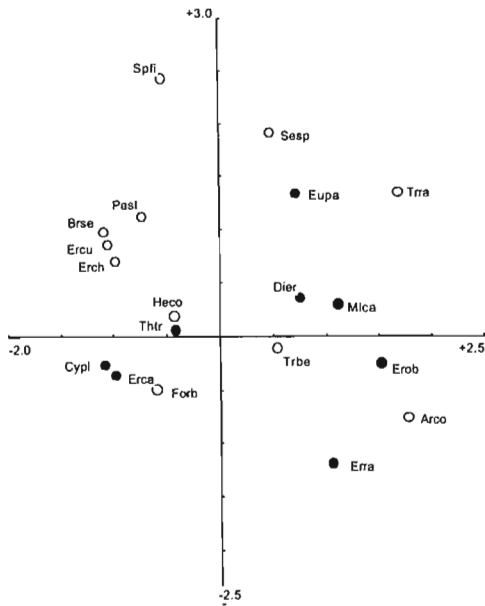


Figure 5.6 Canonical correspondence analysis plot (axes 1 and 2) of all sites at Kroomie showing species. Eigen values for axes 1 and 2 are 0.375 and 0.058 respectively. Species represented by solid circles have >10% of their variance accounted for by the first two axes of the ordination. See Table 5.1 for species codes.

### 5.3 DEGRADATION OF PATCHES

#### 5.3.1 INTRODUCTION

Themeda is the most abundant grass present at Kroomie, and is generally accepted to be the most useful grass, from a production viewpoint, in the region. The paradigm generally accepted by pasture scientists and farmers alike, is that themeda will decrease to the benefit of other, less desirable species, under conditions of overgrazing (e.g. Booysen 1969, Booysen & Tainton 1978, Edwards 1981). As patches comprise veld that has been grazed, and non-patches comprise veld that has not been grazed (or grazed to a lesser extent), one would expect themeda to be less abundant on patches.

The currently advocated management paradigm for sweet grassveld areas, regarding the three basic animal management variables is as follows (Danckwerts 1989b):

1. rotationally stock paddocks;
2. stock at conservative rates;

3. stock with cattle rather than with sheep; and
4. rotationally rest veld for a full season.

These recommendations are for, *inter alia*, maintaining or improving the proportion of Decreaser species in the sward. One would expect, therefore, themeda to be negatively impacted by one or a combination of the following: continuous stocking, heavy stocking, stocking with sheep, or the absence of a season long rest.

Therefore, the density of themeda plants on patches and non-patches was measured, and used as an index of degradation. This absolute measure of abundance is used in place of the relative measure of abundance used earlier (Section 5.2).

### 5.3.2 METHODS

During April and May 1999, the density of themeda plants on patches and non-patches was estimated (at this time of year all the themeda plants were established, and no young seedlings were encountered). Adjacent patches and non-patches were identified using a disc-meter (as described in Chapter 3). The number of living themeda plants (plants were defined as living if they had any green plant material) in 1 x 1 m quadrats were counted. Thirty-six patch/non-patch comparisons were made in each treatment (i.e. 72 quadrats per treatment, or 360 transects in total).

### 5.3.3 RESULTS AND DISCUSSION

#### 5.3.3.1 Density of themeda on patches and non-patches

Density data were square-root transformed and compared using two-way analysis of variance (using patches as reps, *sensu* Webster 1992). Results indicated that the main effect of treatment was significant ( $P < 0.0001$ ), while that of sward structure (i.e. patch vs. non-patch) was not significant ( $P = 0.82$ ). This indicates that the density of themeda on patches and on non-patches differs significantly across treatments, but that the density of themeda on patches is not significantly different from that of non-patches for all treatments combined. Of more importance, however, is that the treatment by sward structure interaction was significant ( $P < 0.0001$ ), indicating that the density of themeda varies significantly according to sward structure in the different treatments (Figure 5.7).

Treatment means were compared using least significant differences (LSD), for equal n across treatments. In all treatments, the density of themeda on patches and on non-patches differed significantly. For the SC, CC, and CH treatments, themeda densities on non-patches were lower than on patches, while the reverse was true for the CR and SR treatments. There were large differences in themeda density between the SC, CC, and CH treatments (high), and the CR and SR treatments (low). On non-patches, the SR treatment had the highest themeda densities, followed by the SC, CC, and CR treatments, while the CH treatment had the lowest themeda densities.

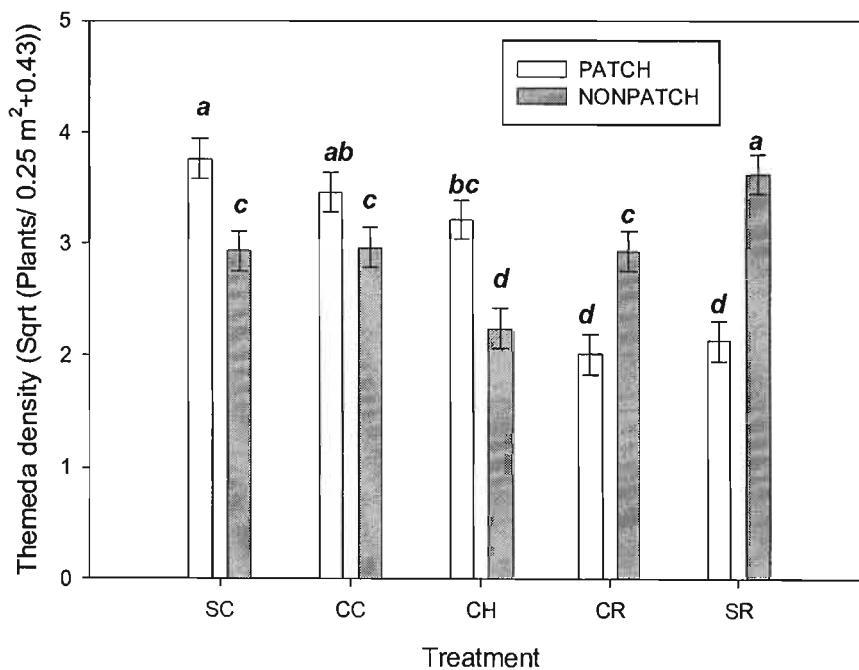


Figure 5.7 The density of themeda plants on patches and non-patches across five treatments at Kroomie. Bars sharing the same letter are not significantly different ( $P = 0.05$ ).

### 5.3.3.2 Relation between patch size and density of themeda

The average size of patches and non-patches was calculated using the data presented in Section 4.3.2. These data were log (natural) transformed and related to the density of themeda of patches and non-patches (square-root transformed), respectively (Figure 5.8). There was a positive correlation between themeda density and patch size (Figure 5.8a). The regression coefficient was high (0.725), though not significant at the 5% level ( $P = 0.067$ ), due to the low number of points ( $n = 5$ ). However, the data demonstrate

that themeda levels are higher on large patches, and lower on small patches. There is a similar relation between themeda density and non-patch size (Figure 5.8b). The regression co-efficient is high (0.789) and the regression is significant ( $P = 0.044$ ).

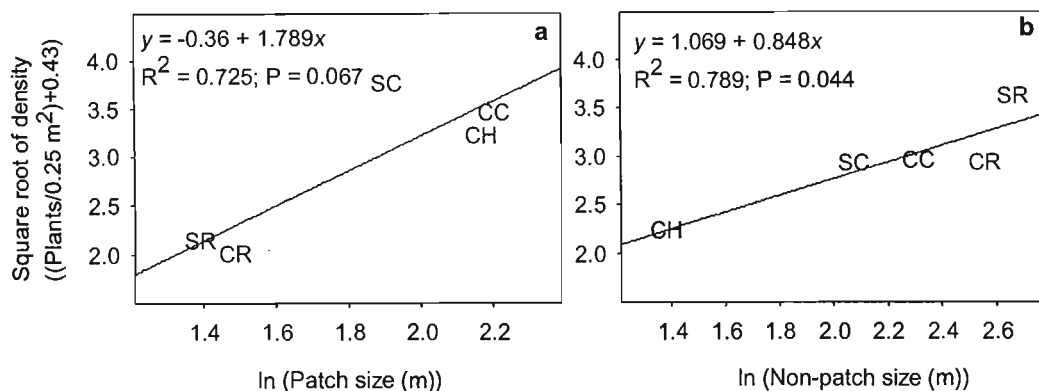


Figure 5.8 The relation between a) patch size and b) non-patch size and the density of themeda plants for each of the five treatments studied at Kroomie.

This correlation between themeda density and patch size concurs with results obtained by Morris & Tainton (1993), where tall (ungrazed) grasses exerted a considerable competitive effect on short (grazed) grasses. Where patches are large, the relative amount of competition between short and tall grasses will be lower than where patches are small. This is because the perimeter:area ratio of an object decreases as the object increases in size. It appears that themeda plants in small patches may suffer fatal competition from vigorous, ungrazed grasses (possibly of any species) of adjacent non-patches. In the rotationally stocked treatments at conservative stocking rates, the proportion of large patches was very low, which explains the low density of themeda plants. Similarly, at high stocking rates the overall area patch-grazed increased, with a corresponding increase in the proportion of large patches, which in turn appears to have resulted in higher density of themeda plants. This further suggests that under conditions of rotational stocking, stocking at high stocking rates is preferable to stocking at low stocking rates for the conservation of themeda.

The relation between the size of non-patches and density of themeda is intuitively unexpected. One would expect the density of themeda in a non-patch to be unaffected by the size of that non-patch. These results demonstrate that high densities of themeda

occur when the patches or non-patches are greater than about seven meters (i.e.  $\ln(7.38) = 2$ ; Figure 5.8). Therefore, using the density of themeda plants as an indicator of rangeland health, a sward comprising large patches and non-patches is preferable to one comprising small patches and non-patches.

### 5.3.3.3 General discussion on the density of themeda

The results presented here are unexpected, or differ from predicted results, in various ways.

1. **The density of themeda on non-patches.** The density of themeda on non-patches, as discussed, is positively related to patch size. The same relation between patch size and density of themeda may be explained by considering the competitive effect of large grass plants on short grass plants, but this does not hold for non-patches.
2. **The effect of animal type on the density of themeda on patches.** There was very little apparent effect of animal type on the density of themeda on patches (compare the SC and SR to the CC and CR treatments). Other literature indicates that sheep are more damaging to veld than cattle (e.g. Roux & Vorster 1983, Danckwerts 1989a), but such effects have not been manifest at Kroomie. This may be due to the low stocking rates at Kroomie (they are below the already conservative recommended stocking rates of the Department of Agriculture), as other studies have demonstrated that sheep are more detrimental (O'Reagain & Turner 1992).
3. **The effect of grazing system on the density of themeda on patches.** Some form of rotational stocking system has often been advocated as a means for preventing veld degradation. Using the density of themeda as a measure of degradation (low densities being equivalent to degradation), the trials at Kroomie have indicated that continuous stocking systems (for cattle and for sheep) are preferable to rotational systems (compare SC and CC treatments to the SR and CR treatments).
4. **The effect of stocking rate on the density of themeda on patches.** Contrary to expectation, the density of themeda was higher on the CH than the CR treatment (the only difference being stocking rate). This

suggests that stocking rate *per se* does not necessarily lead to veld degradation.

#### 5.4 SUMMARY AND CONCLUSION

Species composition and sward structure are related at Kroomie. Individual species are related to sward height (and thereby to grazing pressure) in a manner predicted by the classical rangeland succession model. This demonstrates that the veld at Kroomie displays equilibrium characteristics (*c.f.* non-equilibrium characteristics; Ellis & Swift (1988)).

Species composition was also affected by sward structure. Canonical correspondence analysis demonstrated that the overall species composition of the five treatments were relatively similar, although the CC treatment differed somewhat, perhaps due to lower abundances of *Themeda* and higher abundances of *Eustachys paspaloides*. In contrast, patches and non-patches were noticeably different in species composition, and this difference was related to sward structure. This is of interest, as it demonstrates that differences in species composition have greater variability within treatments than between treatments (and these differences are consistent between treatments).

The density of *Themeda* is determined by an interaction between treatment and sward structure. In three treatments (CH, CC, and SC) the density of *Themeda* plants is higher on patches than on non-patches, and the reverse is true for the SR and CR treatments. There is an interesting relation between the density of *Themeda* plants and the size of patches and non-patches. The former may be explained in terms of competition between short and tall plants, while the latter requires further investigation and validation.

There are also some unexpected results when considering management paradigms for the management of sweetveld (cattle vs. sheep, rotational vs. continuous stocking, and heavy vs. light stocking rates). Fortunately, these unexpected results are explained (at least partially) when considering the sizes of patches formed in the five treatments. In all cases, *Themeda* densities have been low when the mean patch size has been small. Therefore, those treatments that promote the formation of small patches (*i.e.* SR and CR treatments) might lead to veld degradation at the patch level.

There is also the relation between the density of themeda and the size of non-patches to consider. The treatments that were prone to degradation (using the density of themeda plants as an index) were also characterised by large non-patches, and these non-patches had high densities of themeda.

Overall, therefore, where treatments display degradation at one level, it is usually counterbalanced by an absence of degradation at another level. Ironically, the treatment that displayed the net highest densities of themeda for patches and non-patches was the SC treatment, which had been stocked continuously with sheep for many years.



## 6. MOVEMENT OF PATCHES

### 6.1 INTRODUCTION

In this chapter, I provide some anecdotal evidence regarding whether patches are spatially and temporally stable or dynamic. As all the transects at Kroomie have been marked rather robustly, it will be possible, at a later stage, to objectively determine the spatial structure of the sward.

### 6.2 CAN PATCHES MOVE?

Firstly, a patch may be considered as an entity – it has certain characteristics (size, shape, etc.) – and can change its position in the landscape. It may be likened to a wave in water – the wave moves, but the individual water molecules remain essentially stationary apart from a certain vertical displacement. In the same way, a patch can move across the landscape, with the grass plants exhibiting vertical movement (i.e. being grazed or ungrazed).

Secondly, a patch may be considered as being a collection of grazed or ungrazed plants. If plants outside the current perimeter are grazed, or plants within the perimeter stop being grazed, the original patch no longer exists, and a new patch comes into existence.

Both approaches have their merits and shortfalls. The first approach does not allow for the formation or collapse of patches in the landscape. The second approach allows patches to have no temporal element – even one grass plant changing its grazing status would entail the death of the original patch, and the birth of a new patch.

Within the realm of biological relevance, it is useful to recognize the merits of each approach. Firstly, it is useful to consider a patch as a discrete entity, which has the ability to change shape or move across the landscape. Secondly, one should accommodate the idea that patches can appear and disappear, and that if a patch changes its nature considerably (e.g. a small patch evolving into a large patch, or small patches coalescing to form one big patch), it may be redefined as a new patch.

### 6.3 ANECDOTAL EVIDENCE ON THE MOVEMENT OF PATCHES

#### 6.3.1 OLD FENCELINE CONTRAST

It was mentioned, in section 2.3.2, that two of the paddocks of a three-paddock sheep treatment were merged to form a single paddock. This new paddock was used for the SC treatment. Before the fence was removed, the sheep had formed a large patch, against the fence, in one paddock. Over the fence, in the adjacent paddock, no such patch was formed. The fence was subsequently removed, and the sheep allowed to graze the whole paddock freely.

After seven years, the original fenceline was still very evident: the patch/non-patch interface extends in a straight line for approximately fifty meters (Figure 6.1). The effect is quite remarkable, and invokes considerable interest from visitors to the site.

This suggests that, at least with sheep that are continuously stocked, patches are retained over the long term.



Figure 6.1 Photograph at a site in the SC treatment at Kroomie. An old fenceline contrast is evident, with the area on the left being a patch, and that on the right being a non-patch.

### 6.3.2 RESIDUES FROM A PREVIOUS STUDY

In 1996, a study was initiated to study, *inter alia*, the life histories of grass plants on adjacent patches and non-patches (Martens 1996, unpublished data). During the course of the study presented in this dissertation, I came across collections of wire rings that had been used during the 1996 study to identify specific plants. In almost all cases, there was a set of such rings on a patch, and a similar set nearby (less than a meter away) on a non-patch.

This evidence tentatively suggests that, as was found with the fenceline contrast, patches are relatively stationary over the medium-term.

### 6.3.3 ACACIA TREES THAT HAVE FALLEN OVER

*Acacia karroo* trees occasionally fall over, perhaps having been pushed over by animals (the trees are usually quite small, less than two meters high). Sometimes this happens on a grazed patch, and the area that the fallen tree covers is protected from grazing – a type of natural enclosure plot. In this area, a non-patch effectively forms (being an ungrazed area). In all the cases I observed, the grass grew tall in the protected area, and usually quite quickly (several months). Furthermore, themeda was usually present, even if it was absent in the surrounding patch.

This shows that grass in a patch, when relieved of grazing pressure, regains its vigor and grows tall. Furthermore, it suggests that themeda may be present in the seed bank, and germinates and develops in the absence of grazing.

Regarding the movement of patches, this anecdotal evidence demonstrates that non-patches can form within patches.

### 6.3.4 GRAZING OF NON-PATCHES AFTER A PERIOD OF LOW RAINFALL

Rainfall is erratic at Kroomie, and the years during which data were recorded for this study were below average. During dry spells, the grass on patches was grazed short, and it grew relatively slowly. At these times, animals started grazing off the patches, in the non-patches. It did not appear that animals selected the edges of existing patches in favour to areas distant from existing patches. However, the style of grazing exhibited by the animals was different. Animals (cattle and sheep) grazed primarily themeda plants, selecting the inflorescences (probably without seeds) and external leaves.

Similar grazing habits were noted by Ring *et al.* (1985). The residual plant was consequently roughly spherical, consisting mainly of stems and some leaves. Once it had rained again, these ball-like plants grew new leaves, and appeared as they had before grazing.

This lends weight to the argument that patches remain similar in size over time. During periods of food shortage, animals do graze non-patches, but not in such a way as to convert them into typical patches. Speculatively, the patches, after rain, would have begun growing again, providing more nutritious, and acceptable, feed to the animals, as they would be free of residual stubble and senescent leaves.

#### **6.4 CONCLUSION**

The evidence presented here is anecdotal, and inferences are speculative. However, the observations do suggest that:

1. patches are relatively stable over time;
2. patches have the ability to convert back to non-patches (with *favourable* species) in the absence of grazing; and
3. animals do graze non-patches, but return to graze on patches once the patches can provide adequate feed.

## 7. CONCLUSIONS

### 7.1 GENERAL REVIEW AND CONCLUSIONS

The trials at Kroomie were designed to test the consequences of various management actions, namely stocking rate, grazing system, and animal type, on vegetation dynamics and animal performance.

Not all the treatments on the trials were considered. Rather, a selection of several treatments was made, in order to investigate the various management variables on at least one level.

The study was conducted over two years, both of which experienced below-average rainfall (66 and 84% of mean annual rainfall for 97/98 and 98/99 seasons, respectively).

#### 7.1.1 SEPARATING PATCHES AND NON-PATCHES

The first facet of the study was to develop a model to objectively separate patches from non-patches. The first attempt, using Maximum Likelihood Estimation techniques, demonstrated that all treatments reflected a bimodal height structure. However, the interface (in cm) between patches and non-patches was inconsistent, and thus this method was not used. The bimodal structure of the grass sward may not always be primarily related to patches and non-patches, but perhaps to other factors, such as the presence of very tall grass clumps. This is especially likely when the grass sward is essentially a mosaic of very small patches and non-patches, such as on the SR treatment. When sheep were stocked rotationally at low stocking rates, there was little evidence of a distinct patch/non-patch structure to the grass sward (as estimated using MLE).

The second attempt proved successful, and demonstrated, using species composition in conjunction with height data, that a patch/non-patch interface occurs at 6 cm. This was consistent for all treatments. This demonstrates that there are at least two distinct grass communities at Kroomie, one associated with short (grazed) swards, and the other with tall (ungrazed) swards. Therefore, it is possible to rapidly and objectively describe the patch structure using a disc-meter.

### 7.1.2 SWARD STRUCTURE

Sward geometry differed considerably across the five treatments. The SR and CR treatments had a relatively low proportion of the total area patch-grazed (less than a third). The SC and CC treatments had approximately half the area patch-grazed, while for the CH treatment this value was two thirds.

These results indicate that animal type had relatively little effect on the total area grazed. This is in contradiction with other studies, but may be due to the low stocking rates of animals at Kroomie. Grazing system had a marked effect on sward geometry, which was consistent for both sheep and cattle. Animals stocked continuously grazed larger areas than those stocked rotationally, providing the stocking rate was low. A 50% increase in stocking rate increased the total area grazed by approximately 100%. Due to the nature of the trials, the effect of sheep at high stocking rates could not be tested.

Similar trends were evident when considering the size of patches formed in the five treatments. Cattle and sheep grazed mainly in small patches, if stocked continuously at low stocking rates, and in small and large patches if stocked continuously or at high stocking rates. As expected, there was a general inverse relation between the size of patches and of non-patches.

### 7.1.3 SPECIES COMPOSITION

Themeda is the most abundant grass at Kroomie, and it occurs (somewhat unexpectedly) in both short and tall swards. The abundance of most other species is directly related to sward height, with Increaser II species being associated with short swards, and Decreaser and Increaser I species being associated with tall swards. Such associations are intuitively expected, but it is of interest that themeda can survive under conditions of both light and heavy defoliation.

The species compositions of patches were generally similar across treatments – this too was the case for non-patches. In turn, the species composition differed between patches and non-patches, and this difference was similar for all treatments. This lends support to the idea that there are two distinct grass communities at Kroomie, related to sward structure. Short swards displayed higher species richness than tall swards.

There was an interaction between treatment and sward structure regarding the density of themeda plants. There was a positive correlation between the density of themeda

plants and the average size of patches of the five treatments. This suggested that grazed themeda plants may be out-competed by their tall, ungrazed neighbours (of any species). A similar correlation was evident between themeda density and the size of non-patches.

#### 7.1.4 MOVEMENT OF PATCHES

There is some anecdotal evidence to suggest that patches (and, therefore, non-patches), are spatially stable over time. However, if patches are protected from grazing, they change into a non-patch – it appears that this may take only one season.

### 7.2 OVERALL CONCLUSIONS, AND COMMENTS ON FUTURE RESEARCH

1. The formation of patches is a ubiquitous consequence of grazing at Kroomie.
2. There are two distinct grass communities at Kroomie, each at different heights (the interface is 6 cm) and characterised by different grass species compositions.
3. Sward geometry at Kroomie is affected primarily by stocking rate and grazing system, and slightly by animal type.
4. Themeda has the ability to survive under conditions of locally heavy grazing, though appears to be negatively impacted when in competition with tall, ungrazed, neighbours.
5. Patches appear to be spatially stable over time.
6. This study provided no results to support the contention that rotational stocking at low stocking rates, with cattle or with sheep, is particularly beneficial.

The research reported here has provided an objective method for the separation of patches and non-patches at Kroomie. The technique is sensitive and consistent in swards grazed by both small-mouthed (sheep) and large-mouthed (cattle) species, under conditions of rotational and continuous stocking, and at high and low stocking rates. It may, therefore, also be useful in the investigation of animal/plant dynamics at other sites, and perhaps in multi-species systems.

The techniques, and the conclusions that follow from the work, now provide an opportunity to improve our understanding of the dynamics of patches (and of non-

patches). The indication here is that the grass sward comprises two distinct communities (related to sward height), and that the structure is relatively stable over time. A critical question is whether this is consistent over several seasons, and what role the existence of patches and non-patches plays in plant dynamics in relation to plant species richness and diversity.



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## APPENDICES

Appendix 1. Monthly rainfall values at Kroomie from October 1961 to September 1999.

Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
1961 /62	0	53	39	50	54	105	15	25	0	0	16	0	357
1962 /63	61	60	33	159	43	168	94	12	10	59	0	7	706
1963 /64	107	83	76	20	91	91	25	6	74	6	19	28	626
1964 /65	21	17	64	22	9	32	39	43	31	20	21	9	328
1965 /66	124	98	0	23	74	34	19	26	0	1	55	45	499
1966 /67	14	109	7	67	38	156	94	73	15	45	13	9	640
1967 /68	19	29	25	5	13	51	57	13	27	4	25	65	333
1968 /69	28	25	30	12	67	68	21	14	11	11	8	11	306
1969 /70	53	62	17	8	107	28	14	18	46	9	132	12	506
1970 /71	61	33	162	106	172	64	59	28	2	68	101	6	862
1971 /72	63	48	27	84	62	104	15	14	38	1	9	38	503
1972 /73	34	44	8	15	118	62	45	25	0	8	56	29	444
1973 /74	50	76	88	190	84	245	22	39	16	0	95	12	917
1974 /75	23	87	35	12	48	72	20	8	64	19	4	106	498
1975 /76	2	47	115	61	160	259	26	49	9	46	9	25	808
1976 /77	99	65	42	17	136	12	65	81	6	0	13	52	588
1977 /78	28	53	96	25	7	43	70	14	32	3	26	4	401
1978 /79	45	38	19	40	68	54	9	35	1	110	99	40	558
1979 /80	60	37	22	33	15	17	10	8	15	3	19	38	277
1980 /81	20	66	53	58	41	81	8	48	10	7	49	5	446
1981 /82	49	24	54	4	35	51	46	0	59	54	6	39	421
1982 /83	92	32	17	4	11	13	19	18	25	94	0	33	358
1983 /84	84	72	53	33	11	36	39	17	20	20	8	16	409
1984 /85	61	58	28	50	112	32	40	6	19	0	0	9	415
1985 /86	89	186	161	86	31	47	76	3	12	7	31	32	761
1986 /87	109	73	12	13	67	24	32	14	17	12	16	98	487
1987 /88	42	32	26	14	125	50	32	28	4	30	7	55	445
1988 /89	45	57	131	40	42	116	106	26	5	12	0	10	590
1989 /90	138	174	18	61	63	105	22	21	18	0	19	22	661
1990 /91	52	43	27	78	84	49	2	10	18	7	27	22	419
1991 /92	159	58	74	16	41	77	15	5	28	0	54	11	538
1992 /93	47	35	8	80	39	10	61	12	26	6	10	57	391
1993 /94	31	92	152	85	111	20	18	11	15	45	30	3	613
1994 /95	77	0	161	68	20	72	34	19	5	8	0	18	482
1995 /96	34	76	134	173	110	81	14	10	6	3	12	5	658
1996 /97	40	187	49	76	30	70	116	16	86	13	12	9	704
1997 /98	44	25	8	25	66	79	31	0	0	9	31	27	345
1998 /99	59	88	49	42	32	73	16	0	3	44	5	26	437
Average (mm)	56.94	64.26	55.78	51.44	64.13	72.39	38.05	20.92	20.34	20.63	27.28	27.18	519.4



Appendix 2. Example of estimation of species composition.

<b>Subquadrat 1</b> 1. <i>Cymbopogon plurinodis</i> 3 2. <i>Themeda triandra</i> 2 3. <i>Digiteria eriantha</i> 1	<b>Subquadrat 2</b> 1. <i>Themeda triandra</i> 3 2. <i>Digiteria eriantha</i> 2
<b>Subquadrat 3</b> 1. <i>Digiteria eriantha</i> 3 2. <i>Eragrostis racemosa</i> 2 3. <i>Eragrostis obtusa</i> 1	<b>Subquadrat 4</b> 1. <i>Themeda triandra</i> 3

Score:

<i>Themeda triandra</i>	=	2+3+0+3	=	8	40%
<i>Cymbopogon plurinodis</i>	=	3+0+0+0	=	3	15%
<i>Digiteria eriantha</i>	=	1+2+3+0	=	6	30%
<i>Eragrostis racemosa</i>	=	0+0+2+0	=	2	10%
<i>Eragrostis obtusa</i>	=	0+0+1+0	=	1	5%
				<b>20</b>	<b>100%</b>